

METABOLIC PATTERNS OF A GROUP OF OVERWEIGHT, UNDERWEIGHT
AND AVERAGE WEIGHT WOMEN

By

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AN ABSTRACT

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METABOLIC PATTERNS OF A GROUP OF OVERWEIGHT, UNDERWEIGHT
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Possible metabolic differences in the utilization of fat and carbohydrate by women of average, above and less than average body weight were investigated through simultaneous respiration studies and analyses of various blood and urinary constituents at fasting and at intervals for five hours following two test meals. Twenty-one apparently healthy women, seven overweight, seven underweight and seven average weight, served as subjects; their weights ranged from +66 to -21 percent of desirable weight. Fat, carbohydrate and protein, respectively, contributed 70, 25 and 5 percent of the calories in the high fat test meal and 0.5, 94.5 and 5 percent of the calories in the high carbohydrate test meal.

The mean basal energy expenditure of the overweight subjects was significantly higher and of the underweight subjects was significantly lower than that of the average weight subjects. Fasting blood glucose concentrations were significantly higher among the overweight than among the other subjects. Fasting blood pyruvic acid concentrations were significantly higher among the overweight than among the underweight subjects. There were no significant group differences in fasting mean non-protein respiratory quotients, hourly urinary nitrogen excretions, in concentrations of venous serum alkaline phosphatase or of the various serum lipid constituents: total lipids, total cholesterol, lipoproteins or chylomicrons.

Following both test meals, hourly calorie expenditures of the overweight subjects were consistently higher than those of the other subjects.

Cumulative energy increments were significantly higher among the underweight subjects than among the other groups following the high fat test meal. There were no significant differences in mean non-protein respiratory quotients following either test meal. Following the high fat test meal blood glucose concentrations increased more slowly among the overweight than among the other subjects, were elevated for a longer period and then decreased significantly below fasting values at the fourth and fifth hours. The overweight subjects had the highest one-half hour blood glucose concentrations following the high carbohydrate test meal and the fifth hour glucose concentrations were significantly below fasting concentrations. Blood pyruvic acid changes were slight following the high fat test meal; following the high carbohydrate test meal, blood pyruvic acid increases from fasting were significantly lower among the overweight than among the average weight subjects. Following the high fat test meal, chylomicron concentrations showed a significantly earlier rise, reached higher peak values and decreased more rapidly toward fasting among the underweight than among the overweight subjects; there were no significant group differences in serum total lipid concentrations. Following the high carbohydrate test meal, serum total lipids and/or chylomicron concentrations were increased above fasting among the overweight subjects but not among the average or underweight subjects; mean serum total lipid increments were greater among the overweight subjects following the high carbohydrate than following the high fat test meal.

The results appeared to indicate that the overweight women had a delayed utilization of carbohydrate of the test meals, whereas the underweight women showed some greater preference for carbohydrate in metabolism.

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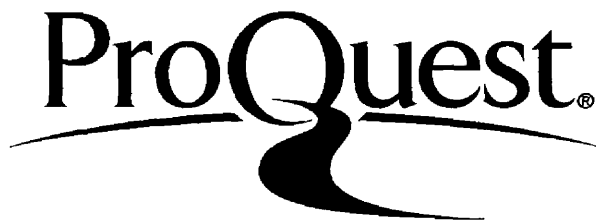
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INTRODUCTION

The causes and characteristics of obesity and leanness have long been of interest to nutritionists. That obesity and leanness represent disproportions between caloric intakes and caloric expenditures has been an axiom of energy metabolism since the time of Voit. From earliest times food scarcity has been the predisposing factor to caloric undernutrition. Overeating is recognized as the basic cause of obesity. Historically, overeating in times of plenty as insurance for an uncertain future was often a wise course of action. This may also be true in some cultures today. Currently, however, an excess of body weight is more commonly condemned as "one of the subtler and more serious health hazards of our time" (Armstrong, et al., 1951).

Obesity is regarded as an increasingly serious health problem in this country (Ibid) and in Great Britain (Meiklejohn, 1953). The striking increases of mortality and morbidity rates with increasing degrees of overweight have been well established (Armstrong, et al., 1951). Downes (1953) has recently compiled new evidences of the significant association of heart disease, hypertensive vascular disease, arthritis, diabetes and gall-bladder disease with overweight states. Other associated degenerative conditions such as cancer, nephritis, atherosclerosis, toxemia of pregnancy, cirrhosis of the liver, emphysema and varicose veins, are frequently cited (Gastineau, Ryneerson and Irmisch, 1949).

An underweight state is less strikingly related to disease and increased mortality. Although an increased incidence of tuberculosis in

underweight adolescents and young adults has been observed, Keys (1950a) stated: "Severe undernutrition seems to be beneficial, if anything, in the so-called degenerative diseases". Animal studies of McGay (1947), Riesen, et al. (1947) and others are of interest in this regard, because these studies demonstrated that increased longevity accompanied life-time restrictions of caloric intakes, particularly restrictions of carbohydrate intakes.

Research on obesity has been extensive in recent years with particular attention directed toward an increased understanding of the underlying cause or causes of overeating. Appetite control is generally recognized as the result of interrelations and interactions between humoral substances, both endocrine and non-endocrine, certain nerve centers in the hypothalamus, and subconscious and conscious areas of the cortical region of the brain. The amazing accuracy of the appetite as a regulator of caloric balance in the majority of people under varied circumstances has been emphasized by many, e.g. Keys (1950a) and Newburgh (1950). Overeating by others has been ascribed to a wide variety of causes; evidence for some causes is well defined, whereas for others there is still considerable controversy. Current theories of causes of overeating may be classed generally as environmental, psychological, physiological (endocrine and non-endocrine) and constitutional.

The influences of the senses, emotions, habits and training on food selection have been cited as strong environmental and neural factors (Gastineau, et al., 1949; McCance, 1953; Mayer, 1953b) and the association of certain psychologic patterns with states of obesity have been reported both in children and in adults (e.g. Bruch, 1943; Kotkov

and Murawski, 1952). That dysfunction of nervous elements associated with the hypothalamus is capable of producing a marked increase in desire for food has been substantiated by numerous experiments in which animals have been subjected to hypothalamic lesions. These studies have been reviewed by Mayer (1953). The importance of the functioning of the hypothalamus in appetite regulation in the control animal is less well defined, but the sensitivity of the hypothalamic nerve centers to humoral (McCance, 1953) and nervous (Mayer, 1953b) stimuli has been investigated.

Physiologically, the existence of metabolic anomalies as hypoglycemia, lipophilia and hypolipemia has been held responsible for desires to eat excessively, presumably due to decreased or delayed satiety (Eulatao and Carlson, 1924; Wilder and Wilbur, 1938; Bauer, 1941; Wilder and Sprague, 1945), but the mechanisms of the reactions have not been satisfactorily defined. Recently arteriovenous glucose differences, rather than simple hypoglycemia, have been correlated with hunger in both animals and humans and the glucostatic theory of appetite regulation has been proposed (Mayer, 1953a). According to this theory the hypothalamic glucoreceptors are influenced by "effective sugar levels", which in turn are regulated by a hyperglycemic, glycogenolytic hormone. The effects of several endocrine factors, from the pancreas, adrenals, thyroid, pituitary and gonads, upon tissue and blood constituents, which in turn may affect the hypothalamus or other nervous centers are recognized.

Blood glucose and lipid concentrations also have been associated with differences in the rates of transformation of carbohydrate into fat (Hagedorn, Holten and Johansen, 1927; Strang and McClugage, 1931; Lyon, Dunlop and Stewart, 1932) and qualitative and quantitative

differences in the overall or preferential ability of the tissues to metabolize different foodstuffs (Brooks, 1946; Gilmore and Samuels, 1949; Pennington, 1953a, 1953b). The concept of adipose tissue as an active tissue with special metabolic functions subject to neural control instead of a relatively inert reserve (Rose, Stern and Shapiro, 1953; Wertheimer and Shapiro, 1948) has contributed to the conclusion that abnormally functioning fat storage mechanisms might result in hypolipemia (Pennington, 1953a; Wilder and Sprague, 1945). That greater total efficiency in the digestion and absorption of foodstuffs is not a factor is commonly agreed (Wilder and Wilbur, 1938; Newburgh, 1944; Brooks, et al., 1946; Thomas and Friedman, 1949; Mitchell, 1952).

Although obesity, which is uncomplicated by endocrine dystrophy, has not been shown to be associated definitely with a lowered specific dynamic action of food or with a lowered basal metabolism, expressions as "degree of utilization of metabolizable energy" (Deuel, et al., 1947), "wasteful expenditure of energy" (Brody, 1945) and "economy of utilization" (Forbes, et al., 1946a, 1946b) have been applied to describe differences in specific dynamic action observed under varying experimental and natural conditions. Mitchell (1952) proposed that the efficiency of the homeostatic mechanisms of appetite control and the conversion into heat of food which is consumed above current needs may vary with constitutional types. He stated: "Differences between endomorphy and ectomorphy in disposition of food energy may rest not so much in the peak dynamic effect as in its duration". Metabolic individuality was emphasized also by Conn (1944) in his observation that the same endocrine dysfunction may not affect the energy balance of two individuals in the same way; however, he

concluded, "while the influence of environmental factors is well established, there is little positive information presented for the case of 'hereditary obesity' in humans".

Keys (1950a) discussed the incidence of caloric undernutrition or semi-starvation in the United States as being primarily among: 1) persons with appetite failure from either psychic or physical reasons, 2) persons with impediments to food ingestion or digestion, and 3) persons with abnormal avenues of caloric loss, e.g. febrile states and hyperthyroidism. Appetite controls or homeostatic mechanisms responsible for the habitual mild caloric undernutrition of the lean in the presence of an adequate supply of food are no more clarified than those operating toward the development of obesity.

Metabolic qualities associated with obesity and leanness have received less emphasis than causal factors. Etiological studies, however, have yielded data on individual factors of metabolic patterns of the obese, and, to a lesser extent, of the lean, which deviate from those found in average weight individuals. Still, the question as to whether or not there are basic differences in the physiology and the biochemistry of the overweight or the underweight individual as compared to the individual of average weight has not been satisfactorily answered.

This study was planned therefore to investigate further possible biochemical differences in the metabolism of fat and carbohydrate among women of average, above and less than average body weight through simultaneous respiration studies and analyses of various blood and urinary constituents before and following test meals of high fat and high carbohydrate composition.

REVIEW OF LITERATURE

A review of the literature on obesity and leanness revealed that attention during the late nineteenth and early twentieth centuries was centered largely about etiology. Interest in caloric nutrition as a whole then waned with the discovery of the vitamins and the emphasis on vitamin research which followed. By the early 1940's, food shortages in certain areas of the world, coupled with an increasing incidence of obesity in others, stimulated a renewed interest in energy metabolism, particularly in caloric imbalances. Causes still were stressed, but effects and metabolic qualities associated with caloric imbalances began to receive more emphasis.

An attempt has been made in this review to compile reported evidence of metabolic qualities associated with obesity and leanness, with particular emphasis on metabolic patterns in women. Such a review increases one's recognition of the many interrelated factors in metabolism as a whole and in energy metabolism in particular.

Patterns of Energy Metabolism

There is general agreement that the total energy expenditure in performing a measured amount of work by the obese individual is greater than that expended by a person of average weight but of similar age, height and sex (Keys, 1950b; Newburgh, 1950; Meiklejohn, 1953; Pennington, 1953c). Similarly, the lean individual expends less total energy for a given task than the person of average weight but of the same age, height and sex.

There is less agreement concerning differences in basal metabolic rates and specific dynamic effects of foods in overweight and underweight individuals when compared to those of average weight. The existence of differences in preferential metabolism of carbohydrates or fats by individuals of differing body weights also is debated.

Basal Metabolism

It is generally recognized that the total basal energy expenditure of obese individuals without endocrine disorder is higher than average. Basal metabolism data, however, have been expressed in terms of various bases by different investigators in attempts to relate total metabolism to active tissue. Per unit of height the obese individual has a greater heat production than a person of average weight; the lean individual has a lower heat production. Per unit of weight obese individuals have less heat production than the average, lean individuals have more. Neither height nor weight alone, however, has been found to be a reliable basis of comparison of metabolic rates even among persons of average weight. Early experiences, particularly the early studies of Rubner and Lusk, led to the selection of heat production per square meter of body surface as the most satisfactory basis for comparisons.

In 1936 DuBois summarized the studies on basal metabolism in the underweight and the obese as well as those used in establishing basal metabolism standards. Moderate caloric undernutrition did not seem to result in much deviation of basal metabolic rates from averages in either adult men or women when surface area calculated on actual weight was used as a basis of comparison. Studies on underweight women which were reviewed showed only slight average deviations: twenty-three distinctly

underweight young women in the Harris and Benedict series averaged 1.8 percent below the overall mean determined; seven subjects averaged -0.3 percent of the mean in another study; six subjects in another laboratory deviated $\pm$ 7.7 percent from controls; in a further group, nine underweight women averaged $\pm$ 2 percent of the mean of the group; and, in ninety-six college women who were studied, the underweight averaged -1.3 percent of Harris-Benedict standards or showed "essentially no difference from those of normal weight women in the same areas".

Commenting on the similarity of basal metabolic rates in the underweight and the average weight individual, Keys and co-workers (1950) stated:

"The basal metabolic rate of apparently normal underweight people is of great interest in view of the decreased basal metabolic rate produced by semi-starvation. It is possible that a reduction in metabolic rate is associated with the process of weight loss and normal rate is associated with caloric equilibrium".

Declines of basal metabolism during caloric undernutrition have been demonstrated both in average weight individuals (DuBois, 1936; Taylor and Keys, 1950) and in the obese (Strang and Evans, 1929; Brown and Ohlson, 1946). However, decreased basal metabolism in the post-reduction maintenance period of obese women also has been reported (Brown and Ohlson, 1946).

In the obese basal metabolic rates per square meter of body surface based on actual weight have frequently tended to be subnormal but the decreases were inconsistent and often not significant (e.g. Gastineau, et al., 1949; Newburgh, 1950; Mitchell, 1952). Among the studies reviewed by DuBois (1936) were the following in which the basal metabolic rates per square meter of actual surface area of obese persons were compared with those of average weight. Boothby and Sandiford measured basal heat production in ninety-four obese patients and found that rates

were within 10 percent of average in seventy-six (81 percent). Strouse, Wang and Dye compared the metabolic rates of seventeen overweight men and women with six average weight and nine underweight subjects and found essentially no differences. Grafe found only three out of one hundred and eighty cases of extreme obesity showed a definite decrease in metabolic rate.

Basal metabolic rate also has been expressed per square meter of surface area based on ideal weight (weight at average weight for height) rather than actual weight. Expressed in this way basal metabolic rates of the obese were frequently high (Keys and Brozek, 1953).

Interpretations of basal metabolic rates based on surface area calculated from either actual or ideal body weight have been criticized. The "surface area law" as commonly applied has been criticized by Pennington (1951a) for obscuring differences that may exist between the lean and the obese because the "law" was developed as a law of uniformity equating the variables of differences in weight. Many workers have agreed that surface area is not a satisfactory unit for the expression of basal metabolism. Benedict and Talbot (1921) recognized that the body surface area was an empirical formula, although it was accepted as the best answer at the time for a numerical estimate of body mass. The problems of actual measurements of surface area are many and relatively few such measurements have been made. In estimating surface area DuBois (1936) pointed out that it was unimportant whether one used a formula based on power of body weight (the two-thirds power being an approximation of surface area) or a "linear formula" involving both height and weight, in dealing with persons of average build. Concerning the

estimation of surface area in the overweight and the underweight individual, DuBois (1936) stated: "The linear formula seems to be the only one that can be applied with any degree of accuracy to people of widely differing form".

Although Rubner and Lusk (DuBois, 1936) demonstrated the general proportionality of basal heat production of all mammals to their surface area, more recent results in studying homeotherms from mice to cattle (Brody, 1945) have indicated that the metabolic rate per unit of surface area tends to increase with size. Brody (Ibid) found that metabolism was expressed more uniformly as the 0.73 power of body weight; fasting homeotherms averaged 70.5 calories of heat per kilogram^{0.73} per twenty-four hours. Kleiber (1947) suggested the 0.75 power of body weight and stated:

"At present there seems to be no sufficient reason against the intraspecific application of the three-fourths power rule of metabolic rate. Modulating factors for age and specific stature may be incorporated into prediction equations for human metabolic rate based on the three-fourths power rule".

Recently "lean body mass", the "fat-free body" or "active tissue mass" have been proposed as more appropriate physiological reference standards for basal metabolism (Behnke, 1952; Keys, et al., 1950; Keys and Brozek, 1953; Miller and Blyth, 1952). Methods for the assessment of the "fat-free body" by indirect estimates of body fat using

- 1) anthropometric data, including skinfold measurements and roentgenograms,
- 2) body density, 3) total body water, and 4) fat-soluble indicators have

been reviewed (Keys and Brozek, 1953). The percentage of body fat was found to increase with age, to be higher in women than in men, to be lower in the physically active than in the sedentary and to vary with body build.

In an investigation of the relative effects of the "fat-free body" and surface area as bases for expressing basal metabolism, Miller and Blyth (1952) reported no significant differences in the correlation coefficients between basal oxygen uptake and gross body weight, body surface or the fat-free body weight among a group of university students. Using similar subjects for a similar study, Keys and Brozek (1953) also reported no significant differences. When subjects with greater extremes of fatness were used, however, the Minnesota workers (Ibid) found the greatest constancy of basal metabolic rate when basal metabolism was referred to units of fat-free body mass or of active tissue. Apparent differences of basal metabolic rate in age and in sex were reduced markedly when rates were referred to the fat-free body determined by densitometric measurements. The mean percent of body weight as fat in "normal" women (93.3 to 97.2 percent of standard weight) was estimated as 26.5, 30.5, 34.5 and 38.5 for ages twenty-five, thirty-five, forty-five and fifty-five years, respectively; the determined percentages of fat content at the same ages in men were 13.1, 17.3, 21.6 and 25.9, respectively (Brozek, Pei Chen, Carlson and Brenczyk, 1953). A further study was made of the basal metabolism of one hundred and thirty-five clinically healthy young men who ranged in weight from 75.6 to 151.5 percent of standard average body weight. Although the basal metabolic rate per kilogram of gross weight decreased from underweight to overweight subjects, the differences largely disappeared when body weights were corrected for differences in fat as estimated from skinfolds or from body density. The authors stated: "Hence it appears that the intensity of the basal metabolism per unit mass of non-fat tissue in the body is not reduced with increasing obesity".

This conclusion is in agreement with that of earlier investigators who found no appreciable decrease in basal metabolic rate with increasing degrees of adiposity when metabolism was referred to surface area.

The question arises, however, whether the "fat-free body" or the fat-free body corrected by estimated extracellular fluid and bone mineral to "mass of active tissue" is yet the true physiological basis for comparisons of metabolic activities of tissue. Adipose tissue has been recognized as having some small but definite oxygen consumption (e.g. Wertheimer and Shapiro, 1948). Studies of Keys and Brozek (1953) have yielded data for estimating the composition of adipose tissue in obesity; they determined that the composition of the tissue mass gained by "normal, well-fed men" through forced overeating, was 62 percent pure fat, 24 percent cellular matter and 14 percent extracellular water, and, it was suggested, that the tissue lost in reduction of obese people might be similar. The physiological description of metabolically active tissue as the "fat-free body" assumes that all metabolism of adipose tissue is related to the percent "cellular matter". Yet a dynamic state of the fat of adipose tissue has been demonstrated (e.g. Schoenheimer, 1942).

The metabolic activity of fat is slower than that of non-fat tissues of the body; yet, as the amount of adipose tissue increases, the quantitative contribution of fat to total metabolic activity must also increase. If the quantitative contribution of fat to total metabolic activity is at all significant, then the amount of the metabolism of fat tissue would proportionately decrease that of non-fat tissue in any total metabolism measured. If total basal metabolism expressed on the bases of the "fat-free body" or the "active mass" is similar in the old and in the young

adult and in the obese and in the lean individual, as Keys and Brozek have indicated, then the metabolism of non-fat tissue in the aged and in the obese adult, who have a greater proportion of fat tissue, must be less than that in the young and in the lean adult. Similarly, one might have to conclude that a lower metabolic rate exists in women than in men.

That the metabolic rate of the "active mass" does alter in adults under certain physiological circumstances has been demonstrated. In 1950 Taylor and Keys reported that a decrease of oxygen consumption was observed during semi-starvation in young men. The metabolic rate during six months of semi-starvation decreased 31.2 percent per square meter of body surface, 19.3 percent per kilogram of body weight and 15.5 percent per kilogram of "active tissue". They concluded that 65 percent of the decrease in basal metabolic rate in starvation reflected the shrinkage of the metabolizing mass of tissue and that 35 percent should be ascribed to a decrease in the intensity of metabolism. Keys and Brozek (1953) reported experimental evidence indicating that in actively developing obesity the basal metabolic rate per unit of non-fat tissue increased. The metabolic picture in active tissue growth was likened to that in juvenile growth.

Kleiber and Cole (1950) reported differences in the metabolic rate per unit of estimated "active tissue" in two strains of rats significantly different in body size at 55 to 100 days of age. The average metabolic rate per rat was greater for the heavier strain but the mean metabolic rates per unit of weight, per unit of weight to the three-fourths power, and per unit of body surface were lower for the heavier strain. Metabolic studies of tissue slices of these two strains should

be interesting in view of previous findings by Kleiber (1947) that in vitro oxygen consumption per unit weight of liver slices of rats, rabbits and sheep decreased consistently with increasing size of the animal to almost the same extent as the metabolic rate of the animal.

Whether a quantitative difference in basal metabolic activity of metabolizing tissue exists among overweight, underweight and average weight individuals has not been finally defined. Evidence would indicate that if it exists, it must be relatively small. That the total basal energy expenditure does increase with increasing degrees of adiposity has been clearly established.

Specific Dynamic Action of Food

Reports of measurements of specific dynamic effects in underweight individuals are few. Wang, Streuse and Saunders (1924) observed high values of specific dynamic action of protein in thin subjects in contrast to low values in the obese. Mason (1927) reported six cases of under-nutrition in which the specific dynamic action showed various abnormalities that tended to disappear as the subjects approached their respective desirable weights. Strang and McClugage (1931) compared the total calorie increment for eight hours after a test meal of 40 grams of protein, 52 grams of carbohydrate and 26 grams of fat among obese, thin and control subjects. The mean eight-hour cumulative increment for the underweight subjects was 67 calories compared to cumulative mean increments of 58 calories for eight obese subjects and 51 calories for five control subjects. No measurements of specific dynamic effect were made in the Minnesota human starvation study; however, Keys, et al. (1950)

stated, "In starvation or severe undernutrition the basal metabolic rate is sharply diminished....Presumably there is also a proportional reduction in specific dynamic action".

DuBois (1936) reported that Jaquet and Svenson in 1900 were apparently the first to observe a diminished specific dynamic action in obesity. Diminished specific dynamic effects in obesity have been reported by others. Wang, Strouse and Saunders (1924) found lower heat production increments in obese subjects compared to those of average weight subjects after the administration of protein and relatively slight differences between the two groups after carbohydrate and fat. Kestner and co-workers (1926) reported on eighty-eight cases of "constitutional obesity"; seventy-eight had average basal metabolic rates but showed diminished specific dynamic effect while ten had depressed basal metabolic rates and showed apparently average specific dynamic effect. Masen (DuBois, 1936) reported ten cases of simple obesity in which the specific dynamic action of protein was depressed. Bernhardt (1930) found that the specific dynamic action in obesity was usually lower than average and later in appearance.

Several reports, on the other hand, have indicated that the obese show nothing unusual in their specific dynamic reactions. Lauter (1926) studied a large number of patients in Germany and found no significant difference between normal controls and obese patients studied for six to eight hours after a meal of 200 grams of beef. McClellan, Spencer, Falk and DuBois (DuBois, 1936) made twelve calorimeter experiments on four obese and three normal men after meals of 300 to 500 grams of lean meat. Considerable individual variation was observed; the average surplus heat

output for the obese was reported as 13 percent compared with 17 percent for average weight individuals. Twenty obese and twelve controls showed no essential difference in specific dynamic action, when based on total heat produced for five hours after test meals (Bowen, Griffith and Sly, 1934).

Variations which have been reported may be due in part to differences in the interpretation of data and the length of time in which caloric responses were measured. Strang and McClugage (1931) demonstrated the fallacy of expressing specific dynamic effects as a percent of basal calories rather than as specific calorie increments above a base line with the following example: a ten calorie increase represents a 16 percent increase over basal to an individual with a sixty calorie per hour basal, whereas a ten calorie increase represents only an 11 percent increase to an individual with a ninety calorie per hour basal. Since obese individuals produce more basal heat, their response to a test diet appears low on a percentage basis. Similarly, heat increment data expressed per square meter of surface area can be misleading.

Strang and McClugage (Ibid) emphasized the hourly irregularities observed for their subjects and agreed with Benedict and Carpenter (1918) that the truest evaluation of dynamic effect was gained by measurement of the total increment. Few investigators, however, have been able to continue measurements throughout the duration of dynamic effect, which may last twelve hours or more. Recently Mitchell (1952) has reaffirmed the importance of the measurement of total heat increment by stating that a difference between endomorphy and ectomorphy may rest not so much in peak but rather in total dynamic effect.

Individual variation in specific dynamic effect has occurred in all studies and has been a complicating factor in the interpretation of results. Newburgh (1944), in summarizing a number of studies, emphasized the inconsistent results found in humans of all body types. DuBois (1936) stated, "It is notoriously difficult to establish good curves showing the specific dynamic action of feed".

Because of the variations observed in studies of specific dynamic action and the relatively small increments measured in all subjects, the differences that have been found have been minimized with the argument that they were quantitatively too small to account for the gains or losses in weights of the overweight or the underweight individual. For example:

"The average normal increase for the day caused by feed is only about 6 percent of the total metabolism and if it were halved or abolished it would not account for the enormous discrepancies between the alleged food intake and weight changes reported by some observers", (DuBois, 1936).

This same thought has been reiterated by Newburgh (1942b; 1944; 1950). Yet it is possible that differences among individuals in the heat increment in response to feed may represent some significant qualitative difference in metabolic pattern of energy metabolism, even though it may not account quantitatively for gains or losses of weight.

Support for this hypothesis was provided by Forbes (1946b) who stated that measurements of specific dynamic action of nutrients based on heat production above fasting level are without definite significance as measures of energy expense of nutrient utilization. Forbes and co-workers (Ibid), Brody (1945) and others have considered that in animals the heat production of fasting actually comprises a net energy or an energy expense of utilization exactly as does metabolizable energy of

food origin. A part of the energy value of nutrients fed to fasting animals is to spare the catabolism of body nutrients. Therefore the observed heat production is less than the true energy expense of utilization. Individual differences in metabolic pattern might result then in individual differences in the heat increment response measured after a given test meal.

Recent reports by Fenton and co-workers on differences in oxygen consumption in response to food intakes in two strains of mice are pertinent (Fenton and Carr, 1951; Fenton and Dowling, 1953; Lyon, Dowling and Fenton, 1953). In 1951 a marked strain difference in mice was noted in response to various amounts of fat in the diet. Two strains increased their rate of weight gain with increasing fat contents of the ration; two strains showed no further increases in rates of weight gain when the fat content was increased above 15 percent. In 1953 data were presented showing that both C₃H and C₅₇ strain mice would consume more calories when fed a 50 percent fat diet than when fed a 5 percent fat diet, both fed ad libitum.

"Mice of the C₅₇ strain responded to the increased caloric intake with increased oxygen consumption and thus presumably increased heat production. The C₃H strain showed no increase in oxygen uptake, a factor likely to contribute to the obesity so readily induced in this strain" (Lyon, Dowling and Fenton, 1953).

In discussing the current concepts of specific dynamic action which ascribe the extra heat incident to the utilization of food to intermediary chemical and physical processes, Brody (1945) summarized the following as factors which affect the heat increment: the balance of nutrients (absence of a limiting component); the general plane of nutrition (higher on high levels); the environmental temperature (less

in low temperatures); whether the nutrient is stored or otherwise usefully employed; muscular or other productive activity; and age. With respect to previous diet, DuBois (1936) observed:

"Under-nourished individuals or those who have for any cause diminished glycogen stores in the liver give curves that are quite different from those of well-nourished subjects who have previously been on a high carbohydrate diet. . . This fact has been overlooked in a great many studies of the specific dynamic action".

The measured dynamic effect of a nutrient is affected therefore by the nutrient combination in which it is metabolized and the method of disposition of absorbed nutrients by the individual as well as by the technique of measurement. Small differences in measured dynamic effects may have significance in evaluating qualitative differences in metabolic patterns in energy metabolism. The various factors influencing measured dynamic effects may mask any differences associated with different weight groups, however.

Respiratory Quotients

Attempts to evaluate the type of energy metabolism occurring at any time still center in determinations of respiratory quotients. A high respiratory quotient is interpreted as indicating a predominance of oxidation of carbohydrate; a low respiratory quotient is interpreted as indicating a predominance of oxidation of fat. Soskin and Levine (1952) discussed the composite nature of the measured respiratory quotient of intact animals or men and showed that the respiratory quotient of the whole body is a combination of different respiratory quotients which arise in the various organs and tissues; the respiratory quotients of the individual reactions may range from 0 to 8.0. The individual

respiratory quotients are derived from multiple interconversions of organic radicals as well as from purely catabolic oxidations; hence, the authors concluded that the total or average respiratory quotient could not represent merely the kind and amount of foodstuff being oxidized. Despite its inherent limitations as a quantitative index of the type of food that is being completely oxidized, the composite respiratory quotient can indicate the trend of the reactions which are occurring, a trend which has been called, "the final displacement in the carbohydrate balance and fat balance during metabolism" (Forbeck, 1938).

In 1925 Wang, Strouse and Saunders studied the qualitative aspects of energy production in the basal state and post-prandially in obese subjects and concluded from the higher than usual respiratory quotients observed after eating that the obese oxidized less fat than did people of average weight. In a review of these data, Hagedorn, Holten and Johansen (1927) questioned the interpretation of the investigators and assumed rather that the higher elevations represented a more rapid than usual rate of transformation of carbohydrate into fat. In their own study among thirty obese and fourteen control subjects large individual differences in fasting respiratory quotients were observed, but they also noted that the mean respiratory quotient in the obese was lower than that of their control subjects. Further, they observed a relation between the percentage overweight of their obese subjects and the respiratory quotient; the more overweight subjects had particularly low respiratory quotients. Forty single determinations of fasting respiratory quotients in normal subjects following two days on high carbohydrate intakes averaged 0.864 with 13 percent below 0.825; fifty-eight single

determinations on obese subjects under similar circumstances averaged 0.816 with 59 percent below 0.825. In a later report, Hagedorn (1928) made further observations on studies previously reported from his laboratory. In obese patients with a respiratory quotient below 0.825 the mean basal metabolic rate was ± 5 percent, whereas in the group with basal respiratory quotients above 0.825 the mean metabolic rate was ± 0.5 percent. He concluded that in obesity one is dealing with two factors, usually not found together: a difference in type and a difference in quantity of metabolism.

Strang and McClugage (1931) determined respiratory quotients as a part of a study of the specific dynamic action of food in abnormal states of nutrition. Fasting values obtained from seven obese patients ranged from 0.698 to 0.830, averaging 0.757, whereas values of controls ranged from 0.770 to 0.848, averaging 0.783. These same people were studied again after a test meal of 40 grams of protein, 26 grams of fat and 52 grams of carbohydrate; respiratory quotients were determined at the first, second, third, fourth, sixth and eighth hours. The average values obtained for the controls were 0.838, 0.810, 0.804, 0.823, 0.812, and 0.819 and for the obese were 0.746, 0.772, 0.752, 0.740, 0.761, and 0.795, respectively. It is difficult to state whether or not the fact that the obese subjects were all hospital patients who had been on a reducing regimen for varying periods of time might be a factor in the differences in responses observed. That previous high fat or high carbohydrate intakes influence fasting respiratory quotients has been observed by many. The influence of quantitative differences in the previous diet, which would also influence the quality of the metabolic mixture, was indicated by the data of Lyon, Dunlop and Stewart (1932). These investigators

also reported on obese subjects who were under treatment; the subjects were patients in the Royal Infirmary, Edinburgh. Data accumulated over many months showed that, whereas the basal metabolic rate was generally within normal limits, although somewhat lower than average, the respiratory quotients were usually low and often below 0.70. The average respiratory quotient of thirty-four determinations was 0.755 for subjects on 2,000 to 2,500 calorie diets; on 1,000 to 2,000 calorie diets, the respiratory quotients averaged 0.721. The authors interpreted the low respiratory quotients of their obese subjects as evidence of the formation of carbohydrate from fatty acids. There was no assumption that carbohydrate was not being oxidized, only that it was being produced at a more rapid rate than it was being oxidized. It was noted that ketonuria did not accompany the respiratory quotients observed below 0.70. When the respiratory quotient was determined for these subjects after a carbohydrate-containing meal (66 grams of protein, 38 grams of fat and 100 grams of carbohydrate), abnormally high respiratory quotients were not obtained; the respiratory quotients were greater than 0.70, however.

Since low post-absorptive respiratory quotients in obese subjects had been found by other workers, Bowen, Griffith and Sly (1934) investigated the "possibility that a qualitative metabolic variation exists in the obese person" by measuring the effect of a high fat meal on the respiratory quotient. A high fat meal was selected for their study, since in preliminary tests no differences were found in their subjects following protein and glucose ingestion; one of the first obese subjects to be studied, however, showed a consistent rise in respiratory quotient after a fat meal. Twelve control subjects, six of whom were slightly

underweight, and twenty non-diabetic obese subjects, averaging 81 percent overweight (56 - 169 percent), were fed a test meal containing 128 grams of fat immediately after the determination of fasting respiratory quotients. Fasting respiratory quotients ranged from 0.76 to 0.88, averaging 0.825, in the control subjects and ranged from 0.72 to 0.83, averaging 0.765, in the obese. The two groups showed no real difference in response during the six hours following the meal; in general, there was no change in the respiratory quotient at the first hour, a depression occurred from the second to the fifth hour and at the sixth hour there was a slight rise in value. The amount of fat fed was exceedingly large which might have obscured any possible differences in preferential use.

A report of respiratory quotients observed in the experimental hypothalamic obesity of rats (Brooks, 1946) compared the basal respiratory quotient during the dynamic and static phases of obesity:

"During the dynamic phase of obesity the ingestion of food or glucose solutions by the obese rats raised the respiratory quotient above unity. During the static phase the respiratory quotient responses to food and glucose ingestion were not essentially different from those of normal animals".

Basal respiratory quotients of hypothalamic obese animals, however, were not significantly different from those of normal controls. Similar results have been reported by Mayer (1952) in the hereditary-obesity syndrome of mice studied in his laboratory. Fasting respiratory quotients were normal whereas non-fasting respiratory quotients were higher than normal. The author interpreted these data as indicating an increased rate of lipogenesis.

The higher post-prandial respiratory quotients of animals in the dynamic phase of obesity were similar to those observed by Wang, Streuse

and Saunders (1925) in their obese human subjects. The post-prandial quotients of the obese subjects studied by Strang and McClugage (1931) did not show similar elevations. It is possible that there was a difference in the phase of obesity as all of the obese subjects of Strang and McClugage were patients undergoing weight reduction treatment. However, Bowen, et al. (1934) also reported no difference between control and obese subjects in respiratory quotients obtained following carbohydrate, protein or fat feeding.

There apparently have been few measurements of respiratory quotients in underweight individuals. Keys, et al. (1950) found that the respiratory quotients were not changed in the Minnesota semi-starvation experiment and ascribed the uniformity to the fact that components which were metabolized during restriction were similar to those being metabolized on a maintenance diet; the tissues supplied the supplementary portions of protein and fat. Fasting, on the other hand, had been found to result in decreases of the respiratory quotient toward 0.70 or below.

Interpretations of respiratory quotients are difficult because of the composite which they represent and the ability of the body to adapt to different metabolic mixtures. The difficulty of assessing correctly the actual metabolic picture from a measured respiratory quotient is illustrated by the following (Seskin and Levine, 1952): the complete oxidation of acetoacetic acid and certain amino acids yields theoretical respiratory quotients of 1.0, exactly as does the complete oxidation of glucose; and, a certain fatty acid which would yield a theoretical respiratory quotient of 0.693 upon being completely oxidized would also yield a respiratory quotient of 0.693 if it were first converted to carbohydrate and then oxidized.

Adaptation has been emphasized by a report from Gilmore and Samuels (1949) on the metabolic activity of isolated rat diaphragm. Following four weeks of forced feeding of high fat or high carbohydrate diets, the diaphragm muscles preferentially utilized the products of metabolism from the major type of feedstuff which had been fed, although the ability to utilize either type had not been abolished. That "preferential" or "retarded" catabolism of a feedstuff might be a factor in obesity was proposed by Brooks (1946) in explaining the retarded mobilization of fat found in hereditary obesity of yellow mice. Yet there was no question but that the obese mice could oxidize fat because loss of weight occurred during starvation. Adaptation in man has been suggested by Rabinowitch and co-workers (Rabinowitch and Smith, 1936; Corcoran and Rabinowitch, 1937) in reports of a brief study of the Canadian eastern arctic Eskimo. The low fasting respiratory quotients without evidence of ketonuria were attributed to an unusual metabolic mechanism adapted to the high fat diet usually consumed by these subjects. A possibly similar adaptation in man has been indicated by the data of Lyon, et al. (1932). It is interesting to contemplate the extent and degree of adaptation that may exist in the metabolism of feedstuffs in view of the general physiological adaptation mechanisms currently being elucidated by Selye and co-workers (1949) and others.

Lower fasting respiratory quotients would appear to be a metabolic pattern associated with obesity in man; post-prandial respiratory quotients may vary with different phases of obesity, dynamic or static, or with adaptation. Conflict in current evaluations of the qualitative

metabolism of the obese is illustrated by the following two quotations:

"Since both the quotients obtained during fasting and after the ingestion of food are lower in obese subjects (noting particularly the study of Strang and McClugage, 1931), we have before us classic evidence that such persons are metabolizing more fat than the normal controls. They cannot at the same time be storing more fat or withholding more of it in depots" (Newburgh, 1950);

and

"their study of respiratory quotients of normal and obese subjects in the post-absorptive period after a standard meal . . . (referring to studies of Hagedorn, Holten and Johansen, 1927) offer circumstantial support to . . . the . . . hypothesis that obesity in many cases might be due to an abnormally increased transformation of carbohydrate into fat which would also involve differences in S.D.A., since dietary carbohydrate transformed into fat could not contribute to the oxidative metabolism" (Mitchell, 1952).

Blood Patterns

Blood concentrations of glucose and fat have been determined in obese individuals primarily to investigate the possible roles of these factors in maintaining homeostatic mechanisms related to hunger and appetite. Similar investigations in underweight individuals have been limited. Few reports of concentrations of other blood constituents in relation to body weight have been found.

Blood Sugar Concentrations

Blood sugar concentrations are influenced by a variety of factors and caution in the interpretation of glucose tolerance values has been emphasized. Soskin and Levine (1952) stated the problem in general terms:

"The blood-sugar level represents a dynamic balance between the rate at which sugar is entering the blood stream from the liver and from any exogenous source and the rate at which it is being removed from the blood by the tissues of the body. Thus, a rise in the blood-sugar level may result either from an increased rate

of sugar supply or from a decreased rate of sugar utilization, or from both together. Conversely, a fall in the blood-sugar level may be due to decreased supply or increased utilization, or both. Nor is it possible to tell which factor is responsible from the mere change in blood-sugar unless one is controlled or eliminated while the other is observed⁸.

Endocrine regulation of blood sugar has long been apparent. The critical influences of the hormones of the pancreas, anterior pituitary and adrenal cortices have been reviewed (Conn, 1953).

Generally it is agreed that the effect of exercise on blood sugar values is slight when exercise is moderate; however, with strenuous exercise, even of short duration, the blood concentration is raised significantly (Rakestraw, 1921). The immediate rise in blood sugar in response to strenuous exercise with a subsequent decrease, sometimes to hypoglycemic values, is typical of the general course of blood sugar in response to all stress (Selye, 1949).

Orent-Keiles and Hallman (1949) have presented data showing highly significant seasonal differences in fasting blood sugar concentrations in nine women studied over a two year period. Although all of the figures were within generally accepted ranges of "normal", the fasting values were higher in the winter months than during the summer months. The authors' search of the literature revealed only two previous observations of such change. Their data indicate the need for caution in comparisons of fasting blood sugar values when there is an appreciable time lapse.

The previous diet pattern of an individual, particularly the carbohydrate intake, frequently has been reported to have a significant influence on the glucose tolerance which is measured; previous high carbohydrate intakes increase the tolerance of an individual to a given

carbohydrate intake. These effects have been reviewed and restated by Beaudeau, Van Itallie and Mayer (1953). Previous self-selected diets had no significant influence on fasting glucose concentrations in young adults, however (Addison, Tuttle, Daum and Larsen, 1953).

The protein composition of the test meal has been found to have an important influence on glucose tolerance. Investigators at the University of Iowa (Ibid; Coleman, Tuttle and Daum, 1953) and Orent-Keiles and Hallman (1949) have presented conclusive evidence that increased amounts of protein in a test meal delay significantly the rate of fall of blood sugar concentrations after initial peak values are reached. These studies emphasize the fallacy of comparing carbohydrate curves determined in different laboratories following test meals in which the protein content of the diet is varied, even though the carbohydrate and fat contents might be similar.

The influence of age on glucose tolerance response has been reported by Schneeberg and Finestone (1952). They found that normal subjects over forty years of age had a decreased tolerance to intravenous glucose as compared to subjects sixteen to thirty-nine years of age. Liver dysfunction, deficient stores of available liver glycogen or a previously low carbohydrate diet were eliminated as causes. As several older subjects tolerated glucose well, however, the authors questioned "whether the older subjects' mean might not have been heavily weighted with potential diabetics". Increasing fasting sugar values with increasing age in children have been reported (Mayer, 1951); gradual but not linear increases from a mean of 77 milligrams per 100 milliliters of blood at two years to 92 milligrams per 100 milliliters of blood at fifteen years were found in a study of 700 children.

The influence of obesity on glucose tolerance test responses has been observed for many years; past findings have been summarized by Beaudoin, Van Itallie and Mayer (1953). The documentation of evidence for a decreased carbohydrate tolerance associated with obesity in middle age is large. Results of studies of glucose tolerance in obesity at all ages, however, have not been consistent. Beaudoin, et al. (1953) suggested that the inconsistency of findings may be due in part to a lack of differentiation between "active" and "static" obesity. The authors subjected the data of Despisch and Hasenohrl, 1927, Ogilvie, 1935 and Godlawski, 1946, who had reported no consistent abnormality in the obese but who had noted tendencies to secondary hypoglycemia, to a re-evaluation. A significant correlation between the activity and the duration of obesity and increased tolerance to glucose was found. In early obesity glucose tolerance curves were lower or displayed a more frequent tendency to drop to hypoglycemic values than did those of non-obese subjects or persons with arrested or long-standing obesity. From these results and from a more recent study Beaudoin and co-workers (Ibid) postulated that there is a metabolic disorder in "active" obesity which has two mechanisms: 1) increased lipogenesis and 2) decreased oxidation of fat with a proportionally increased oxidation of glucose. Obese women and controls of the same sex and approximate height and age were matched and the obese subjects, whose weights ranged from 18 to 84 percent above "desirable" weight, were divided into "active" or "static" groups depending on their weight history. The controls ranged in weight from +3 to -18 percent of "desirable" weight. Previous diet patterns of the obese and the controls were similar. Blood glucose concentrations were determined at fasting

and at fifteen minute intervals for one hour following a self-selected noon meal on one day and following the ingestion of 50 grams of glucose on another. For the one hour period in which determinations were made the six "active" obese subjects displayed a markedly increased average tolerance both to the meal and to the glucose in comparison with the controls; the "static" obese showed a normal or decreased tolerance. Considerable individual variation did occur, however. The results agreed with findings of Mayer, Bates and Van Itallie (1952) on experimental animals in which increased carbohydrate tolerance occurred while weight was accumulating in animals with lesions of the hypothalamus; after obesity was established, the animals displayed normal or decreased carbohydrate tolerance.

Blood Lipids

Blood lipid patterns have been investigated widely but their relations to abnormal states are not well defined. Blood lipids present a more complex picture than that of blood sugar because of the many constituents composing "total blood lipids" and because of the wide range of values found in apparently healthy individuals. Peters and Van Slyke (1946) reviewed the literature on fasting values of blood lipid constituents, which occur mainly as cholesterol, both free and esterified, phospholipids, neutral fat and free fatty acids, and concluded that the range of concentration of any one constituent was wide though the variability of a single constituent in any one individual was relatively limited. They further observed that "a proper balance between the lipids appears to be more sedulously protected. . . . than the absolute concentration of any one or all of the lipid components". In healthy people the ratio of

cholesterol to lipid phosphorus was more constant than the absolute concentration of either of the individual fractions; free and ester cholesterol were even more closely related; however, neutral fat was comparatively independent of other blood constituents.

The variations in fasting concentrations of lipid constituents among individuals was illustrated by data reported by Wilmot and Swank (1952). Eight women and six men, consuming their usual diets, were studied weekly over periods ranging from four to twelve weeks. The plasma lipid fractions and reported ranges and mean values in milligrams per 100 milliliters were as follows: phospholipids, 177 - 268 (214); total cholesterol, 112 - 241 (188); free cholesterol, 43 - 82 (59); cholesterol esters, 68 - 169 (129); neutral fat, 37 - 157 (107); and total lipids, 477 - 722 (591). Phospholipids, cholesterol fractions and total fatty acids were determined; neutral fat and total lipid values were calculated.

Lesser degrees of variation in concentrations of single blood lipid constituents for individual subjects were reported by Man and Gildea (1937). In a study of changes of blood cholesterol, lipid phosphorus and fatty acids in four healthy men and six healthy women for time intervals of three months to four years, the extreme ranges of deviation from the mean for a single individual were 31 percent, 23 percent and 37 percent, respectively. The changes were not related to hemoconcentration, slight changes in weight, season of the year, or, in women, to the menstrual cycle. Further evidence of variations of serum cholesterol values was obtained from serial determinations in nineteen healthy young women during a period of 196 to 413 days (Wagner and Poindexter, 1952). The differences from high to low values for individual subjects ranged from 13 to 60 milligrams per 100 milliliters.

Cyclic variations of various lipid fractions have been observed by several workers, but the significance of the changes is questionable. Wilmot and Swank (1952) commented on a cyclic variation in neutral fat values which seemed to be independent of the diet or other apparent influences; cyclic variations of phospholipids and cholesterol to lesser degrees were also observed. Changes of plasma lipids related to the menstrual cycle have been reviewed and evidence of regular cyclic variations of cholesterol esters and phospholipids have been presented by Oliver and Boyd (1953). These authors reported fluctuations of cholesterol esters from -10 to +8 percent and of phospholipids from +4 to -5 percent of the twenty-eight day means. Other investigators have agreed that regular menstrual cycle changes occur, though the timing and degree of variations have differed.

Aging as a factor affecting individual variations in lipid fraction concentrations has been studied. In 1953 Man and Peters reported on variations of serum total fatty acids, lipid phosphorus and cholesterol of seven men and nine women re-measured after ten to twenty years, the ages of the subjects having changed from an original range of 20 to 48 years to a final range of 30 to 65 years. They found no consistency in the direction of change of any of the components measured, although the concentrations increased more often than they decreased. These results were similar to the conclusions of Sperry and Webb (1950), who reported that an increase in serum cholesterol concentration was not "an obligatory concomitant of aging". Comparing serum concentrations in fourteen men and eight women after a thirteen to fifteen year interval, Sperry and Webb (Ibid) found no change in eight men and one woman and increases of

15 to 30 percent in six men and six women. Kornerup (1950), on the other hand, reported observations of concentrations of cholesterol, total fat and phospholipids in the serum of "normal" adults and observed a tendency for higher serum lipid values in females than males, in the elderly than in the young and in the pyknic than in the leptosomatic types. He stated, however: "That elderly normal subjects present higher serum lipids than young normal subjects may possibly be due to the presence of latent characteristic morbid alterations in pyknic subjects of this age group".

Changes in the physical form of serum lipids with age have been observed. Serum lipoproteins of the S_f10-20 class were found to be significantly higher in males from twenty to forty years of age than in females of the same age group (Gofman, et al., 1950). More recently this same class of lipoproteins, S_f12-20 (previously included with S_f10-20), was found to increase in air force flying personnel with increasing age; interestingly, the standard deviations also increased with progressive age groups. The reported means and standard deviations for the three age groups were: 20 to 25 years, 20 ± 17 , 30 to 35 years, 31 ± 19 , and 40 to 45 years, 40 ± 27 milligrams per 100 milliliters of serum (Milch, et al., 1952).

The relation of overweight and underweight states to blood lipid patterns has not been well defined. In 1936 Hetényi reported total blood lipid values for obese and control subjects under their usual dietary regime; total lipids averaged 890 milligrams per 100 milliliters of serum for the obese and 591 milligrams per 100 milliliters of serum for the controls, although the ranges for both groups were wide. In 1937 Man and Gildea observed that lipid values were usually higher for healthy men of

pyknic build than for men of the leptosomatic type; no similar correlation was found for women subjects. Peters and Van Slyke (1946) in reviewing the data available stated: "The simple state of obesity, like the state of leanness, in humans appears to be associated with no abnormal patterns of serum lipids". Kornerup (1950) again, however, observed a tendency for higher serum lipid values in pyknic than in leptosomatic individuals.

Man and Gildea (1937) were the first to observe that wasting diseases and malnutrition resulted in lowered cholesterol and phospholipid values; values increased as nutrition was improved. Neutral fat on the other hand responded less regularly. Keys (1953) observed that serum cholesterol was decreased in severe caloric undernutrition at all ages but was high in starvation.

In active weight gain serum cholesterol was reported to increase, an increase which was not dependent upon the addition of fat to the diet (Keys, 1953). No significant correlation of degree of obesity with serum cholesterol was found, however (Ibid). Similarly serum lipoproteins of the S_f10-20 class have been reported to increase in active caloric over-nutrition (Anderson, Lawler, Lowen and Keys, 1952), although the correlation with weight gain was not as significant as was that of the elevated cholesterol values. Walker and co-workers (1953) have reported the effect of weight reduction and caloric balance on the serum lipoprotein and cholesterol levels. It was observed by these investigators that serum lipid fractions tended to fall during negative caloric balance and to rise when the balance was positive only if the S_f12-20 class of lipoproteins initially measured 50 milligrams per 100 milliliters of serum or more; with lower initial lipoprotein concentrations, no correlation with weight change was found.

Direct correlations of concentrations of several lipoprotein classes with weight have been reported. Gofman and Jones (1952) found that $S_f35-100$ concentrations were significantly associated with weight in 241 normal males; S_f12-20 concentrations were less closely associated. In 1952 Walker and co-workers reported a progressive increase of S_f12-20 concentrations with increasing degrees of overweight in one thousand subjects from thirty to sixty years of age; the increment was greater in males than in females.

Measurements of total lipids in obese and control subjects early led to postulation of increased "lipophilia" as a metabolic characteristic of the obese (Bergman, in Dorland, 1948). Lipophilia was defined as an "affinity for fat" (Ibid) and the term has been used to indicate a special tendency to deposit fat as well as a resistance against the mobilization of fat from adipose tissue (Bauer, 1941). The work of Hetényi has been cited frequently as evidence to support the concept of abnormal lipophilia in obese individuals. Hetényi (1936) studied blood lipid concentrations in obese and normal subjects under their usual dietary regime and again after eight days of restricted diet. Total blood lipid values on usual diets averaged 890 milligrams per 100 milliliters (range, 544-1117) for the obese and 591 milligrams per 100 milliliters (range, 371-1005) for the controls. After caloric restriction, the blood values averaged 630 milligrams per 100 milliliters (range, 446-802) and 605 milligrams per 100 milliliters (range, 414-897), respectively. Hetényi interpreted the lowering of blood lipid values in the obese as evidence of difficulty in releasing fat from adipose tissues. Blood fat values were also determined at intervals after feeding 200 milliliters of cream. The average maximum

increase of blood fat values of the controls was 84 percent above fasting concentrations, whereas maximum increases in the obese averaged only 17 percent above fasting; wide individual variations were, however, observed. Further, the production of artificial fever in five "normal" and seven obese subjects resulted in blood fat increases of 15 to 36 percent for the controls but no more than 11 percent in the obese. Finally, 50 milliliters of olive oil were injected subcutaneously into six obese and five control subjects and blood lipids were determined at two, four and six hours thereafter. Blood fat values increased as much as 10 to 48 percent for the controls but only 1 to 8 percent for the obese. Wilder and Wilbur (1938) in reviewing Hetényi's experiments commented that the observations indicated that mobilization of fat from fat depots was resisted in obesity and that deposition was accelerated. They stated: "The slightly greater than normal withdrawal of fat from the circulation postprandially could explain the delayed sense of satiety encountered in obese people and also the frequently abnormal taste for carbohydrate". Pennington (1953a) endorsed the view of Wilder and stressed the conformity of the lipophilia theory with the current concept of the dynamic state of adipose tissue in that the lipophilia theory presumes "active regulation of the size of adipose deposits, rather than mere passive response of these tissues to balance between caloric intake and output".

In contrast to these views Newburgh (1944; 1950) has interpreted the data of Hetényi as indicating more rapid oxidation of fat rather than as evidence supporting difficulty in the release of fat from adipose tissues. He attacked the lipophilia theory on the basis that, if it were true that the obese had an abnormal resistance to mobilization of fat, loss of

weight in the obese should be accompanied by increased urinary nitrogen. He stated that a variety of studies did not indicate that urinary excretion of nitrogen was increased during weight loss of the obese and presented original data of three control and three obese women on restricted caloric intakes. Weight loss and urinary nitrogen were measured for successive one-week periods on unrestricted diet and diets providing 80, 60, 40, and 20 percent of basal energy needs, respectively. Weight losses were close to predicted losses and only negligible losses of urinary nitrogen were observed; the obese showed slightly better nitrogen balances than the control subjects. However, decreased nitrogen retentions during weight reduction of young women have been reported by Brown, Herman and Ohlsen (1946), Brewer, et al. (1952) and Young (1952). Under conditions of severe restriction, Newman (Keys and Brozek, 1953) found an average total weight loss of 1.69 kilograms and a total nitrogen loss of 15 grams for ten soldiers who subsisted for nine days on 900 caloric rations.

Fat loading studies in which total serum lipid concentrations were measured at intervals following fat ingestions have shown individual variations in response; in general, there was some increase, although the amplitude and time of peak concentration depended upon the quantity of fat ingested (Peters and Van Slyke, 1946). In a comparison of ten young subjects (24.9 ± 5.2^1 years) and eleven older subjects (62.0 ± 6.2^1 years), the effect of a fat meal equivalent to one gram of fat per kilogram of body weight resulted in a higher mean rise in the older group and a greater number of delayed peaks (Herstein, Wang and Adlersberg, 1953). Distinct

¹ Standard deviation

patterns were not evident, however; maximum values occurred at various intervals with no regularity.

A composite picture of changes in individual lipid fractions following fat-loading tests is difficult to obtain due to the relatively large amount of blood required for complete analyses. The number of such studies is few. Most studies of post-prandial blood lipid responses have determined the changes in concentration of individual lipid constituents. Wilmot (1950) reported that the feeding of a fat meal of two grams of butter per kilogram of body weight resulted in a rise in the neutral fat fraction which reached a peak in four to eight hours; phospholipids reached an indefinite peak in eight hours and there were inconsistent changes in the cholesterol fraction. When the amount of fat was varied from one-half to one or two grams of butterfat per kilogram, the phospholipids, neutral fat and chylomicrons increased with the amount of fat ingested; the cholesterol changes were so slight as to be of no consequence. Small and inconsistent changes in the cholesterol fraction following the feeding of varying types and amounts of fat to control subjects have been reported by others (Rony and Levy, 1929; Blotner, 1935; Corcoran and Rabinowitch, 1937; Frazer and Stewart, 1937; Oppenheimer, et al., 1943; Peters and Van Slyke, 1946). In studies in which the responses of obese and control subjects have been compared, Oppenheimer and co-workers (1943) and Rony and Levy (1929) found no differences between the two groups; Blotner (1935), on the other hand, reported a marked rise in blood cholesterol in his obese subjects following the feeding of 500 milliliters of 20 percent cream but no increases among his control subjects.

A general increase in the concentration of blood phospholipids following fat feeding has been reported (Peters and Van Slyke, 1946); no comparisons of responses of obese and non-obese subjects were found.

The blood fraction most commonly determined by chemical methods after fat feeding is total fatty acids because the greater part of the post-prandial blood fat concentration has been found to be due to increased neutral fat concentrations (Peters and Van Slyke, 1946). Comparisons of increases of total fatty acid concentration between obese and non-obese subjects following fat feeding have been limited. In 1929 Rony and Levy reported fat tolerances in eight control and eighteen obese subjects following the ingestion of one pint of 20 percent cream plus five hundred milliliters of water. All of the control subjects showed some rise of total fatty acid concentrations to peak concentrations at three to five hours after the feeding; increases in concentration ranged from 12 to 30 percent above fasting. On the other hand, total fatty acid concentrations in some obese subjects remained near fasting values or decreased during the seven hour period after fat feeding. In others there were sharp increases to concentrations as high as 60 percent above fasting values. The authors commented on the "high fat tolerance" and "low fat tolerance" as well as the "normal fat tolerance" observed in obese subjects. The "high fat tolerance" response of some of the obese subjects was similar to the lower total fat concentration increases in obese subjects as compared to controls reported by Hetényi (1936).

Chylomicrons, a particular physical form of blood fat, have been studied in response to fat feeding. Blood lipids, like blood glucose, represent a balance between the absorption and formation of lipids and

their deposition, transformation and dissimilation. Since Gage and Fish (1924) first carried out their investigations relating chylomicrons of the blood to fat absorption, counts of the concentration of these particles have been an aid in clarifying problems of fat absorption and metabolism. A resumé of the development of chylomicron counts has been published (Frailing and Owen, 1951). The chylomicrons are largely neutral fat with a layer of protein at the interface; they contain, however, only a relatively small fraction of the total neutral fat of the plasma (Van Eck, Peters and Man, 1952; Elkes, Frazer and Stewart, 1939; Wilmot, 1950). Details of their composition as 80 to 85 percent tri-glycerides and 15 to 20 percent sterol esters, free sterols and substances with properties of unsaturated complex hydrocarbons have been reported (Marder, Becker, Maizil and Necheles, 1952). Eighty percent of the sterol was found to resemble cholesterol with sixty-five percent in the ester form. No free lecithin, cephalin or sphingomyelin was reported.

Fasting chylomicron concentrations have been found to be influenced by the time interval since the last meal and its composition (Frazer and Stewart, 1936a). Wilmot (1950) further indicated that previous diet influenced the speed at which fat was removed from the blood after a fat meal; a previous high fat diet resulted in an increased tolerance to fat.

Values for chylomicron concentrations following test fat meals have shown different patterns in older as compared to younger subjects. Necheles and co-workers (Becker, Meyer and Necheles, 1949; 1950; Marder, et al., 1952) interpreted their results as representing a definite delay in the rate of absorption and a difference in particle-size of transport of fat in aged compared to young subjects. Activity and exertion have

been reported to affect the chylomicrographs obtained in fat tolerance tests; chylomicron concentrations were increased (Marder, et al., 1952; White, Ralston and Carne, 1951). Smoking increased and prolonged the chylomicron curve of young individuals, resulting in a marked increase and a shift of maximum concentration to the right (Marder, et al., 1952).

Frazer and Stewart (1939) stated that obese subjects showed a higher maximum chylomicron concentration than did thin persons after a standard meal, although detailed data were not published; normal individuals had intermediate concentrations. Frazer and Stewart suggested that more lipolysis occurred in thin subjects and stated:

"In accordance with the partition theory of fat absorption there is less lipolysis in the fat subject and therefore more fat passes into the systemic blood to be deposited in the fat depots. In the thin person more fat passes to the liver by the portal vein and less is stored".

Considerable differences in fat tolerance, measured by chylomicron counts, in "normal" subjects were observed by Mereten (1950), but it is noted that his classification of "normal" was only in contrast to atherosclerotic subjects. Tests at six months intervals in his study revealed that an individual tended to remain constant in his chylomicrograph pattern.

Peters and Van Slyke (1946) stated, in summarizing their discussion of studies of fat feeding, "Evidently, it is not the amount of fat metabolized per se that determines the concentration of lipid in serum but more subtle circumstances of its metabolism which are as yet ill-defined". Studies since 1946 have not yet defined these circumstances.

Blood Pyruvic Acid

Increased understanding of the pathways of intermediary metabolism of carbohydrates, fats and amino acids has emphasized the importance of the oxidation of pyruvic acid in the catabolism of carbohydrates and certain amino acids and in the anabolism of fatty acids. The determinations of blood pyruvic acid concentrations and the blood lactate-pyruvate relationship have been used as indications of disorder in a variety of metabolic anomalies (Bueding, Stein and Wertis, 1941; Goldsmith, 1948).

Determined fasting blood pyruvic acid concentrations in control subjects have approximated 1.0 milligram per 100 milliliters of blood. Concentrations above 1.3 milligrams per 100 milliliters of blood were considered abnormal by Bueding and co-workers (1941) and Goldsmith (1948), but fasting concentrations determined in 220 individuals from sixteen to above eighty years of age ranged from 0.2 to 2.8 milligrams per 100 milliliters of blood (Kirk and Chieffi, 1949). In thiamine, riboflavin and niacin deficiencies, fasting blood pyruvic acid concentrations up to 2.0 milligrams per 100 milliliters were reported (Bueding, et al., 1941; Goldsmith, 1948); increased blood pyruvic acid concentrations were significantly associated with decreased blood thiamine concentrations in four subjects on thiamine restricted intakes (Hawthorne, Wu and Storvick, 1953). Blood pyruvic acid concentrations have not been found significantly changed with aging (Kirk and Chieffi, 1949).

Following the ingestion of glucose by control subjects, blood pyruvic acid increased to maximum concentrations at one to two hours and returned to fasting values within three to four hours (Bueding, et al., 1941; Goldsmith, 1948). Food, exercise and anoxia were the most important

factors influencing the concentrations of pyruvic acid in the blood of normal persons (Friedemann, Haugen and Kmiecik, 1945; Goldsmith, 1948).

Specific studies of pyruvic acid values in human obesity and leanness were not found in the literature. Meyer and Winkler (1952) reported the behavior of pyruvic acid in different types of endocrine disturbances in which they included adiposity, loss of weight, diabetes and others. In nineteen of the thirty-eight cases studied, the fasting blood pyruvic acid concentration was higher than normal and in twelve of these the concentration rose in an abnormal fashion following the ingestion of sugar. One case showed a lower fasting concentration and no rise following the sugar ingestion. The authors found no close correlation between the type of endocrine disturbance and the slope of the curves.

Pyruvic acid was observed to be depressed in obese mice of the hereditary obesity-diabetes syndrome strain (Guggenheim and Mayer, 1952) but to a lesser extent than in alloxan-diabetic non-obese mice. A metabolic defect in the utilization of pyruvic acid has been postulated to occur in some individuals and by its stimulation of fatty acid synthesis to be a primary defect contributing to obesity (Stadie, 1940; Pennington, 1953a). If this is true, one would expect to find higher than normal blood values in the obese similar to those found in thiamine-deficient individuals, particularly following the ingestion of carbohydrates.

Blood Ketones

Both higher and lower blood concentrations of ketone substances in obese compared to control subjects have been found following various test procedures (Bretano, 1933 in Bauer, 1941; Keeney, Sherrill and MacKay, 1936).

Ketone concentrations increased more slowly in obese subjects than in controls when carbohydrate was eliminated from the diet. After a carbohydrate-free diet, the ingestion of olive oil caused a greater increase in the concentration of ketone substances in the blood of obese subjects than in that of controls. Prolonged hyperventilation resulting in alkalosis raised the concentration of ketone bodies in the blood of control subjects but had no effect on blood ketone concentrations in the obese. These results were interpreted as substantiating the existence of lower glycogen reserves and the stability of fat deposits in the obese (Bauer, 1941).

Urinary Patterns of the Obese and Lean

In 1951, as part of an exploratory study of individual metabolic patterns and human disease, Brown and Beerstecher (1951) investigated a group of seven overweight and ten underweight men, ranging in age from twenty to thirty-one years. These subjects showed a decided tendency to be either overweight or underweight and experienced great difficulty in trying to alter their weights toward normal. They exhibited no other abnormalities according to the authors. Three complete morning samples of urine were collected at intervals of three to five days; no attempt was made to control the diets of the subjects. Previous studies by this group and co-workers had indicated that a study of urinary constituents was of value in observing individual metabolic differences; paper chromatographic methods were used. Of a large group of metabolic factors which were measured, the following showed significant differences between the overweight and underweight subjects: modified creatinine coefficient and pigment to creatinine ratios were higher in the underweight group; and

urinary phosphate and calcium excretions were significantly higher in the overweight group.

The urinary concentrations of ketone substances following low carbohydrate intakes have been lower among overweight subjects than among average weight subjects according to several investigators (DuBois, 1936; Corcoran and Rabinowitch, 1937; Bauer, 1941). Unpublished data from this laboratory likewise confirm the absence of ketonuria among overweight subjects on a low-carbohydrate reducing diet (Brewer, 1952). Similarly the absence of ketonuria in obese subjects on sub-maintenance diets, even when respiratory quotients were below 0.70, was observed (Lyon, Dunlop and Stewart, 1932). Average weight subjects who were fasting or who were on very low carbohydrate diets usually excreted ketone bodies when the respiratory quotient was less than 0.76 (DuBois, 1936).

On the other hand Brown and Beerstecher (1951) found that ketone concentrations in the urine were similar among overweight and underweight subjects on their usual dietary patterns. MacKay and Sherrill (1937) found that certain of their obese subjects excreted appreciably less ketone substances than control subjects, whereas others excreted as much and often greater amounts than average. On this basis they attempted to differentiate between the two groups of overweight subjects; they postulated that a metabolic disorder resulted in increased stability of fat deposits among the first group, whereas the latter group were diagnosed as cases of simple "exogenous" obesity.

Creatinuria was more easily produced in obese than in average weight subjects by eliminating carbohydrate from the diet (Bauer, 1941). The increased creatinuria was attributed to glycogen mobilization in the

muscles and it was concluded that obese subjects had lower glycogen reserves in the liver than average weight subjects (Ibid).

Summary

Evidences of metabolic qualities associated with obesity or leanness which have been reported may be summarized as follows: 1) basal metabolic rates of the obese or the lean showed slight or no deviations from average when based on surface area or the "fat-free body", but there is some question whether the "fat-free body" is yet the true physiological description of all active metabolic tissue; 2) specific dynamic increments showed no consistent differences with differences in weights of subjects, but individual variations have indicated that various metabolic patterns exist, although it is uncertain whether or not they are related to body weight; 3) obese subjects had lower post-absorptive respiratory quotients but post-prandial measurements of respiratory quotients showed no consistent pattern; 4) glucose tolerance was decreased with obesity in middle-age, whereas increased tolerance with obesity in younger subjects, particularly in "active" obesity, was reported; 5) fasting total lipids, cholesterol and phospholipid concentrations showed no consistent pattern in either obesity or leanness, whereas significant positive correlations of the S_{f12-20} and $S_{f35-100}$ lipoprotein classes with weight were found; 6) greater lipolysis of dietary fat in thin subjects and greater post-prandial withdrawal of fat from the circulation by obese subjects were indicated; 7) blood concentrations of ketone substances increased more slowly than average following low carbohydrate feeding in obese subjects; 8) higher modified creatinine coefficients and pigment to creatinine

ratios were measured in underweights than in overweights; 9) higher urinary excretions of calcium and phosphorus were measured in overweights than in underweights; 10) lower than average ketone excretions in response to low carbohydrate feeding were frequently found in the obese; and 11) the significant association of a number of degenerative conditions with obesity was convincingly established.

THE INVESTIGATION

Experimental Procedure

Experimental Plan

This experiment was designed to investigate certain characteristics of the metabolic patterns of overweight, underweight and average weight women, both in the fasting state and following test meals of high fat and high carbohydrate composition. Each test meal was administered to each subject on a single day; the interval between experimental days was usually two weeks but ranged from four days to two and one-half months. Respiratory quotients and oxygen consumption were determined simultaneously with blood glucose, blood pyruvic acid, serum total lipid and serum chylomicron counts in the fasting state and at the first, third and fifth hours following the test meals. Quantitative urinalyses for total nitrogen and qualitative tests for albumin, sugar and acetone were also included at these same time intervals. In addition, blood glucose and serum chylomicron counts were determined at the one-half, second and fourth hours. Serum total cholesterol, certain classes of serum lipoproteins (S_{f12-20} , S_{f21-35} , and $S_{f35-100}$), serum alkaline phosphatase, serum total lipid and serum chylomicron counts were determined on fasting venous blood samples obtained on the same experimental days.

Hematocrits, white blood cell counts and differential counts were determined on non-fasting capillary blood on both experimental days for each subject; in addition, red blood cell counts and hemoglobin determinations were obtained for some subjects. A non-fasting resting blood

pressure measurement¹ was made and fasting body temperature and resting pulse were measured each day.

General medical histories, including body weight changes in adult life, menstrual history and personal and family histories of degenerative diseases, were procured for each subject. A recall diet record of the day immediately preceding each experimental day was recorded; in addition, a single random day's diet record and a diet history were obtained for each subject.

Subjects

Twenty-one women ranging in age from 25 to 57 years acted as subjects. The women were all active, either professionally or as homemakers; seven were married, six had had children. All were in general good health. The weights of the subjects ranged from +66 percent to -21 percent of "desirable weight" according to frame (Metropolitan Life Insurance Company, 1951); body builds were evaluated from anthropometric data. Measurements for each subject included height, weight, chest breadth, chest depth, breadth iliac crest, breadth great trochanter, right calf girth, right and left arm girths and right and left hand grips. In addition, an inspection of body fat pads was made. On the basis of the data, subjects were classified as having large, medium-large, medium, medium-small or small frames². Anthropometric data for the subjects are tabulated in Table I.

¹ Appreciation is expressed to Dr. Wilma Brewer for blood pressure measurements.

² Appreciation is expressed to Dr. Wilma Brewer for the anthropometric measurements and to Dr. Margaret Ohlson for evaluation of the data.

TABLE I

ANTHROPOMETRIC DATA AND EVALUATED BODY BUILDS OF SUBJECTS

Subject	Body Build	Height	Weight	Chest Breadth	Chest Depth
		cm.	kg.	cm.	cm.
RM	Large	167.75	112.0	30.8	23.6
SM	Large	167.75	106.4	31.4	26.5
HM	Large	161.5	82.2	24.3	22.5
HT	Medium-large	165.0	82.0	25.8	20.8
RT	Medium-large	164.0	76.2	25.4	21.5
MR	Large	162.0	76.4	25.4	20.4
YL	Large	163.5	77.5	27.5	21.9
GN	Medium	165.5	69.9	25.8	18.8
LP	Large	157.0	63.6	26.8	19.9
NH	Medium-large	168.0	67.1	24.7	19.2
RW	Medium	163.5	60.1	26.5	17.5
SL	Medium-small	162.5	53.5	24.2	16.9
NS	Medium-small	164.0	54.5	23.7	16.5
EN	Medium-small	173.0	57.7	26.2	16.6
RD	Small	167.5	52.5	24.5	19.2
NM	Medium	160.5	51.0	24.6	17.8
YK	Medium	168.0	54.8	25.2	14.7
RL	Small	165.5	49.8	22.2	16.3
RK	Medium	154.5	45.0	22.7	16.2
EL	Small	168.0	49.7	23.5	15.2
NL	Medium	160.0	46.0	24.6	16.5

TABLE I continued

Iliac Crest Breadth cm.	Great Trochanter Breadth cm.	Right Calf Girth cm.	Right Arm Girth cm.	Left Arm Girth cm.	Right Hand Grip kg.	Left Hand Grip kg.
36.2	40.4	44.0	37.5	36.5	45	43
35.5	41.5	40.0	34.0	34.5	30	36
32.2	35.2	40.5	32.0	32.0	35	31
31.5	34.2	37.5	34.0	35.0	30	22
31.5	33.5	37.0	31.3	32.0	32	33
31.6	34.2	41.0	33.0	34.0	26	32
32.5	35.9	40.0	32.0	32.0	38	32
30.3	32.8	40.0	29.0	28.5	34	20
29.1	34.1	38.0	31.9	30.6	40	35
31.2	34.9	35.0	30.5	30.5	32	22
27.9	31.1	35.0	27.1	26.5	35	25
24.8	30.2	36.0	24.5	24.5	34	32
27.3	29.7	32.5	25.0	24.5	28	29
27.8	30.2	35.0	25.3	25.0	30	32
27.5	29.4	35.5	24.0	23.0	23	20
26.2	31.0	33.0	25.0	24.5	53	48
28.2	32.3	30.5	24.5	24.5	25	25
27.4	32.2	31.5	22.2	22.0	32	32
23.4	28.2	34.5	23.0	22.5	25	28
27.6	31.7	33.0	24.0	22.5	35	30
26.8	31.0	28.0	22.0	22.0	30	26

Using the Metropolitan Life Insurance Company table, "Desirable weights for women - weight in pounds according to frame" (1951), the desirable weight for each subject was determined and the percent deviation of the actual weight from the desirable weight was calculated. It was recognized that body density of skin fold measurements result in more exact appraisals of degrees of fatness or leanness but facilities for these measurements were not available. The subjects were grouped into three classes: overweight class, greater than 15 percent above desirable weight; average weight class, within ± 15 to -10 percent of desirable weight; and underweight class, more than 10 percent below desirable weight. There were seven women in each group; overweight subjects ranged from ± 21 to ± 66 percent (average, ± 35.5 percent), average weight subjects ranged from ± 13 to -10 percent (average, -0.5 percent), and underweight subjects ranged from -12 to -21 percent (average, -15.5 percent) of desirable weight.

The subjects were further classified as to whether their body weight pattern was in an "active" or "static" state on the basis of the medical histories. The classifications were adapted from those of "active" and "static" obesity used by Beaudoin, Van Itallie and Mayer (1953). An "active" state was defined as existing when the subject was a) gaining or losing appreciable amounts of weight at the time the study was performed or b) if the obesity or leanness was of relatively recent onset regardless of whether strict dietary treatment had interrupted the progress of weight change. A "static" state was defined as a long-established weight pattern. On this basis all but three subjects were determined to be "static" in their body weight patterns; two overweight subjects and one underweight subject were adjudged to be in "active" states.

The age, height and weight data of the subjects are presented in Table II. Sixteen of the subjects were from 25 to 45 years of age; five were between 50 and 57 years. Among the five women above 50 years two were in the overweight class, one in the average weight class and two in the underweight class. The mean ages of each group were similar, 39.7 ± 4.7^1 , 36.1 ± 3.3 and 36.4 ± 4.2 years, respectively. The average heights of the three groups also were similar: 164.5 ± 1.0 , 164.8 ± 1.9 and 163.4 ± 2.0 centimeters for the overweight, average weight and underweight groups, respectively. The average weights in kilograms for the groups in the same order were: 87.5 ± 5.7 , 60.9 ± 2.4 and 49.8 ± 1.3 . The differences in age and height among the three groups were not significant by analysis of variance. The differences in weight, as would be expected, were highly significant.

Test Meals

The test meals were designed to provide a high proportion of either carbohydrate or fat calories from common food sources. Data on the composition of the test meals are presented in Table III. In the high fat test meal 70 percent of the calories were obtained from fat, 25.0 percent from carbohydrate, and 5.0 percent from protein. In the high carbohydrate meal the relative proportions of the calories were 94.5 percent from carbohydrate, 0.5 percent from fat and 5.0 percent from protein. Fluid intake was maintained constant for both meals. The same brand of bread, orange juice, jelly and butter were used throughout.

¹ Standard error of the mean.

TABLE II
THE AGES, HEIGHTS AND WEIGHTS OF SUBJECTS CLASSIFIED
ACCORDING TO BODY WEIGHT

Weight Class	Subject	Age	Height cm.	Weight kg.	% Deviation from Desirable Weight	Weight Status
Overweight class	RM	39	167.75	112.0	+66	Static
	SM	53	167.75	106.4	+58	Static
	HM	30	161.5	82.2	+31	Static
	HT	45	165.0	82.0	+29	Active
	RT	57	164.0	76.2	+22	Static
	MR	29	162.0	76.4	+22	Static
	YL	25	163.5	77.5	+21	Active
Mean		39.7	164.5	87.5	+35.5	
Standard error		4.7	1.0	5.7		
Average weight class	GN	38	165.5	69.9	+13	Static
	LP	40	157.0	63.6	+ 6	Static
	NH	52	168.0	67.1	+ 2.5	Static
	RW	37	163.5	60.1	- 0.5	Static
	SL	25	162.5	53.5	- 7	Static
	NS	29	164.0	54.5	- 7	Static
	EN	32	173.0	57.7	-10	Static
Mean		36.1	164.8	60.9	- 0.5	
Standard error		3.3	1.9	2.4		
Underweight class	RD	51	167.5	52.5	-12	Static
	NM	40	160.5	51.0	-13	Static
	YK	51	168.0	54.8	-14	Active
	RL	34	165.5	49.8	-15	Static
	RK	25	154.5	45.0	-17	Static
	EL	27	168.0	49.7	-17	Static
	NL	27	160.0	46.0	-21	Static
Mean		36.4	163.4	49.8	-15.5	
Standard error		4.2	2.0	1.3		

TABLE III
COMPOSITION OF TEST MEALS¹

Test Meals	Calories	Fat gm.	Carbohydrate gm.	Protein gm.
<u>High fat test meal:</u>				
White bread, toasted, 2 slices, 50 gm.	137	1.6	26.	4.2
Butter, 38 gm.	279	30.8		0.2
Water, 100 gm.	0	0	0	0
Coffee, 1 cup ²	0	0	0	0
Totals	416	32.4	26.	4.4
% Total calories		70.	25.0	5.0
<u>High carbohydrate test meal:</u>				
White bread, toasted, 2 slices, 50 gm.	137	1.6	26.	4.2
Apple jelly, 86 gm.	216	0	56.	0.1
Orange juice, frozen, 40 gm. to 100 gm. with water	60	0	14.8	0.7
Coffee, 1 cup ²	0	0	0	0
Totals	413	1.6	96.9	5.0
% Total calories		0.5	94.5	5.0

¹Compositions by computation using U.S.D.A. Agriculture Handbook No. 8 (Watt and Merrill, 1950).

²Tea was substituted for subject HM; the subject had shown a previous intolerance for coffee.

Identical amounts were fed to all subjects. Although it was recognized that carbohydrate and fat tolerance feedings were frequently based on amounts related to body weight or surface area, it was felt that there was considerable question as to a true comparative basis in working with overweight and underweight subjects.

Experimental Methods

Collection of Samples and Experimental Data

Each woman was visited prior to her participation as an experimental subject and the general plan of procedure was explained. No attempt was made to regulate her dietary pattern prior to the experimental days except that each subject was requested to eat a dinner of low fat content and to consume no food after 7 P.M. on the day immediately preceding an experimental day. She was requested to obtain at least eight hours of sleep and rest the night before coming to the laboratory. She was asked to arise on the experimental day in sufficient time that she could be leisurely concerning necessary morning activity. It was requested that the bladder be emptied on arising and that one glass of water be drunk. The subject came to the laboratory at 7 A.M. in a post-absorptive state.

As soon as the subject arrived at the laboratory, she was weighed with minimum clothing, her height measured, and then she lay down to rest for thirty to forty-five minutes. Fasting body temperature was measured just prior to the collection of the first basal sample of expired air. When the subject appeared to have relaxed completely, duplicate basal expiratory air samples of six minutes duration each were measured and

collected using a Kofranyi-Michaelis respirometer¹. Six-tenths percent aliquots of the expired air were collected into a rubber bladder and immediately at the end of the collecting period were transferred to Bailey gas-sampling bottles² for storage under mercury until analyzed. Resting pulse rates and respiration rates were observed and recorded.

While the subject was still reclining, a fasting venous blood sample of 25 to 30 milliliters was obtained from the antecubital vein. The blood sample was transferred to a 50 milliliter centrifuge tube, covered with parafilm and allowed to clot at room temperature for two hours. The sample was centrifuged at 2,000 revolutions per minute for one-half hour and the serum removed. The serum sample was mixed thoroughly before being sampled for total lipid, chylomicron, lipoprotein, cholesterol and alkaline phosphatase analyses. Aliquots for cholesterol and alkaline phosphatase determinations were immediately placed in frozen storage at -5° Centigrade. Eight to twelve milliliter serum samples for lipoprotein classes determinations were placed in cold storage, +5° Centigrade. These serum samples were later packed in chipped ice in thermos containers and shipped within five days by air express to the Harvard School of Public Health for analysis of lipoprotein S_f12-20, S_f20-35, and S_f35-100 fractions.³

Fasting capillary blood was obtained by finger puncture using a Bard-Parker blade; two small vials of approximately one milliliter capacity were used for collection. The blood was immediately sampled for

¹ Max Planck Institut für Arbeitsphysiologie, Dortmund, Germany.

² Arthur H. Thomas Company.

³ Appreciation is expressed to Dr. George V. Mann, Harvard School of Public Health, for the lipoprotein determinations.

glucose determinations; duplicate 0.1 milliliter aliquots were rinsed into 1.5 milliliters of distilled water in a five milliliter centrifuge tube. The whole blood was also sampled for pyruvic acid determinations; duplicate 0.1 milliliter aliquots were delivered and rinsed with caution into 0.5 milliliters of a ten percent solution of meta-phosphoric acid. The second vial of blood was capped with parafilm and allowed to clot at room temperature for subsequent serum chylomicron and total lipid determinations.

A fasting urine sample was obtained and the time interval from the previous voiding was recorded so that nitrogen excretion per hour could be calculated. Urine samples were held under refrigeration without added preservative for filtering and qualitative analyses later in the day; aliquots of filtered urine samples were then preserved under toluene and refrigerated for subsequent nitrogen analyses.

The high fat test meal was fed on the first experimental day and the high carbohydrate test meal on the second day. The test meal was consumed within ten to fifteen minutes. All subsequent timing was made from the completion of the meal.

At one-half hour a capillary blood sample was obtained. Blood was sampled for glucose determinations and serum was obtained for chylomicron counts. Samplings for hematological analyses also were made at this period.

Single expired air samples of eight minutes duration were measured and collected at the one hour, three hour and five hour intervals. The subject rested in a reclining position for one-half hour before the three and five hour collections; however, before the one hour sampling a rest period of twenty minutes only was possible. The sampling of expiratory air was begun in sufficient time that it was completed at the

stated time interval. Pulse and respiration rates were counted as during the basal measurements. The collected aliquot was transferred immediately to a Bailey bottle for storage under mercury until later analysis.

Additional capillary blood samples were obtained at the one, two, three, four and five hour intervals. Blood was sampled for glucose at each hour, sampled for pyruvic acid at one, three and five hours and serum samples were obtained at each hour. Chylo-micron counts were made on each serum sample; serum total lipids were determined on serum samples obtained at the one, three and five hour intervals. Capillary samples were treated and centrifuged with exact timing and speed in order to obtain uniformity for chylo-micron counts. After sampling of individual serums for chylo-micron counts was completed, the serum samples to be used for analyses of total lipid were placed in frozen storage.

Urine samples were obtained at one, three and five hours after completion of the test meal. These samples were treated in a manner identical to that used with the fasting sample.

The subjects remained in the laboratory room during the entire period of the experiment. They were allowed to converse, read, write or sew except for periods of bed rest before each expiratory air sampling period. During intervals between the collection of experimental samples, the diet records, the medical history and the diet history were obtained and anthropometric and blood pressure measurements were made. No food other than the test meal was consumed and water was permitted only in small amounts at the end of each expiratory air sampling period. There was no smoking. An effort was made to keep the subjects as relaxed and contented as possible within the requirements of the experimental procedure. All of the subjects had volunteered and cooperation was excellent.

Analysis of Expired Air Samples

Samples of expired air were analyzed for carbon dioxide and oxygen by the conventional Haldane-Henderson-Bailey method (Peters and Van Slyke, 1932). Analyses of gas samples were performed until duplicate determinations checked within 0.04 percent whenever possible. In cases where differences between duplicate analyses were slightly greater but were of insufficient magnitude to affect the real value of the calculated respiratory quotient or heat production figures, averages of the two analyses were included. Technical difficulties in a few cases resulted in single values only being determined for either carbon dioxide or oxygen. The respiratory quotients and heat production figures calculated from these values are so indicated in the data which are presented.

Overall respiratory quotients, total oxygen consumption, non-protein respiratory quotients and total heat production were calculated according to Brody (1945). The Zuntz non-protein respiratory quotient factors were used for converting oxygen consumption to calories per liter. When the determined non-protein respiratory quotients were greater than 1.00 or less than 0.70, the Zuntz factors for 1.00 and 0.70, respectively, were used. DuBois (1936) has shown that the error of such a procedure is negligible.

Hematological Measurements¹

Red blood cell, white blood cell and routine differential counts were made according to techniques described by Simmons and Gentzkow (1944).

¹ Appreciation is expressed to Janet Tam, Hazel Amen and Marilyn Guild for red blood cell, white blood cell and differential counts and for hemoglobin determinations.

Hemoglobin was determined colorimetrically as alkaline hematin using a photelometer¹; the factor of conversion was determined previously in this laboratory by comparison with the Van Slyke analysis. Hematocrits were determined in duplicate by a modification of the method of Lowry (Storvick, Hathaway and Nitchals, 1951). Capillary blood was drawn into 3 x 100 millimeter tubes in which 5 cubic millimeters of a 200 milligram percent heparin solution had been dried. One end of the tube was sealed with Plicene Cement²; the tops were covered with parafilm. The tubes were centrifuged³ one hour at 2,500 revolutions per minute.

Chemical Methods of Blood Analysis

Blood Glucose. Blood glucose was determined in duplicate by the Nelson (1944) photometric adaptation of the Somogyi method, using 0.1 milliliter samples of whole blood. The deproteinized filtrates for each daily series were held under refrigeration until all samples were collected; the colorimetric analyses of the filtrates were performed at the same time. The percent transmission of the color produced was read at a wavelength of 540 mμ using a Coleman Photoelectric colorimeter⁴. The stability of the barium hydroxide-zinc sulfate filtrates had previously been shown in this laboratory and was verified under the conditions of this experiment. Duplicates checking within six milligrams

¹ Cenco-Sheard-Sanford photelometer, Central Scientific Company.

² Central Scientific Company.

³ Clay-Adams Model No. 1004, Clay Adams Company.

⁴ Coleman Instruments, Incorporated.

of glucose per 100 milliliters of blood were averaged. Standards were determined frequently and new standard curves established whenever any reagent was newly prepared.

Blood Pyruvic Acid. The micro-method for pyruvic acid determinations of Tsao and Brown (1950) was used. Duplicate 0.1 milliliter samples were delivered into 0.5 milliliters of a solution of ten percent meta-phosphoric acid (prepared fresh daily) in five milliliter centrifuge tubes. The pipette was rinsed twelve times to insure complete deproteinization and rinsing. The tubes, capped with parafilm, were allowed to stand thirty minutes and then were centrifuged at 2,500 revolutions per minute for ten minutes. The supernatant filtrates were transferred to 10 x 70 millimeter tubes, sealed with parafilm and immediately placed in frozen storage. Aliquots of the solution of ten percent meta-phosphoric acid were frozen daily for corresponding blank determinations. All pyruvic acid filtrates were held by freezing until the completion of the collection of experimental samples for the entire study. It had been demonstrated previously by the author (unpublished data) that the pyruvic acid content of blood filtrates was not altered by this freezing procedure.

The principle of the analysis for pyruvic acid involves the formation of the hydrazones of pyruvic acid and other keto-acids by 2,4-dinitro-phenylhydrazine reagent, extraction of the hydrazones from the filtrate by xylene, further selective extraction of the hydrazone of pyruvic acid from the xylene by ten percent sodium carbonate, and the development of a colored tautomer by a reaction of the hydrazone with concentrated sodium hydroxide. The optical density of the colored tautomer, which is relatively unstable, is measured spectrophotometrically at a wave length

of 520 mμ. This method has a distinct advantage in that it has adapted the principles of macro-methods, principally the method of Friedemann and Haugen, for use with capillary blood samples. The method does, however, have several sources of technical error which make it highly desirable to have as many individual aliquot determinations of each blood sample as is practical. The principal sources of technical difficulty may be enumerated as: 1) the loss of xylene in the shaking processes due to the difficulty of complete stoppering of tubes against this organic solvent of low surface tension; 2) the difficulty of complete separation of the water and xylene fractions in removal of the water layer from beneath the xylene layer, as the occurrence of any emulsification greatly increases the error; and 3) the turbidity and markedly increased measured density, if any xylene is included in transferring the lower sodium carbonate layer to the microcuvette.

Only duplicate samplings of blood were practical in this experimental procedure, although Tsao and Brown (1950) recommend the desirability of triplicate sampling. One hundred cubic millimeter aliquots of the pyruvic acid filtrates were analyzed in triplicate for each of the duplicate samples¹. Filtrates were removed from the freezer one-half hour before beginning the analyses and were thoroughly mixed before sampling of aliquots. The 10 x 70 millimeter tubes were tightly stoppered with rubber stoppers covered with cellophane during the mixing and shaking processes; shaking was accomplished with a Kahn shaker² which was fitted with a

¹ Appreciation is expressed to Eva Hwang for assistance with the pyruvic acid determinations.

² Fisher Scientific Company.

sponge rubber base for accomodating the small-sized tubes. Occasional loss of xylene occurred but this loss was reduced by inserting the covered rubber stoppers carefully and tightly. Occasional samples showed emulsification which persisted after centrifuging; the emulsification, though slight, inhibited complete removal of the water layer from the xylene layer and introduced error. In spite of precaution some xylene was occasionally carried over to the cuvette in transferring the sodium carbonate aliquot; this resulted in turbidity and the aliquot had to be discarded. Optical densities were read at a wavelength of 520 mμ using the micro-attachment to a Beckman Quartz Spectrophotometer, Model DU¹ at exactly two minutes after the addition of the sodium hydroxide. Mixing was accomplished by careful but thorough shaking of the entire carriage of cuvettes. Duplicate blanks were prepared and analyzed in triplicate for each day's series. Standards were determined using pyruvic acid prepared in this laboratory by distillation in vacuo^{2,3}. Aliquots of the pyruvic acid had been immediately frozen and stored at -5° Centigrade until withdrawn for use. The stability of the frozen aliquots was checked by determination of the melting point. The standard analyses corresponded closely to those previously obtained in this laboratory.

Measured density readings of sample aliquots showed wider variations than are usually found in quantitative determinations. However, usually

¹ National Technical Laboratories.

² Appreciation is expressed to Mary Mills and Hazel Amen for preparation of the pyruvic acid distilled in vacuo.

³ Acid Pyruvic c.p., A-270, Fisher Scientific Company.

two of the three aliquots checked closely. When there was doubt, low values were discarded, as the most likely errors in this method involve loss of pyruvic acid. (Aliquots showing turbidity were immediately discarded from consideration.) Excluding the results of questionable aliquots, average density values of most duplicate samples checked within ten percent. Variations greater than ten percent are indicated in the data which are presented. Occasionally it was possible to obtain only single blood samples. In these cases quadruplicate aliquots were analyzed and averaged.

Serum Alkaline Phosphatase¹. Serum alkaline phosphatase values were determined in triplicate on fasting venous blood serum samples; capillary blood serum was substituted for three samples when no venous serum was available. Serum alkaline phosphatase was determined by the micro-method of Bessey, Lowry, and Brock (1946).

Serum Total Cholesterol². The concentration of total cholesterol was determined on fasting venous serum samples by a modification of the method of Schoenheimer and Sperry, 1934, routinely in use in this laboratory (Amen, 1951). Triplicate analyses were made on the acetone-alcohol extract of single aliquots of serum. Capillary serum was substituted when no venous serum was available; it had previously been determined that there was no significant difference between venous and capillary total cholesterol concentrations (Ibid).

¹ Appreciation is expressed to Eva Hwang for the serum alkaline phosphatase determinations.

² Appreciation is expressed to Hazel C. Amen for the determinations of serum total cholesterol.

Serum Total Lipid¹. Serum total lipids were determined in duplicate by a modification of Bragdon's "Colorimetric determination of blood lipides" (1951); the modification to a micro procedure permitted analyses on one-tenth milliliter aliquots of serum. The conventional alcohol-ether extraction of Bloor (Peters and Van Slyke, 1932) was used but was modified in proportions. One-tenth milliliter of serum was delivered slowly into nine milliliters of alcohol-ether mixture (three parts redistilled 95 percent ethyl alcohol and one part redistilled ethyl ether) in a ten milliliter volumetric flask. The contents were made to volume, stoppered, shaken and allowed to stand one-half hour. The contents were then filtered through fat-free filter paper and immediately a 5.0 milliliter aliquot was sampled and transferred into a ten milliliter beaker. The contents of the beaker were evaporated on a water bath until the odor of alcohol just disappeared. Re-extraction was accomplished by the addition of three one-milliliter portions of petroleum ether (redistilled); the ether was added to the beaker, brought to boiling and immediately poured off into a ten milliliter volumetric flask. The solvent was evaporated on a water bath in air; the last traces of the vapor were removed by a current of carbon dioxide gas.

Oxidation was performed using 4.0 milliliters of dichromate reagent (Bragdon, 1951). The flasks were stoppered, sealed with a drop of reagent and then heated in a boiling water bath for one hour. Blanks were prepared with each series and heated simultaneously. After heating, the flasks were cooled, distilled water added with caution, cooled again,

¹ Appreciation is expressed to Omer Curtis for some preliminary investigations with this method and for the analyses of the serum samples.

and then made up to volume with distilled water. Optical density at a wavelength of 590 mμ was determined spectrophotometrically¹ without delay.

Oleic acid was the standard used for comparison. Bragdon (1951) had shown that standard curves for palmitic acid, cholesterol and cholesterol stearate all superimposed, indicating that oxidation proceeded to the same degree in each case. And Bloor (1947) in a similar procedure for the determination of small amounts of fatty acids indicated that either palmitic, stearic, or oleic acid could be used as a standard, since "the differences in values are within the limit of error of the method". Bloor reported, however, that cholesterol gave significantly higher values; his method of oxidation differed from that of Braydon principally in the use of a Nicloux-type sulfuric acid-dichromate reagent.

The sensitivity of the method was established for 0.1 to 2.5 milligrams of oleic acid in petroleum ether. These amounts of fatty acid corresponded to 200 to 5000 milligrams of total lipid per one hundred milliliters of serum. Recoveries of oleic acid added to serum were 93.9 to 95.6 percent.

It was recognized that the method employed for total lipid determinations lacked specificity in that the color reagent may react with any organic material that might be present. The extraction and re-extraction procedures, however, eliminated major sources of organic contamination. No differentiation of oxidation reactions of the different total lipid fractions was made, but the references cited (Bloor, 1947; Bragdon, 1951) indicated such differences were small. The lack of specificity of the

¹ Beckman Quartz Spectrophotometer, Model DU, National Technical Laboratories.

oxidation reagent emphasized the need for redistilling all reagents, most particularly the petroleum ether.

The small size of the sample relative to the sources of error involved in the extracting and re-extracting procedures limited the degree of accuracy expected. Duplicate determinations in this experiment, however, agreed within five percent for the majority of analyses. The few values for which duplicate analyses differed by more than ten percent are so indicated in the data.

The micro-adaptation of Bragdon's method for the determination of total lipid in serum had certain definite limitations but offered a tool for measuring changes in total blood lipids when the amount of serum for analysis was limited. It was considered a better tool for analyzing relative changes than for determining absolute values.

Chemical Methods of Urinalysis

Urine samples were measured and filtered. Aliquots were analyzed qualitatively for albumin by heating with the subsequent addition of acetic acid, for glucose by heating in Benedict's reagent and for acetone by the Rantzman modification using sodium nitroprusside (Simmons and Gentzkow, 1944)¹.

Urinary nitrogen was determined quantitatively on aliquots which were preserved by toluene and refrigeration. One milliliter samples of diluted urine were digested by the micro-Kjeldahl procedure and subsequently nesslerized according to the method of Folin and Wu (Hawk, Oser and Summerson, 1947). The percent transmission of the color produced

¹ Appreciation is expressed to Janet Tam and to Hazel Amen who assisted with the qualitative urinalyses.

was measured spectrophotometrically¹ at a wavelength of 480 mμ. Determinations were performed until duplicates checked within five percent. Preserved samples were routinely analyzed within two weeks; one sample, however, was held six weeks. The stability of the samples preserved in this manner was demonstrated for a period of two months.

Counting of Chylomicrons

Chylomicron counts were made on serum samples using a darkfield microscope² which was fitted with a net micrometer³ (squared 10 x 10) placed into the eyepiece. Special darkfield slides, 1.0 to 1.2 millimeters in thickness, and No. 1 cover slips were used⁴. The slides and cover glasses were cleaned with detergent, rinsed with tap and distilled water, stored in 1:1 alcohol and ethyl ether, and dried with clean cheese cloth immediately prior to use.

Chylomicrons were counted on both venous and capillary fasting serum samples and on capillary serum samples obtained at the one-half, first, second, third, fourth, and fifth hours after the completion of the test meal on both experimental days. Sampling of venous serum was previously described. The method of handling capillary samples was similar to that reported by Marder, et al. (1952). Capillary blood samples were allowed to clot at room temperature in the small tubes in which they were collected. The clot was loosened and the tube centrifuged for six

¹ Coleman Spectrophotometer, Coleman Company, Inc.

² Spencer darkfield illuminator with built-in light source, 95X ocular with built-in diaphragm, 9X eyepiece, American Optical Company.

³ Net Reticule, 21.15 mm. diameter, 5 mm. square ruled into 0.5 mm. squares, American Optical Company.

⁴ Arthur H. Thomas Company.

minutes at 2,500 revolutions per minute. All serum was transferred to a second tube (6 x 50 mm.) and re-centrifuged for six minutes at 2,500 revolutions per minute. All serum was transferred to a clean tube. Serum samples were sealed with parafilm and held at room temperature until all of one day's samples were collected. Serums were thoroughly mixed prior to sampling.

An aliquot of seven cubic millimeters¹ of serum was placed on a cover slip which was immediately inverted onto a slide. Spontaneous, even and complete spreading was required. The cover slip was sealed to the slide by vaseline delivered from a syringe. Duplicate slides were prepared and counted for each serum sample. The ruled area of 100 small squares was counted in at least four separate fields of the slide; countings were averaged for each slide. If the two slides showed a difference of count greater than ten percent, except in very low concentrations, further slides were prepared and counted.

Slides were counted with the microscope focused to the brightest illumination of the chylomicrons but with care taken to count in one plane only. In low concentrations the entire ruled area was counted; in higher concentrations 50, 20, or 10 small squares were counted and the average results were converted to the entire ruled area by the appropriate factors. Total counts only were made; in preliminary trials attempts to distinguish size and brightness by this observer were too uncertain to yield results of significant comparative value.

¹ Semi-pipette 7 mm. No. 23, volume 7.12 mm., Made in Denmark, Arthur H. Thomas Company.

Counts in low and medium concentrations were felt to represent actual total counts in the field and plane under consideration. In high concentrations it was recognized that total counts were perhaps underestimated because it was difficult to distinguish separate particles for actual count and small, dull particles were masked by the high concentrations of large, bright particles. This factor was considered also by Marder, et al. (1952) who used diluting methods for high concentrations. Dilutions were not made in this study because there were very few samples of high concentrations and the diluting itself would be a further source of error. Care in maintenance of a suitable colloidal suspension is a significant problem in the use of any diluent (Frailing and Owen, 1951).

Both serum and whole blood have been used for chylomicron counting. Whole blood without coagulant has been favored by Frailing and Owen (1951) and Swank (1951); both groups have reported the occurrence of aggregations of particles, or clustering, with serum samples. Swank (1951) also noted the marked tendency for clustering in heparinized blood; he further observed that clustering varied with individuals, was less after feeding unsaturated than saturated fats and was decreased by a low fat diet. Frazer and Stewart (1937), Cooper and Lusk (1942), Becker, Meyer and Necheles (1949), Zinn and Griffith (1950) and Marder, et al. (1952) have reported the successful use of serum for chylomicron counts. Serum was used in this study because of the necessity of holding samples for several hours prior to counting. No diminution of Brownian movement was noted when samples were held at room temperature for periods up to twelve hours and no clustering was observed. Bohm, Gernandt and Holmgreen (1941) also reported no change in chylomicrons in samples standing several hours.

A measured amount of serum was used in preparing slides. Seven cubic millimeters was found to be sufficient to cover the area of the cover slip without excess. It would be desirable to have a basis for relating chylomicron concentrations to serum volumes, but preliminary efforts with equipment available were unsuccessful. The use of a special counting chamber which allows quantitative determinations of chylomicrons has been reported (Setälä and Ermala, 1951), but details of its construction have not yet been encountered. Some preliminary attempts at photomicrographs were made but without sufficient success to warrant their use. It has been reported by Moreton (1950) that photomicrographs of chylomicrons are of interest but "subject to many of the same shortcomings" of chylomicron counting. Photomicrographs were considered as a method for evaluation of differences in chylomicron sizes as well as a method for confirmation of counts.

Counting of chylomicrons was felt by the author to be an approximate evaluation of the changes which occurred. The validity of the quantitative evaluation depends upon the constancy of technique and a developed sense of observation. Without standard counting chambers results from different laboratories can be compared only as to relative changes. Within a single laboratory, however, the validity of comparisons may be justified, particularly when counts have been made by one person throughout the study. In this study the ability to check average counts of duplicate slides within ten percent and the relatively similar fasting values obtained for the same individual at even two or three months intervals lent increased confidence in the results obtained.

Analysis of Dietary Data

The diet records were evaluated for total calories and total grams of protein, fat and carbohydrate using the United States Department of Agriculture Handbook Number 8 (Watt and Merrill, 1950). Data were supplemented from Bowes and Church (1951) where necessary.

Statistical Treatment of Data

Various statistical treatments were used in evaluation of the data. These were correlation, regression, analyses of variance and covariance, including subdivision into linear and quadratic components, least significant differences between group means, and Fisher's t-test (Snedecor, 1946; Cochran and Cox, 1950).

The Use and Verification of the Kofranyi-Michaelis Respirometer

Samples of expired air were measured and collected by use of the Kofranyi-Michaelis respirometer. This respirometer, first described by Kofranyi and Michaelis (1941), was designed to facilitate indirect calorimetric determinations of the energy-cost of various types of industrial work. The details of its construction and operation have been reviewed (Müller and Franz, 1952). The Kofranyi-Michaelis instrument is a dry gas-meter which measures the total expired air passing through the meter and at the same time continuously samples an aliquot (0.3 or 0.6 percent) which is collected in a small attached rubber bag. Although the respirometer was primarily designed for experiments requiring portable equipment, its convenience of size and simplicity also recommends its use in resting experiments where gas samples for both carbon dioxide and oxygen analyses are desired. Use of the instrument for

basal heat measurements as a part of a study of the metabolic cost of various activities has been reported (Passmore, Thomson, and Warnock, 1952).

The directions accompanying the Kofranyi-Michaelis respirometer suggested the desirability of calibrating the metering device of the instrument using a previously calibrated wet-test meter; the importance of checking the meter over the range of flow rates to which it would be subjected was particularly noted. The possibilities of carbon dioxide absorption by the rubber bladder (collecting bag) as well as carbon dioxide and oxygen diffusion through the bladder were indicated. It was suggested that the rubber bladder be rinsed two or three times with expired air before each experiment, that the collecting bag be emptied into an appropriate storage container as soon as possible at the conclusion of an experiment and that carbon dioxide and oxygen concentration changes occurring in any collecting bag be established by thorough investigation.

Orsini and Passmore (1951) in Great Britain investigated these problems and found the metering of their instrument to be consistently low over the rates of flow found under physiological conditions but corrected by a factor of 1.18. Their original rubber sampling bladder was lost. Substituting an ordinary football bladder, they found diffusion losses negligible in a one-half hour period of storage. Further, they found good agreement between the measured metabolic costs of simple activities determined first by measurement and analysis of samples of expired air collected in Douglas bags and secondly by measurement and analysis of samples of expired air collected by the Kofranyi-Michaelis respirometer.

The experience in this investigation was somewhat less fortunate. Due to circumstances of timing, calibrations were deferred until after the collection of experimental data had commenced. When fasting respiratory quotients and rates of oxygen consumption were calculated from the data of respiratory gas analyses of the first subjects, both were found to be abnormally low. Therefore it became apparent that changes in the concentrations of carbon dioxide and oxygen far greater than those predicted by the experiences of the German and British workers were occurring during the collection of the expired air samples.

The procedure devised for the calibration of the rates of carbon dioxide and oxygen concentration changes of the expired air during collections was to duplicate in every detail the method used for experimental collections except that air of a uniform composition from a Douglas bag served as the source of gas flow rather than the expired air of an experimental subject.

With the experimental subjects this procedure for collection of expired air samples was followed. The rubber collecting bladder was stored at all times containing some expired air. It was rinsed and freshly filled with expired air the night prior to an experiment. In the morning the rubber bladder was rinsed three times with expired air blown in by the operator; it was completely emptied by tight rolling and attached to the collecting valve of the respirometer. The subject was then attached to the respirometer by means of the rubber mouthpiece, breathing valve and connecting tube and the nose clamp was attached. Eight liters of expired air were metered through the instrument and the resulting aliquot collected as a pre-rinse of the instrument and the

bladder. Six-tenths percent aliquots were collected consistently. The bladder was again completely emptied and attached to the instrument. The first six-minute basal sample was then measured; the aliquot was collected in the rubber bladder and transferred immediately at the end of the collecting period to a Bailey gas-sampling bottle for storage under mercury until later analysis. Another eight-liter rinse preceded the timing of the second six-minute basal sample; the collection and transfer procedure was identical to the first sampling. Some expired air remained in the bladder between all collections. Preceding the eight-minute measurement at the first, third and fifth hour collection periods, the rubber bladder was rinsed by the operator three times and the instrument and the bladder were pre-rinsed with eight liters of the sample expired air and the consequent aliquot. All transfers to Bailey bottles were accomplished within one minute. Gas samples were analyzed for carbon dioxide and oxygen by the conventional Haldane-Henderson-Bailey method (Peters and Van Slyke, 1932) as previously described.

For the calibrations a Douglas bag of one hundred liters capacity was filled with expired air; the contents were thoroughly mixed by gentle kneading of the closed bag. The composition of the Douglas bag contents was determined by sampling the contents for analysis directly into a Bailey gas-sampling bottle. A re-sampling of the contents of the Douglas bag into another Bailey bottle was always performed at the end of a calibration to check against any change occurring in the gas source. The Douglas bag was substituted for the experimental subject in the procedure in as identical a manner as was possible. The rubber bladder was stored and pre-treated in an identical manner. The Douglas

bag was attached to the respirometer by means of the connecting tube. Eight liters of air were metered through the instrument and the resulting aliquot collected as a pre-rinse of the instrument and bladder. Timed samples were then collected for either six or eight minutes. The rate of flow of air through the meter was regulated by varied kneading motions. It became evident that the concentration changes of oxygen and carbon dioxide of the gas samples was a function of both the length of time of collection and the rate of expiration. Therefore calibrations were determined at rates of three, four and five liters per minute for the duplicate six-minute periods and at rates of three, four, five and six liters per minute for single eight-minute periods. A new Douglas bag of air was required for each individual time and rate of expiration; it was possible to obtain duplicate six-minute samples from the same bag. The percentage composition of each Douglas bag of air was determined and rechecked as previously described.

The results of the calibration of the carbon dioxide and oxygen concentration changes in collection are summarized in Tables IV and V. The carbon dioxide decrease showed significant correlations ($P < 0.05$) with the rate of expiration during all sampling periods. The calculated lines of regressions with their standard deviations, plotting percent of original carbon dioxide remaining against rate of expiration, are presented in Figure 1 and Figure 2. These lines were used to determine the appropriate correction factor to be applied to experimental samples. The average rate of flow of each expired air sample was calculated and the interpolated percentage factor was read from the graph. Whether carbon dioxide concentrations of the expired air samples were physio-

TABLE IV

CALIBRATIONS OF CONCENTRATION CHANGES OF CARBON DIOXIDE
AND OXYGEN DURING THE COLLECTION IN RUBBER BLADDER
OF SIX MINUTE EXPIRED AIR SAMPLES

Rate of Expiration Through Respirometer	Determined		Percent of Original	
	% CO ₂	% O ₂	CO ₂	O ₂
5 liters per minute:				
Original	3.18	17.79		
1st six minutes	2.86	18.10	89.94	101.74
2nd six minutes	3.00	17.79	94.34	100.00
Original	3.01	18.26		
1st six minutes	2.83	18.61	94.02	101.92
2nd six minutes	2.84	18.61	94.35	101.92
Original	2.99	18.05		
1st six minutes	2.64	18.44	88.29	102.16
2nd six minutes	2.73	18.37	91.30	101.77
Original	3.24	17.96		
1st six minutes	2.94	18.20	90.74	101.34
2nd six minutes	3.07	18.07	94.75	100.61
4 liters per minute:				
Original	3.41	17.99		
1st six minutes	3.01	() ¹	88.27	() ¹
2nd six minutes	3.08	() ¹	90.32	() ¹
Original	3.46	18.02		
1st six minutes	3.10	18.46	89.60	102.44
2nd six minutes	3.15	18.33	91.04	101.72
Original	3.48	17.48		
1st six minutes	3.16	17.74	90.80	101.49
2nd six minutes	3.22	17.56	92.53	100.46
Original	3.43	17.69		
1st six minutes	2.98	17.98	86.88	101.64
2nd six minutes	3.10	17.89	90.38	101.13
Original	3.34	17.87		
1st six minutes	3.09	18.14	92.51	101.51
2nd six minutes	3.10	18.09	92.81	101.23

TABLE IV continued

Rate of Expiration Through Respirometer	Determined		Percent of Original	
	% CO ₂	% O ₂	CO ₂	O ₂
4 liters per minute cont'd.				
Original	3.88	16.94		
1st six minutes	3.41	17.27	87.89	101.95
2nd six minutes	3.58	17.13	92.27	101.12
3 liters per minute:				
Original	3.37	17.24		
1st six minutes	2.93	17.64	86.94	102.32
2nd six minutes	3.00	17.58	89.02	101.97
Original	2.86	18.27		
1st six minutes	2.45	18.64	85.66	102.03
2nd six minutes	2.58	18.55	90.21	101.53

¹ Data incomplete

TABLE V

CALIBRATIONS OF CONCENTRATION CHANGES OF CARBON DIOXIDE
AND OXYGEN DURING THE COLLECTION IN RUBBER BLADDER
OF EIGHT MINUTE EXPIRED AIR SAMPLES

Rate of Expiration through Respirometer	Determined		Percent of Original	
	% CO ₂	% O ₂	CO ₂	O ₂
6 liters per minute:				
Original	3.61	17.20		
Eight minute sample	3.28	17.36	90.86	100.93
Original	3.43	17.90		
Eight minute sample	3.24	17.99	94.46	100.50
5 liters per minute:				
Original	3.34	17.15		
Eight minute sample	3.02	17.42	90.42	101.57
Original	2.88	18.54		
Eight minute sample	2.69	18.65	93.40	100.59
4 liters per minute:				
Original	3.33	17.64		
Eight minute sample	2.98	17.97	89.49	101.87
Original	3.30	17.71		
Eight minute sample	2.87	18.00	86.97	101.64
3 liters per minute:				
Original	2.85	18.66		
Eight minute sample	2.47	18.86	86.67	101.07
Original	2.94	18.34		
Eight minute sample	2.60	18.59	88.44	101.36

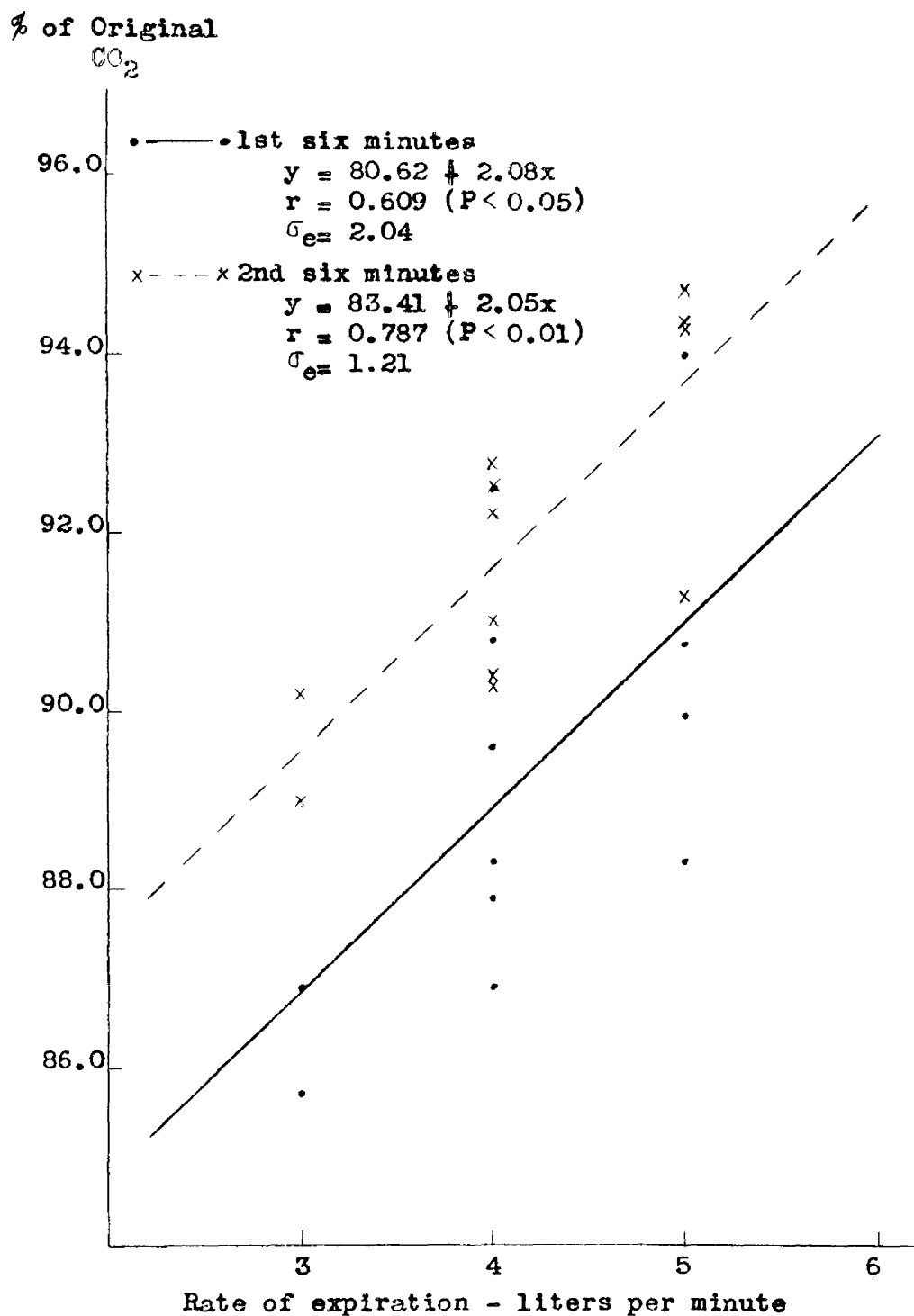


Figure 1. Influence of expiration rate during six-minute periods of collection of expired air on percent carbon dioxide remaining in rubber bladder of Kofranyi-Michaelis respirometer.

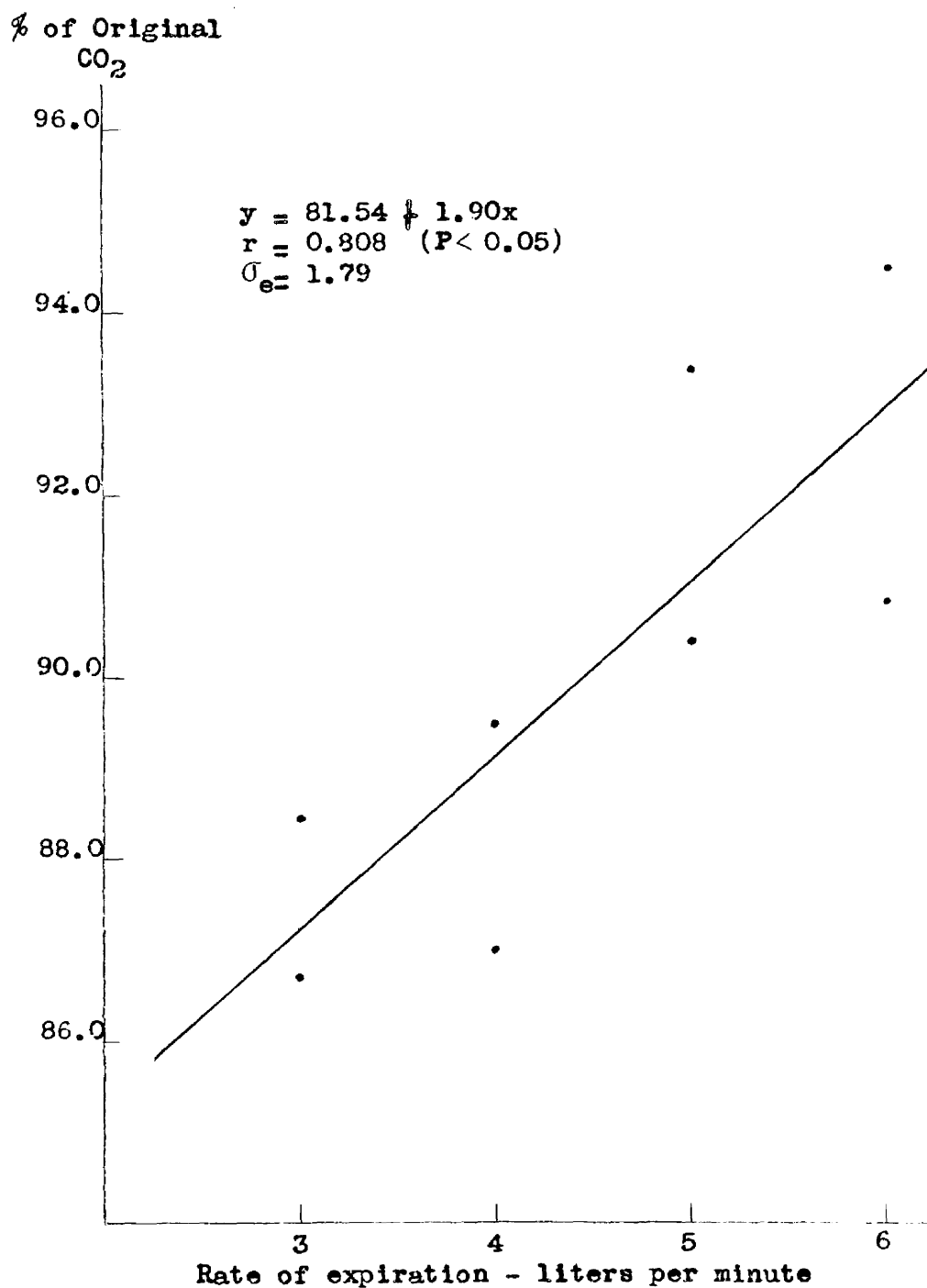


Figure 2. Influence of expiration rate during eight minute periods of collection of expired air on percent carbon dioxide remaining in rubber bladder of Kofranyi-Michaelis respirometer.

logically high or low was found to be unimportant; the gradient of carbon dioxide of expired air to carbon dioxide of room air is always high.

Oxygen diffusion did not show a significant correlation with the rates of expiration tested. The respective means and standard deviations expressed as percent of original oxygen sample were: first six-minute sample, 101.87 ± 0.36 ; second six-minute sample, 101.22 ± 0.65 ; and eight minute samples, 101.19 ± 0.50 . The determined averages were applied as correction factors to the experimental samples.

Calibration of the metering device was accomplished by use of a previously calibrated wet-test meter¹ and a Benedict-Roth spirometer². Both expired air and nitrogen gas were passed in series through the wet-test meter and the Kofranyi-Michaelis respirometer; expired air was measured both with the Benedict-Roth spirometer and the respirometer. All expired air measurements in this investigation were resting measurements and therefore within a narrow range of flow rates; the meter was calibrated within the range of flow rates used. A summary of four series of determinations is tabulated in Table VI. The average factors for correction of volume determined in the four series were 1.11, 1.10, 1.11 and 1.14. The over-all average was 1.12; the correction factor of 1.12 was applied to all metered volumes.

In order to test the validity of the determined correction factors, the collection of six-minute duplicate basal samples by use of the Kofranyi-Michaelis respirometer was followed in one subject by duplicate determinations of basal metabolism using the Benedict-Roth Metabolism

¹ Precision Instrument Company.

² Benedict-Roth Metabolism Apparatus, Warren E. Collins, Inc.

TABLE VI
CALIBRATIONS OF THE METERING DEVICE OF THE
KOFRANYI-MICHAELIS RESPIROMETER

Method of Calibration	Corrected Volume Wet-test Meter STP ¹ liters	Corrected Recorded Volume K-M Respirometer STP ¹ liters	Calculated Correction Factor
A. Expired air passed through Wet-test meter and K-M respirometer in series	9.969 25.075 10.979 5.754 7.026 3.878 11.774	9.255 22.920 9.918 5.056 6.256 3.428 10.498	1.08 1.09 1.11 1.14 1.12 1.13 1.12
		Average	1.114
B. Nitrogen gas passed in series through Wet-test meter and K-M respirometer (100% vapor pressure assumed in both).	20.936 30.632 43.875	18.831 28.225 40.203	1.11 1.09 1.09
		Average	1.097
C. Nitrogen gas passed in series through Wet-test meter and K-M respirometer (Gas dried after leaving Wet-test meter).	2.656 20.731 22.125	2.369 18.996 19.555	1.12 1.09 1.13
		Average	1.113
	Benedict-Roth spirometer STP ¹ liters		
D. Gas from Benedict-Roth spirometer delivered through K-M respirometer.	3.563 3.275 3.194 2.789	3.118 2.944 2.771 2.425	1.14 1.11 1.15 1.15
		Average	1.139

¹All volumes corrected to standard temperature and pressure

Apparatus¹. The average determined basal metabolism using the Benedict-Roth was 49.0 calories per hour. Duplicate determinations by means of the Kofranyi-Michaelis respirometer and subsequent gas analyses were 48.9 calories per hour and 49.1 calories per hour.

Since the standard deviations for the carbon dioxide and oxygen diffusion correction factors were relatively large, the effect of using values of plus and minus one standard deviation of the carbon dioxide and oxygen correction factors on the measured respiratory quotient and energy expenditure was calculated for one subject on duplicate basal six-minute expired air samples. The extremes of the respiratory quotients thus calculated on the duplicate samples were 0.813 and 0.876 compared to the duplicate six-minute respiratory quotients of 0.851 and 0.835 obtained using the mean correction factors; the extremes of heat production calculated were 47.9 and 50.0 calories per hour compared to the duplicate values of 49.0 and 49.1 calories per hour using the mean correction factors. The effect on the determined heat production was relatively small, less than five percent, but the effect on the respiratory quotients was sufficient to lessen the precision with which the respiratory quotients determined in this investigation could be interpreted.

The same rubber bladder was used throughout experiments reported in this study. The changes of gas concentrations occurring during the collection period suggested the strong desirability for further work seeking a collection bag of such composition that diffusion and/or absorption could be lessened or eliminated.

¹ Benedict-Roth Metabolism Apparatus, Warren E. Collins, Inc.

RESULTS AND DISCUSSION

In evaluating the data of this study, it was desirable: 1) to investigate the relationship of certain metabolic qualities with percent deviations from desirable weight of the individual subjects; and 2) to compare metabolic patterns of three groups of subjects: underweight, average weight and overweight. Both approaches have been used in the presentation of results and in the discussions of metabolic qualities which follow. Individual deviations from group patterns were observed and analyzed.

Individual data for all determinations are tabulated in Tables XXV through XLI (Appendix). Summaries of the metabolic pattern of each individual subject in relation to the mean metabolic pattern of her respective weight group are appended.

Classification of Subjects

The use of the Metropolitan Life Insurance Company tables of desirable weights as standards in the evaluation of weight status of subjects is a common practice, although the limitations of such evaluations have been emphasized (Keys and Brozek, 1953). In this investigation the validity of using these standards was increased by evaluations of body frame through anthropometric measurements and clinical appraisals of muscular development and subcutaneous fat deposits. Although the

preciseness of the calculated percent deviations from desirable weight has recognized limitations, these calculations provided a quantitative basis of comparison for the observed qualitative differences.

The division of the subjects into three groups of seven subjects each was presented in Table II: overweight class, more than 15 percent above desirable weight; average weight class, from -10 to +15 percent of desirable weight; and underweight class, more than 10 percent below desirable weight. It was recognized that any classification into such groups was arbitrary. The literature revealed considerable variation in quantitative definitions of overweight and underweight. Keys (1950a) defined degrees of caloric undernutrition as "slight" when body weight was no greater than -10 percent underweight, "moderate", between -10 to -20 percent underweight, "severe", between -20 to -30 percent underweight, and "extreme", greater than -30 percent underweight. In the treatment of Metropolitan Life Insurance Company statistics, Dublin and Lotka (1936) subdivided underweight individuals into two groups: moderate, those whose body weights were -5 to -14 percent of average, and severe, those whose weights were -15 to -34 percent of average. Overweight individuals were divided into three groups, 5 to 14 percent, 15 to 24 percent and more than 25 percent above average weight. Armstrong, et al. (1951) defined overweight as "any deviation of 10% or more above the ideal weight for the person". In a nutritional status survey of Groton Township, New York, overweight and underweight groups were listed as 10 percent above or below standard weights from the tables of Davenport (Moore and Shaw, 1951). Strang and McClugage (1931), whose study is referred to frequently, included in their normal group subjects whose

weights ranged from +6 to -6 percent of average, in their obese group those whose weights ranged from +18 to +159 percent of average, and in their thin group, those whose weights ranged from -15 to -20 percent of average. Beaudoin, Van Itallie and Mayer (1953) compared "obese", 18 to 84 percent above desirable weight, with "controls", +3 to -18 percent of desirable weight. Brozek and Keys (1953) have questioned any height-weight relationships within a plus or minus 20 percent deviation from average.

The division established in this study between the overweight and average weight subjects was quite clear-cut, although two subjects, LP and GN, +6 and +13 percent of desirable weight, respectively, have for years shown tendencies toward slight gains in weight and have maintained their weight in the upper-average range with effort. The division between the average group and the underweight group was less clear-cut. Subjects SL and NS were probably true representatives of a low-average group; subject EN's history was one of frequent minor weight variations and a pattern of general difficulty in gaining weight, but her weight at the time of the experiment was slightly lower than usual. At all times in the analyses of data attempts were made to recognize the limitations of the classifications used and to observe the effect of over-lappings between groups.

The importance of "active" or "static" status of body weight to metabolic pattern has been emphasized by Beaudoin, Van Itallie and Mayer (1953) and the implications of body weight status have been reviewed. All of the subjects in this study were determined to be "static" in their weight pattern, Table II, with the exceptions of subjects HT and YL in the overweight group who had been actively gaining weight and

subject YK in the underweight group who had been actively losing weight. Average weight subjects EN and NS had both undergone changes in weight during the previous year but the changes were minor and irregular. Data from the medical histories on body weight changes in adult life are included in Table VII.

All of the subjects in this investigation were adjudged to be in general good health at the time of the study. Table VII is a summary of pertinent data from the general medical history procured from each subject and certain clinical and hematological data secured on the experimental days. All blood pressure measurements were within recognized average ranges (Houssay, 1951); none of the overweight subjects were of the hypertensive type. One unusually high white blood corpuscle count was obtained for subject YK on the first experimental day, but no subsequent evidence of infection became apparent. This experimental day was in the midst of a period of unusually warm weather; abnormally high white blood counts have been observed previously in hot weather unrelated to any infectious state (Ohlson, 1953). Likewise, no indications of infection became evident in subjects MR, GN, SL and NM although the differential counts for these subjects appeared abnormal on single days. The only regular medications that were used by the subjects were liver tablets by one, thyroid by one, and antihistamines, either regularly or occasionally, by three.

Food Intake Patterns

Three twenty-four hour recall diet records were obtained for each subject: one single random day twenty-four hour recall record and recall

TABLE VII
SUMMARY OF CLINICAL, HEMATOLOGICAL AND MEDICAL HISTORY
DATA OF ALL SUBJECTS

Sub- ject	Age	Deviation from "Desirable Weight" %	Date of Experi- ment	Hemato- crit %	Hemo- globin gm./100ml.	Hematological Data						
						RBC	WBC	Differentials ³				
						1	2	M %	L %	N %	E %	B %
RM	39	+66	7-29-53	41.6	14.0	4.4	6.2	5	28	64	2	1
			8-3-53	40.7	13.0	4.3	7.1	5	25	67	3	0
SM	53	+58	3-11-53	40.3	-----	---	5.0	7	52	40	1	0
			3-18-53	41.4	-----	---	5.0	2	38	59	1	0
HM	30	+31	6-13-53	45.7	14.9	4.3	8.8	2	32	65	1	0
			6-23-53	46.0	14.4	4.9	4.1	-	---	---	-	-
HT	45	+29	5-5-53	45.7	14.3	4.2	4.4	8	22	69	0	1
			5-19-53	42.8	13.5	4.3	4.9	3	30	64	2	1
RT	57	+22	4-14-53	46.6	-----	---	8.2	3	37	59	1	0
			4-21-53	45.6	-----	---	7.8	3	33	62	2	0
MR	29	+22	3-14-53	44.0	-----	---	7.0	5	33	57	4	1
			3-27-53	43.1	-----	---	7.6	15	33	48	4	0
YL	25	+21	5-22-53	-----	14.5	6.0	4.4	5	35	55	3	2
			6-2-53	45.2	15.3	4.6	7.2	4	49	40	7	0

TABLE VII continued

Blood Pressure (non-fasting)	Fasting Body Temp. °F	Resting Pulse per min.	Initial Date Last Menstrual Period	Body Weight History	Comments
128/80	98.1 98.0	69 64	7-7-53	Range 190-250# in adult life; gained 10# last year.	Family history of diabetes, cancer.
128/86	97.6 97.6	63 60	post- menopause	Overweight from childhood; no gain in last year.	Gall bladder re- moved; family history of cancer, heart disease.
106/74	98.0 97.5	60 65	5-5-53 6-17-53	Overweight from childhood; adulthood, 30# loss; no gain or loss last year.	Some tendency to diarrhea; no family history of degenerative disease.
106/74	97.4 98.3	60 60	4-25-53	Overweight as child; 50# gain as adult with ups and downs; steady 20# gain in last year.	Diagnosed low blood pressure; no family history of degenerative disease.
140/84	97.7 97.4	65 61	post- menopause	Steady gain for 25 years; 8# gain in last year.	Slight arthritis; family history of arthritis or gout and high blood pressure.
109/68	97.3 97.5	68 75	3-3-53	200# at 20 years of age; lost 50#, re- gained some; no gain last year.	Heart murmur one year ago; family history of heart disease, arthritis.
120/87	98.4 97.6	64 57	4-20-53	145# at 18 yrs. age; up and down four times in 7 years; gained 20# last 6 mos.	Takes 1 grain thyroid per day; no family history of degenerative disease.

TABLE VII continued

Sub- ject	Age	Deviation from "Desirable Weight" %	Date of Experi- ment	Hematological Data								
				Hemato- crit %	Hemo- globin gm./100ml.	RBC 1	WBC 2	Differentials ³				
								M %	L %	N %	E %	B %
GN	38	+13	2-14-53	43.6	----	---	7.2	24	54	19	2	1
			4-3-53	40.6	----	---	6.0	3	30	62	3	2
LP	40	+6	5-26-53	40.1	14.3	4.4	4.0	5	40	50	5	0
			8-14-53	41.1	13.5	4.7	6.7	7	31	59	3	0
NH	52	+2.5	8-6-53	43.0	14.3	4.7	5.5	4	20	66	1	0
			8-12-53	40.4	13.5	3.7	4.5	-	--	--	-	-
RW	37	-0.5	1-14-53	37.8	----	---	4.4	10	27	53	3	7
			2-7-53	37.9	----	---	7.0	5	35	54	6	0
SL	25	-7	1-22-53	39.3	----	---	5.4	4	52	39	4	1
			2-10-53	36.1	----	---	6.6	4	76	17	3	0

TABLE VII continued

Blood Pressure (non-fasting)	Fasting Body Temp. °F	Resting Pulse per min.	Initial Date Last Menstrual Period	Body Weight History	Comments
111/79	97.6 98.3	64 65	1-29-53 3-5-53	Gained 10# jr. high school to jr. college; thyroid therapy college fr.; av. adult, 150-160# no change last yr.	Family history of heart disease.
100/62	98.1 98.4	65 67	5-3-53 7-25-53	120# 6th grade; 165# college; lost to 130#, generally 135-145#; no gain or loss last year.	Takes benadryl regularly; no family history of degenerative disease.
108/66	97.0 97.2	73 71	post-menopause	130# at 25; then gain to 145#; held 145# except 1941-2 (hyperthyroid); no change last year.	Arrested tuberculosis and mild arthritis; thyroidectomy, 1942; takes anti-histamines; family history of heart disease, tuberculosis, xanthomatosis.
112/70	98.0 97.6	64 60	1-2-53 2-1-53	115-120# from 20 to 33 years; to 125# at 35; to 133# at 37; gain of 3-4# last year.	Takes benadryl occasionally; family history of diabetes and heart disease.
104/76	98.2 98.4	60 61	1-1-53 1-29-53	As adult always in range of 116-122#.	Heart murmur and sl. gall bladder distur. as child; no family history of degenerative disease.

TABLE VII continued

Sub- ject	Age	Deviation from "Desirable Weight" %	Date of Experi- ment	Hemato- crit %	Hemo- globin gm./100ml.	Hematological Data						
						RBC	WBC	Differentials ³				
						1	2	M %	L %	N %	E %	B %
NS	29	-7	4-17-53	46.7	15.8	5.3	5.0	10	54	33	3	0
			5-1-53	44.1	15.8	4.8	5.0	4	55	32	8	1
EN	32	-10	7-22-53	42.8	14.0	5.7	8.6	2	17	80	1	1
			7-31-53	42.3	14.0	5.1	6.4	4	23	73	0	0
RD	51	-12	3-25-53	41.7	----	---	6.8	2	27	66	5	0
			3-31-53	41.5	----	---	6.4	7	31	57	5	0
NM	40	-13	2-18-53	35.5	----	---	6.8	2	30	64	3	1
			3-1-53	37.2	----	---	5.8	8	53	35	4	0
YK	51	-14	7-16-53	42.7	13.0	4.9	13.1	6	42	50	2	0
			7-20-53	42.6	13.0	4.7	6.6	4	35	60	1	0
RL	34	-15	5-8-53	43.3	16.0	5.0	4.2	8	22	69	0	1
			5-15-53	40.0	13.8	4.8	5.2	5	33	57	3	2
BK	25	-17	6-5-53	42.1	14.0	4.5	6.4	4	45	51	0	0
			6-19-53	40.6	14.0	4.2	---	-	--	--	-	-
EL	27	-17	3-7-53	43.2	----	---	5.8	6	47	44	3	0
			3-21-53	42.5	----	---	6.4	1	46	50	3	0

TABLE VII continued

Blood Pressure (non-fasting)	Fasting Body Temp. °F	Resting Pulse per min.	Initial Date Last Menstrual Period	Body Weight History	Comments
125/78	98.0 98.6	68 67	3-30-53	Adult range, 115-125#; last year lost 10#, gained 5#.	No family history of degenerative disease; mother overweight.
102/70	98.0 97.8	80 78	7-15-53	Adult range, 125-135#; once, 1950, 140#; 8# loss in fall, 1952.	Family history of heart disease, arthritis.
104/74	97.5 97.5	60 67	post-menopause	Adult range, 114-120#; lost 5# fall, 1952.	Family history of heart disease.
100/69	97.4 98.0	78 72	-----	Average 110#; 3 years ago to 98# after ill.	No family history degenerative diseases.
112/64	97.5 97.4	61 60	post-menopause	At 30 years, 110#; usual adult, 130-135#; lost 15# last yr.	Family history of heart disease.
110/74	98.0 98.2	86 84	5-3-53	At 19, 90#; usual range, 100-106#; max. 112#.	Liver tablet daily; some gall bladder distur.; no family history of degenerative diseases.
96/58	98.3 97.8	63 64	5-30-53	At 20, 98#; usual range around 100#.	No family history of degenerative disease.
90/56	97.8 98.4	74 76	-----	At 20, 96#; av. adult range, 103-110#; no change last year.	Kidney stone surgery last year; no family history of degenerative diseases.

TABLE VII continued

Sub- ject	Age	Deviation from Desirable Weight %	Date of Experi- ment	Hemato- crit %	Hemo- globin gm./100ml.	Hematological Data						
						RBC	WBC	Differentials ³				
						1	2	M %	L %	N %	E %	B %
NL	27	-21	7-11-53	38.6	13.5	3.6	8.1	-	--	--	-	-
			7-25-53	37.4	12.8	5.4	5.4	5	37	56	2	0

¹ Millions/cmm.

² Thousands/cmm.

³ White blood corpuscles differentiated as monocytes, lymphocytes, neutrophils, eosinophils and basophils.

TABLE VII continued

Blood Pressure (non-fasting)	Fasting Body Temp. °F	Resting Pulse per min.	Initial Date Last Menstrual Period	Body Weight History	Comments
104/70	97.6 98.3	69 73	7-5-53	100-104# last five years.	Family history of diabetes and arthritis.

records for the twenty-four hours preceding each experimental day.

The contributions of protein, fat and carbohydrate to the total twenty-four hour calorie intakes for the single random day records are tabulated in Table VIII. Although the mean calculated twenty-four hour calorie intakes were 2,343 for the underweight subjects, 2,026 for the average weight subjects and 1,802 for the overweight subjects, there were wide individual differences observed among the subjects in each group. The group mean differences were not statistically significant according to analysis of variance. The percentages of the total calories contributed by protein, fat and carbohydrate were calculated, Table IX; no significant differences in the proportions of carbohydrate or fat were found among the three groups. The mean proportion of fat calories was 46.3 percent and of carbohydrate calories was 37.9 percent for the three groups; the mean proportions of protein calories were 14.5, 14.0 and 17.7 percent for the underweight, average weight and overweight groups, respectively.

The limitations of single twenty-four hour recall food records in assessing diet patterns of individuals were recognized, although their use in evaluating group patterns has been justified (Bransby, Daubney and King, 1948; Maynard, 1950; Young, et al., 1953). In groups of subjects similar in age to those in this investigation but numbering from fourteen to twenty-one in each group, Young and co-workers (1953) found little difference in the calculated total calories and total protein between estimated and measured intakes. In this study the more obvious errors introduced by varied week-end eating habits were avoided as recommended by Eppright, et al. (1952) but seasonal variations emphasized by the studies of Thomas, et al. (1950) were unavoidably introduced since random

TABLE VIII

CONTRIBUTIONS OF PROTEIN, FAT AND CARBOHYDRATE TO CALORIE
INTAKES OF SINGLE RANDOM DAY DIET RECORDS

Subject	Total Calories	Protein gms.	Fat gms.	Carbohydrate gms.
Underweight:				
NL	2175	79	132	171
EL	2816	127	137	283
RK	2064	84	113	189
RL	2302	91	129	203
YK	2072	56	100	250
NM	2291	76	126	222
RD	2682	100	140	262
Mean	2343	87	125	225
Standard error	111	8.5	5.5	15.3
Average weight:				
EN	2543	76	119	302
NS	2399	74	147	214
SL	1746	58	86	197
RW	1952	76	87	224
NH	1886	61	118	157
LP	1682	76	80	176
GN	1972	80	105	182
Mean	2026	71	106	207
Standard error	122	3.3	9.1	17.9
Overweight:				
YL	1204	66	61	103
MR	1672	63	82	139
RT	1929	75	117	155
HT	1130	57	59	107
HM	1654	96	79	153
SM	2030	74	99	208
RM	2992	123	154	295
Mean	1802	79	93	165
Standard error	235	8.5	12.8	25.1
F-Value¹				
(Analysis of variance)	2.55	1.22	2.95	2.41

¹F-values: P < 0.05, 3.55; P < 0.01, 6.01

TABLE IX
MEAN CONTRIBUTIONS OF PROTEIN, FAT AND CARBOHYDRATE TO CALORIE INTAKES OF SINGLE RANDOM DAY DIETS

Source of Calories	Subjects		F-Value ²	
	Underweight	Average weight	Overweight	Analysis of Variance Total
Total calories	2343 ± 111 ¹	2026 ± 122 ¹	1802 ± 235 ¹	2.55
Protein, % total calories	14.5 ± 0.85	14.0 ± 0.85	17.7 ± 1.26	4.01*
Fat, % total calories	47.6 ± 1.42	46.0 ± 2.28	45.3 ± 1.33	0.44
Carbohydrate, % total calories	37.9 ± 1.86	40.0 ± 2.09	35.7 ± 1.45	1.49
Alcohol, % total calories			(1.3)	

¹ Standard error of the mean

² * = P < 0.05 (F-values: P < 0.05, 3.55; P < 0.01, 6.01)

day records were collected throughout the whole period from January through August.

Limitations of calculated rather than analytical values in evaluating food intakes have been reviewed by Maynard (1950) and Hunscher and Macy (1951). Bransby and co-workers (1948) have emphasized the common over-estimation of calories, carbohydrate and fat by calculated as compared to analyzed values. Thomas, et al. (1950), however, recognized a seasonal variation; analytical values for fat and protein were higher in the fall and lower in the spring than calculated estimates.

Food habits of obese individuals have been studied by a variety of techniques which have yielded a variety of conclusions. In summarizing a number of such studies, Mayer (1953b) stated:

"Representative opinions expressed in the literature are as follows: obese individuals exhibit an unusually high intake of carbohydrate, ... or fat or fat-rich food, ... or normal intakes accompanied by decreased activity;

and

"it has been said that obese individuals eat more often, ... often eat enormous amounts of food at one sitting, ... that a larger proportion of their caloric intake is derived from evening meals and snacks, ... or that they consume most of their food at one meal".

Beaudoin and Mayer (1953) reported that obese women tended to underestimate afternoon and evening snacks and the evening meal. Using the research dietary history technique rather than the simple recall record, however, food intake patterns were revealed which were in agreement with physiologic considerations; calorie intakes of the obese women were equal to or greater than those of their controls. Proportions of carbohydrate, fat and protein in the caloric intakes were similar for both groups. Lower calorie intakes among obese children compared to "skinny" children have been

reported, however; obese children had a mean caloric intake of 87.6 percent of National Research Council recommended allowances compared to a mean intake of 103.5 percent by linear children (Peckos, 1953).

In this investigation contributions of fat and carbohydrate to the total caloric intakes were similar among the three groups of subjects, although the pattern differed from that reported by Beaudoin and Mayer (1953). In this study the average contributions of fat and carbohydrate to the total daily calorie intakes were 46 percent and 38 percent, respectively; the percentage contributions reported by Beaudoin and Mayer were 37 percent by fat and 49 percent by carbohydrate.

The intakes of carbohydrate and fat for the twenty-four hours preceding each experimental day were calculated because of the reported relationship of previous diet to carbohydrate and fat tolerances. These data are tabulated in Table X. No significant differences between groups were determined; marked individual variations within groups again were noted. All subjects had been requested to limit fat intake in the evening meal; it was observed that all daily fat intakes were decreased from random day totals. The mean fat intakes in the random day's diet and in the two pre-experimental days for the underweight subjects were 125, 91 and 88 grams, respectively, for the average weight subjects, 106, 76 and 92 grams, respectively, and for the overweight subjects, 93, 64 and 76 grams, respectively; comparisons for individual subjects may be made by examining the data in Tables VIII and X. The contributions of protein, fat and carbohydrate to the calorie intakes for the three days by individual meals are tabulated in Table XXV (Appendix).

TABLE X

TOTAL FAT AND CARBOHYDRATE INTAKES OF INDIVIDUAL SUBJECTS FOR
TWENTY-FOUR HOURS PRECEDING EXPERIMENTAL DAYS

Subject	Calculated Twenty-four Hour Intakes			
	Preceding High Fat Test Meal		Preceding High Carbohydrate Test Meal	
	Total Fat gms.	Total Carbohydrate gms.	Total Fat gms.	Total Carbohydrate gms.
Underweight:				
NL	66	133	96	212
EL	128	292	122	240
RK	71	136	85	251
RL	84	235	74	167
YK	93	227	78	271
NM	81	197	66	232
RD	112	189	95	186
Mean	91	202	88	223
Standard error	8.3	22.5	7.1	14.1
Average weight:				
EN	73	174	92	269
NS	81	201	119	268
SL	35	149	55	115
RW	66	171	91	189
NH	100	184	63	199
LP	105	115	152	198
GN	77	196	73	178
Mean	76	170	92	202
Standard error	8.8	35.7	12.8	20.1
Overweight:				
YL	53	105	61	98
MR	39	44	57	50
RT	52	169	41	263
HT	27	83	71	151
HM	111	154	83	142
SM	95	199	88	133
RM	75	252	131	237
Mean	64	143	76	154
Standard error	11.4	27.1	10.8	28.2
F-Value¹				
(Analysis of Variance)	1.86	1.91	0.62	2.68

¹F-values: P < 0.05, 3.55; P < 0.01, 6.01

Energy Metabolism

Energy expenditures in this investigation were evaluated in terms of total calories per hour; the energy expenditure in calories was calculated from the measured oxygen consumption and non-protein respiratory quotient. Non-protein respiratory quotients were determined to indicate trends in the type of energy metabolism occurring. Oxygen consumption, overall respiratory quotient, non-protein respiratory quotient and calorie data are tabulated in the Appendix, Tables XXVIII to XXXI.

Basal Energy Expenditures

Basal energy expenditures expressed in total calories per hour of the individual subjects showed a significantly positive correlation ($P < 0.01$) with percent deviations from desirable weight. The basal data are plotted in Figure 3. Individual variation was apparent among all groups; energy expenditures ranged from 60 to 76 calories per hour among the overweight subjects, from 45 to 58 calories per hour among the average weight subjects, and from 42 to 50 calories per hour among the underweight subjects. The correlation with percent deviation from desirable weight was least evident among the underweight subjects, where differences in weight were the least. An inspection of the scatter diagram revealed a digression of data at both extremes of deviation from desirable weight. The regression coefficients were calculated therefore for data of all subjects and then omitting the data for the three subjects, RM, SM and NL, whose body weights deviated +66 percent, +58 percent and -21 percent, respectively, from desirable weight. The regression coefficients thus calculated were 0.303 and 0.416, respectively; the difference between

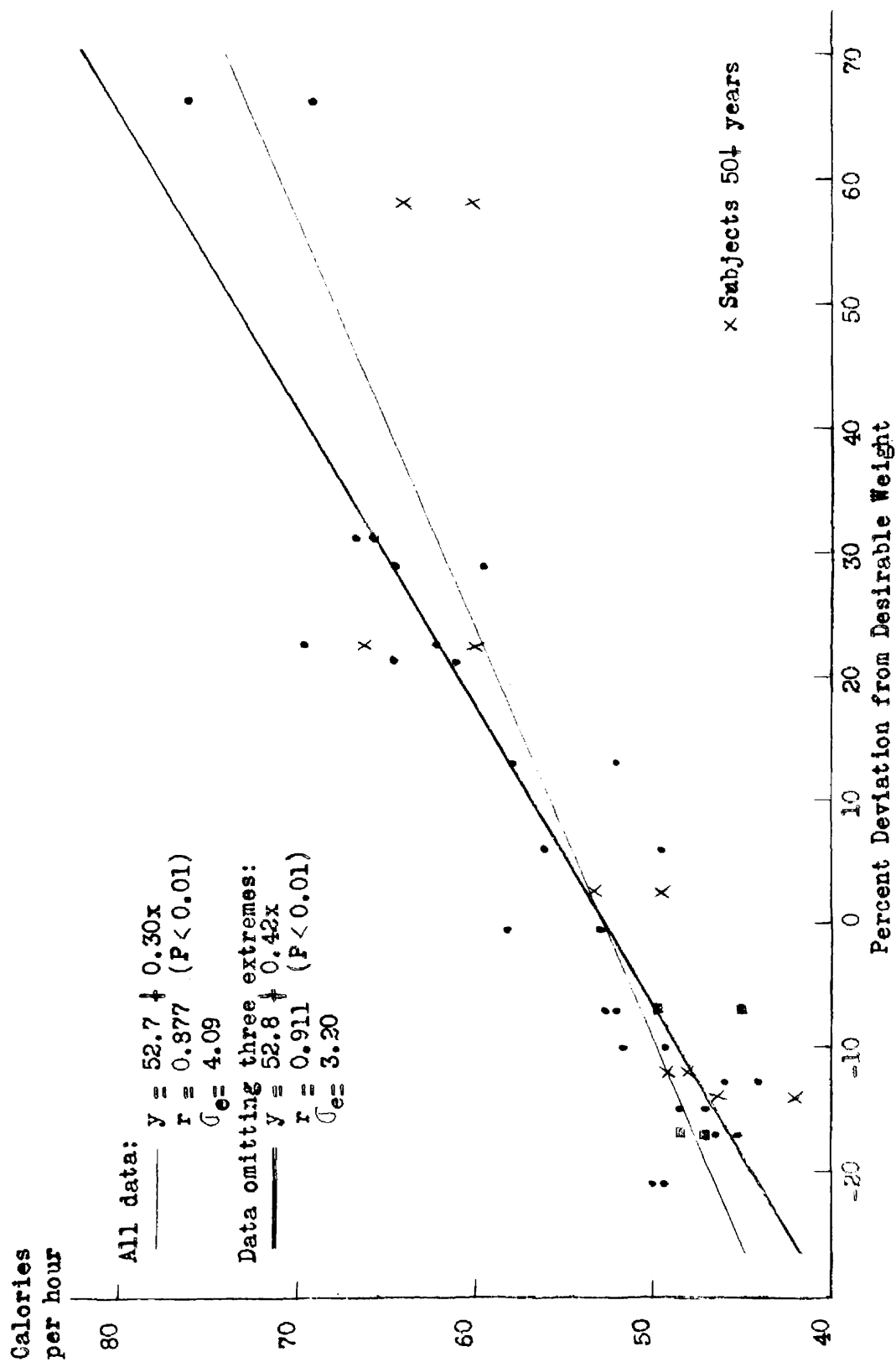


Figure 3. Regressions of basal hourly energy expenditures on percent deviations from desirable weight for twenty-one women on two test days.

the regression coefficients was significant by Fisher's t-test (Snedecor, 1946), $P < 0.05$. The predicted energy expenditures at zero percent deviation from desirable weight, however, were practically identical: 52.7 and 52.8 calories per hour. Although age is a commonly recognized factor influencing basal metabolism, the rate of energy expenditure was not consistently decreased with age among the subjects in this study (Figure 3).

The relationship of basal metabolism to body weight was examined also by a comparison of the mean values of the three groups of subjects: overweight, average weight and underweight. The mean total calories expended in the fasting basal state on both experimental days were significantly higher among the overweight subjects than among the average weight or underweight subjects; there were smaller and less consistent differences between the average weight and underweight subjects due to the smaller differences in body size included. The means and standard errors of the means at fasting, as well as at each hour measured following both test meals, together with the F-values for the analyses of variance and covariance, are presented in Table XI.

Although some individual variation between determined basal metabolic rates on the two experimental days was observed, mean fasting values for the overweight and underweight groups showed no significant differences between the high fat and the high carbohydrate test days; the difference between the mean fasting values for the average weight group was significant, however, $P < 0.05$. Comparisons between the two test days for the overweight and the underweight groups are valid; comparisons between the two test days for the average weight group may be influenced by the individual variations in basal calories.

TABLE XI
MEAN ENERGY EXPENDITURES AT INTERVALS ON TWO TEST DAYS

Intervals of test days	Subjects		F-Value ²		Analysis of Covariance Total
	Underweight	Average weight	Overweight	Analysis of Variance	
	Calories/hr.	Calories/hr.	Calories/hr.	Total Linear Quadratic	
High fat test meal:					
Fasting ³	47.0 ± 0.68 ¹	53.1 ± 1.25 ¹	65.6 ± 2.00 ¹	45.05** 86.70** 3.39	
1st hour ³	56.5 ± 1.32	57.6 ± 2.07	71.2 ± 2.43	17.26** 28.40** 6.81*	1.69
3rd hour ³	53.6 ± 1.38	54.3 ± 1.80	66.3 ± 2.03	16.48** 26.03** 6.94*	2.38
5th hour ³	50.3 ± 0.79	55.6 ± 1.50	67.7 ± 1.65	42.27** 80.42** 4.12	1.64
High carbohydrate test meal:					
Fasting ³	47.0 ± 1.03	51.2 ± 1.53	64.3 ± 1.55	41.85** 76.94** 6.77*	
1st hour ³	59.0 ± 1.15	62.3 ± 1.87	76.1 ± 2.21	25.52** 45.22** 5.81*	0.53
3rd hour ³	50.6 ± 1.66	53.2 ± 1.74	63.8 ± 1.80	16.19** 28.82** 3.58	0.07
5th hour ³	49.7 ± 1.60	51.8 ± 1.51	64.9 ± 1.92	23.21** 43.96** 7.56*	0.44

¹ Standard error of the mean

² * = P < 0.05; ** = P < 0.01

³ Least significant differences for P < 0.05 and P < 0.01, respectively: high fat test meal, fasting, 4.4 and 6.1, 1st hour, 6.0 and 8.4, 3rd hour, 5.4 and 7.6, and 5th hour, 4.2 and 5.9; high carbohydrate test meal, fasting, 4.3 and 6.0, 1st hour, 5.6 and 7.8, 3rd hour, 5.3 and 7.5, and 5th hour, 5.0 and 7.0

When the basal energy expenditure data were combined for all subjects for both experimental days, the mean expenditures for the three groups were 47.0, 52.3 and 65.1 calories per hour for the underweight, average weight and overweight groups, respectively. The analysis of variance showed highly significant differences among the groups as compared to differences among individuals within groups, $P < 0.01$. The mean of the overweight group was significantly higher than the mean of the average weight group, ($P < 0.01$); further, there was no over-lapping of individual values for basal calorie expenditures between the overweight and the average weight subjects. The difference between the means of the average and underweight groups was not significant by the method of least significant differences (Snedecor, 1946). The estimated variance of the underweight group was unduly influenced, however, by the spread of data among the overweight subjects. The difference between the means of the average and underweight groups was significant by Fisher's t-test, $P < 0.01$.

Energy Expenditures Following Test Meals

The total calories per hour expended at rest at intervals after the test meals were consistently higher for the overweight subjects than for the average weight or underweight subjects at each hour measured. The mean hourly calorie expenditures at the first, third, and fifth hours, respectively, following the high fat test meal were 71, 66 and 68 for the overweight subjects, 58, 54 and 56 for the average weight subjects and 57, 54 and 50 for the underweight subjects; following the high carbohydrate test meal, the hourly calorie expenditures were 76, 64 and 65 for the overweight subjects, 62, 53 and 52 for the average weight subjects

and 59, 51 and 50 for the underweight subjects at the first, third and fifth hours, respectively, Table XI. Individual data are presented graphically in Figure 4.

A significant linear variation among groups compared to the variation of individuals within groups occurred at all hours measured after both test meals; significant deviations from linearity (significant quadratic variance) occurred, however, at the first and third hours following the high fat meal and at the first and fifth hours following the high carbohydrate meal, Table XI (Cochran and Cox, 1950). Differences between average weight and underweight subjects were quantitatively less than those between overweight and average weight subjects. Differences between the overweight and average weight subjects were highly significant at every hour; differences between average weight and underweight subjects were not significant at the first and third hours following the high fat test meal and at the first, third and fifth hours following the high carbohydrate test meal as evaluated by least significant differences.

The significant differences between groups at each hour were shown to be related mainly to differences in rates of fasting calorie expenditures; analyses of covariance, relating each hourly calorie expenditure to the mean fasting calorie expenditure of the group, showed no significant differences at any hour, Table XI. The F-values obtained after the high fat meal were considerably greater than those obtained after the high carbohydrate meal, however; the higher F-values following the high fat meal indicated greater group differences in calorie increments in response to fat than to carbohydrate.

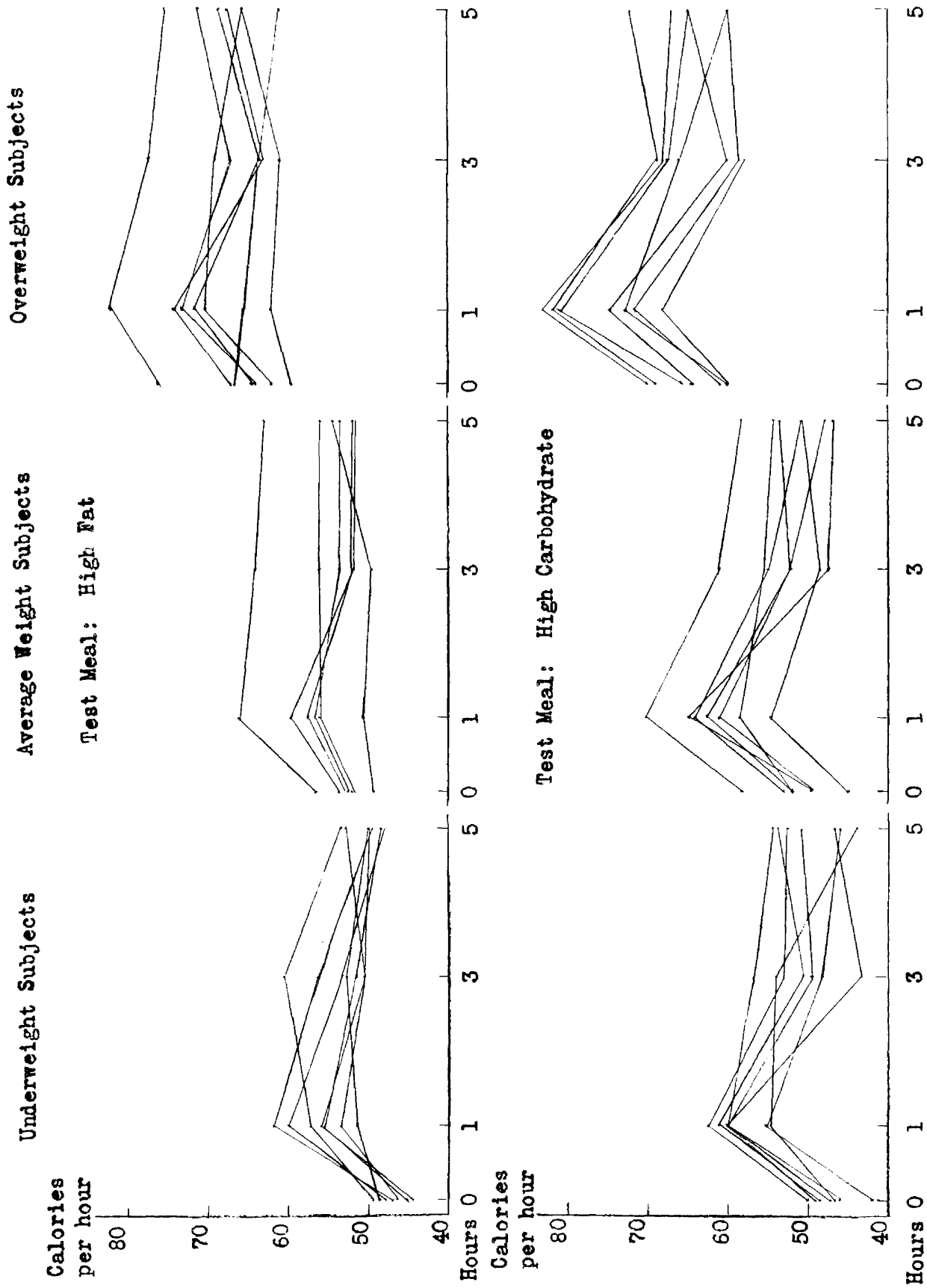


Figure 4. Hourly energy expenditures at intervals on two test days.

A comparison of the calorie response to the two test meals by the three groups of subjects was seen more clearly in a tabulation of measured calorie increments above basal. The mean increments for each group are tabulated in Table XII. The method of plotting the hourly energy expenditures above the basal energy expenditures and then deriving the total expenditure for a given time period by estimating the area under the curve was similar to that used by Strang and McClugage (1931) and Glickman, Mitchell, Lambert and Keeton (1948). As the number of resting energy expenditure measurements made in this investigation was limited to those at the first, third and fifth hours after completion of the test meals, the total increments so estimated were not considered an exact measurement of specific dynamic effect of the test meals. As the measurements were comparable for all subjects, however, comparisons of the total increments measured between groups were valid.

From Table XII it was apparent that the group of underweight subjects showed a greater total calorie response to both test meals than either the average weight or the overweight subjects; differences among groups were significant only following the high fat meal, however. The mean cumulative calorie increments above basal at the fifth hour for the underweight, average weight and overweight subjects were 30, 15 and 11 calories, respectively, following the high fat test meal and 25, 20 and 17 calories, respectively, following the high carbohydrate test meal. The calorie expenditures above basal for the five hours following the high fat test meal were significantly greater among the underweight subjects than among the average weight or the overweight subjects. Differences between mean caloric responses of the average weight and overweight subjects were

TABLE XII

MEAN CALORIE EXPENDITURES ABOVE BASAL DURING FIVE
HOUR PERIODS FOLLOWING TWO TEST MEALS

Subject	Total Cumulative Calories Above Basal					
	Following High Fat Test Meal			Following High Carbo- hydrate Test Meal		
	1st Hour	3rd Hour	5th Hour	1st Hour	3rd Hour	5th Hour
Underweight	4.7	20.6	29.9 $\pm$ 3.6 ¹	5.8	20.4	24.9 $\pm$ 4.2 ¹
Average weight	2.8	10.3	15.4 $\pm$ 4.8	5.4	18.0	20.4 $\pm$ 2.3
Overweight	2.6	8.4	11.0 $\pm$ 4.8	5.6	16.6	17.3 $\pm$ 3.6
F-Value ² (Analysis of Variance)	5.31*			1.27		

¹ Standard error of the mean

² * = P < 0.05. (F-values: P < 0.05, 3.55; P < 0.01, 6.01)

slight at any hour or for the entire five hours following both test meals. The mean increase in resting calorie expenditure following the high fat test meal was greater than that following the high carbohydrate test meal for the underweight subjects; for the average weight and overweight subjects, there were greater mean calorie expenditures following the high carbohydrate meal, the difference being the greater for the overweight subjects.

Strang and McClugage (1931) observed a higher mean calorie expenditure among their underweight subjects than among their controls during six hours following a test meal which provided 26 grams of fat, 52 grams of carbohydrate and 40 grams of protein. Their overweight subjects also showed a mean caloric expenditure higher than that of their average weight subjects, although not as great as that of their underweight group. The test meals in this study supplied 32 grams of fat, 26 grams of carbohydrate and 4 grams of protein in one and 1.6 grams of fat, 97 grams of carbohydrate and 5 grams of protein in the other. Since the compositions of these meals were quite different from that in the study of Strang and McClugage, it is difficult to make exact comparisons. Further, the fact that the overweight and underweight subjects of Strang and McClugage were on reducing or up-building regimens, respectively, might have affected the metabolic responses which occurred.

Reports of studies of the heat increment of carbohydrates, fats and proteins have emphasized the influence of previous diets of the subjects on the caloric responses observed. More nearly uniform responses have been demonstrated when the previous dietary pattern of the subject was controlled. In this study, however, the influence of previous diet was considered a part of the metabolic pattern of the subject.

Individual variations among the subjects in their caloric responses following the test meals were apparent, Figure 4, but there was a pattern of response in each group following both test meals, particularly among the average weight and underweight subjects. Total cumulative caloric increments were higher following the high carbohydrate test meal for five of the six average weight subjects for whom data were complete and were higher following the high fat test meal for five of the seven underweight subjects; average weight subject LP and underweight subjects YK and NM deviated from their respective group patterns. Among the six overweight subjects for whom data were complete, three subjects, RM, HM and RT, had higher energy responses following high carbohydrate feeding, two, HT and MR, following high fat feeding and for one, YL, there was essentially no difference. The lack of significant differences by the analyses of covariance at individual hour intervals following the test meals was a reflection of the spread of individual data, both at fasting and at the individual hour intervals measured. The estimation of total caloric increment was a better measure of the caloric effect of the test meals to the individual. Measurements of caloric expenditures at more frequent intervals would result in a more exact estimation of the true caloric response for the time measured and would also allow extrapolations to the total caloric response by the method of Glickman, et al. (1948).

Bases of Expressions of Energy Expenditures

The data on energy expenditures in this study have been compared on the basis of total calories per hour. The basal data plotted as total calories per hour against percent deviations from desirable weight of

the subjects, Figure 3, incorporated a consideration of differences of height and body build of the subjects because these were a part of the determined percent deviation from desirable weight. No other attempt to evaluate differences in the amount of active tissue was included in this factor, however.

Basal calorie expenditures were calculated and considered relative to bases commonly proposed as estimates of metabolically active tissue. The basal data were calculated as 1) calories per square meter (actual weight) per hour, 2) calories per kilogram of desirable weight per hour, 3) calories per square meter (desirable weight) per hour, 4) calories per kilogram (desirable weight)^{0.75} per hour and 5) calories per kilogram (actual weight)^{0.75} per hour and plotted against percent deviations from desirable weight in a manner identical to that in which total calories per hour were presented in Figure 3. Compared to the significant positive correlation between percent deviations from desirable weight and the data expressed in total calories per hour, the following relations were observed: the data calculated as calories per square meter (actual weight) per hour showed greater spread and no apparent digression with percent deviations from desirable weight; calculated as calories per kilogram (desirable weight) per hour, as calories per square meter (desirable weight) per hour, or as calories per kilogram (desirable weight)^{0.75} per hour, there was always a greater spread of data but there were positive relations with percent deviations from desirable weight of varying degrees; calculated as calories per kilogram (actual weight)^{0.75} per hour a wider spread of data was apparent and there was an obvious negative relation with percent deviation from desirable weight. The variations of these

relations can be observed by comparing the fasting data presented in Figure 5. Individual data are presented in Tables XXXI and XXXIII (Appendix).

The spread of data and shifts of individual data observed made it apparent that plotting "calories per kilogram (desirable weight) per hour" against percent deviation from desirable weight introduced a compounded factor of height and build which became an artifact. This was also true in plotting "calories per square meter (desirable weight) per hour" and "calories per kilogram (desirable weight)^{0.75} per hour" against percent deviations from desirable weight; in these cases, however, the factors of height and build became increasingly compounded. Even in plotting "calories per square meter (actual weight) per hour" against percent deviations from desirable weight there was a compounding of the factor of height.

Expression of the post-prandial hourly calorie expenditure data as "calories per kilogram (desirable weight) per hour" represented an identical treatment to plotting basal data as "total calories per hour" against percent deviations from desirable weight; both presentations took account of height and body build and these factors only. That these were identical treatments was demonstrated by the fact that the zero hour data in calories per hour occurred in the same order as deviations from the regression line in the basal data plotted in Figure 3. Hourly calorie data calculated as "total calories per hour" took no account of height or body build. Comparing plotted curves of "calories per kilogram (desirable weight) per hour" to curves of "calories per hour" for the data of this study, it was observed that all shifts were

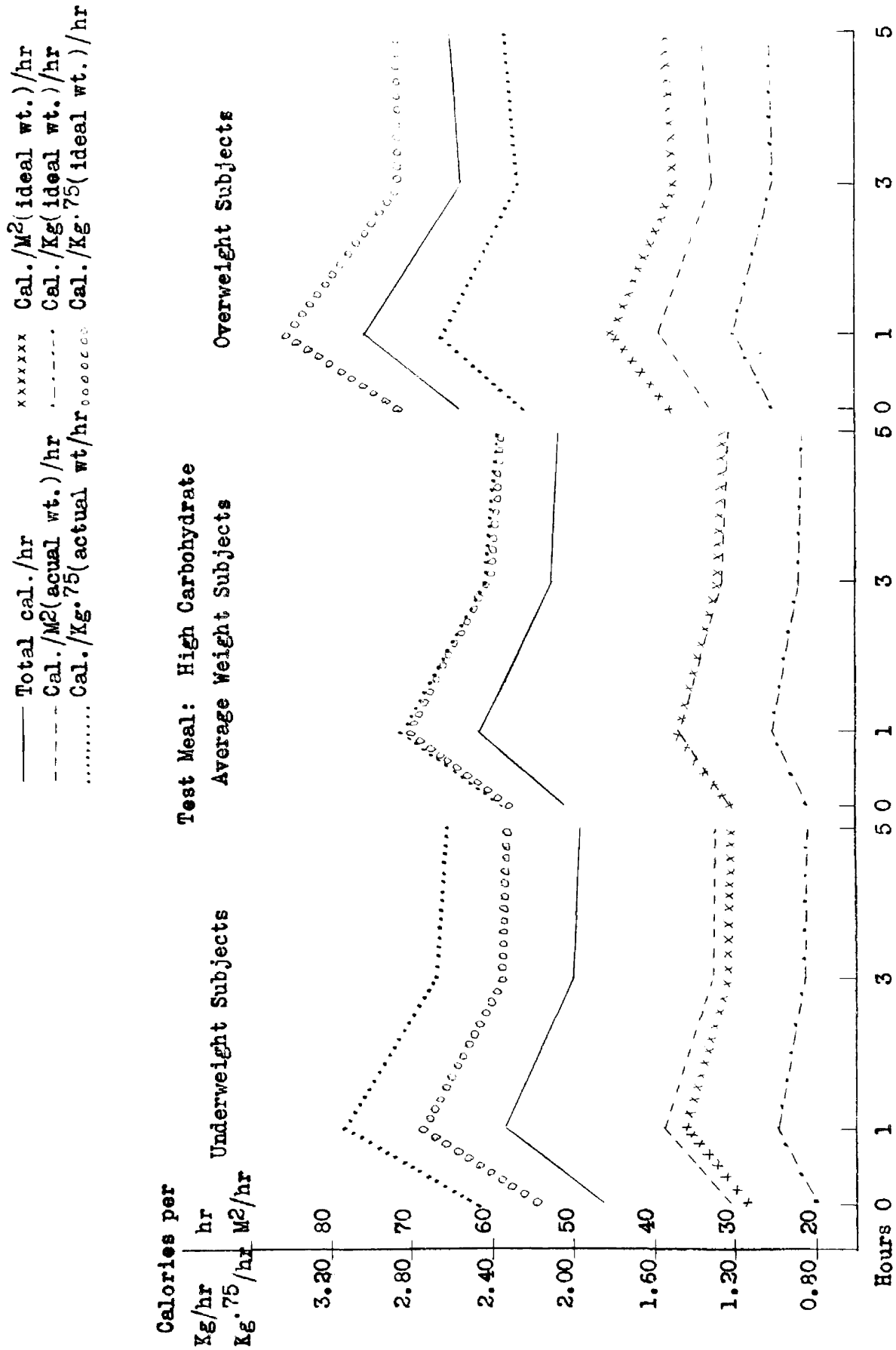


Figure 5. A comparison of mean hourly calorie expenditures according to various methods of expression.

related to height in particular but also to differences in build; values for the shorter subjects were adjusted upwards and the curves relatively heightened, whereas values for the taller subjects were adjusted downwards and the curves relatively leveled. There were, however, very few shifts in the relative order of the response curves of the individual subjects from that shown in Figure 4. In these data, furthermore, the difference in the relative position of the mean curves was affected only slightly due to the similar mean heights of each group. Hourly increment calorie data were therefore presented as total calories per hour rather than as calories per kilogram (desirable weight) per hour, because of the greater familiarity in the use of the former. In Figure 5 the mean hourly calorie expenditures preceding and following the high carbohydrate test meal expressed as "total calories per hour", "calories per square meter (actual weight) per hour", "calories per kilogram (desirable weight) per hour", "calories per square meter (desirable weight) per hour", "calories per kilogram (actual weight)^{0.75} per hour" and "calories per kilogram (desirable weight)^{0.75} per hour" are superimposed so that the relationships relative to the various bases frequently proposed may be observed.

When investigators have expressed energy expenditure data in terms of weight in kilograms^{0.75} or square meters of surface area, based either on actual or desirable weight, an attempt has been made to relate energy metabolism to some measure of metabolically active tissue more complex than that represented by height and build alone. That there is no commonly recognized basis for assessing the amount of active tissue has been indicated previously. This investigation does not present sufficient data to permit any selection of a basis of "active tissue"; rather it was merely of interest to compare the use of the variously proposed bases.

Non-Protein Respiratory Quotients

The mean fasting non-protein respiratory quotient was lower for the overweight subjects than for the average weight or underweight subjects; the mean quotients were 0.79, 0.83 and 0.83, respectively. This trend was similar to results reported by previous investigators (Wang, Strouse and Saunders, 1925; Hagedorn, Holten and Johansen, 1927; Strang and McClugage, 1931; Lyon, Dunlop and Stewart, 1932; and Bowen, Griffith and Sly, 1934).

The differences in the non-protein respiratory quotients among the three groups of subjects in the basal state and at intervals following both test meals were not statistically significant, Table XIII. The large variations due to individual differences within groups found at all hours in which the respiratory quotients were determined were typical of observations reported by other investigators. In addition, it was recognized that the magnitude of the standard deviation of the determined factor which was applied to expired gas analyses to correct for oxygen and carbon dioxide concentration changes which occurred during the collection of the gas samples limited the precision of these measurements in this investigation.

There was a significantly negative correlation of fasting non-protein respiratory quotients with fasting blood glucose concentrations, $r = -0.512$ ($P < 0.05$); lower glucose concentrations were associated with higher measured respiratory quotients. On the other hand there was almost zero correlation between fasting non-protein respiratory quotients and the determined fasting serum total lipid concentrations, $r = -0.027$.

Following the high fat test meal the mean non-protein respiratory quotients of all three groups showed an increase from fasting values in

TABLE XIII

MEAN NON-PROTEIN RESPIRATORY QUOTIENTS AT INTERVALS ON TWO TEST DAYS

Intervals of test days	Subjects		F-Value ² Analysis of Variance Total
	Underweight	Average weight Overweight	
High fat test meal:			
Fasting	0.84 ± .011 ¹	0.81 ± .030 ¹	2.29
1st hour	0.94 ± .020	0.89 ± .025	3.45
3rd hour	0.86 ± .020	0.86 ± .017	0.24
5th hour	0.81 ± .023	0.81 ± .017	0.82
High carbohydrate test meal:			
Fasting	0.83 ± .014	0.84 ± .007	1.00
1st hour	1.01 ± .032	1.03 ± .028	0.64
3rd hour	0.98 ± .035	0.91 ± .034	1.79
5th hour	0.84 ± .035	0.82 ± .019	0.17

¹ Standard error of the mean² F-values: $P < 0.05 = 3.55$; $P < 0.01 = 6.01$

response to the carbohydrate which was included in the test meal; mean quotients of the first, third and fifth hours, respectively, were 0.83, 0.85 and 0.78 for the overweight subjects, 0.89, 0.86 and 0.81 for the average weight subjects and 0.94, 0.86 and 0.81 for the underweight subjects. The non-protein respiratory quotients of the underweight and average weight subjects generally tended to rise more quickly than those of the overweight subjects and then decreased more rapidly toward basal quotients or below. The delayed rise of the quotients among the overweight subjects was more apparent when it was noted that only one overweight subject, HT, reached peak quotient value at the first hour, while three of the average weight, EN, LP and GN, and four of the underweight subjects, RK, RL, NM and RD, had reached their maximum measured quotients by the first hour, Figure 6. That this was the hour of the most significant group differences is shown in Table XIII. Other individual distinct variations from group patterns were: average weight subject NH showed no change in quotient at the first hour followed by a consistent decrease to a quotient markedly below fasting value by the fifth hour; and underweight subject RL, after an initial increase in quotient at first hour, showed a decrease to a fifth hour quotient markedly below fasting value.

Following the high carbohydrate test meal, the changes in mean respiratory quotients of the overweight and average weight groups were more similar. Mean non-protein respiratory quotients at the first, third and fifth hours for the overweight, average weight and underweight subjects, respectively, were: 0.99, 0.91, and 0.83; 1.03, 0.91 and 0.82; and 1.01, 0.98 and 0.84. The mean non-protein respiratory quotients of all groups were influenced by individual subjects who deviated from group

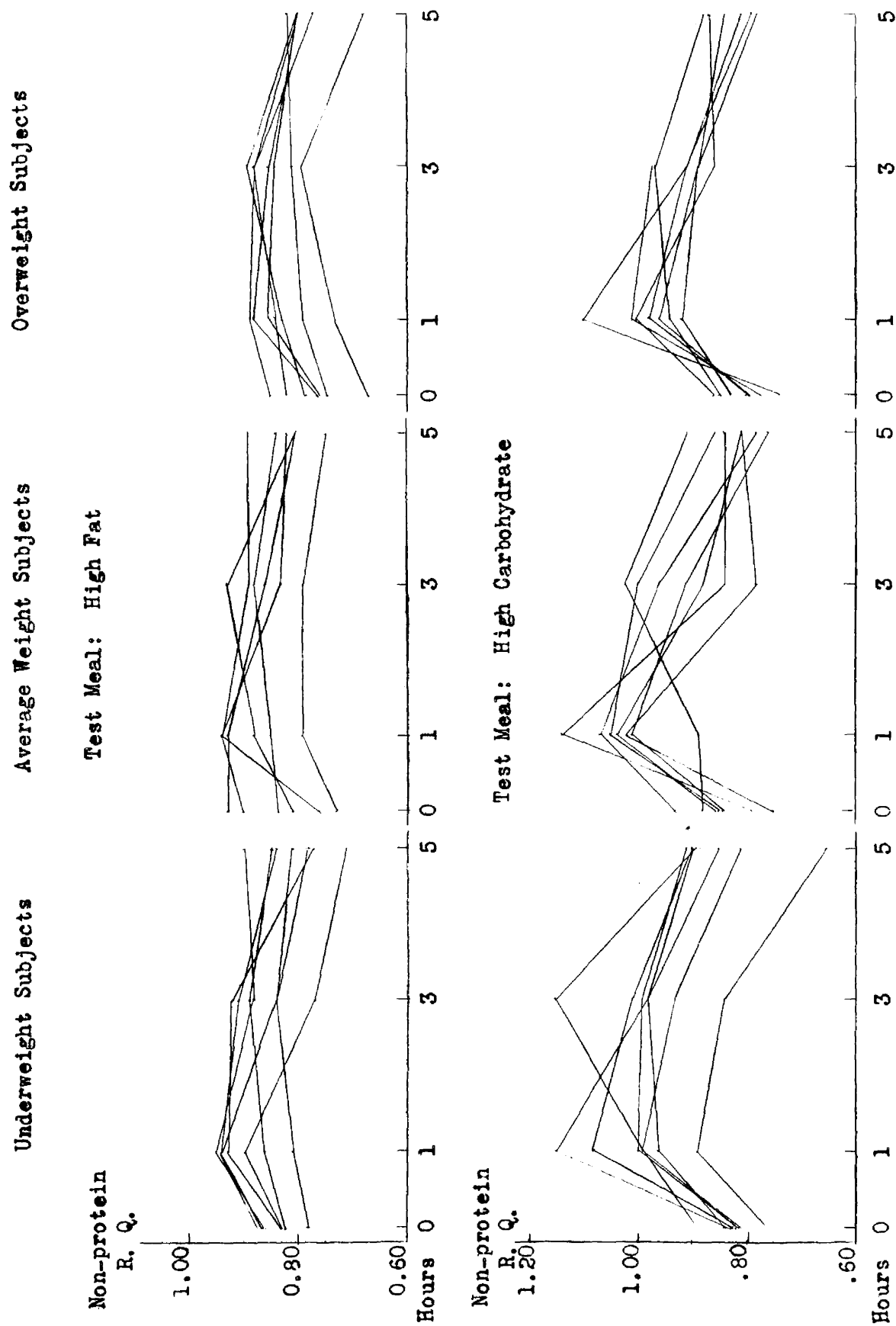


Figure 6. Non-protein respiratory quotients at intervals on two test days.

pattern, however, Figure 6. Overweight subject HT and average weight subject SL had maximum respiratory quotients at the third hour; overweight subject MR had an unusually high first hour quotient and a fifth hour quotient which was still elevated from fasting value; and average weight subjects NH and LP had fifth hour respiratory quotients markedly lower than fasting values. The apparent delay in fall from peak quotient of the mean of the underweight group was weighted heavily by one subject, YL, with a delayed rise to peak value, but the fifth hour mean quotient was also weighted heavily by a value of 0.65 of one subject, RL.

It was interesting to observe the number of measured non-protein respiratory quotients which were greater than 1.0. There were three among the underweight subjects, two among the overweight subjects, while all seven of the average weight subjects showed such elevated quotients. It was unfortunate that measurements of non-protein respiratory quotients could not have been made at more frequent intervals, particularly at the one-half and second hours. The one and three hour quotients determined for the individual subjects, together with the rates of change observed from fasting to the first hour and from the third to the fifth hours, might indicate that the non-protein respiratory quotients for all but one of the underweight subjects may have risen above 1.0 sometime between the first and second hours; similar evidence might indicate also that the respiratory quotients for two more of the overweight subjects may have risen to above 1.0.

The respiratory quotients determined following the high fat test meal in this investigation agreed in general with the pattern of the data of Strang and McClugage (1931) in that the mean non-protein

respiratory quotients of the overweight group were generally lower than those of either the average weight or underweight subjects and the maximum respiratory quotient of the obese group occurred later than that of the control group. The diets fed in the two investigations were quite dissimilar, however, and the differences in respiratory quotients observed by Strang and McClugage were of a greater magnitude. There was no evidence of a different pattern in the two overweight subjects who were classed as "active" overweight subjects from that of the others who were considered "static"; such a difference has been postulated by Brooks (1946b) and Mayer (1952).

Energy Metabolism Patterns: Summary of Observations

Consistent and significantly higher calorie expenditures by the overweight compared to the average and underweight subjects both in the fasting state and at each interval after the test meals were observed; this observation was in agreement with investigations previously reviewed. The lack of large or consistent differences in total energy expenditures measured at the various hour intervals between the underweight and the average weight subjects was also in general agreement with investigations reviewed previously, although few studies have been reported for underweight subjects.

The basal energy expenditures expressed in total calories showed a significant regression with percent deviation from desirable weight. Although this study allowed no assessment of metabolic activity of "active tissue", the significant deviations from linear regression observed among three subjects at the extremes of weight classifications indicated a difference of metabolic activity in these subjects.

A difference in metabolic patterns did seem apparent between the underweight as compared to the average weight subjects, and to the overweight subjects to a lesser degree, from the measured calorie increments following the high fat and high carbohydrate test meals. The underweight subjects showed a significantly higher calorie response following the high fat test meal than did the average or overweight subjects. There was also a lesser mean calorie expenditure observed following the high carbohydrate test meal than following the high fat test meal among the underweight subjects; a majority of the overweight and average weight subjects showed the usual greater calorie response to carbohydrate than to fat.

Non-protein respiratory quotients, at fasting and at the several hour intervals following the test meals, indicated no distinct group patterns in the type of energy metabolism occurring. Fasting respiratory quotients were lower, however, for the overweight subjects and increases in quotients following the test meals tended to be more delayed and of lesser magnitude than those of the average weight subjects. The mean non-protein respiratory quotients of the underweight subjects were, in general, higher than those of the average weight subjects, and hence those of the overweight subjects.

Blood Sugar Concentrations

Fasting Concentrations

The mean fasting glucose concentrations of the blood for the overweight, average weight and underweight subjects, including determinations of both experimental days, were: 93 ± 1.2^1 , 83 ± 1.8 and 81 ± 1.5 milligrams

¹ Standard error of the mean.

per 100 milliliters, respectively. The glucose concentrations showed highly significant differences among the three groups of subjects compared to the differences among individuals within the groups ($P < 0.01$). The overweight group had a significantly higher mean fasting concentration than the average weight or underweight groups ($P < 0.01$); the difference between the mean of the average weight and the mean of the underweight group was not significant.

Fasting blood glucose concentrations showed a highly significant correlation with percent deviations from desirable weight, $r = 0.581$ ($P < 0.01$). Eleven of the fourteen values for the seven overweight subjects were between 90 and 101 milligrams per 100 milliliters of blood, whereas only three values for the average weight and one for the underweight subjects equaled or exceeded 90 milligrams per 100 milliliters. None of the fourteen fasting values for the overweight subjects was below 85 milligrams of glucose per 100 milliliters of blood. On the other hand, seven fasting blood glucose values for the underweight group and five for the average weight group, were between 70 and 80 milligrams per 100 milliliters of blood (Table XXXIV, Appendix).

Strenuous exercise, season of the year, age and obesity are influences which have been reported to affect fasting glucose concentrations. Exercise was limited among these subjects during the test days. Inasmuch as the experimental period of the study was from January through August, the data were examined to determine whether or not monthly or seasonal variations in fasting glucose concentrations were apparent. No seasonal trend was observed in these data; further, there was a relatively equal distribution of subjects from among the three groups each month which

would tend to equate in mean values any differences that might have existed. Age was not an apparent factor influencing fasting blood glucose values among the subjects in this study; the distribution of the fasting blood glucose concentrations of the subjects over fifty years of age displayed no irregularities from those of the other subjects.

Previous studies which have indicated that fasting blood glucose concentrations were higher among overweight than among average weight subjects usually have been clinical investigations concerned with diabetics or potential diabetics. In this study none of the fasting blood glucose concentrations for the overweight subjects were pathological in the customary sense; all were well within the range of values reported for healthy adults (Peters and Van Slyke, 1946; Best and Taylor, 1950). Further, all overweight subjects were aglycosuric. Individually, none of the fasting glucose values would appear unusually high. However, the method employed in the blood glucose determinations (Nelson, 1944) precipitates the blood proteins with barium hydroxide and zinc sulfate and yields lower results than many methods which precipitate with tungstate; a greater number of non-specific reducing substances are eliminated from the filtrate by the former method than by the latter method (Hawk, Oser and Summerson, 1947). The existence of a statistically significant difference in fasting glucose concentrations among the overweight subjects compared to the average weight and underweight subjects in this study might be considered a difference in metabolic pattern among the groups.

Responses to Test Meals

The blood glucose concentrations at the various time intervals following the test meals displayed much greater individual variations within groups than did the fasting glucose concentrations, Figure 7. The mean blood glucose concentrations, together with the F-values for the analyses of variance and covariance, at each hour measured are presented in Table XIV.

Following the high fat test meal, mean blood glucose concentrations at one-half hour and at the first, second, third, fourth and fifth hours for the overweight subjects were 117, 112, 102, 85, 85 and 82 milligrams per 100 milliliters; for the average weight subjects were 113, 91, 87, 79, 86, and 84 milligrams per 100 milliliters; and for the underweight subjects were 98, 91, 81, 83, 82 and 82 milligrams per 100 milliliters.

Analyses of variance indicated that significantly different mean concentrations existed among the three groups at the first and second hours, $P < 0.01$; the mean concentrations of the overweight subjects were significantly higher than those of the average and the underweight subjects at both hours. However, the significantly higher concentrations at these hours in the overweight subjects were shown to be related to the higher mean fasting concentrations in this group by analyses of covariance; the increments of rise were not significantly higher among the overweight subjects than among the average or underweight subjects.

Although the mean fasting glucose concentration for the overweight subjects was significantly higher than those for the other two groups, there were no significant differences between groups at the third, fourth and fifth hours following the high fat test meal. Individually all

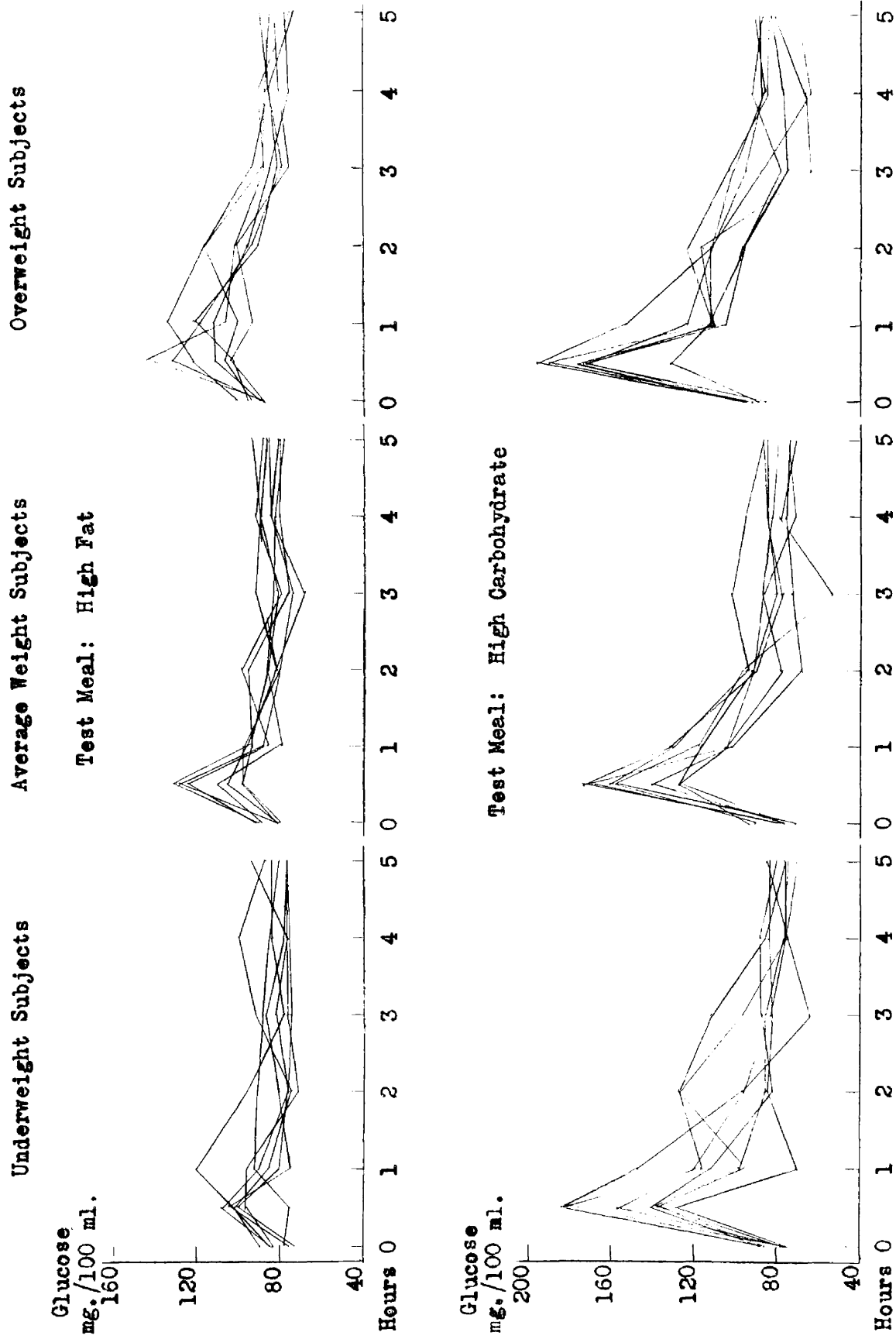


Figure 7. Blood Glucose Concentrations at intervals on two test days.

TABLE XIV
MEAN BLOOD GLUCOSE CONCENTRATIONS AT INTERVALS ON TWO TEST DAYS

Intervals of test days	Subjects			F-Value ²		
				Analysis of Variance		Analysis of Covariance Total
	Underweight mg./100 ml.	Average weight mg./100 ml.	Overweight mg./100 ml.	Total	Linear	
High fat test meal: ³						
Fasting ³	81 ± 2.3 ¹	85 ± 1.8 ¹	92 ± 1.7 ¹	8.42**	16.22**	0.61
½ hour	98 ± 4.1	113 ± 5.4	117 ± 6.0	3.42		0.88
1st hour ³	91 ± 5.4	91 ± 2.5	112 ± 5.2	7.11**	10.41**	2.11
2nd hour ³	81 ± 3.4	87 ± 2.6	102 ± 3.9	10.52**	19.83**	2.04
3rd hour	83 ± 2.5	79 ± 2.8	85 ± 2.3	1.38		1.03
4th hour	82 ± 3.2	86 ± 1.6	85 ± 1.8	0.55		1.11
5th hour	82 ± 2.4	84 ± 2.0	82 ± 2.4	0.32		0.29
High carbohydrate test meal: ³						
Fasting ³	81 ± 2.1	81 ± 3.1	93 ± 1.8	8.39**	12.20**	4.57*
½ hour	152 ± 8.5	151 ± 7.4	174 ± 7.7	2.68		1.15
1st hour ³	109 ± 9.4	115 ± 4.7	119 ± 6.3	0.54		0.65
2nd hour ³	99 ± 7.3	87 ± 3.8	110 ± 7.2	4.87*	2.10	2.93
3rd hour	87 ± 5.5	80 ± 5.6	87 ± 5.9	0.44		0.48
4th hour	80 ± 2.1	82 ± 2.9	80 ± 4.1	0.10		1.26
5th hour	78 ± 2.0	80 ± 2.5	84 ± 2.7	1.88		0.60

¹ Standard error of the mean

² * = $P < 0.05$; ** = $P < 0.01$

³ Least significant differences for $P < 0.05$ and $P < 0.01$, respectively; high fat test meal, fasting, 5.6 and 8.5, 1st hour, 14.1 and 19.7, 2nd hour, 10.4 and 14.6; high carbohydrate test meal, fasting, 7.4 and 10.4, 2nd hour, 16.1 and 22.6.

glucose concentrations of the overweight subjects were considerably below fasting values at the fifth hour; this was true also for six of the seven subjects at the fourth hour. The mean blood glucose concentrations of the overweight subjects were significantly lower than fasting concentrations at the fourth hour, $P < 0.05$, and at the fifth hour, $P < 0.01$, by Fisher's t-test. This pattern was not observed among the average weight nor among the underweight subjects.

All subjects, with the exception of overweight subject HT, showed increased blood glucose concentrations in response to the twenty-six grams of carbohydrate in the high fat test meal. Wide individual variations in response occurred within groups, particularly among the overweight and the underweight subjects: two underweight subjects, YK and RD, and three overweight subjects, HM, MR and YL, had maximum blood glucose concentrations delayed beyond one-half hour; overweight subject RT showed a distinct maximum at one-half hour, which was atypical of the overweight subjects; and overweight subject HT had essentially no change in blood glucose concentrations for two hours and then a decrease.

Following the high carbohydrate test meal, mean blood glucose concentrations at one-half hour and at the first, second, third, fourth and fifth hours for the overweight subjects were 174, 119, 110, 87, 80 and 84 milligrams per 100 milliliters; for the average weight subjects were 151, 115, 87, 80, 82 and 80 milligrams per 100 milliliters; and for the underweight subjects were 152, 109, 99, 87, 80 and 78 milligrams per 100 milliliters.

Blood glucose concentrations of the one-half hour blood samples following the high carbohydrate test meal for the underweight subjects

ranged from 128 to 183 milligrams per 100 milliliters; four subjects had values of 140 milligrams per 100 milliliters or less. In contrast, one-half hour blood glucose concentrations of six of the seven overweight subjects ranged from 174 to 195 milligrams per 100 milliliters; one subject, RM, had a half-hour glucose concentration of only 132 milligrams per 100 milliliters of blood. The range of half-hour blood glucose concentrations among the average weight subjects was similar to that of the underweight group; values ranged from 126 to 173 milligrams per 100 milliliters.

Blood glucose concentrations of the subjects in all groups decreased rapidly after one-half hour maximum values were reached. The mean concentrations, and most individual responses, showed decreases until the third hour. At the first, second and third hours, ranges of concentrations among the underweight subjects were greater than for the other two groups; at the third hour, there were wide variations in glucose concentrations among all groups. By the fourth hour variations among the individual underweight subjects had been minimized; among the overweight subjects, individual variations were more marked. By analyses of variance the mean glucose concentrations at the second hour only showed significant differences among groups; the mean blood glucose concentration of the overweight subjects was significantly higher than that of the average weight subjects, but not of the underweight subjects. This higher concentration again was determined to be related in part to the higher fasting concentration of the overweight subjects (analysis of covariance).

At the fifth hour the blood glucose concentrations of all of the overweight subjects were considerably below their fasting concentrations,

and the mean concentration was significantly lower than the mean fasting concentration ($P < 0.05$); this decrease below fasting was particularly interesting in view of the high concentrations for six of this group at the one-half hour period. Greater post-absorptive hypoglycemias among obese than among average weight subjects, however, have been observed previously (Ogilvie, 1935). There was not a significant lowering by the fourth hour following the high carbohydrate test meal as was true following the high fat test meal. Again no significant lowering of the mean blood glucose concentrations of the average weight or underweight subjects below fasting concentrations occurred at any hour.

It has been shown by many that carbohydrate tolerance is influenced by previous diet. Control of previous diet thus has an important role in carbohydrate tolerance tests where diagnosis of endocrine function, for example, is the desired purpose; it is desirable in such tests to limit other factors known to increase or decrease tolerance. In a study of metabolic patterns of subjects representative of a type or group, however, dietary habits may be considered contributory to the overall metabolic picture. Therefore in this investigation, it was deemed desirable for the subjects to pursue their customary diet patterns prior to testing.

It was shown by the data presented in Tables VIII, IX, and X that no significant differences existed among the three groups either in the total quantity of carbohydrate consumed or in the percent contributed by carbohydrate to the total daily caloric intakes evaluated. The mean carbohydrate intakes of the overweight subjects were consistently lower, however, than those of the average weight or underweight subjects in the three calculated daily intakes. For the underweight, average weight and

overweight subjects, respectively, the mean estimated carbohydrate intakes were 225, 207 and 165 grams for the random diets, 202, 170 and 143 grams for the day preceding the first experimental day and 223, 202 and 154 grams for the day preceding the second test day. Lower carbohydrate intakes may have contributed to the tendency for the lower carbohydrate tolerances exhibited by the overweight subjects. However, there was no consistent relationship in individuals between calculated carbohydrate intakes and one-half hour blood glucose concentrations.

Data from this investigation do not lend themselves to precise interpretation in terms of "high" or "low" carbohydrate tolerance, since pure glucose was not administered and blood sampling intervals were thirty minutes during the first hour. Furthermore, identical amounts of carbohydrate, fat and protein were provided in the test meals for all subjects, although it was recognized that carbohydrate and fat tolerance feedings are frequently based on amounts related to body weight or surface area. The latter method has certain advantages, but in studying overweight and underweight subjects, there was considerable question as to the best comparative basis for feeding. High and low glucose tolerances observed among these subjects were not related to large or small body builds. The low amount of protein used in the test meal also was recognized as a factor in the type of tolerance curve obtained in these subjects in view of the studies of Addison, et al. (1953) and Orent-Keiles and Hallman (1950).

Delayed utilization of carbohydrate, or decreased tolerance, has been reported to be a common accompaniment of obesity (Newburgh, 1942) and to be related to the duration more than to the degree of obesity (Ogilvie, 1935). Again, however, most studies of delayed utilization among overweight

subjects have been complicated by clinical considerations of diabetes. None of the observed delays in carbohydrate utilization among the overweight subjects in this study were of the diabetic-type. Further, subject RM, who had a long history of being overweight, had one of the lowest one-half hour blood glucose concentrations of all subjects following the high carbohydrate feeding.

There was an apparent tendency for increased carbohydrate tolerance among the most underweight subjects and a generally decreased tolerance among the overweight subjects. There was no evidence of increased carbohydrate tolerance by the two subjects with "active" obesity. Likewise, there were no apparent abnormal deviations from group patterns by the subjects of fifty years or more of age. The most interesting observations in blood glucose concentration changes following the test meals were: the prolonged elevation of blood glucose concentrations above fasting among the overweight subjects, particularly following the high fat test meal; and the distinct trend among the overweight subjects for glucose concentrations to fall below fasting concentrations at the fourth or fifth hours, while fasting concentrations were significantly higher among the overweight subjects than among the other two groups.

Serum Lipid Patterns

Fasting Serum Lipid Concentrations

Conspicuous individual variations rather than group differences characterized the fasting values of the various serum lipid constituents measured in this investigation. This was true for total lipids, total cholesterol, the various lipoprotein fractions and for the chylomicron

counts. Fasting serum total cholesterol and lipoprotein data are presented graphically in Figures 8 and 9. Fasting serum chylomicron and total lipid data are included in Figures 10 and 11 which are on pages 146 and 152, respectively. The wide range of values for all individual constituents was typical of results of studies previously reviewed. Individual data are tabulated in Tables XXXV through XXXVIII (Appendix).

There were no significant differences among the means for the underweight, average weight or overweight subjects for any of the individual lipid constituents measured, and no constituent showed a significant correlation with the subjects' percent deviations from desirable weight. Mean fasting values of the three groups for the various lipid fractions are tabulated in Table XV.

Capillary serum total lipids showed a trend of increasing mean values from underweight to average weight to overweight subjects of 750, 808 and 826 milligrams per 100 milliliters of serum, respectively; this trend also was observed by Man and Gildea (1937) and Kornerup (1950). The difference between the mean concentrations of the average weight and overweight subjects in this study was less than the difference between the values of 591 and 890 milligrams per 100 milliliters of serum which were reported by Hetényi (1936) for his control and obese subjects, respectively. The ranges of concentrations measured were, however, quite comparable. The ranges among the subjects in this study were 505 - 990, 557 - 1166, and 699 - 1064 milligrams of total lipids per 100 milliliters of serum in the underweight, average weight and overweight groups, respectively. Hetényi reported a range of 371 - 1005 milligrams of total lipids per 100 milliliters of serum for control subjects and 544 - 1117

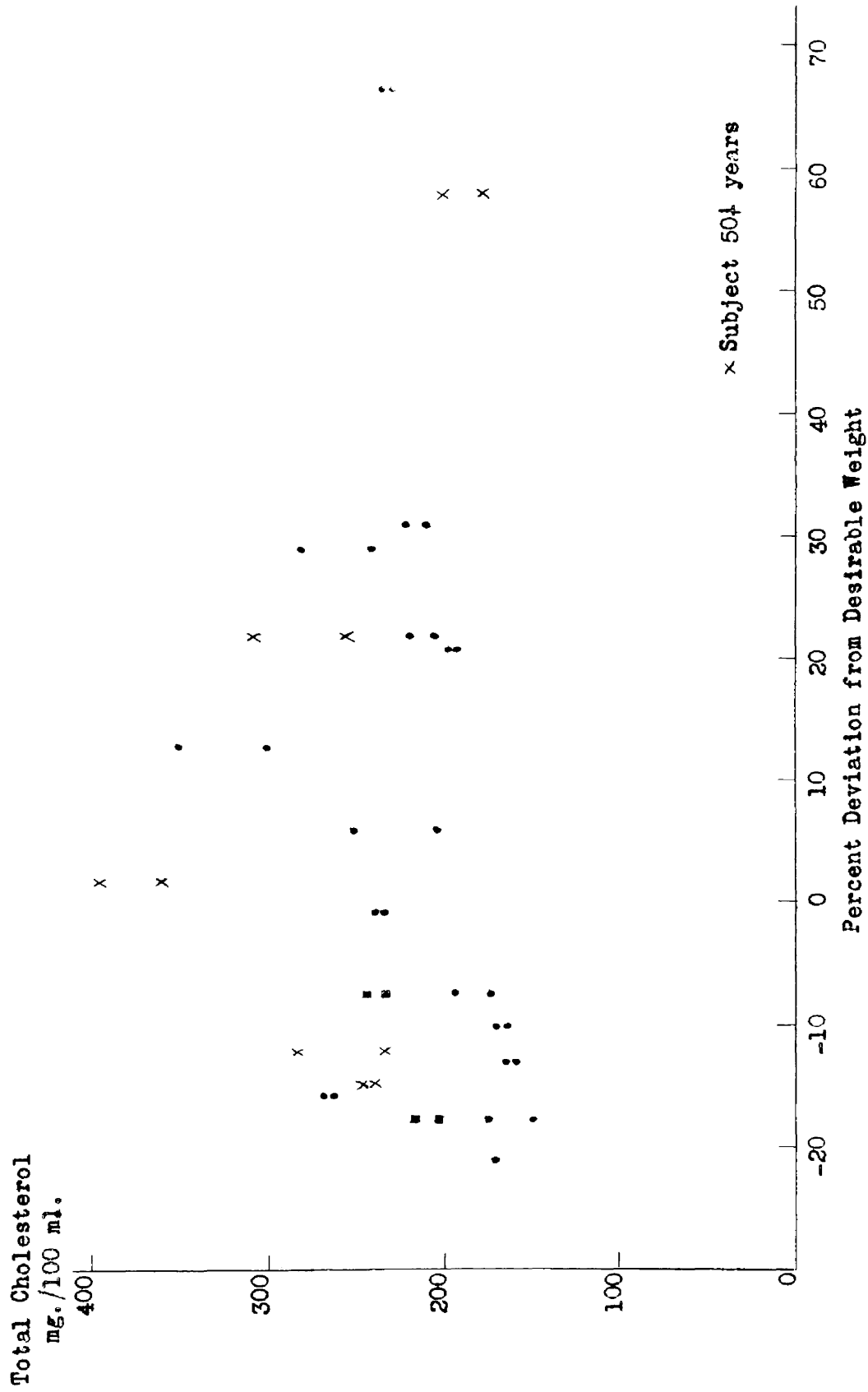


Figure 8. Fasting serum total cholesterol concentrations for twenty-one women on two test days in relation to percent deviations from desirable weight.

x Subject 50½ years

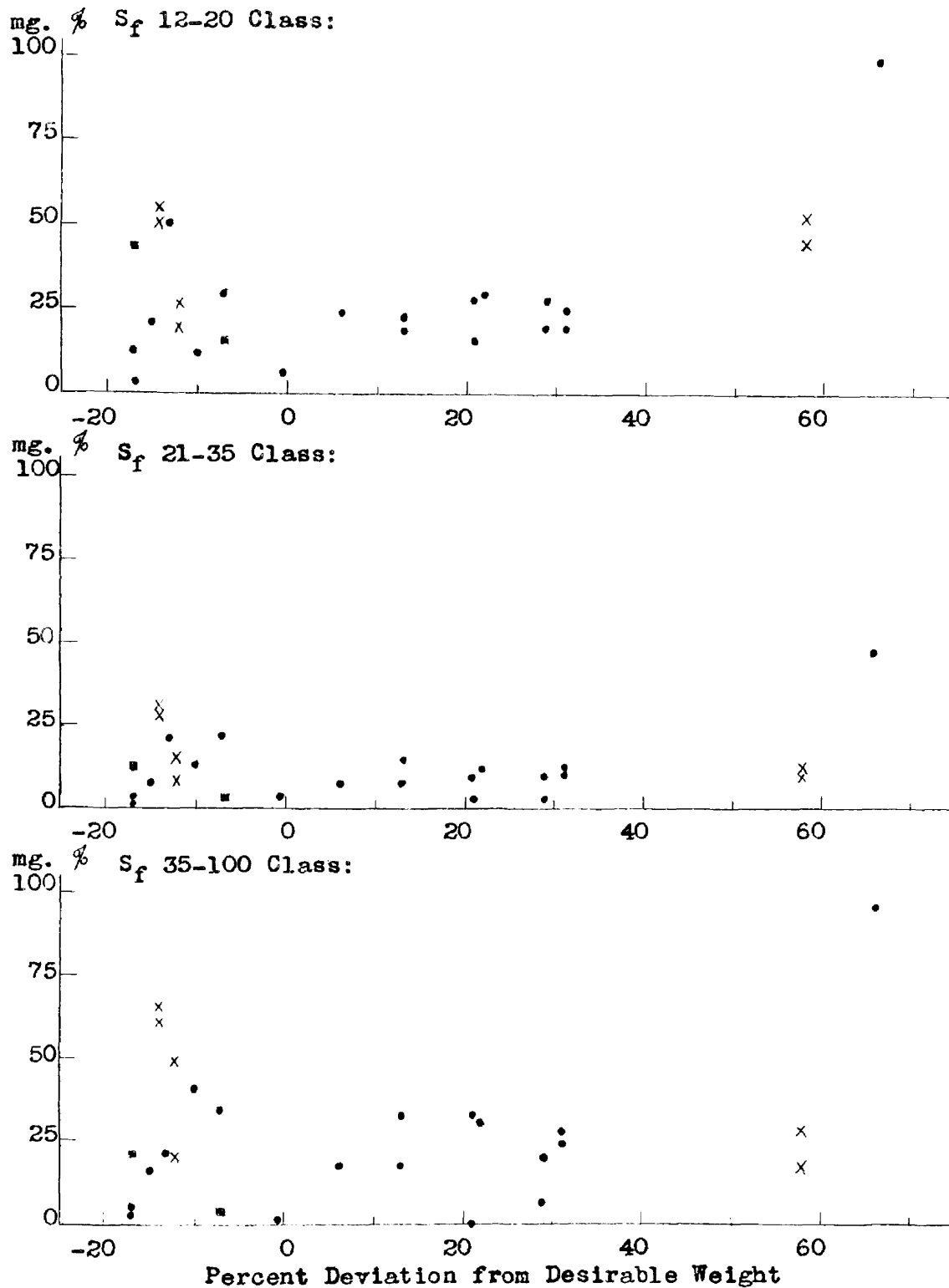


Figure 9. Fasting serum lipoprotein class concentrations in relation to percent deviations from desirable weight.

TABLE XV

MEAN FASTING SERUM LIPID CONSTITUENTS

Serum Lipid Constituent	Subjects		F-Value ² Analysis of Variance Total
	Underweight	Average weight Overweight	
Total lipids, venous, ³ mg./100 ml.	795 ± 46.3 ¹	685 ± 62.6 ¹	796 ± 50.0 ¹ 0.25
Total lipids, capillary, ⁴ mg./100 ml.	750 ± 42.5	808 ± 76.5	826 ± 35.3 0.41
Total cholesterol, venous, mg./100 ml.	214 ± 12.7	253 ± 19.7	228 ± 9.6 0.90
Lipoprotein fractions, venous: ⁵			
S _f 12-20, mg./100 ml.	34 ± 6.8	18 ± 3.3	38 ± 13.1 1.37
S _f 21-35, mg./100 ml.	14 ± 2.3	10 ± 3.0	14 ± 6.8 0.21
S _f 35-100, mg./100 ml.	29 ± 9.1	22 ± 6.9	31 ± 14.0 0.22
S _f 12-100, mg./100 ml.	77 ± 17.5	50 ± 12.0	83 ± 33.7 0.57
Chylomicron Counts, ⁶ venous ³	60 ± 13	35 ± 7	91 ± 15 3.50
Chylomicron Counts, ⁶ capillary	67 ± 12	48 ± 7	105 ± 17 3.52

¹ Standard error of the mean² F-values: P<0.05, 3.55; P<0.01, 6.01³ Venous total lipid and chylomicron count data include those of only six underweight and six average weight subjects⁴ Data of 7 underweight, 6 average weight and 6 overweight subjects⁵ Data of 6 underweight, 6 average weight and 6 overweight subjects⁶ Chylomicron counts, particles per standard dark ground field

milligrams per 100 milliliters of serum for obese subjects when they were consuming their usual diets.

Fasting total lipid concentrations determined in this study were higher than mean values frequently reported (Cecil, 1947; Peters and Van Slyke, 1946) and were particularly higher than total lipid values calculated from determined constituents, e. g. Wilmot and Swank (1952). Values in this study were comparable to those reported by Herzstein, Wang and Adlersberg (1953), who determined total serum lipids by the Bloor method, and to those of Goldbloom (1952) and Kornerup (1950), who determined total lipids by a gravimetric method.

Age was an observed factor in individual variation among the subjects; lower total lipid concentrations occurred generally in younger subjects. The relationship of age and serum total lipid concentrations was not consistent, however, conforming to previous studies reported (Herzstein, Wang and Adlersberg, 1953; Man and Peters, 1953). The most atypical value among all three groups of subjects was that of average weight subject NH; fasting serum total lipid concentrations were 1146 and 1166 milligrams per 100 milliliters for the two days, respectively.

Variations in individuals between the two fasting concentrations of serum total lipids determined ranged from one percent to one extreme case of forty percent. Most between-day variations measured were less than ten percent (Appendix, Table XXXV).

Individual differences between fasting venous and capillary serum total lipids determined simultaneously varied up to almost twenty percent; differences among individuals of all groups were not consistently higher or lower for either venous or capillary concentrations. Mean venous

capillary serum total lipids were higher, lower, and higher than capillary serum total lipids among the overweight, average weight and underweight subjects, respectively, Table XV, but none of the differences were statistically significant. Further, for various reasons, the determinations of venous serum total lipids were not complete for all subjects. The lack of consistency of capillary and venous serum total lipid concentrations has been reported. Frazer and Stewart (1939b) concluded that more reliable information was gained from capillary blood fat determinations. The cholesterol fraction, however, has been found not to differ significantly in capillary and venous serum, (Amen, 1951).

Fasting serum total cholesterols ranged from 151 to 396 milligrams per 100 milliliters; the two subjects with the highest concentrations were of the average weight group, Figure 8; GN and NE had fasting serum cholesterol concentrations greater than 300 milligrams per 100 milliliters. Two underweight, RL and RD, and two overweight subjects, HT and RT, had serum total cholesterol concentrations between 250 and 299 milligrams per 100 milliliters, Table XVI. The mean concentrations were 214, 253 and 228 milligrams per 100 milliliters of serum, respectively, for the underweight, average weight and overweight groups, differences among the groups were not significant. Age had no consistent effect on the marked individual variation within groups, although the subjects over fifty years of age tended to have higher concentrations. Although individual variations between the two days were found, the maximum range between days for an individual was 15 milligrams per 100 milliliters of serum; for the most part, between-day variations of an individual were slight compared to the variations among individuals.

TABLE XVI

DISTRIBUTION OF SUBJECTS ACCORDING TO FASTING
SERUM LIPID FRACTION CONCENTRATIONS¹

Serum Lipid Fractions	Number of Subjects		
	Underweight	Average Weight	Overweight
Cholesterol, milligrams per 100 milliliters			
< 250	5	5	5
250 - 299	2	0	2
> 300	0	2	0
Lipoprotein class, S _f 12-30, milligrams per 100 milliliters			
0 - 49	4	6	4
50 - 79	2	0	1
> 80	0	0	1
Lipoprotein class, S _f 35-100, milligrams per 100 milliliters			
0 - 49	5	6	5
50 - 100	1	0	1
> 100	0	0	0

¹ Groupings reported by Walker, Lawry, Love and Mann (1953)

The fasting venous total cholesterol concentrations showed a highly significant positive correlation with fasting venous serum total lipid determinations, $r = 0.795$, ($P < 0.01$). No significant correlation was found between total cholesterol and chylomicron counts.

Greatest group differences among the lipoprotein concentrations were in the S_{f12-20} class, Table XV. It was regrettable that duplicate venous samples for lipoprotein determinations were not obtained for all subjects; in fact, no venous samples were obtained for one underweight, one average weight and one overweight subject. Two underweight, YK and NM, and two overweight subjects, RM and SM, had S_{f12-20} concentrations above 50 milligrams per 100 milliliters of serum and one underweight, YK, and one overweight subject RM, had $S_{f35-100}$ concentrations above 50 milligrams per 100 milliliters of serum, Table XVI.

Chylomicron counts were determined as a measure of particulate triglycerides in the serum. Alipemic blood plasma was reported as containing only a very low triglyceride concentration (Frazer, 1953), but some chylomicrons have always been observed in fasting serum (e.g. Frazer and Stewart, 1939b; Becker, et al., 1949). Venous and capillary fasting chylomicron counts for each subject on both experimental days were determined. Mean capillary serum chylomicron counts were higher in the overweight than in the average or underweight groups; the mean counts were 105, 48, and 67 per standard dark-ground field for the overweight, average weight and underweight groups, respectively, Table XV. The group variation was not significant due to wide individual variations within each group, although the probability of the group mean differences being due to chance was only slightly greater than one in twenty. Mean venous

serum chylomicron counts were lower than those of capillary serum for each group, but again, like those of total lipids, individual deviations were not consistent in direction. The greater differences between capillary and venous serum chylomicron counts were found among the upper average and overweight subjects. Frazer and Stewart (1937) reported that capillary and venous chylomicron counts were similar when particle counts were low but that there was a marked difference when particle counts were high. Marder, et al. (1952) found venous counts five to fifteen percent higher than capillary counts in their determinations following high fat test meals.

Fasting chylomicron counts showed no correlations with either serum fasting total lipid concentrations or with total cholesterol concentrations; this was anticipated in view of the small fraction of fasting blood lipids which is found in the form of triglycerides (Frazer, 1953). Age had no apparent effect on individual variations within groups; Becker, Meyer and Necheles (1949) likewise recorded no difference in fasting chylomicron concentrations between their young and aged subjects. In this study higher fat intakes on the day prior to an experiment were not correlated with higher chylomicron counts. However, one subject, EL, failed to follow instructions not to eat a high fat food in the evening prior to the study; the subject reported that she had eaten two doughnuts at 10 P.M. The fasting chylomicron count on the following day was decidedly higher than on the other experimental day.

The lack of any significant correlation of fasting chylomicron concentrations with differences in degrees of adiposity was in agreement with the one report of a similar study which was found. Chylomicrographs for a normal, fat and thin subject, respectively, presented by Frazer

and Stewart (1939b), showed no real difference in fasting chylomicron counts.

It was of interest to note the lower fasting serum total lipids, serum cholesterol and serum chylomicron concentrations for subjects SM and RM, +58 and +66 percent of desirable weight, respectively, relative to values of the other overweight subjects. These women were the most overweight of the subjects in this investigation and both had long histories of being overweight. This same pattern was not true for the various serum lipoprotein classes measured. RM consistently had high lipoprotein concentrations; SM had an S_f12-20 class concentration of 45 and 52 on the two days but other lipoprotein class concentrations measured were low.

Serum Total Lipids and Chylomicron Concentrations Following Test Meals

Following the test meals, capillary serum chylomicrons and capillary serum total lipids were the only lipid constituents measured. Chylomicrons have been shown to be largely neutral fat and to be related to fat absorption following fat meals (e. g. Marder, et al., 1952). Chylomicrographs of the overweight and underweight subjects showed distinct group variations following both test meals, Figure 10.

Following the high fat test meal the serum chylomicron concentrations of the underweight subjects increased more quickly, reached higher peak concentrations, and then decreased more rapidly than did those of the overweight subjects. Mean chylomicron counts per standard dark-ground field at fasting, at one-half hour and at the first, second, third, fourth and fifth hours were 67, 185, 388, 541, 466, 393 and 277 for the underweight subjects, 44, 75, 347, 412, 372, 356, and 290 for the average

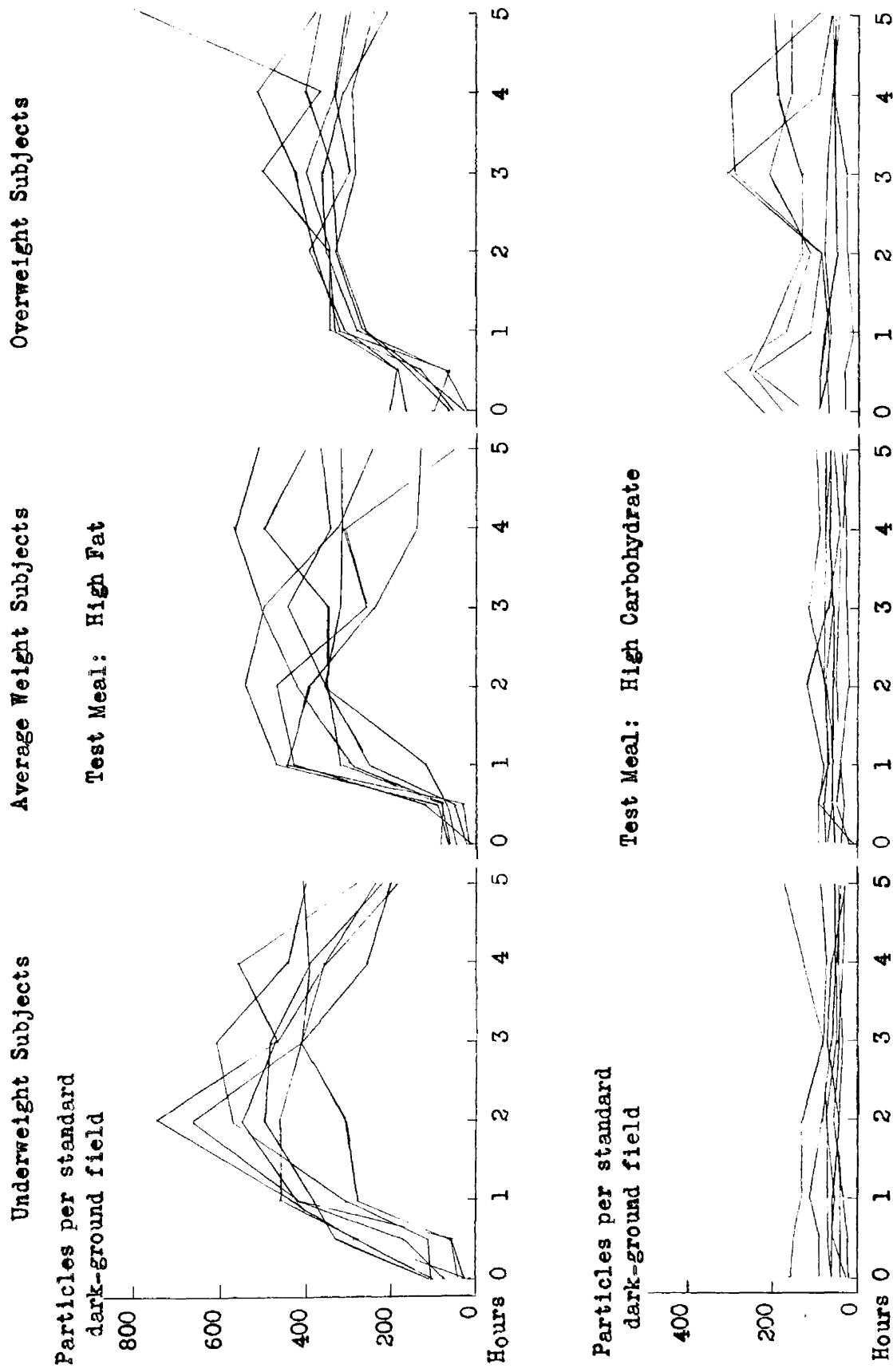


Figure 10. Chylomicron counts at intervals on two test days.

weight subjects and 94, 135, 303, 351, 375, 366 and 373 for the overweight subjects. Although there were individual variations within each group, the patterns of six of the underweight and six of the overweight subjects were distinct. Underweight subject, NM, showed a response typical of the overweight subjects, whereas overweight subject, ML, showed a response typical of the underweight subjects. The average weight subjects individually tended to display patterns typical of the other two groups and generally in order of their evaluated percentage deviations from desirable weight. The chylomicrographs of NS, NH, LP and GN were typical of the overweight subjects, whereas those of EN, SL and RW were typical of the underweight subjects.

Certain conspicuous individual variations in chylomicrograph patterns were observed. Variations were not the result of differences in fluid intakes however; fluid intakes were maintained constant throughout the experimental periods. One overweight subject, HM, showed an extremely high concentration of chylomicrons at the fifth hour; the serum sample was visibly milky. The only other serum sample showing the same visible milkiness was the second hour sample of underweight subject, NL. In both of these cases the chylomicron counts were above 600 for the standard field counted. Underweight subject, RK, also responded with a second hour serum sample having a very high count; this serum sample, however, was not visibly creamy. Although no consistent attempt was made to differentiate sizes of chylomicrons, the smallness of the chylomicrons of the serum of subject RK was in striking contrast to those of other subjects; the chylomicrons were small and numerous, but distinct.

Significant differences in chylomicron concentrations among the three groups following the high fat test meal were observed at one-half hour, $P < 0.05$, when the mean serum chylomicron concentration of the underweight group was significantly higher than that of the average weight subjects, and at the second hour, $P < 0.01$, when the underweight group showed a significantly higher mean serum chylomicron concentration than did the average weight and overweight groups, Table XVII. It was noted that the mean increment increase at one-half hour was marked only in the underweight group; the higher one-half hour mean concentration for the overweight group was related to the higher mean fasting concentration in this group. The highest group mean concentrations were found at the second hour for both the underweight and the average weight subjects; the highest mean concentration of the overweight group was at the third hour but there was little change in concentration from the second through the fifth hours. Fifth hour chylomicron concentrations were still well above fasting concentrations for all groups; individually this was also true. Only one subject, RW, even approached fasting concentration by the fifth hour. For individual subjects, the peaks of chylomicrographs shifted toward a later hour with increasing positive deviations from desirable weight; the pattern was not, however, consistent. Age had no apparent effect on the chylomicrographs of these subjects as was observed by Necheles and co-workers (Becker, Mayer and Necheles, 1949; 1950; Marder, et al., 1952) and by Frazer and Stewart, (1937). Age differences in this study were not as great, however, as those reported by these workers.

The chylomicrographs determined in this study were in contrast to the results reported by Frazer and Stewart (1939b) who stated that their

TABLE XVII

MEAN CAPILLARY SERUM CHYLOMICRON COUNTS AT INTERVALS ON TWO TEST DAYS

(Particles per standard dark-ground field)

Intervals of test days	Subjects			F-Value ²		
	Underweight	Average weight	Overweight	Total	Linear	Quadratic
High fat test meal:						
Fasting	67 ± 15 ¹	44 ± 10 ¹	94 ± 26 ¹	1.88		
½ hour ³	185 ± 43	75 ± 10	135 ± 18	3.91*	1.61	6.21*
1st hour	388 ± 25	347 ± 55	303 ± 13	1.42		
2nd hour ³	541 ± 54	412 ± 27	351 ± 11	7.62**	14.60**	0.64
3rd hour	466 ± 27	372 ± 42	375 ± 29	2.61		
4th hour	393 ± 34	356 ± 53	366 ± 28	0.24		
5th hour	277 ± 34	290 ± 60	373 ± 74	0.79		
High carbohydrate test meal:						
Fasting	66 ± 18	51 ± 12	116 ± 25	3.24		
½ hour ³	70 ± 15	67 ± 8	156 ± 43	3.62*	5.29*	1.96
1st hour	69 ± 14	58 ± 6	106 ± 26	2.09		
2nd hour	69 ± 12	68 ± 11	84 ± 14	0.57		
3rd hour ³	58 ± 10	66 ± 11	157 ± 42	4.59*	7.44*	1.73
4th hour	61 ± 12	63 ± 9	130 ± 34	3.38		
5th hour	64 ± 19	62 ± 9	97 ± 22	1.17		

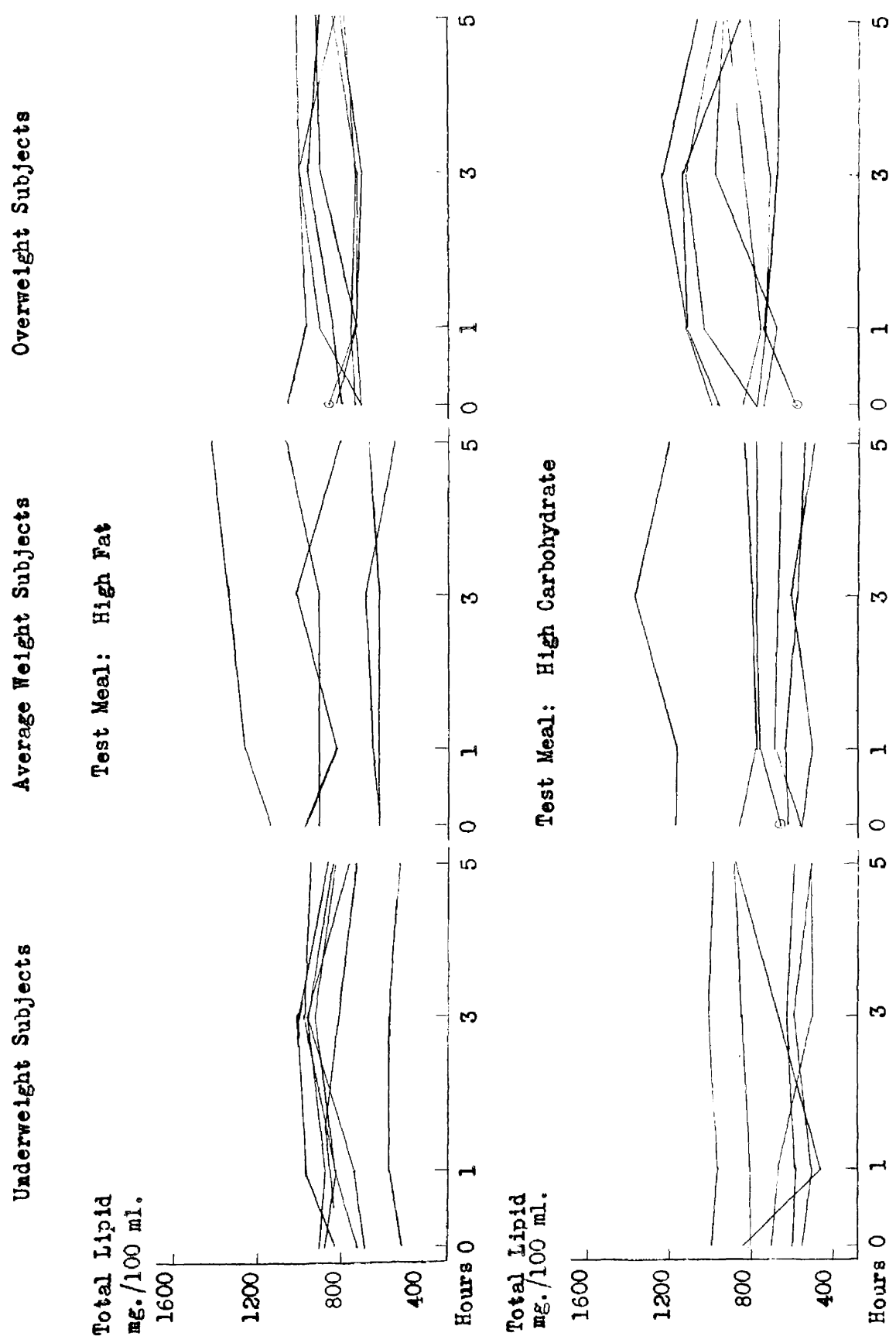
¹ Standard error of the mean² * = P < 0.05; ** = P < 0.01³ Least significant differences for P < 0.05 and P < 0.01, respectively: high fat test meal, ½ hour, 86 and 120, 2nd hour, 108 and 152; high carbohydrate test meal, ½ hour, 82 and 115, 3rd hour, 79 and 111

obese subjects always showed much higher chylomicron concentrations than did their thin subjects taking an identical standard meal. In the chylomicrographs they presented, the peak value of the fat subject was shown above "good normal limits" while that of the thin subject was below these limits. Wilmot (1950) stated that a previous high fat intake increased the speed with which fat was removed from the blood after a fat meal. Although no significant differences were found in the quantity of fat eaten by the three groups of subjects in this study, Tables VIII and X, the mean fat intakes during both the day previous to the high fat test meal and in the random day recall diets were highest among the underweight subjects. The rate of removal of fat from the blood of the underweight subjects in this study appeared more rapid than that of the other groups in that chylomicron concentrations decreased more rapidly after reaching peak values. If one presupposes that this same effect was in operation throughout the absorption period as indicated by Frazer (1953), then the rate of absorption of particulate triglycerides into the systemic blood among the underweight subjects must have been more rapid than that of the overweight subjects. This evidence was in contrast to the suggestion of Frazer and Stewart (1939b) that more lipolysis apparently occurred in thin than in fat subjects. The total length of time in which particulate triglycerides would be concentrated in the blood would, however, appear to be longer in the overweight subjects, particularly following an evening meal; higher chylomicron concentrations have been suggested by Moreton (1947) as possibly being an underlying factor in the intimal lipid deposition in human atherosclerosis. The higher fasting chylomicron concentrations of the overweight subjects would substantiate the

slower rate of removal observed during the five hours following the test meal.

Following the high carbohydrate test meal, unexpected fluctuations in serum chylomicron concentrations were observed among four of the overweight subjects, HM, HT, MR and YL. Three of the overweight subjects, six of the average weight and six of the underweight subjects showed slight changes from hour to hour in chylomicron concentrations throughout the five hour period; one average weight subject, SL, and one underweight subject, RK, showed minor fluctuations, Figure 10. Although there were individual differences in the patterns of chylomicron concentrations of the four overweight subjects, there tended to be elevations at the one-half and third hours; the mean concentration of the overweight group was significantly higher than those of the average weight or underweight groups at both of these hours ($P < 0.05$), Table XVII. Mean chylomicron counts per standard dark-ground field at fasting, at one-half hour and at the first, second, third, fourth and fifth hours were 116, 156, 106, 84, 157, 130 and 97 for the overweight subjects; 51, 67, 58, 68, 66, 63 and 62 for the average weight subjects and 66, 70, 69, 69, 58, 61 and 64 for the underweight subjects.

Increases in the concentrations of capillary serum total lipids also were observed following the high carbohydrate test meal in five overweight subjects; two average weight subjects showed a similar rise, Figure 11. Elevated serum total lipid concentrations occurred in three of the same subjects in which elevated chylomicron counts were observed, but four subjects showed elevated serum total lipid concentrations without increases in chylomicron concentrations. Further, increased



⊙ Venous serum

Figure 11. Serum total lipid concentrations at intervals on two test days.

concentrations of total lipid and of chylomicrons did not necessarily occur concurrently even when both were observed in the same individual. (Data for individual subjects are presented in Tables XXXV and XXXVI, Appendix).

Because of the great variation of fasting serum total lipid concentrations among the individual subjects in each group, hourly responses to both test meals also showed wide individual variations that tended to mask any trends of change that might be occurring. Standard errors of means were exceedingly high for all groups following both test meals; no significant differences in mean values were determined, Table XVIII. Data of serum total lipid concentrations were not obtained for all subjects. The number of missing data made analyses of covariance impractical; therefore, the data for serum total lipid concentrations following both test meals were calculated as percent changes from fasting. Only subjects for whom complete capillary data were available were included. At the first, third and fifth hours, following the high fat test meal, the serum total lipid concentrations for the overweight subjects were 104, 111 and 110 percent of fasting, for the average weight subjects, 100, 107 and 104 percent of fasting and for the underweight subjects, 107, 120 and 105 percent of fasting, respectively. Following the high carbohydrate test meal, the serum total lipid concentrations for the overweight subjects were 106, 118, and 110 percent of fasting, for the average weight subjects were 94, 101 and 92 percent of fasting and for the underweight subjects were 96, 97 and 94 percent of fasting at the first, third and fifth hours, respectively. These data are tabulated in Table XIX. No significant differences in the mean percentage change from fasting of total

TABLE XVIII
MEAN CAPILLARY SERUM TOTAL LIPID CONCENTRATIONS AT INTERVALS ON TWO TEST DAYS

Intervals of test days	Subjects				F-Value ² Analysis of Variance Total		
	No. of Sub-jects	Underweight mg./100 ml.	No. of Sub-jects	Average weight mg./100 ml.			
High fat test meal: Fasting 1st hour 3rd hour 5th hour	6	751 ± 58.5 ¹	5	845 ± 103.3 ¹	6	800 ± 57.0 ¹	0.45
	7	802 ± 47.6	5	847 ± 117.3	7	806 ± 38.0	0.15
	6	897 ± 68.5	5	911 ± 128.6	7	858 ± 50.4	0.12
	7	780 ± 51.5	5	896 ± 155.6	7	869 ± 30.9	0.57
High carbohydrate test meal: Fasting 1st hour 3rd hour 5th hour	6	749 ± 66.2	5	771 ± 122.2	6	853 ± 44.4	0.51
	6	662 ± 78.5	6	748 ± 89.5	7	882 ± 72.6	1.97
	5	711 ± 91.4	5	826 ± 144.5	7	959 ± 83.4	1.46
	6	720 ± 85.0	6	754 ± 105.8	7	888 ± 46.9	1.30

¹ Standard error of the mean

² No F-values significant at $P < 0.05$ or $P < 0.01$

TABLE XIX

MEAN CAPILLARY SERUM TOTAL LIPID CONCENTRATIONS EXPRESSED
AS PERCENTAGE OF FASTING CONCENTRATIONS

Intervals of test days	Subjects		F-Value ² Analysis of Variance Total
	Underweight %	Average weight % Overweight %	
High fat test meal: ³ 1st hour 3rd hour 5th hour	106.9 ± 3.60 ¹	100.0 ± 4.02 ¹	0.52
	119.9 ± 5.23	107.0 ± 3.26	1.32
	105.4 ± 2.99	104.3 ± 7.84	0.44
High carbohydrate test meal: ⁴ 1st hour 3rd hour 5th hour	95.8 ± 1.82	93.5 ± 4.53	1.58
	97.3 ± 6.26	100.6 ± 7.70	2.93
	94.0 ± 5.59	91.9 ± 3.98	3.23

¹ Standard error of the mean

² F-values: high fat test meal, $P < 0.05$, 3.74, $P < 0.01$, 6.51;
high carbohydrate test meal, $P < 0.05$, 3.88, $P < 0.01$, 6.93

³ Data of 6 underweight, 5 average weight and 6 overweight subjects

⁴ Data of 5 underweight, 4 average weight and 6 overweight subjects

lipid concentrations between groups was found at any hour after either test meal.

The rise in total lipid concentrations measured following the high fat test meal were erratic and relatively slight. The underweight subjects showed the highest mean percent deviation, +20 percent, compared to +11 and +7 percents, respectively, for the overweight and average weight groups. The underweight subjects, who showed the greatest increase, also showed the most rapid decrease toward fasting concentration by the fifth hour. Following the high carbohydrate test meal, mean serum total lipid concentrations of the underweight subjects were below fasting at all hours measured. The third hour increase of the mean serum lipid concentration of the average weight group was influenced largely by a marked increase for subject NH and a lesser increase by SL. The mean of the overweight group, on the other hand, increased above fasting at the first hour, continued to rise to the third hour, then decreased between the third and the fifth hours; two subjects, SM and MR, of this group showed an early decrease and then a gradual increase to concentrations above fasting values. At each hour the mean total lipid concentrations were higher following the high carbohydrate test meal than they were following the high fat test meal among the overweight subjects.

The low mean serum total lipid increases of all three groups of subjects following the high fat test meal seemed inconsistent with the marked chylomicron responses observed and the generally accepted view that there is a significant rise in total serum lipids following the ingestion of fat. In Hetényi's study (1936), which is frequently cited, blood fat values were reported as increasing an average of 84 percent of

fasting values in control subjects after a feeding of 200 milliliters of cream. Peters and Van Slyke (1946) reported that fatty acids rose to an average 60 percent increase, reaching a peak in four to six hours, after eating. Frazer (1953) stated: "After a fat-containing meal, human subjects normally show an increase of about 300 to 500 mg./100 ml. of glycerides in the blood". Individual variations in the amplitudes of responses, however, have been generally recognized.

Reports in the literature were examined further for some explanation of the data of this study. Responses to exogenous fat have been studied more frequently for individual blood constituents than for composite data of all lipid fractions simultaneously, mainly because of the large amount of blood which has been required for complete analyses. Individual variations in the responses of various blood fractions following fat meals were reviewed in an earlier section. The largest proportion of change was generally believed to be in triglyceride fat.

Similarity of the trends of neutral fat values and of chylomicron counts have been demonstrated (Elkes, Frazer and Stewart, 1939; Cooper and Lusk, 1942; Wilmot, 1950), but the magnitude of changes were not necessarily similar. The reliability of chylomicron counts as a measure of total lipids was early questioned. Knudson and Grigg (1923) reported an association of chylomicrons with fats in the blood, but concluded that their number does not conform with the total fatty acids determined by chemical methods. MacArthur (1930) reported some correlation between total lipids and chylomicrons but stated that it was not very high. Recognizing that chylomicrons were largely neutral fat but that they represented only a small part of the total serum triglycerides, it

became apparent that the count of these particles per standard dark-ground field indicated at best only changes in the concentration of the tri-glyceride fraction of the serum lipids and specifically indicated only changes in particulate triglycerides of a structural size visible in dark-field magnification. Frazer (1953) stated: "For many reasons (the chylomicrograph technique) . . is not a satisfactory method for the quantitative assessment of fat absorption".

Three studies of fat tolerance following fat feeding reported rises of total lipid concentrations of magnitudes similar to those found in this investigation. Rony and Levy (1929) reported increased fatty acid concentrations from 12 to 30 percent of fasting in his control subjects following the ingestion of one pint of 20 percent cream, while fatty acid concentrations in several obese subjects remained at fasting concentrations or even fell during the seven hour post-prandial period; Corcoran and Rabinowitch (1937) observed decreasing concentrations of total lipids as well as total fatty acids, cholesterol esters and phospholipids in some Canadian eastern arctic Eskimos following the ingestion of 200 milliliters of soya oil; and Herzstein, Wang and Adlersberg (1953) reported mean maximum rises above fasting of 81 and 117 milligrams of total lipids per 100 milliliters of serum for their young and old groups, respectively, following the feeding of one gram of fat per kilogram of body weight to their subjects.

The mean maximum rises of total lipid concentrations in this study were 146 milligrams per 100 milliliters of serum in underweights, 66 milligrams per 100 milliliters in average weights and 69 milligrams per 100 milliliters in overweights following the intake of 32 grams of fat

with 26 grams of carbohydrate and 4.4 grams of protein. The fat intake in this investigation was considerably less than the amounts fed in the studies cited above, but was similar to the amounts fed by Frazer and co-workers (Frazer and Stewart, 1939a). The lower increases in serum lipid concentrations observed in this study compared to those reported by Frazer and others might be influenced by the restriction of exercise which was imposed. Herzstein and co-workers (1953), who reported similar values, described their subjects as being at rest with no smoking permitted. Greater rises of serum total lipids have been associated with exercise (Peters and Van Slyke, 1946); higher elevations of chylomicron concentrations also have been reported with activity (White, Ralston and Carne, 1951; Marder, et al., 1952). Further, the carbohydrate content of the test fat meal may have had a role in the degree of alimentary lipemia measured. Rony and Ching (1930) reported that the administration of glucose by mouth or parenterally inhibited alimentary lipemia in dogs; insulin was found likewise to inhibit alimentary lipemia in their animals. The authors concluded that carbohydrate metabolism played an important, if not essential role, in the regulation of blood fat concentrations of normal dogs during alimentary absorption of fat. Finally, it was recognized that total lipids in this study were determined on capillary serum rather than the venous serum commonly used for blood lipid determinations. Differences of blood lipid concentrations in venous and capillary serum have been reported (MacArthur, 1931; Frazer and Stewart, 1939b; Marder, et al., 1952). Arterio-venous differences of other blood constituents are well recognized (e. g. Macy, et al., 1954). The reported altered pattern of arterio-venous glucose differences in active

obesity (Mayer, 1953a) emphasized the variations one might expect to find between capillary and venous concentrations of other constituents in overweight and underweight as well as in average weight individuals.

That some of the difference in amplitude of rise observed among the three groups of subjects in this study might be due to differences in blood volume was considered possible. There was no apparent individual correlation with differences in body build, however.

The increased concentrations of chylomicrons and/or of total lipids observed in six of the overweight and two of the average weight subjects following the high carbohydrate test meal seemed to indicate an increased rate of mobilization of depot fat in these subjects. That fats are being continually mobilized from the depots is well established, although the mechanism of this mobilization is unknown (Frazer, 1953). Glycerides have been observed to increase in the blood in starvation; in normal people deprived of food, hyperlipemia has been found to start after about the thirty-sixth hour. The increases of fat observed were transient, usually lasting about an hour (Ibid). Remobilized fat in prolonged fasting was reported to appear as chylomicrons by Gage and Fish (1924). Attempts have been made to differentiate the particles derived from such sources as the fat depots as lipomicrons in contrast to the chylomicrons which are used to describe the particles derived from the fat laden chyle (Elkes, Frazer and Stewart, 1939). Actually, however, the two are indistinguishable microscopically, a fact which was emphasized by Gage and Fish in 1924. These periodic "fat crises", or transient lipemic outbursts have shown chylomicron rises from a base of 10 to concentrations of about 500 particles per standard field (Frazer, 1948). Frazer

postulated that they were caused by nervous factors, hormones and possibly by varying metabolic demands.

Previous reports of increased chylomicron concentrations in the serum following high carbohydrate feeding were not found. Rather, Gage and Fish (1924) stated that "the feeding of neither protein nor carbohydrate nor any combination of them resulted in chylomicron increases in healthy men and animals". Frazer and Stewart (1937) likewise reported no marked changes in chylomicron counts following the feeding of a non-fatty breakfast. A slight initial rise within ten minutes was seen which the authors ascribed to a stimulus to intestinal movement which caused a consequent passage of chyle, laden with fat from the previous meal, into the blood stream. Minor intermittent diurnal maxima and minima in chylomicron concentrations, particularly during the night, have been reported (Bohm, Gernandt and Holmgren, 1941).

Reports of previous studies in which total lipids were measured following non-fat feeding were not found.

That marked and sustained increases of total lipid concentrations occurred in five of the overweight subjects and to the same degree in only one average weight subject, NH, and in none of the underweight subjects would indicate a metabolic pattern which appears to be associated with obesity. Further, the two other overweight subjects after an initial fall were both showing rising total lipid concentrations above fasting values from the third to the fifth hours. This same pattern was observed in only one other subject, YK, an underweight subject, but the amplitude of rise in this subject was much less.

Blood Pyruvic Acid Concentrations

Fasting Concentrations

Fasting blood pyruvic acid concentrations were significantly different among the three groups of subjects, $P < 0.01$; the analysis of variance revealed a linear response among the groups. The mean fasting concentrations for the underweight, average weight and overweight subjects were, respectively, 0.85, 1.02 and 1.22 milligrams per 100 milliliters of blood. The mean fasting pyruvic acid concentrations of the overweight and underweight groups were not significantly different from that of the average weight group but the difference between the mean values of the overweight and the underweight groups was highly significant ($P < 0.01$). The fasting blood pyruvic acid concentrations were not significantly correlated with percent deviations from desirable weight of the subjects, however.

Individual variations were marked among the overweight and underweight subjects; the average weight subjects showed less individual variation. Four of the seven overweight subjects had fasting blood pyruvic acid concentrations greater than 1.3 milligrams per 100 milliliters of blood on at least one of the two experimental days; the concentrations for both days were above that value for one subject, MR. Concentrations above 1.3 milligrams per 100 milliliters of blood have been considered abnormal (Bueding, Stein and Wortis, 1941; Goldsmith, 1948), but many of the 220 subjects of Kirk and Chieffi (1949) had fasting pyruvic acid concentrations equal to or greater than those of these subjects. One underweight subject, NL, had particularly low fasting blood pyruvic acid concentrations, but again they were well within ranges reported (Ibid). Underweight subject YK had fasting blood pyruvic acid

concentrations high for her group and overweight subjects RM and HM had concentrations low for their group on both experimental days. Individual variations between the two experimental days were quite high among all three groups of subjects, but variations were particularly high among the overweight subjects.

A significant positive correlation between fasting blood pyruvic acid concentrations and fasting blood glucose concentrations was found $r = 0.526$ ($P < 0.05$), although the relationship was skewed. Fasting pyruvic acid values were concentrated between 0.90 and 1.00 milligrams per 100 milliliters of blood for a wide range of fasting glucose concentrations, but high glucose concentrations were accompanied by high pyruvic acid concentrations. There was no significant correlation of fasting blood pyruvic acid concentrations with fasting non-protein respiratory quotients, although fasting glucose concentrations and fasting non-protein respiratory quotients were found to have a significantly negative correlation.

The differences in fasting blood pyruvic acid concentrations among the overweight, average weight and underweight subjects in this study were indicative of a possible difference in metabolic pattern. The overweight and underweight subjects of Meyer and Winkler (1952) displayed similar tendencies toward higher and lower fasting blood pyruvic acid concentrations, respectively; the mean fasting blood pyruvic acid concentrations for their two groups were, overweights, 1.08, and underweights, 0.89 milligrams per 100 milliliters. Wide individual variations occurred, however; their subjects were all patients with a variety of diagnosed metabolic disorders, classed by the authors as "endocrine disorders".

Following Test Meals

The mean blood pyruvic acid concentrations at the various time intervals measured following both test meals, together with the F-values for the analyses of variance and covariance, are presented in Table XX. No significant differences among the group mean concentrations occurred at any hour following either test meal; at the first hour following the high carbohydrate test meal there was a significant difference among the groups, however, in change from fasting concentration (F-value of covariance was 4.12, $P < 0.05$). Individual data are presented graphically in Figure 12 and Table XXXIX (Appendix).

Following the high fat test meal, blood pyruvic acid concentrations at the first, third, and fifth hours, respectively, in milligrams per 100 milliliters were: 1.27, 1.06 and 1.17 for the overweight subjects; 1.00, 0.94 and 1.05 for the average weight subjects; and 1.11, 0.86 and 0.91 for the underweight subjects. In general, there was little change in blood pyruvic acid concentrations from hour to hour although individual variations occurred among all groups. Two of the underweight, RL and RD, none of the average weight and one of the overweight subjects, SM, had increases at the first hour of approximately 0.50 milligrams per 100 milliliters; by contrast, overweight subject MR had definite decreases from fasting value at the first and third hours and underweight subject RK showed no change from fasting at any hour. At the third hour six of the overweight subjects, five of the average weight and only one of the underweight subjects, YK, had blood pyruvic acid concentrations below fasting values. Fifth hour concentrations were similar to fasting values among all groups.

TABLE XX
MEAN BLOOD PYRUVIC ACID CONCENTRATIONS AT INTERVALS ON TWO TEST DAYS

Intervals of test days	Subjects			F-Value ²		Analysis of Covariance Total
	Underweight mg./100 ml.	Average weight mg./100 ml.	Overweight mg./100 ml.	Total	Linear Quadratic	
High fat test meal: Fasting ³	0.84 ± 0.07 ¹	1.04 ± 0.03 ¹	1.20 ± 0.12 ¹	4.36**	8.66**	2.76
1st hour	1.11 ± 0.12	1.00 ± 0.07	1.27 ± 0.14	1.43		0.27
3rd hour	0.86 ± 0.07	0.94 ± 0.09	1.06 ± 0.15	0.86		0.02
5th hour	0.91 ± 0.05	1.05 ± 0.07	1.17 ± 0.12	2.39		
High carbohydrate test meal: Fasting ³	0.86 ± 0.06	1.00 ± 0.05	1.24 ± 0.11	6.26**	12.26**	4.12*
1st hour	1.41 ± 0.11	1.92 ± 0.26	1.55 ± 0.15	2.10		0.02
3rd hour	0.88 ± 0.12	0.87 ± 0.10	1.09 ± 0.08	1.53		0.28
5th hour	0.92 ± 0.08	0.98 ± 0.07	1.12 ± 0.10	1.70	0.25	

¹ Standard error of the mean

² * = P < 0.05; ** = P < 0.01

³ Least significant differences for P < 0.05 and P < 0.01, respectively: high fat test meal, fasting, 0.27 and 0.37; high carbohydrate test meal, fasting, 0.23 and 0.33

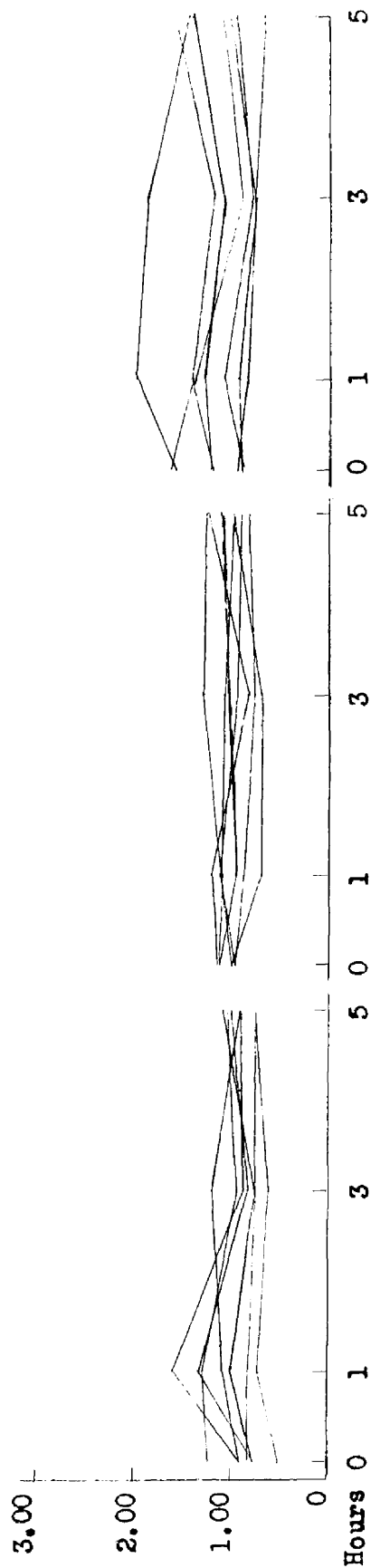
Underweight Subjects

Average Weight Subjects

Overweight Subjects

Pyruvic Acid
mg./100 ml.

Test Meal: High Fat



Pyruvic Acid
mg./100 ml.

Test Meal: High Carbohydrate

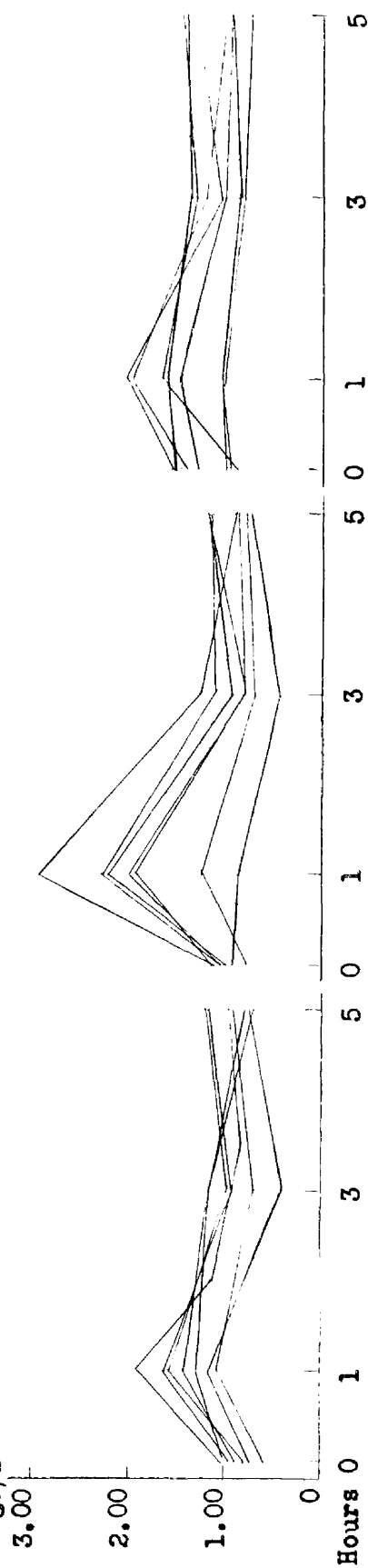


Figure 12. Blood pyruvic acid concentrations at intervals on two test days.

Following the high carbohydrate test meal, the mean blood pyruvic acid concentrations of the three groups showed an increase at the first hour, a decrease toward fasting values or below at the third hour and a slight increase at the fifth hour. From fasting mean pyruvic acid concentrations of 0.86, 1.00 and 1.24 milligrams per 100 milliliters of blood in the underweight, average weight and overweight groups, respectively, the mean concentrations at the intervals measured were: first hour, 1.41, 1.92 and 1.55, third hour, 0.88, 0.87 and 1.09 and fifth hour, 0.92, 0.98 and 1.13 milligrams per 100 milliliters of blood. The differences in elevation from fasting concentrations among the three groups were significant at the first hour; the increase in mean concentration from fasting for the average weight group was significantly higher than was that of the overweight group, though not higher than that of the underweight group (Fisher's t-test). There were three overweight subjects, YL, HM and RM, and one average weight subject, SL, who displayed no increase in blood pyruvic acid concentration in response to the high carbohydrate test meal.

It is difficult to evaluate the significance of the measured blood pyruvic acid concentrations in response to the test meals. The minor changes following the high fat test meal were anticipated. The marked increases in pyruvic acid concentrations, ranging from 0.76 to 1.81 milligrams per 100 milliliters of blood, among five of the seven average weight subjects in response to the ingestion of ninety-seven grams of carbohydrate were unexpected in view of maximum rises of 0.14 to 0.93 milligrams per 100 milliliters of blood reported by Bueding, Stein and Wortis (1941) following similar carbohydrate intakes; Bueding and co-workers fed 1.75 grams of glucose per kilogram of body weight to their

subjects. Goldsmith (1948) reported a mean maximum rise of 0.40 milligrams per 100 milliliters of blood in normal subjects following glucose administration. Among the twenty-four underweight and overweight patients of Meyer and Winkler (1953), the maximum increase in blood pyruvic acid concentration reported in response to a one-hundred gram test dose of glucose was 1.00 milligrams per 100 milliliters; one underweight and three overweight subjects responded with increased concentrations greater than 0.50 milligrams per 100 milliliters; two underweight and five overweight subjects showed depressed concentrations. The responses of the underweight and overweight subjects in this investigation were quite similar to those reported by Meyer and Winkler (1952), except that all of the underweight subjects in this study showed some increase in blood pyruvic acid concentration at the first hour.

It is possible that elevations of blood pyruvic acid concentrations occurred at some time other than the hours measured in this investigation. The data of Meyer and Winkler (1952) in which measurements were made at one-half, one, one and one-half and two hours after glucose ingestion indicated irregularities in the hour of peak concentrations. Among the underweight subjects, peak concentrations occurred at fasting for one, at one-half hour for two, at the first hour for four and at one and one-half hours for two of the subjects; among the overweight subjects the concentrations were highest at fasting for five, at one-half hour for one, at the first hour for seven and at one and one-half hours for two of the subjects. The greatest proportion of peak concentrations for all subjects occurred at the first hour. Smith (1950) observed maximum blood pyruvic acid concentrations at thirty to fifty minutes after intravenous injections of glucose.

A metabolic defect in the utilization of pyruvic acid by the obese has been postulated (Stadie, 1940; Pennington, 1953a), whereas depressed pyruvic acid responses have been reported for obese mice of the hereditary obesity-diabetes syndrome strain (Guggenheim and Mayer, 1952). Five of the fifteen overweight subjects of Meyer and Winkler (1952) had decreases from fasting values of blood pyruvic acid following high carbohydrate feeding. Three of the seven overweight subjects in this study exhibited a depressed blood pyruvic acid response to high carbohydrate feeding. No high elevations of blood pyruvic acid concentrations occurred among the overweight subjects following high carbohydrate feeding. Fasting blood pyruvic acid concentrations among the overweight subjects were higher, however, than those of the average weight subjects and significantly higher than those of the underweight subjects.

Fasting Serum Alkaline Phosphatase Concentrations

Phosphatase enzymes are distributed widely among various tissues. Serum alkaline phosphatase concentrations are elevated from average ranges in a number of diseases of osseous origin and in several nonosseous conditions, particularly in certain liver disorders (Hawk, Oser and Summerson, 1947; Goldsmith, 1950). Bessey (Goldsmith, 1950) has suggested that determinations of serum alkaline phosphatase might be as useful a tool as hemoglobin determinations in assessing general nutritional status. Fasting venous serum alkaline phosphatase concentrations were determined for the subjects in this investigation as a possible indication of metabolic stability or instability.

Fasting serum alkaline phosphatase concentrations for all subjects are presented in Figure 13. There was no consistent relationship between fasting serum alkaline phosphatase concentrations and the percent deviations from desirable weight of the subjects. The mean concentrations of serum alkaline phosphatase for the underweight, average weight and overweight subjects were 1.25 ± 0.11^1 , 1.25 ± 0.13 and 1.45 ± 0.08 nitrophenol units, respectively. Although the mean concentration of the overweight group was higher than those of the average weight or underweight subjects, the differences among the groups were not statistically significant. Age was not a factor of individual differences.

Three of the forty-two serum alkaline phosphatase determinations were made on capillary rather than venous serum. These individual values are indicated in Figure 13. An inconsistent difference between venous and capillary serum alkaline phosphatase concentrations has been reported (Macy, et al., 1954).

The mean fasting serum alkaline phosphatase values of the three groups of subjects were similar to the median value of 1.36 nitrophenol units, using the same method of Bessey, Lowry and Brock (1946), reported by Macy and co-workers (1954) for four hundred and one non-pregnant, white subjects. The range of values of the individual subjects in this study also was well within the tenth to ninetieth percentile range of 0.90 to 1.96 nitrophenol units reported by Macy, et al. (1954) as a standard for normality.

No differences in metabolic pattern among the overweight, average weight or underweight subjects in this study were revealed by the determinations of serum alkaline phosphatase concentrations.

¹ Standard error of the mean.

Nitrophenol Units

x Subject 50½ years
o Capillary blood

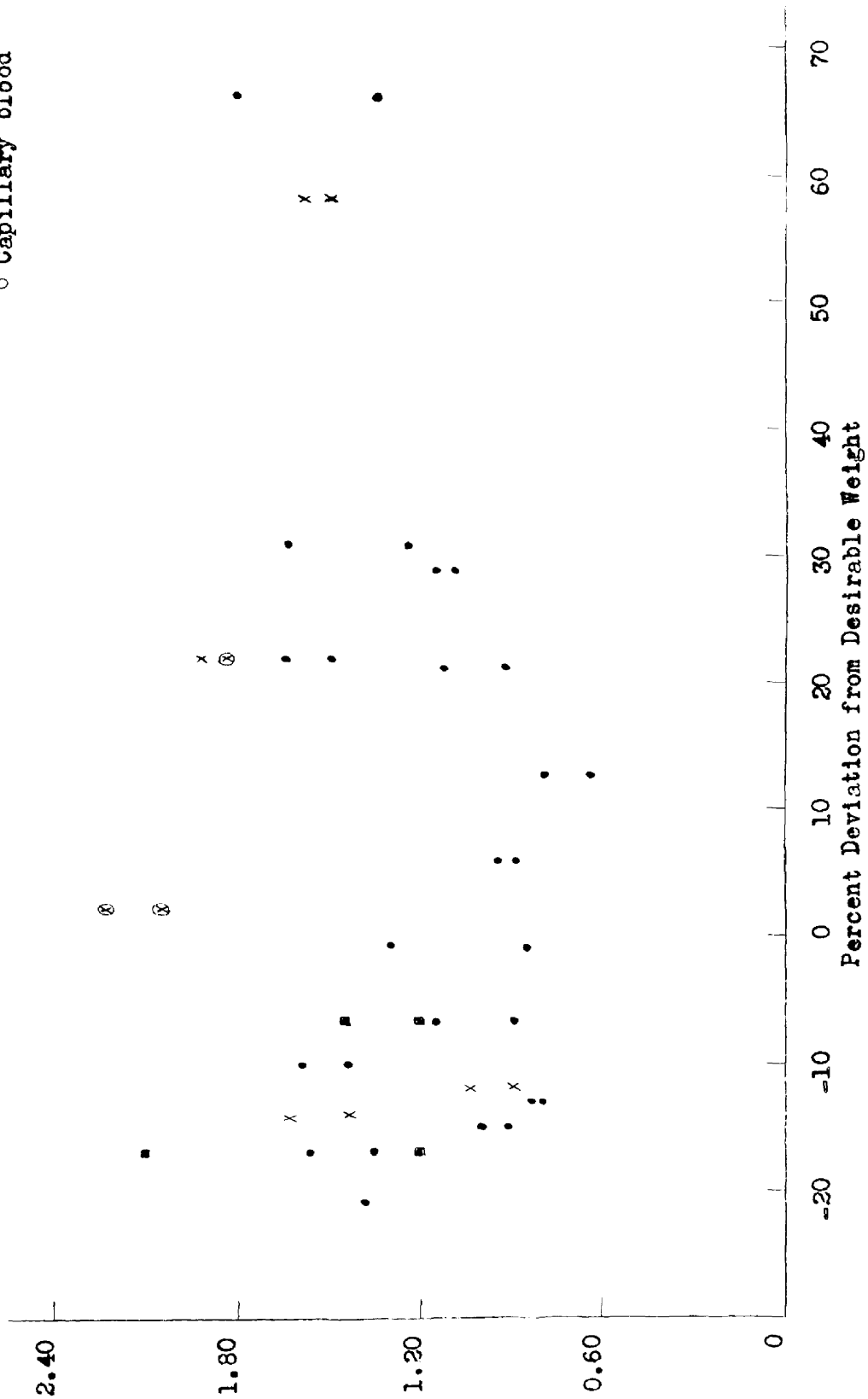


Figure 13. Fasting venous serum alkaline phosphatase concentrations from twenty-one women on two test days in relation to percent deviations from desirable weight.

Urinary Patterns

Urinary Albumin, Sugar and Acetone Bodies

The results of the qualitative determinations for albumin, sugar and acetone bodies in fasting urine samples and complete collections for the first hour period, the first to third hour period and the third to fifth hour period following both test meals are tabulated in Table XXI. The data revealed no group patterns. There were no positive determinations for urinary albumin. There were two positive urinary sugar tests; both positive tests were in the first hour collection following the high carbohydrate test meal and both were for underweight subjects. One of these subjects, NM, also showed a trace at the third hour. Acetone bodies were not determined for the entire series of experimental days. Among the subjects for whom this test was determined, only one showed a sufficient excretion of acetone substances for a positive test. Underweight subject, RL, excreted acetone substances in the fifth hour sample following both test meals; marked depressions of non-protein respiratory quotients occurred concurrently. In response to the high fat test meal, the non-protein respiratory quotient was depressed from a fasting value of 0.83 to 0.71 by the fifth hour; in response to the high carbohydrate test meal, the non-protein respiratory quotient was depressed from 0.76 to 0.65 by the fifth hour, Figure 8. Traces of acetone excretions were found for one overweight and one other underweight subject, YL and RD, respectively, following the high fat test meal. Under the conditions of this study, there was no evidence of lower urinary concentrations of ketone substances following low carbohydrate intakes among overweight than among average weight subjects as has been reported (DuBois, 1936; Bauer, 1941).

TABLE XXI

QUALITATIVE TESTS FOR URINARY ALBUMIN, SUGAR AND
ACETONE BODIES AT INTERVALS ON TWO TEST DAYS

[illegible]

TABLE XXI continued

[illegible]

Urinary Nitrogen Excretions

Marked individual variation characterized the fasting hourly urinary nitrogen excretions among these subjects; this variation existed both within groups and between days for the same individual. The mean fasting hourly urinary excretions, including data of both experimental days, were 350, 484 and 550 milligrams for the underweight, average weight and overweight groups, respectively. Because of the individual variations, the differences among groups were not statistically significant.

The mean hourly fasting urinary nitrogen excretions and the excretions for the intervals from fasting to the first hour, first to third hours and third to fifth hours following each test meal are presented in Table XXII. The individual data by groups are presented graphically in Figure 14. Individual variations in response in each weight group were apparent.

Following the high fat test meal, the mean hourly urinary nitrogen excretions were 350, 311 and 258 milligrams for the underweight subjects, 437, 422 and 346 milligrams for the average weight subjects and 395, 475 and 351 milligrams for the overweight subjects. The mean hourly nitrogen excretions of the underweight subjects showed little change from fasting values during the first hour and then a small decrease during the next two collection periods; average weight subjects showed a rather consistent decrease in hourly excretions from fasting values during all collection periods, but a more marked decrease from the third to the fifth hours; the overweight subjects showed an initial marked decrease from fasting values, an increase during the subsequent two hour period and a decrease again during the final two hour period. Differences among groups were

TABLE XXII
MEAN URINARY NITROGEN EXCRETIONS AT INTERVALS ON TWO TEST DAYS

Intervals of test days	Subjects		F-Value ² Analysis of Variance		
	Underweight mg. per hr.	Average weight mg. per hr.	Overweight mg. per hr.	Total	Linear Quadratic
High fat test meal: Fasting 1st hour 1st to 3rd hours ³ 3rd to 5th hours	346 ± 37 ¹	466 ± 24 ¹	509 ± 86 ¹	2.32	
	350 ± 35	437 ± 45	395 ± 59	0.84	
	311 ± 23	422 ± 39	475 ± 42	5.55*	10.66**
	258 ± 13	346 ± 35	351 ± 32	3.17	0.43
High carbohydrate test meal: Fasting 1st hour ³ 1st to 3rd hours ³ 3rd to 5th hours ³	358 ± 58	503 ± 30	592 ± 42	3.24	
	389 ± 26	404 ± 24	510 ± 43	4.25*	7.12**
	349 ± 24	431 ± 21	462 ± 34	4.80*	8.98**
	294 ± 10	395 ± 12	387 ± 33	7.13**	9.73**

¹ Standard error of the mean

² * = P < 0.05; ** = P < 0.01

³ Least significant differences for P < 0.05 and P < 0.01, respectively: high fat test meal, 1st to 3rd hours, 110 and 154; high carbohydrate test meal, 1st hour, 99 and 138, 1st to 3rd hour, 83 and 116, and 3rd to 5th hours, 65 and 90

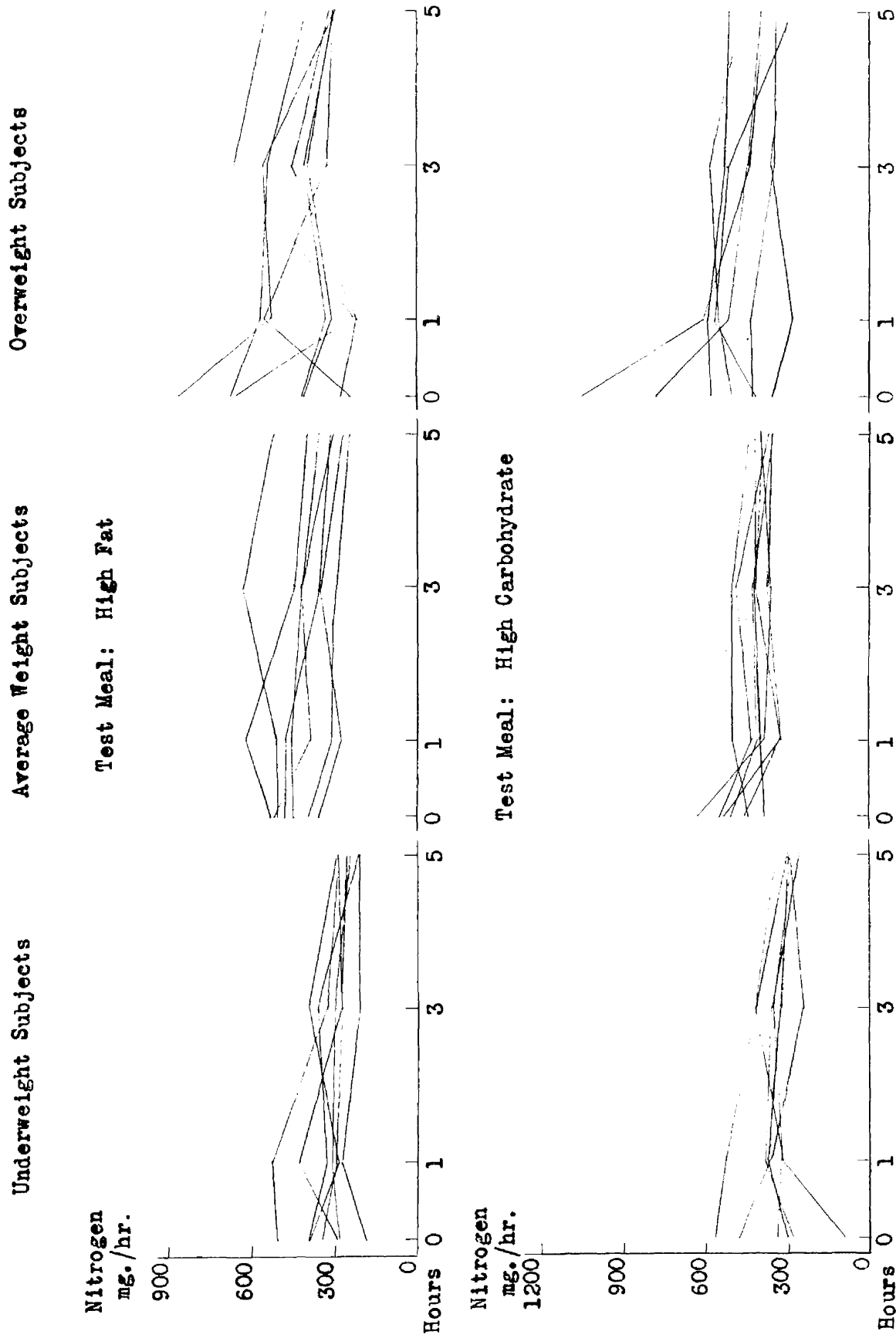


Figure 14. Hourly urinary nitrogen excretions at intervals on two test days.

statistically significant for the first to third hour collection, $P < 0.05$; the mean hourly nitrogen excretion of the underweight group was significantly less than those of the average or the overweight groups. The mean total nitrogen excretions for the five hours following the high fat test meal were: overweight subjects, 2,046 milligrams, average weight subjects, 1,971 milligrams and underweight subjects, 1,486 milligrams. The mean nitrogen excretion of the underweight subjects was significantly lower than those of the other two groups, Table XXIII.

Following the high carbohydrate test meal, the mean hourly nitrogen excretions were 389, 349 and 294 milligrams for the underweight subjects, 404, 431 and 395 milligrams for the average weight subjects and 510, 462 and 387 milligrams for the overweight subjects. Again the patterns of the mean values of the three groups were dissimilar: the underweight group showed an initial rise during the first hour with a gradual decrease in mean hourly excretion during the next two two-hour collection periods; the average weight group showed an increase from fasting in the initial hour collection and then small changes in hourly excretions during the next two two-hour periods; the overweight group showed a consistent decrease from fasting value for each period measured but individual variations within the group were marked. There were significant group differences in hourly mean nitrogen excretions during each collection period following the high carbohydrate test meal, $P < 0.01$ (Table XXII). During the first hour the overweight group excreted significantly more nitrogen than the average or underweight groups, $P < 0.05$; from the first to the third hours, the underweight group excreted significantly less nitrogen than the average or overweight groups, $P < 0.05$; during the last

TABLE XXIII
TOTAL URINARY NITROGEN EXCRETIONS DURING FIVE
HOURS FOLLOWING TWO TEST MEALS

Experimental Period	Subjects			F-Value ² Analysis of Variance Total
	Underweight mg.	Average Weight mg.	Overweight mg.	
Following high fat test meal ³	1486 $\pm$ 77 ¹	1971 $\pm$ 180 ¹	2046 $\pm$ 142 ¹	4.72*
Following high carbohydrate test meal ³	1675 $\pm$ 77	2056 $\pm$ 76	2208 $\pm$ 152	6.49**

¹ Standard error of the mean

² * = $P < 0.05$; ** = $P < 0.01$ (F-values: $P < 0.05$, 3.55;
 $P < 0.01$, 6.01)

³ Least significant differences for $P < 0.05$ and $P < 0.01$,
respectively: following high fat test meal, 431 and 605;
following high carbohydrate test meal, 332 and 465

period the underweight group again excreted significantly less nitrogen than the average or the overweight groups, $P < 0.01$. The mean total amounts of nitrogen excreted during the five hour period following the high carbohydrate test meal were: overweight group, 2,208 milligrams; average weight group, 2,056 milligrams; and underweight group, 1,675 milligrams. The mean nitrogen excretions of each group were similar to those for the same period following the high fat test meal, although they were higher in each case, Table XXIII.

The higher, though not significantly higher, mean fasting hourly urinary nitrogen excretions among the overweight compared to the underweight subjects in this study perhaps was influenced by the overweight subjects having a larger musculature. The anthropometric data presented in Table I led to the evaluation of generally larger frames among the overweight subjects. Obese have been reported to have large musculatures (Meikeljohn, 1953); the data of Keys and Brozek (1953) would support an increase of cellular mass with increasing adiposity. Age had no consistent effect on fasting urinary nitrogen among the subjects in this study. No consistent relationship could be discerned between the protein intake of the twenty-four hours preceding experimental collections and fasting hourly urinary nitrogen excretions; there was no apparent relationship between the protein intake and hourly urinary nitrogen excretion among individuals or between the two experimental days for single individuals.

There was less individual variability in urinary nitrogen excretions among the subjects after the test meals, particularly among the average weight and underweight subjects. Both test meals, likewise, had the

effect of decreasing hourly urinary nitrogen excretions among all groups, even though the protein content of both meals was less than five grams. These data indicated a better protein-sparing effect by the high fat test meal, in which calories were 70 percent from fat, 25.0 percent from carbohydrates and 5.0 percent from protein, than by the high carbohydrate test meal, in which calories were 0.5 percent from fat, 94.5 percent from carbohydrate and 5.0 percent from protein. Five of the overweight, three of the average weight and five of the underweight subjects had lower five hour urinary nitrogen excretions following the high fat test meal than following the high carbohydrate test meal. Total five-hour urinary nitrogen excretions were atypically higher following the high fat test meal than following the high carbohydrate test meal for overweight subjects RM and RT and were slightly higher for underweight subjects NM and EL. Average weight subjects LP, NH and SL had higher total five-hour urinary nitrogen excretions following the high fat test meal, GN, NS and EN had higher total excretions following the high carbohydrate test meal, and RW showed no real difference following the two test meals.

Between-Day Variations in Fasting Values

Group metabolic patterns were considered in one further aspect. Between-day variations in the fasting observations were evaluated as an indication of the degree of metabolic stability among the subjects. Fasting values of the two experimental days for each metabolite and metabolic product measured were compared and the mean changes for the three groups of subjects were calculated; absolute changes were considered without regard to whether the individual changes were increases or

decreases. These data are tabulated in Table XXIV. The data indicated that day to day metabolic stability is a quality associated to a greater degree with underweight women than with average weight or overweight women. It was recognized that the absolute variation might be related to the magnitude of actual values; higher variations might be expected to be associated with higher actual values. The degree of variation in these data was not consistent with the magnitude of actual values, however; individual variation appeared to be the more important factor.

Interrelationships of Metabolic Factors

In an attempt to evaluate interrelationships of the various metabolic factors, the data were graphed by a method employing multiple variables adapted from Anderson (1952). These multiple variable scatter diagrams for fasting data and for data of the first, third and fifth hours following both test meals of the overweight, average weight and underweight subjects are presented in Figures 15, 16, 17 and 18. Examination of the data in this way emphasized certain group patterns and individual variations from group trends which have been discussed in previous sections; in addition, interrelationships of the various metabolites and metabolic products between groups and in individuals within groups were readily evident.

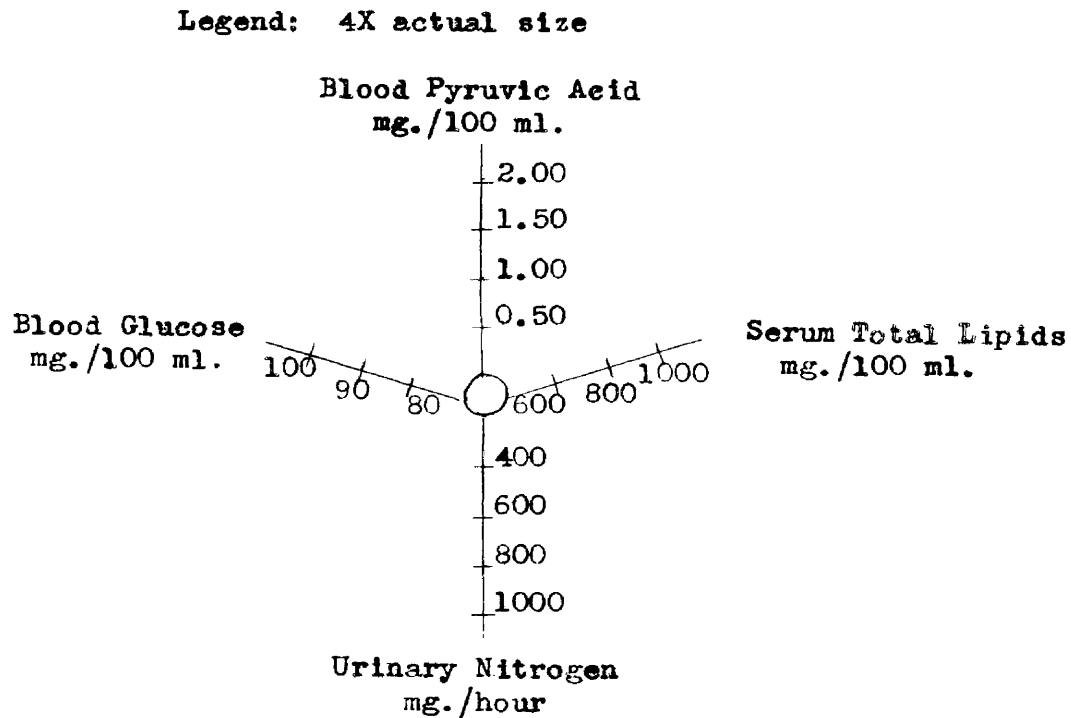
Figure 15 includes the fasting non-protein respiratory quotient, energy expenditure, blood glucose concentration, blood pyruvic acid concentration, serum total lipid concentration and hourly urinary nitrogen excretion for each subject for both experimental days. The fasting energy expenditure of each subject was plotted against the corresponding fasting non-protein respiratory quotient; blood glucose, blood pyruvic acid and

TABLE XXIV

SUMMARY OF THE MEAN DIFFERENCES BETWEEN EXPERIMENTAL
DAYS IN FASTING VALUES OF VARIOUS METABOLITES
AND METABOLIC PRODUCTS

Metabolite or Metabolic Product	Subjects		
	Underweight	Average Weight	Overweight
Blood glucose, mg. per 100 ml.	5.1	8.2	5.1
Blood pyruvic acid, mg. per 100 ml.	0.12	0.15	0.31
Serum alkaline phosphatase, nitrophenol units	0.25	0.21	0.20
Total serum lipids, mg. per 100 ml.	66	94	74
Serum chylomicrons, count per std. area	32	16	47
Serum total cholesterol, mg. per 100 ml.	17	23	21
Urinary nitrogen, mg. per hour	101	85	104
Non-protein respiratory quotient	.039	.068	.063
Energy expenditure, calories per hour	1.8	4.3	4.9

Figure 15. Multiple variable scatter diagrams of fasting hourly energy expenditures, non-protein respiratory quotients, blood glucose, blood pyruvic acid, serum total lipids and hourly urinary nitrogen excretions for twenty-one women on two test days.



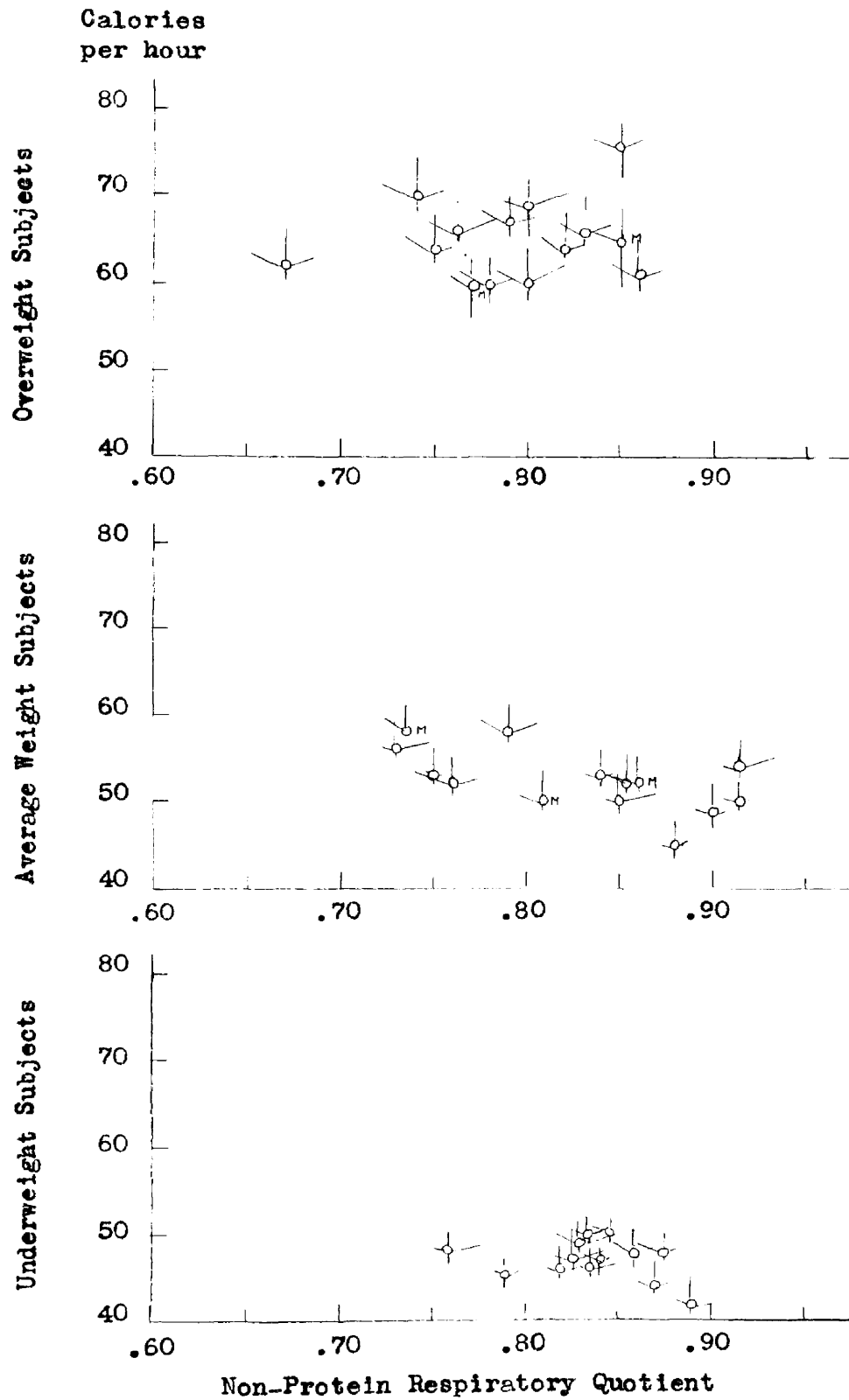
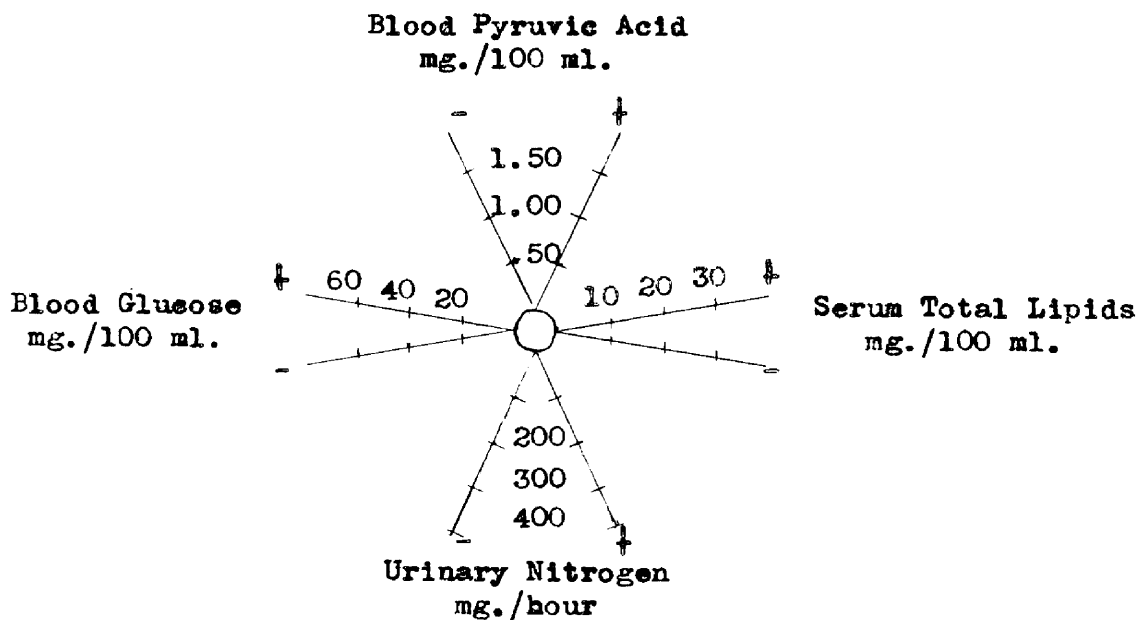


Figure 16. Multiple variable scatter diagrams of increments from fasting of energy expenditures, blood glucose, blood pyruvic acid, serum total lipids, and hourly urinary nitrogen excretions in relation to non-protein respiratory quotients for twenty-one women at the first hour following two test meals.

Legend: Figures 16, 17, and 18.

4X actual size



M - Missing value

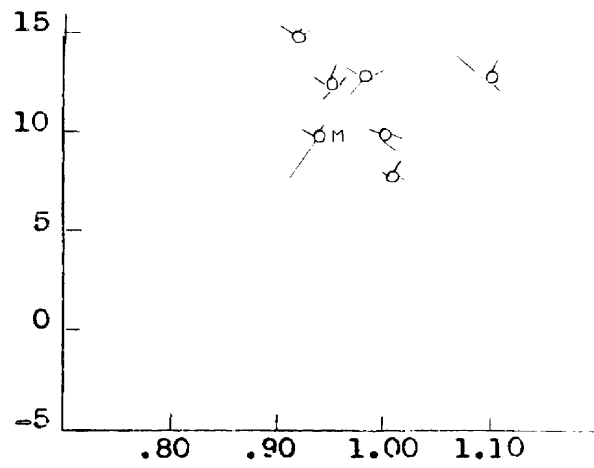
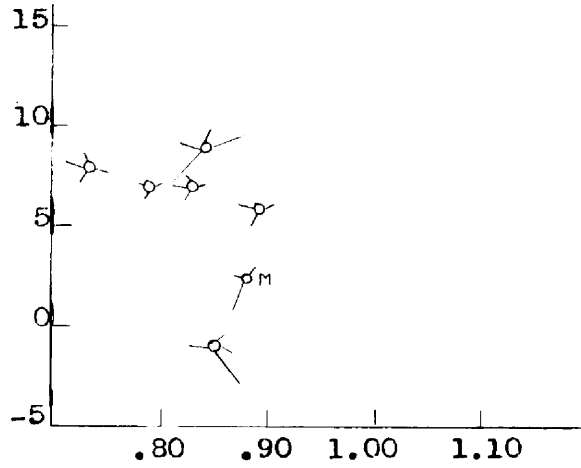
Test Meal: High Fat

Test Meal: High Carbohydrate

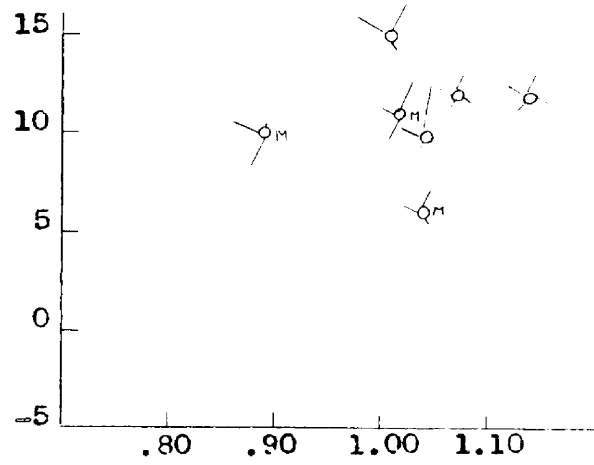
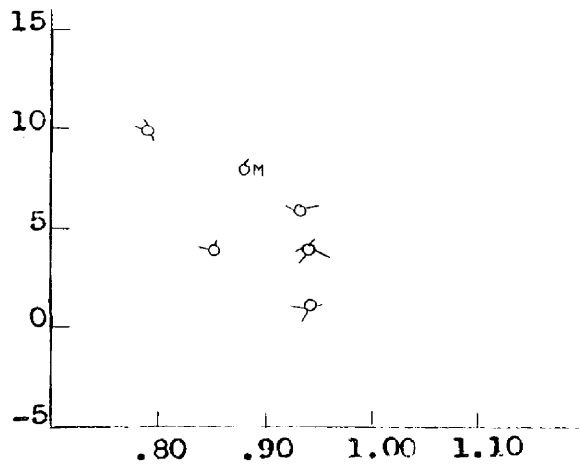
Increment of
Calories
per hour

Increment of
Calories
per hour

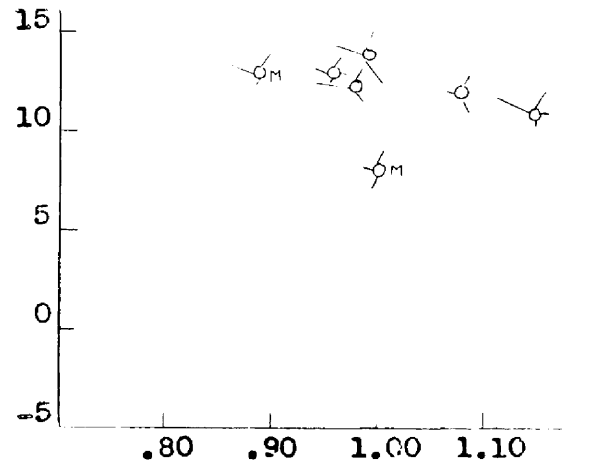
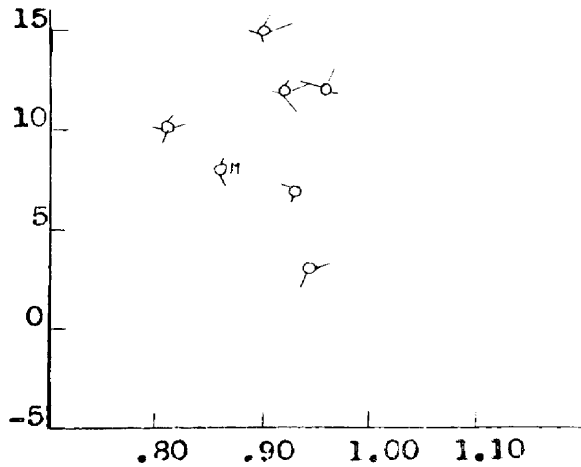
Overweight Subjects



Average Weight Subjects



Underweight Subjects



Non-Protein Respiratory Quotient

Non-Protein Respiratory Quotient

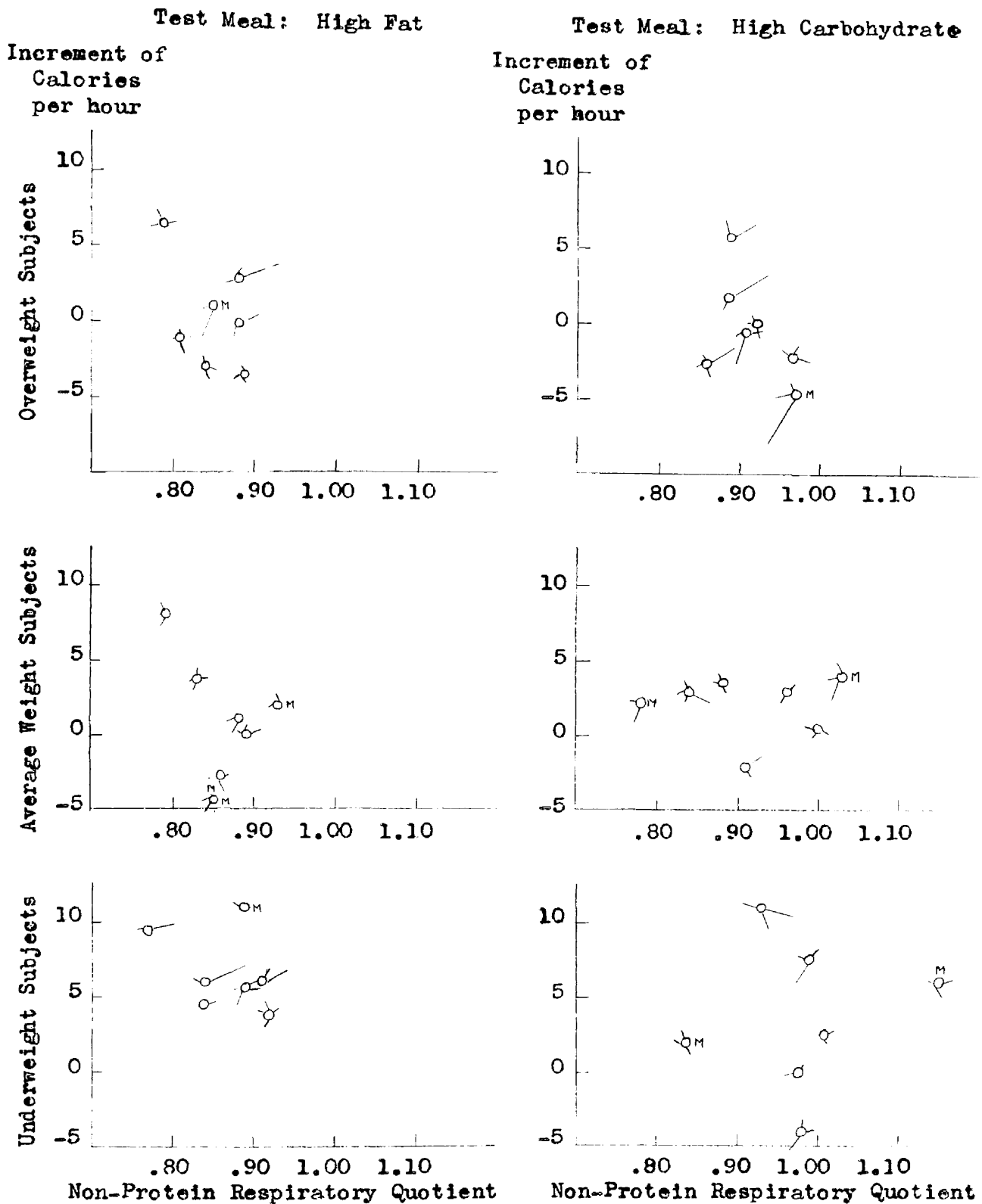


Figure 17. Multiple variable scatter diagrams of increments from fasting of energy expenditures, blood glucose, blood pyruvic acid, serum total lipids, and hourly urinary nitrogen excretions in relation to non-protein respiratory quotients for twenty-one women at the third hour following two test meals. (Legend on page 186)

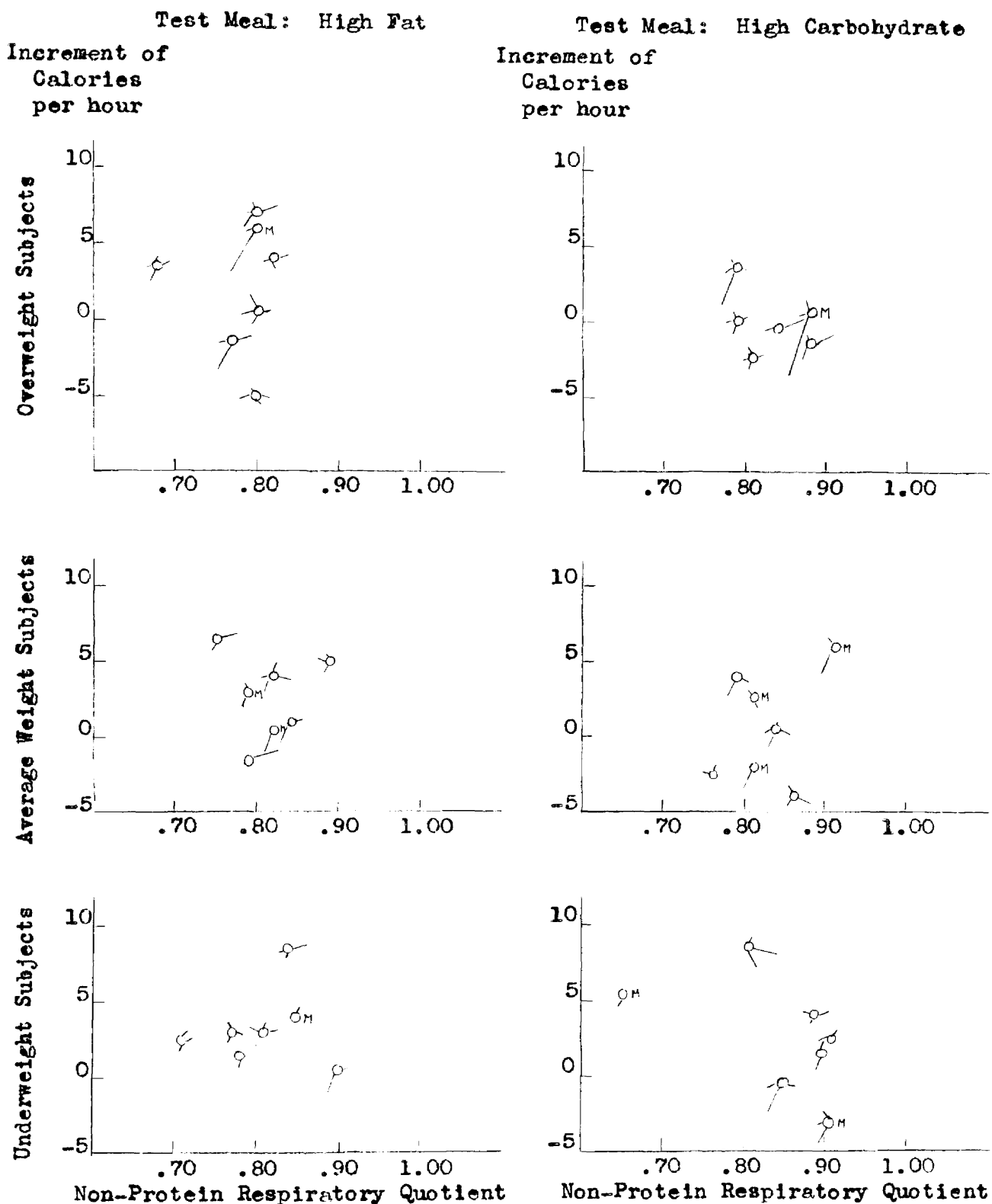


Figure 18. Multiple variable scatter diagrams of increments from fasting of energy expenditures, blood glucose, blood pyruvic acid, serum total lipids, and hourly urinary nitrogen excretions in relation to non-protein respiratory quotients for twenty-one women at the fifth hour following two test meals. (Legend on page 186)

serum total lipid concentrations and hourly urinary nitrogen excretions were indicated by varied lengths of designated appendages to the plotted points.

Figures 16, 17, and 18 are similar scatter diagrams of data for the first, third and fifth hours, respectively, following both test meals. In these Figures, however, energy expenditures, blood glucose, blood pyruvic acid, serum total lipids and hourly urinary nitrogen excretions were all plotted as changes from fasting values. Non-protein respiratory quotients were retained as actual values.

In the diagrams of fasting data for the overweight, average weight and underweight subjects in Figure 15, certain interrelationships were apparent. Higher glucose concentrations were associated with lower non-protein respiratory quotients among the overweight and average weight subjects, whereas there was a greater association of higher glucose concentrations with high non-protein respiratory quotients among the underweight subjects. Lower energy expenditures among the average weight and underweight subjects were somewhat associated with higher non-protein respiratory quotients. There was a greater relative decrease of blood pyruvic acid concentrations than of blood glucose concentrations from overweight to average weight to underweight subjects; the ratio of blood pyruvic acid to glucose was higher among the overweight and lower among the underweight than it was among the average weight subjects.

High or low fasting serum total lipid concentrations showed no consistent relationships with other metabolic factors among the groups, although higher blood lipid concentrations were more often associated with lower blood glucose values within groups. Individual subjects who were

at the extreme ranges of non-protein respiratory quotient and energy expenditure values did not show patterns of glucose, pyruvic acid or total lipid concentrations or hourly urinary nitrogen excretions differing from other individuals within their groups.

At the first hour, Figure 16, differences in relative degrees of change of blood glucose and blood pyruvic acid were evident among the three groups of subjects following both test meals. Following the high fat test meal, increments of both glucose and pyruvic acid were lowest among the average weight subjects, who showed little change from fasting values; glucose elevations were higher and pyruvic acid elevations were lower among the overweight than among the underweight subjects. Following the high carbohydrate test meal, the relative changes of glucose and pyruvic acid were similar among the average and underweight subjects, whereas among the overweight subjects the proportion of increment of pyruvic acid to increment of glucose was again low. The highest increments of both glucose and pyruvic acid occurred among the average weight subjects after the high carbohydrate meal; glucose elevations were similar among the underweight and overweight subjects, but pyruvic acid elevations were lower among the overweight than among the underweight subjects.

No other relationship among changes from fasting values at the first hour were apparent: there was no interrelationship between non-protein respiratory quotients and calorie increments; non-protein respiratory quotients greater than 1.0 were not associated with consistent changes of other metabolites; elevated serum lipid concentrations following both test meals showed no apparent relation to other metabolic changes; and changes in hourly urinary nitrogen excretions did not appear to be associated with changes of any other metabolic factor.

Inspection of the increment data for the third and fifth hours, Figures 17 and 18, revealed no consistent patterns of interrelationships of changes of the various metabolic factors. By the fifth hour, most values approached fasting rates or concentrations. Concerning the hypoglycemia at the fifth hour among the overweight subjects, however, greater decreases from fasting of blood glucose concentrations appeared to be associated with greater decreases of rates of calorie expenditures following the high fat test meal; this relationship was not as apparent following the high carbohydrate test meal.

The more consistent group interrelationships discerned among the fasting data than among the increment data at the first, third and fifth hours after the test meals emphasized the greater constancy of post-absorptive metabolic patterns compared to metabolic changes in the absorptive phase.

Discussion

The interpretation of data of metabolic patterns is difficult because there are individual differences in both the time and intensity of metabolic reactions. Statistical methods for relating the factors of time and degree of change are limited. Variations of individual subjects within the overweight, underweight and average weight groups in this investigation corroborated findings of previous studies which have indicated that no single metabolic pattern is associated with the overweight or underweight states. Further, it was not possible to discern consistent patterns of individual variations from group patterns in the data of this study. Nevertheless, certain metabolic patterns associated with the overweight

and underweight subjects in this investigation were significantly greater than variations among individuals within the groups.

The overweight women as a group appeared to exhibit a delay in utilization of carbohydrate, although not of the degree reported for obese subjects with typical "diabetic glucose tolerance curves" (Newburgh, 1942a). There was no question of the ability of the overweight subjects to utilize carbohydrate; a final clearance as complete as that of the other two groups was demonstrated. Following both test meals the overweight group showed a delay in decreasing blood glucose concentrations toward fasting values. The existence of a different stimulus to glucose removal was indicated by the original delay in glucose removal, the significant decrease in blood glucose concentrations below fasting values by the fourth or fifth hours, and the significantly higher post-absorptive blood glucose concentrations associated with the overweight group.

The significantly lower elevation of blood pyruvic acid concentrations together with mobilization of blood lipids among the overweight subjects following the high carbohydrate test meal likewise indicated the possibility of a different mechanism for the utilization of carbohydrate. Three overweight subjects had no increase in blood pyruvic acid concentrations following the high carbohydrate test meal; the other overweight subjects showed blood pyruvic acid increases lower than those of the average weight subjects and subsequent decreases of concentrations below fasting values. A failure of blood pyruvate concentrations to increase in "normal" subjects following glucose infusion with simultaneous administration of glucagon has been interpreted as evidence of a lack of muscle glycogenolysis together with a prompt deposition as muscle glycogen of glucose derived

from liver glycogen (Kirtley, et al., 1953, in Review, 1954). Although blood pyruvic acid concentrations in the overweight group decreased below fasting values by the fifth hour, the concentrations were higher than those of the average or underweight subjects in the post-absorptive state and fasting pyruvic acid to glucose ratios were higher among the overweight than among the average weight subjects.

Rony and Ching (1930) postulated that carbohydrate metabolism played an important role in the regulation of blood fat concentrations during the alimentary absorption of fat; they reported that the administration of glucose, by mouth or parenterally, or insulin inhibited alimentary lipemia in dogs. The slower rate of removal of chylomicrons and total lipids following fat feeding among the overweight compared to the underweight subjects might further indicate a defect of carbohydrate utilization. The non-protein respiratory quotients provided no real evidence toward clarifying the mechanisms involved; the respiratory quotients, however, increased more slowly following the high fat test meal than those of the average or underweight subjects. Following the high carbohydrate test meal, no difference in non-protein respiratory quotients of the overweight and average weight groups was apparent.

The two most overweight subjects in this investigation, RM and SM, were of particular interest because of their respective metabolic patterns. Both subjects had been overweight for many years. Several observations for these subjects made at fasting and following the two test meals were more similar to those for the average or underweight subjects than for those of the other overweight subjects; the metabolic patterns of the two subjects were not consistent, however. Both subjects had lower fasting

serum total lipids, total cholesterol and chylomicron concentrations than those of the other overweight subjects, although serum lipoprotein concentrations were high. Basal energy expenditures were significantly lower than those predicted by the calculated line of regression. RM had one of the lowest fasting glucose concentrations among the overweight subjects and a low one-half hour maximum blood glucose concentration following the high carbohydrate test meal. Fasting blood pyruvic acid concentrations were relatively low on both days for RM, whereas subject SM had a low value on one day and a very high value on the other. Although RM showed no increase in blood pyruvic acid following either meal, SM showed some increase following both test meals. Neither subject showed any increase in chylomicron concentrations after the high carbohydrate meal. And, SM had a decrease in serum total lipid concentration at the first and third hours after the high carbohydrate test meal. These observations might indicate that some degree of metabolic adjustment had occurred in these subjects during a prolonged overweight condition; evidences of physiological abilities to adjust to low planes of nutrition have been reviewed (Mitchell, 1944).

The underweight subjects as a group displayed a metabolic pattern which differed less from that of the average weight subjects than that of the overweight group, but there were some indications of a preferential utilization of carbohydrate. The ratio of fasting pyruvic acid to glucose concentration was lower than that of the average weight subjects. Following the high fat test meal, particularly, blood glucose concentrations showed lower elevations and decreased to fasting values more rapidly than those of the average weight subjects; concurrently, non-protein respiratory

quotients and blood pyruvic acid concentrations showed the most marked elevations of any group and the most rapid decreases to fasting values. Although chylomicron and total lipid concentrations increased to the greatest extent of any group, the rate of removal of these lipids from the blood was most rapid. Following the high carbohydrate test meal, some trend for an early removal of blood glucose was observed and non-protein respiratory quotients were elevated longer than those of the other groups. Significantly higher cumulative calorie increments following the high fat test meal, significantly lower cumulative nitrogen excretions for five hours following both meals and less between-day variations in fasting values were characteristic of the underweight subjects.

The number of subjects investigated and the individual variations observed limited the interpretation of the data relative to differences in fat and carbohydrate metabolism among the overweight, average weight and underweight subjects. Increased numbers of subjects undoubtedly would clarify group metabolic patterns in relation to individual metabolic patterns; the inclusion of a greater proportion of subjects whose weights were at the extremes of deviations from desirable weight might clarify types of individual metabolic patterns within the overweight and underweight groups.

A clarification of patterns of fat and carbohydrate metabolism among the overweight and underweight individual might be gained also by more frequent measurements of blood glucose, blood pyruvic acid, blood lipids, energy expenditures and non-protein respiratory quotients, particularly during the first and second hours. A variable factor in this investigation was the disproportional distribution of calories from carbohydrate and

fat in the two test meals. The high carbohydrate test meal provided 95 percent of the calories from carbohydrate, but the high fat test meal provided only 70 percent of the calories from fat. Carbohydrate was included in the fat test meal to increase its acceptability to the subjects. Test meals in which the calories from fat and carbohydrate were exactly reversed might be a sounder basis of comparison of metabolic changes following the two test meals. It is suggested that test meals in which approximately 70 percent of the calories were provided by fat and carbohydrate, respectively, should yield more representative data of metabolic patterns than relatively pure fat or pure carbohydrate feedings.

SUMMARY

Metabolic patterns of a group of overweight, underweight and average weight women were investigated at fasting and following two test meals of varying carbohydrate and fat composition. Twenty-one apparently healthy women from twenty-five to fifty-seven years of age served as subjects; their weights ranged from +66 to -21 percent of desirable weight. On the basis of deviations from desirable weights, the women were grouped into three classes: seven overweight subjects, +66 to +21 percent of desirable weight; seven average weight subjects, +13 to -10 percent of desirable weight; and seven underweight subjects, -12 to -21 percent of desirable weight. The test meals each provided approximately four hundred and fifteen calories; in the high fat test meal, fat, carbohydrate and protein contributed 70, 25 and 5 percent of the calories, respectively, whereas in the high carbohydrate test meal, fat, carbohydrate and protein, respectively, contributed 0.5, 94.5 and 5 percent.

Respiratory quotients, hourly energy expenditures, concentrations of blood glucose, blood pyruvic acid, serum alkaline phosphatase, serum total lipids, serum total cholesterol, certain serum lipoprotein classes and serum chylomicron counts and hourly urinary nitrogen excretions were determined at fasting. Following the test meals, respiratory quotients, hourly energy expenditures and hourly urinary nitrogen excretions were determined simultaneously with blood glucose, blood pyruvic acid, serum total lipids and serum chylomicron concentrations at the first, third and fifth hours; blood glucose and serum chylomicron concentrations were determined additionally at the one-half, second and fourth hours.

The mean basal energy expenditure of the overweight subjects was significantly higher than that of the average weight subjects and the mean basal energy expenditure of the underweight subjects was significantly lower than that of the average weight subjects. The hourly mean basal calorie expenditures were 65, 52 and 47 for the overweight, average weight and underweight subjects, respectively. Mean fasting non-protein respiratory quotients were not significantly different among the three groups, although lower respiratory quotients were found among the overweight subjects than among the other subjects; the mean non-protein respiratory quotients of the overweight, average weight and underweight groups were 0.79, 0.83 and 0.83, respectively. Fasting blood glucose concentrations were significantly higher among the overweight than among the average weight or underweight subjects; the mean values were 93, 83 and 81 milligrams per 100 milliliters, respectively. Fasting blood pyruvic acid concentrations were significantly higher among the overweight subjects than among the underweight subjects, but neither group mean was significantly different from that of the average weight group; the mean fasting concentrations were 1.22, 1.02 and 0.85 milligrams per 100 milliliters for the overweight, average weight and underweight subjects, respectively. There were no significant group differences in mean fasting venous serum alkaline phosphatase or in mean fasting concentrations of the various serum lipid constituents, capillary or venous serum total lipids, serum total cholesterol, serum lipoprotein classes S_f12-20, 21-35 and 35-100, or in capillary or venous serum chylomicrons. Hourly fasting urinary nitrogen excretions were lower among the underweight subjects than among the overweight or average weight subjects, but there were no significant

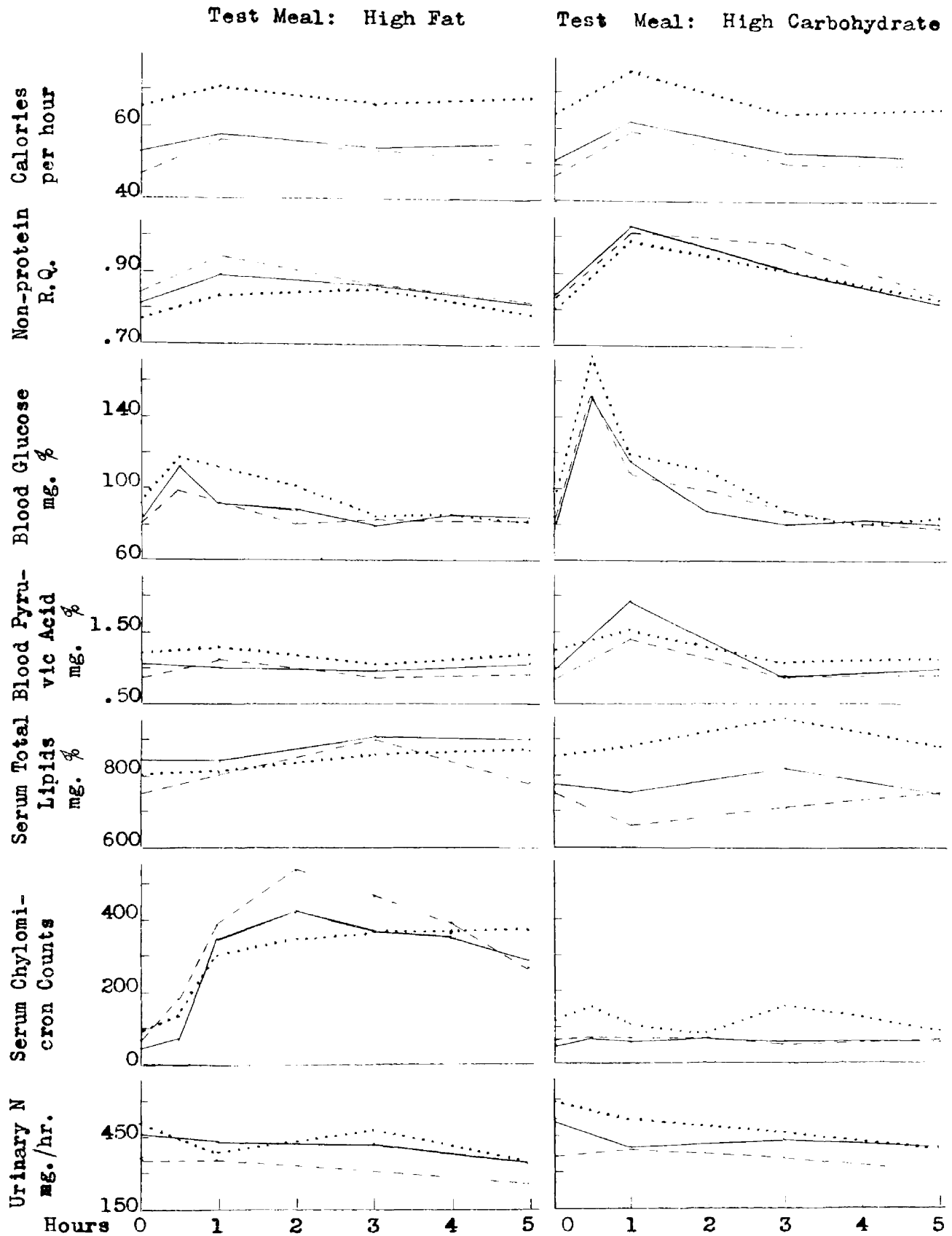
group differences. The mean fasting hourly nitrogen excretions of the overweight, average weight and underweight subjects, respectively, were 550, 484 and 350 milligrams.

Group mean observations of the overweight, average weight, and underweight subjects for all intervals measured on both test days are graphically summarized in Figure 19.

Following the high fat test meal, the hourly calorie expenditures of the overweight subjects were consistently higher at every hour than those of the average or underweight subjects; the cumulative energy increments for five hours, however, were significantly higher among the underweight subjects than among the average weight or overweight subjects. The non-protein respiratory quotients of the overweight subjects increased more slowly than did those of the average or underweight subjects and maximum quotients were lower; quotient increases were highest among the underweight subjects. Blood glucose concentrations increased more slowly among the overweight subjects than among the average or underweight subjects; blood glucose concentrations of the overweight subjects then decreased to concentrations significantly below fasting values at the fourth and fifth hours. Blood pyruvic acid changes were slight among all groups and there were no significant group differences, although the underweight subjects showed a greater first hour increase and the overweight subjects showed a greater third hour decrease in concentrations. Underweight subjects displayed a distinct increase in serum lipid concentrations from fasting to the third hour and then a decrease toward fasting; serum total lipid concentrations among the average and overweight subjects showed gradual, lesser increases with little or no subsequent

Figure 19. Summary of mean metabolic patterns for overweight, average weight and underweight subjects.

Legend: Overweight Subjects
 ———— Average Weight Subjects
 ----- Underweight Subjects



decrease. Chylomicrographs showed distinct pattern differences among the underweight and overweight subjects; chylomicrographs of the average weight subjects were generally typical of those of either the overweight or underweight subjects. Among the underweight subjects, chylomicron concentrations showed a significant initial one-half hour rise, reached the highest peak concentrations, and then decreased most rapidly. In the overweight subjects chylomicron concentrations increased more slowly, reached lower peak concentrations, then maintained near-peak concentrations throughout the remainder of the five hours. Mean hourly urinary nitrogen excretions were generally decreased from fasting values in periodic collections among all three groups; changes among the overweight subjects, who had the highest fasting hourly excretions, were the most irregular. The mean total urinary nitrogen excretion of the underweight subjects for five hours following the high fat test meal was significantly lower than those of the average or overweight subjects.

Following the high carbohydrate test meal, the hourly calorie expenditures of the overweight subjects were again consistently higher at every hour than those of the average or underweight subjects; cumulative calorie increments above basal for five hours were higher among the overweight and average weight subjects than those following the high fat test meal, but were lower among the underweight subjects. Non-protein respiratory quotients of the underweight subjects appeared to reach peak values later than those of the average weight or overweight subjects and quotients generally remained elevated above fasting values longer; measured non-protein respiratory quotients showed no significant differences among the three groups, however. Overweight subjects had the highest

one-half hour blood glucose concentrations in response to the high carbohydrate test meal; at the fifth hour, glucose concentrations of the overweight subjects were significantly below fasting concentrations. Blood pyruvic acid concentration increases from fasting values were significantly lower among the overweight subjects than among the average weight subjects; changes from fasting concentration were not significantly different among the average weight and underweight subjects, although the mean increase for the underweight subjects was less than that for the average weight subjects. Mean serum lipid concentrations were increased from fasting in a greater amount following the high carbohydrate test meal than following the high fat test meal among the overweight subjects; serum total lipid concentrations increased only slightly among the average weight subjects and decreased among the underweight subjects following the high carbohydrate test meal. Chylomicrographs of the mean data of the average weight and underweight groups were characterized by no hourly changes; the chylomicrograph of mean data of the overweight group showed significant peaks at the one-half and the third hours. Mean hourly urinary nitrogen excretions were decreased from fasting to the greatest extent among the overweight subjects, to a lesser degree among the average weight subjects and least among the underweight subjects. Total urinary nitrogen excretions for five hours following the high carbohydrate test meal were significantly less among the underweight than among the average or overweight subjects.

Certain group interrelationships of metabolites were evident. There was an association of higher fasting glucose concentrations with lower fasting non-protein respiratory quotients among the overweight subjects

and higher fasting glucose concentrations with higher fasting non-protein respiratory quotients among the underweight subjects. The ratio of fasting blood pyruvic acid to fasting blood glucose was higher among the overweight and lower among the underweight than it was among the average weight subjects. At the first hour, the ratio of increments from fasting of blood pyruvic acid to blood glucose concentrations were highest among the average weight and underweight subjects and lowest among the overweight subjects following the high carbohydrate test meal; following the high fat test meal, the ratio of pyruvic acid to glucose increments was highest among the underweight and least among the average weight and overweight subjects.

Individual variations from all group metabolic patterns occurred. No consistent patterns of individual variations could be discerned.

CONCLUSION

Certain differences in metabolic patterns were observed among the overweight, underweight and average weight women in this investigation at fasting and following two test meals. The overweight women as a group appeared to exhibit a delay in utilization of carbohydrate in the test meals compared to the average weight and underweight women. There were some indications of a greater preference for carbohydrate in metabolism by the underweight than by the average weight women.

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APPENDIX

TABLE XXV

CALCULATED DAILY INTAKES OF CALORIES, PROTEIN, FAT AND CARBOHYDRATE BY MEALS

Sub- ject	Meal	Random Day				Preceding High Fat Test Meal				Preceding High Carbohydrate Test Meal			
		Calo- ries	Pro- tein	Fat gm.	Carbo- hydrate gm.	Calo- ries	Pro- tein	Fat gm.	Carbo- hydrate gm.	Calo- ries	Pro- tein	Fat gm.	Carbo- hydrate gm.
RM	Breakfast	608	28	38	43	453	20	24	40	622	21	36	57
	Mid-morning Lunch	--	--	--	--	70	3	3	9	--	--	--	--
	Dinner	693	34	32	71	595	14	19	95	1102	45	60	99
	Evening	1492	59	83	130	--	--	--	--	--	--	--	--
	Total	199	2	1	51	791	34	29	108	893	62	35	82
SM	Breakfast	294	9	18	25	427	13	27	36	240	8	18	12
	Lunch	497	22	22	57	740	29	42	65	530	24	28	47
	Dinner	1239	43	59	126	781	41	26	98	817	40	42	74
	Total	2030	74	99	208	1948	83	95	199	1587	72	88	133
HM	Breakfast	448	17	16	65	439	18	24	39	351	12	13	51
	Mid-morning Lunch	--	--	--	--	54	1	--	14	--	--	--	--
	Dinner	596	29	30	56	811	29	53	57	578	46	28	33
	Total	610	50	33	32	658	30	34	44	874	63	42	58
		1654	96	79	153	1962	78	111	154	1803	121	83	142
HT	Breakfast	151	3	6	23	55	2	1	11	132	8	6	12
	Lunch	361	13	16	46	520	20	26	55	975	36	47	108
	Dinner	618	41	37	38	70	2	--	16	308	9	18	31
	Total	1130	57	59	107	645	24	27	83	1415	53	71	151
RT	Breakfast	240	8	18	12	208	8	5	34	208	8	5	34
	Lunch	641	23	38	54	547	17	25	68	730	21	31	96
	Dinner	1048	44	61	89	575	29	22	67	643	15	5	133
	Total	1929	75	117	155	1330	54	52	169	1581	44	41	263

TABLE XXV continued

Sub- ject	Meal	Random Day				Preceding High Fat Test Meal				Preceding High Carbohydrate Test Meal			
		Calo- ries	Pre- tein	Fat	Carbo- hydrate	Calo- ries	Pre- tein	Fat	Carbo- hydrate	Calo- ries	Pre- tein	Fat	Carbo- hydrate
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
MR	Lunch	471	11	7	93	154	12	11	1	301	7	21	23
	Dinner	1201	52	75	46	541	26	29	43	705	31	36	27
	Total	1672	63	82	139	695	38	39	44	1006	38	57	50
YL	Breakfast	178	5	4	30	75	1	--	19	332	6	16	43
	Lunch	467	30	30	22	884	53	52	55	166	9	10	12
	Mid-afternoon Dinner Total	-- 559 1204	-- 31 66	-- 27 61	-- 51 103	107 -- 1066	1 -- 55	1 -- 53	31 -- 105	-- 668 1166	-- 45 60	-- 35 61	-- 43 98
GN	Breakfast	518	18	35	37	455	13	29	38	500	18	26	49
	Lunch	521	32	29	32	651	23	37	60	653	21	28	81
	Mid-afternoon Dinner Evening Total	-- 772 161 1972	-- 30 -- 80	-- 41 -- 105	-- 71 42 182	-- 547 -- 1653	-- 18 -- 54	-- 11 -- 77	-- 98 -- 196	167 283 -- 1603	3 23 -- 65	10 9 -- 73	17 31 -- 178
LP	Breakfast	258	15	17	13	353	15	27	14	323	15	24	13
	Lunch	527	16	23	65	763	30	46	55	1581	105	84	103
	Mid-afternoon Dinner Evening Total	-- 616 281 1682	-- 34 11 76	-- 29 11 80	-- 63 35 176	30 460 -- 1606	-- 16 -- 61	3 29 -- 105	1 45 -- 115	-- 1032 -- 2936	-- 78 -- 198	-- 44 -- 152	-- 82 -- 198
NH	Breakfast	511	14	33	45	330	10	15	43	338	8	11	58
	Lunch	469	7	23	62	1047	31	54	80	673	26	36	60
	Dinner Evening Total	856 50 1886	38 2 61	58 4 118	48 2 157	768 -- 2145	61 -- 102	31 -- 100	61 -- 184	517 -- 1528	18 -- 52	16 -- 63	81 -- 199

TABLE XXV continued

Sub- ject	Meal	Random Day				Preceding High Fat Test Meal				Preceding High Carbohydrate Test Meal			
		Calo- ries	Pro- tein	Fat	Carbo- hydrate	Calo- ries	Pro- tein	Fat	Carbo- hydrate	Calo- ries	Pro- tein	Fat	Carbo- hydrate
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
RW	Breakfast	348	13	21	30	296	10	15	33	285	10	15	30
	Lunch	761	18	31	105	778	31	38	84	772	15	44	83
	Dinner	600	39	26	54	405	20	13	54	727	40	32	76
	Evening	243	6	9	35	--	--	--	--	--	--	--	--
	Total	1952	76	87	224	1479	61	66	171	1784	65	91	189
SL	Breakfast	286	9	8	45	254	6	5	47	262	7	5	49
	Lunch	428	15	24	42	414	25	13	53	440	34	23	27
	Mid-afternoon	--	--	--	--	36	2	2	4	44	--	--	11
	Dinner	923	32	51	91	553	59	15	45	574	52	27	28
	Evening	109	2	3	19	--	--	--	--	--	--	--	--
	Total	1746	58	86	197	1257	92	35	149	1320	93	55	115
NS	Breakfast	307	10	19	27	302	12	15	36	458	15	22	55
	Lunch	881	21	47	99	683	21	30	92	983	31	50	107
	Dinner	913	35	56	73	767	42	36	73	1005	39	47	106
	Evening	298	8	25	15	--	--	--	--	--	--	--	--
	Total	2399	74	147	214	1752	75	81	201	2446	85	119	268
EN	Breakfast	477	12	20	66	448	14	22	55	397	11	20	48
	Mid-morning	--	--	--	--	--	--	--	--	234	4	13	26
	Lunch	549	20	24	64	613	10	34	70	747	27	37	81
	Dinner	1152	39	63	109	473	32	17	49	701	17	22	114
	Evening	365	5	12	63	--	--	--	--	--	--	--	--
	Total	2543	76	119	302	1534	56	73	174	2079	59	92	269

TABLE XXV continued

Sub- ject	Meal	Random Day				Preceding High Fat Test Meal				Preceding High Carbohydrate Test Meal			
		Calo- ries	Pro- tein	Fat gm.	Carbo- hydrate gm.	Calo- ries	Pro- tein	Fat gm.	Carbo- hydrate gm.	Calo- ries	Pro- tein	Fat gm.	Carbo- hydrate gm.
RD	Breakfast	704	20	35	79	635	18	31	73	500	18	20	67
	Lunch	713	26	41	62	755	36	44	53	842	33	49	72
	Dinner	1085	52	52	101	759	42	37	63	544	34	26	47
	Evening	180	2	12	20	--	--	--	--	--	--	--	--
	Total	2682	100	140	262	2149	96	112	189	1886	85	95	186
NM	Breakfast	342	11	22	26	437	14	16	72	377	11	13	68
	Lunch	807	27	40	86	694	27	31	78	580	13	21	88
	Dinner	1142	38	64	110	607	29	34	47	678	23	32	76
	Total	2291	76	126	222	1738	70	81	197	1635	47	66	232
YK	Breakfast	499	11	22	66	562	12	29	66	436	11	15	65
	Lunch	547	8	30	68	896	24	41	112	903	33	45	94
	Dinner	805	33	36	90	473	19	23	49	667	15	18	112
	Evening	221	4	12	26	--	--	--	--	--	--	--	--
	Total	2072	56	100	250	1931	55	93	227	2006	59	78	271
RL	Breakfast	522	21	33	36	325	15	22	17	456	16	34	23
	Mid-morning	--	--	--	--	166	9	10	12	--	--	--	--
	Lunch	758	30	32	91	709	21	29	100	457	18	27	36
	Mid-afternoon	--	--	--	--	166	9	10	12	166	9	10	12
	Dinner	1022	40	64	76	490	10	13	94	404	9	3	96
	Total	2302	91	129	203	1856	64	84	235	1483	52	74	167
RK	Breakfast	311	6	17	38	113	2	6	12	151	4	7	20
	Lunch	708	30	32	77	718	12	39	80	863	26	55	70
	Dinner	630	44	40	24	551	38	26	44	1047	48	23	161
	Evening	415	14	24	50	--	--	--	--	--	--	--	--
	Total	2064	84	113	189	1382	52	71	136	2061	78	85	251

TABLE XXV continued

Sub- ject	Meal	Random Day			Preceding High Fat Test Meal			Preceding High Carbohydrate Test Meal					
		Calo- ries	Pro- tein	Fat gm.	Carbo- hydrate gm.	Calo- ries	Pro- tein	Fat gm.	Carbo- hydrate gm.	Calo- ries	Pro- tein	Fat gm.	Carbo- hydrate gm.
EL	Breakfast	473	22	25	41	547	8	22	75	726	27	48	49
	Lunch	652	27	37	58	430	14	22	47	546	17	25	67
	Mid-afternoon	--	--	--	--	336	11	19	39	367	4	15	56
	Dinner	1691	78	75	184	903	44	43	90	789	52	34	68
	Evening	--	--	--	--	375	5	22	41	--	--	--	--
	Total	2816	127	137	283	2591	82	128	292	2428	100	122	240
NL	Breakfast	310	11	22	16	402	12	22	40	279	10	20	15
	Lunch	753	30	41	66	379	13	25	25	1069	23	48	148
	Mid-afternoon	--	--	--	--	107	--	--	28	--	--	--	--
	Dinner	1034	37	66	75	444	36	19	40	528	23	28	49
	Evening	78	1	3	14	--	--	--	--	--	--	--	--
	Total	2175	79	132	171	1332	61	66	133	1876	56	96	212

TABLE XXVI
PULSE RATES AT INTERVALS ON TWO TEST DAYS
(Beats per minute)

Subject	Test Meal: High Fat					Test Meal: High Carbohydrate				
	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour
RM	70	68	83	71	66	63	64	73	64	70
SM	64	62	66	60	64	60	--	59	55	55
HM	60	60	62	56	64	64	65	68	58	61
HT	--	60	60	60	61	60	60	69	61	67
RT	66	64	64	59	61	60	62	64	55	57
MR	--	68	72	67	63	74	75	76	72	80
YL	64	64	68	65	67	58	56	65	56	56
GN	64	--	65	61	64	64	66	72	67	68
LP	64	66	71	64	62	67	67	75	66	67
NH	73	72	75	71	67	72	70	80	68	68
RW	64	--	--	68	67	--	60	--	57	56
SL	60	60	62	60	58	--	61	64	56	56
NS	--	68	70	72	69	66	67	75	68	66
EN	79	81	84	79	76	77	78	80	81	66
BD	52	60	62	66	64	64	70	72	68	70
NM	78	--	85	74	80	74	70	82	76	74
YE	60	62	69	63	67	63	56	67	67	60
RL	86	86	90	87	85	84	84	87	78	83
RK	62	64	67	66	64	64	63	73	61	59
EL	--	74	76	72	76	76	76	78	78	74
NL	--	69	79	74	70	72	73	83	79	77

TABLE XXVII
VOLUME OF EXPIRED AIR AT INTERVALS ON TWO TEST DAYS
(Liters Per Six Minutes)

Subject	Test Meal: High Fat					Test Meal: High Carbohydrate				
	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour
RM	34.10	35.70	34.65	31.05	28.15	28.70	28.25	33.10	27.55	24.75
SM	29.25	27.45	31.50	27.75	27.75	25.70	25.10	32.00	25.60	24.00
HM	32.95	32.90	35.65	32.35	32.65	28.65	30.30	38.70	31.75	30.85
HT	25.35	23.60	26.45	26.00	27.05	30.55	30.75	38.30	30.25	31.00
RT	28.90	29.10	31.30	30.75	29.35	28.50	27.75	38.35	29.95	26.30
MR	26.70	25.50	28.95	29.10	29.20	29.80	30.05	40.95	31.75	29.65
YL	23.95	23.30	25.70	22.85	24.25	22.65	20.95	27.10	19.45	20.00
GN	28.35	25.00	30.55	26.40	26.70	28.45	29.85	43.60	31.65	29.60
LP	26.20	25.95	32.00	29.45	29.40	26.35	26.70	35.70	28.75	26.80
NH	22.85	22.60	25.70	22.60	22.35	22.15	21.60	31.25	22.70	22.30
RW	24.70	22.30	27.80	24.45	26.50	23.45	23.35	31.45	26.25	23.15
SL	25.85	25.00	30.70	27.45	26.20	21.15	20.85	27.50	24.30	23.30
NS	24.75	22.25	24.00	23.70	23.50	22.65	23.60	30.45	26.35	24.10
EN	23.10	23.00	23.85	23.25	24.75	22.20	21.45	32.65	27.50	21.15
RD	22.45	22.55	30.10	17.45	23.70	21.90	21.45	31.00	23.25	21.95
NM	23.20	22.90	27.80	24.20	25.15	22.90	24.10	32.20	28.75	25.70
YK	23.30	22.00	28.30	26.75	23.80	24.20	22.45	30.15	27.65	23.50
RL	24.60	25.25	32.70	29.05	25.30	---	24.20	28.95	25.20	24.70
RK	22.15	22.30	26.00	25.15	24.85	24.15	22.95	33.70	23.35	24.25
EL	19.20	19.10	22.05	21.30	20.20	21.20	21.35	28.40	27.55	22.90
NL	19.55	20.35	23.40	26.40	22.25	22.05	22.05	34.40	27.70	25.35

TABLE XXVIII
OVERALL RESPIRATORY QUOTIENTS AT INTERVALS ON TWO TEST DAYS

Subject	Test Meal: High Fat					Test Meal: High Carbohydrate				
	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour
RM	0.85	0.83	0.87	0.87	0.78	0.80	0.80	0.95	0.89	0.79
SM	0.83	0.80	0.84	0.86	0.80	0.79 ^a	0.78	0.96	0.93	--
HM	0.81	0.77	0.83	0.88	0.80	0.84	0.81	0.91	0.88	0.83
HT	0.80	0.76	0.87	0.84	0.80	0.84	0.82	0.91	0.94	0.87
RT	0.78	0.75	0.84	0.84	0.80	0.79	0.80	0.94	0.88	0.79
MR	0.68	0.71	0.74	0.79	0.70	0.73	0.77	1.04	0.88	0.81
YL	0.75	0.75	0.79	0.81	0.82	--	0.85	0.96	0.85	0.86
GN	--	0.77	0.92	0.83	0.82	0.79	0.80	1.08	0.83	0.83
LP	0.76	0.74	0.79 ^a	0.79	0.76	0.91	0.88	1.01	0.92	0.79
NH	0.89	--	0.90	0.84	0.80	0.84	0.83	0.96	0.88	0.77
RW	0.75 ^a	--	--	0.84 ^a	0.82	0.75 ^a	0.78	0.99	0.79 ^a	0.81 ^a
SL	--	0.81	0.87	0.90 ^a	0.79 ^a	0.85	--	0.87	0.98	0.88
NS	0.84	0.81	0.84	0.87	0.84	0.83	0.86 ^a	0.99	0.86	0.81
EN	0.90	0.87	0.92	0.87	0.88	0.87	0.82	1.01	0.95	0.85
RD	0.84	--	0.91	0.86	0.88	0.79	0.84	1.08	0.93	0.88
NM	--	0.86	0.91	0.89	0.84	0.82	0.80	0.96 ^a	0.91	0.81
YK	--	0.82	0.91	0.90	0.78	--	0.87	0.95	1.07	0.88
RL	--	0.82	0.88	0.77	0.73	--	0.77	0.88	0.83	0.67
RK	0.83	0.87	0.92	0.83	0.78	0.83	--	0.92	0.93	0.84
EL	0.77	0.81	0.81	0.83	0.81	0.79	0.85	0.96	0.97	0.89
NL	0.82	0.83	0.85	0.88	0.85	0.85	0.80	1.03	0.97	0.88 ^a

^a Based on single gas analysis

TABLE XXIX

NON-PROTEIN RESPIRATORY QUOTIENTS AT INTERVALS ON TWO TEST DAYS

Subject	Test Meal: High Fat					Test Meal: High Carbohydrate				
	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour
RM	0.86	0.84	0.89	0.88	0.77	0.80	0.80	0.98	0.91	0.79
SM	0.84	0.80	0.84	0.88	0.80	0.78 ^a	0.77	1.01	0.97	--
EM	0.81	0.76	0.83	0.89	0.80	0.85	0.81	0.92	0.89	0.84
HT	0.80	0.73	0.88	0.85	0.80	0.87	0.83	0.94	0.97	0.88
RT	0.77	0.75	0.85	0.84	0.80	0.79	0.80	0.96	0.89	0.79
MR	0.65	0.69	0.73	0.79	0.68	0.72	0.76	1.10	0.91	0.81
YL	0.74	0.75	0.79	0.81	0.82	--	0.86	1.00	0.86	0.87
GN	--	0.76	0.94	0.83	0.82	0.78	0.80	1.14	0.84	0.84
LP	0.74	0.72	0.79 ^a	0.79	0.75	0.95	0.91	1.07	0.96	0.78
NH	0.93	--	0.93	0.86	0.79	0.85	0.84	1.01	0.91	0.76
RW	0.73 ^a	--	--	0.85 ^a	0.82	0.72 ^a	0.78	1.02	0.78 ^a	0.81 ^a
SL	--	0.81	0.88	0.93 ^a	0.79 ^a	0.88	--	0.89	1.03	0.91
NS	0.85	0.82	0.85	0.88	0.84	0.84	0.87 ^a	1.04	0.88	0.81
EN	0.92	0.88	0.94	0.89	0.89	0.88	0.82	1.05	1.00	0.86
RD	0.86	--	0.95	0.88	0.90	0.80	0.86	1.15	0.98	0.90
NM	--	0.87	0.94	0.91	0.84	0.83	0.80	0.99 ^a	0.93	0.81
YE	--	0.83	0.93	0.92	0.77	--	0.89	0.99	1.15	0.89
RL	--	0.83	0.90	0.77	0.71	--	0.76	0.89	0.84	0.65
RK	0.84	0.89	0.94	0.84	0.78	0.84	--	0.96	0.98	0.85
EL	0.76	0.81	0.81	0.84	0.81	0.78	0.86	1.00	0.99	0.91
NL	0.82	0.83	0.86	0.89	0.85	0.86	0.79	1.08	1.01	0.90 ^a

^aBased on single gas analysis

TABLE XXX
OXYGEN CONSUMPTION RATES AT INTERVALS ON TWO TEST DAYS
(Liters Per Hour)

Subject	Test Meal: High Fat					Test Meal: High Carbohydrate				
	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour
RM	15.85	16.09	16.99	15.94	15.84	14.82	14.52	16.67	14.15	15.25
SM	13.77	13.28	15.15	14.05	14.99	12.63 ^a	12.93	13.89	11.94	--
HM	13.67	14.60	15.47	13.10	14.16	13.20	14.33	16.63	13.93	13.58
HT	13.11	12.46	12.94	12.76	13.78	14.00	13.52	15.36	12.23	13.49
RT	14.25	13.90	13.69	13.20	12.82	12.93	12.39	14.72	13.59	12.62
MR	13.54	13.18	14.96	14.52	14.06	14.99	14.82	16.79	14.10	14.10
YL	13.61	13.82	14.99	13.40	14.29	--	12.70	14.51	12.21	12.38
GN	--	11.10	11.46	11.64	11.71	12.29	12.32	14.18	12.82	12.20
LP	11.78	12.39	14.01 ^a	13.55	13.41	10.24	10.36	12.42	10.85	11.37
NH	11.10	--	12.25	10.92	11.04	11.05	9.73	13.17	9.90	9.99
RW	12.52 ^a	--	--	11.22 ^a	12.29	11.08	11.61	12.90	11.61 ^a	10.72 ^a
SL	--	10.49	11.95	10.69 ^a	10.95 ^a	9.44	--	11.33	9.84	10.49 ^a
NS	11.64	10.49	11.82	11.07	11.14	10.98	10.72 ^a	11.86	11.50	11.45
EN	10.59	9.83	10.30	10.23	11.24	11.11	10.59	12.62	10.61	10.02
RD	10.03	--	12.29	11.03	9.94	10.79	9.94	12.20	10.10	10.48
NM	--	9.21	11.48	10.37	11.02	9.11	10.02	12.13 ^a	11.60	11.44
YK	--	9.78	10.97	10.37	10.54	--	8.67	11.22	9.71	9.48
RL	--	9.84	12.71	11.93	10.58	--	10.30	12.61	10.57	11.52
RK	10.26	9.95	10.54	11.04	10.60	9.95	--	12.33	8.86	9.69
EL	9.47	9.77	11.65	10.76	10.16	9.87	9.79	11.00	10.85	9.03
NL	10.17	10.48	11.87	12.42	11.10	10.31	10.72	12.62	10.68	10.80 ^a

^aBased on single gas analysis

TABLE XXXI

ENERGY EXPENDITURES AT INTERVALS ON TWO TEST DAYS

(Calories Per Hour)

Subject	Test Meal: High Fat					Test Meal: High Carbohydrate				
	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour	Basal 1	Basal 2	1st Hour	3rd Hour	5th Hour
RM	75.7	76.6	82.0	76.8	74.8	69.7	68.2	82.1	68.7	72.3
SM	65.4	62.5	73.0	67.2	71.0	59.3 ^a	60.6	68.2	58.2	--
HM	65.0	68.7	74.2	63.3	67.4	63.2	68.2	81.1	67.5	65.1
HT	61.4	57.6	62.1	60.8	65.6	65.9	63.2	74.6	59.9	65.1
RT	67.5	65.4	65.3	63.3	61.1	61.3	58.8	72.7	65.8	59.9
MR	63.0	61.3	70.1	68.8	65.5	69.8	69.6	82.9	68.0	67.0
YL	63.9	65.0	71.4	63.6	68.3	--	61.0	71.4	58.3	59.8
GN	--	52.1	56.1	55.7	56.0	57.8	58.2	70.2	61.2	58.4
LP	55.0	57.6	66.0 ^a	64.1	62.8	49.4	49.7	61.2	52.7	53.6
NH	53.6	--	59.3	51.8	52.0	52.8	46.3	64.8	47.5	46.8
RW	58.3 ^a	--	--	53.6 ^a	58.7	51.4 ^a	54.5	64.0	54.8 ^a	50.9 ^a
SL	--	49.6	57.5	51.8 ^a	51.8 ^a	44.7	--	54.6	48.5	50.7
NS	55.5	49.6	56.4	53.4	53.4	52.4	51.5 ^a	58.5	55.3	54.3
EN	51.4	47.3	50.4	49.4	54.5	53.3	50.2	62.6	52.2	47.9
RD	47.8	--	59.8	53.2	48.2	51.0	47.5	60.2	49.4	50.7
NM	--	44.3	55.9	50.5	52.9	43.9	47.9	60.0 ^a	56.7	54.6
YK	--	46.6	53.6	50.5	49.8	--	41.9	55.2	47.8	45.9
RL	--	47.0	61.8	56.3	49.3	--	48.4	61.1	50.5	53.7
RK	48.9	47.9	51.6	52.7	50.1	47.0	--	60.0	43.2	46.5
EL	44.4	46.2	55.5	51.4	48.5	46.3	46.6	54.3	53.8	43.8
NL	48.7	50.3	57.3	60.5	53.5	49.6	50.8	62.4	52.8	52.4 ^a

^aBased on single gas analysis

TABLE XXXII

CUMULATIVE CALORIE INCREMENTS FOR FIVE HOURS
FOLLOWING TEST MEALS

(Calories)

Subject	Test Meal: High Fat			Test Meal: High Carbohydrate		
	1st Hour	3rd Hour	5th Hour	1st Hour	3rd Hour	5th Hour
RM	3.0	10.0	10.0	6.5	18.5	20.5
SM	4.0	15.0	24.0	4.0	11.0	--
HM	3.0	6.0	3.0	6.5	21.5	22.5
HT	1.5	5.5	12.5	5.0	11.0	7.0
RT	-0.5	-3.5	-9.5	6.0	24.0	30.0
MR	4.0	18.0	28.0	6.5	18.5	15.5
YL	3.0	8.0	9.0	5.0	12.0	8.0
GN	2.0	10.0	18.0	5.5	19.5	22.5
LP	5.0	22.0	36.0	5.5	20.5	27.5
NH	3.0	7.0	4.0	8.0	22.0	18.0
RW	--	--	--	5.5	17.5	16.5
SL	4.0	14.0	19.0	5.0	18.0	26.0
NS	1.5	5.5	7.5	3.0	12.0	17.0
EN	1.0	3.0	8.0	5.5	16.5	15.5
RD	6.0	23.0	28.5	5.5	15.0	16.0
NM	5.5	23.5	37.5	7.5	32.5	42.5
YK	3.5	14.5	21.5	6.5	25.5	35.5
RL	7.5	31.5	41.5	6.0	20.0	27.0
RK	1.5	8.5	14.5	6.5	15.5	10.5
EL	5.0	21.0	30.0	3.5	17.5	21.5
NL	4.0	22.0	36.0	5.0	17.0	21.0

TABLE XXXIII

HOURLY CALORIE EXPENDITURES AT FASTING AND AT INTERVALS FOLLOWING HIGH CARBOHYDRATE TEST MEAL ACCORDING TO VARIOUS METHODS OF EXPRESSION

Sub- ject	Per M ² (actual weight)				Per Kg. (desirable weight)				Per M ² (desirable weight)			
	Fast- ing	1st	3rd	5th	Fast- ing	1st	3rd	5th	Fast- ing	1st	3rd	5th
RM	31.5	37.5	35.1	34.2	1.03	1.22	1.02	1.08	39.2	46.6	39.0	41.1
SM	28.0	34.1	31.4	33.2	0.89	1.01	0.86	--	34.1	38.7	33.0	--
EM	35.1	39.7	33.9	36.1	1.05	1.29	1.08	1.04	39.6	48.9	40.7	39.2
HT	34.0	32.7	32.0	34.5	1.02	1.17	0.94	1.02	38.0	43.9	35.3	38.3
RT	32.5	35.3	34.2	33.0	0.96	1.16	1.05	0.96	35.7	43.3	39.2	35.7
MR	38.3	38.5	37.8	36.0	1.11	1.32	1.09	1.07	42.0	49.9	41.0	40.3
YL	33.1	38.8	34.6	37.1	0.95	1.11	0.91	0.93	35.9	42.0	34.3	35.2
GN	32.6	31.5	31.3	31.5	0.94	1.14	0.99	0.95	34.5	41.8	36.5	34.8
LP	30.2	40.2	39.1	38.3	0.83	1.02	0.88	0.89	31.0	38.3	33.0	33.5
NE	28.1	33.7	29.4	29.5	0.76	0.99	0.73	0.71	28.5	37.2	27.3	26.9
RW	32.1	--	32.5	35.6	0.88	1.06	0.91	0.84	32.1	38.8	33.2	30.8
SL	28.7	36.9	33.2	33.2	0.78	0.95	0.84	0.88	27.6	33.7	29.9	31.3
NS	32.9	35.7	33.8	33.8	0.89	1.00	0.95	0.93	31.7	35.7	33.7	33.1
EN	30.4	29.7	29.1	32.1	0.81	0.98	0.81	0.75	29.4	27.3	29.6	27.2
RD	31.2	37.9	33.7	30.5	0.83	1.01	0.83	0.85	29.3	35.9	29.4	30.2
NM	30.2	36.7	33.2	34.8	0.78	1.02	0.97	0.93	28.5	37.3	35.2	33.9
YK	25.9	33.1	31.2	30.7	0.66	0.87	0.75	0.72	24.4	32.1	27.8	26.7
RL	31.4	40.1	36.6	32.0	0.83	1.05	0.86	0.92	29.3	37.0	30.6	32.5
RK	33.6	36.9	37.6	35.8	0.86	1.10	0.79	0.85	30.9	39.5	28.4	30.6
EL	29.8	35.5	33.0	31.1	0.77	0.91	0.90	0.73	27.7	32.3	32.0	26.1
NL	34.9	39.7	42.0	37.2	0.86	1.07	0.91	0.90	31.4	39.0	33.0	32.8

TABLE XXXIII continued

Sub- ject	Per Kg. (desirable weight) ^{0.75}				Per Kg. (actual weight) ^{0.75}			
	Fast- ing	1st	3rd	5th	Fast- ing	1st	3rd	5th
RM	2.93	3.49	2.92	3.08	2.00	2.38	1.99	2.10
SM	2.55	2.90	2.47	--	1.81	2.06	1.76	--
HM	2.95	3.64	3.03	2.92	2.28	2.82	2.35	2.26
HT	2.87	3.32	2.66	2.90	2.37	2.74	2.20	2.39
RT	2.72	3.29	2.98	2.71	2.33	2.82	2.55	2.32
MR	3.13	3.72	3.05	3.00	2.70	3.21	2.63	2.59
YL	2.69	3.14	2.57	2.64	2.33	2.73	2.23	2.29
GN	2.63	3.18	2.77	2.64	2.40	2.91	2.53	2.42
LP	2.29	2.84	2.44	2.48	2.20	2.72	2.34	2.38
NH	2.15	2.82	2.07	2.03	2.11	2.76	2.03	2.00
RW	2.44	2.95	2.53	2.35	2.46	2.97	2.54	2.36
SL	2.14	2.61	2.32	2.43	2.26	2.76	2.45	2.56
NS	2.46	2.77	2.62	2.57	2.59	2.92	2.76	2.71
EN	2.28	2.76	2.30	2.11	2.47	2.99	2.49	2.29
RD	2.30	2.81	2.31	2.37	2.52	3.09	2.53	2.60
NM	2.16	2.83	2.67	2.57	2.40	3.14	2.97	2.86
YK	1.86	2.45	2.13	2.04	2.08	2.74	2.37	2.28
RL	2.29	2.90	2.39	2.54	2.58	3.26	2.69	2.86
RK	2.34	2.99	2.15	2.31	2.71	3.45	2.49	2.67
EL	2.15	2.51	2.49	2.03	2.48	2.90	2.88	2.34
NL	2.38	2.96	2.50	2.48	2.84	3.54	2.99	2.97

TABLE XXXIV
BLOOD GLUCOSE CONCENTRATIONS AT INTERVALS ON TWO TEST DAYS
(Milligrams per 100 Milliliters)

Subject	Fast- ing	Hours After High Fat Test Meal					Fast- ing	Hours After High Carbohydrate Test Meal					
		$\frac{1}{2}$	1	2	3	4		5	$\frac{1}{2}$	1	2	3	4
RM	91	111	113	97	85 ^b	76	90	132	114	96 ^b	75 ^b	79	84
SM	89	131	118	93	81	86	96	177 ^a	109	124	105	86	85
HM	95	103	122	91	82	86	87	174	113	113 ^b	89 ^a	65 ^b	70
HT	88	104	94	101	76	81	92	191	110	117	64	66 ^b	82
RT	90	144	106 ^a	102	88	91 ^b	100	174	125	112	98	87	89
MR	101	122 ^a	134 ^a	116 ^b	94	86	98	196	154	112 ^a	103	86	92
YL	94 ^a	106 ^a	99	117	89	88	91	174	106	98 ^a	77	93 ^b	89
GN	89	110	79	86	83	82 ^b	94	127	116	93	81	85	85
LP	82 ^b	99	94	95	76	81	76	141	102	69	74	76	74
NE	81	129	89	81	74	84	78	174	131	91	78 ^b	85	86
RW	92	123	86 ^a	98	79 ^b	92 ^b	79	170	104	91	87 ^b	82 ^a	80
SL	90	131	94	87 ^a	81	89 ^b	71 ^b	157 ^a	118	95 ^b	54	79 ^a	71
NS	81 ^b	105	96	82 ^a	69	84	79	127	105	78	87	71	75 ^b
EN	81	98	98	82	92	90	91	161	131	94	102	95	87
RD	86	102	120	96	78	83	89	184	147	97	63	74	85
NM	83 ^b	97 ^b	96	71	76	77	79	182	116	126 ^a	111	85 ^b	75
YK	78	75 ^b	92	91	89	85 ^b	76	129	71	84	82 ^b	85	83 ^b
RL	84	108	90 ^b	76 ^b	75	77	76	157	119	96	83 ^b	76	76
RK	90	103	87	75	91	100	87	141	113	82	86	88	81
EL	72	100 ^b	80	77 ^a	86	77	78	138	96	127 ^b	96 ^a	77	70 ^b
NL	77 ^b	105	75	81	87 ^b	79	86	137	99	85	87	77 ^b	75

^a Duplicates differ > 6 mg. %

^b Single aliquot

TABLE XXXV

SERUM TOTAL LIPID CONCENTRATIONS AT INTERVALS ON TWO TEST DAYS

(Milligrams per 100 Milliliters)

Sub- ject	Venous Blood Fasting	Capillary Blood					Venous Blood Fasting	Fast- ing	Capillary Blood					Fast- ing	Capillary Blood				
		Fast- ing	Hours after High Fat Test Meal	1	3	5			Fast- ing	Hours after High Fat Test Meal	1	3	5		Fast- ing	Hours after High Carbohydrate Test Meal	1	3	5
EM	844	794	839	965	911	970 ^b	794	970 ^b	1109	1137 ^b	857								
SM	649	704	902	992	830	776	724	776	745	713	812								
HM	754	727	749	731 ^b	776 ^b	778	765	778	1026	1123 ^{aa}	983 ^{aa}								
HT	848	--	722	722	839	--	577	--	740	686	668								
RT	977	1064 ^b	972	992	1010	1001	--	1001	1114	1243	1046								
MR	970	823 ^a	724	900	918	848	828 ^a	848	756 ^{aa}	828 ^a	918 ^a								
YL	711	688 ^a	731 ^a	706 ^a	799 ^a	744 ^b	909	744 ^b	681 ^b	983 ^a	934								
GN	848	956	821 ^a	1019	803	947	893	947	769	796	839								
LP	916	898	898	902	1055	557	--	557	514 ^a	604	496 ^b								
NH	--	1146	1263 ^b	1335	1416	1166 ^a	--	1166 ^a	1155	1376	1209								
RW	--	--	--	--	--	559 ^b	550	559 ^b	667 ^b	--	658								
SL	--	--	--	--	--	--	645	--	751	776 ^a	778								
NS	629	613	611	613	663	--	--	--	--	--	--								
EN	460	613	640	686	541	627	537	627	636	577	541								
RD	848	869	823	981	936 ^a	990	956	990	965	993	983 ^b								
NM	769	727	819	918	826	691	758	691	668	501	514								
YK	889	902 ^b	884	961	839 ^b	808 ^a	947	808 ^a	799 ^a	853	875								
RL	1004	821 ^b	961 ^b	997	864	844	722	844	460 ^{aa}	--	855								
RK	505 ^a	505	564	559 ^a	514	559 ^a	600 ^a	559 ^a	496 ^a	586	514								
EL	751	684	733	968	758	--	--	--	--	--	--								
NL	--	--	832	--	722	602 ^a	--	--	586 ^a	622	578								

^a Duplicates differ 5-10%^{aa} Duplicates differ >10%^b Single value

TABLE XXXVI
SERUM CHYLOMICRON COUNTS AT INTERVALS ON TWO TEST DAYS
(Counts per Standard Dark-Ground Field)

Sub- ject	Venous Blood Fasting	Capillary Blood					Venous Blood Fasting	Fast- ing					Capillary Blood					
		Fast- ing	$\frac{1}{2}$	1	2	3		Fast- ing	$\frac{1}{2}$	1	2	3	Fast- ing	$\frac{1}{2}$	1	2	3	4
BM	79	56	134	344	343	400	332	303 ^a	58	72	81	75	78	74	58	43		
SM	62	64	155	267 ^a	315	285	295	245	64	91	92	82	53	55	57	61		
HM	91	206	185	330	347 ^a	504	373	797	207	180	254	211	136	135	191	197		
HT	153	165	185	315	390	303	332	305	83	126 ^a	245	115	87	307	94	64		
RT	35	36	143	258	325	340	400	370	--	32	30	10	32	33	59	56		
MR	27	22	71	283 ^a	355	363	313	210	180	220 ^a	317	175	115	205	158	160		
YL	62	106	72	324	384	431	515	381	69	90	73	71	85	289	296	96		
GN	59	46	71	121	352	443 ^a	318	367	22	39	35	40	45	44	43	26		
LP	65	65	82	319	353	346	504	399	--	54	61	59	62	62	72	59		
NH	--	83	80	292	420	505	569	510	--	92	91	70	81	79	81	80		
RW	11	12	118	423	470	258	308	55	21	20	51	36	22	26	31	42		
SL	21	19	32	552	393	237	143 ^a	130	12	8	93	79	109	71	53	64		
NS	25	24	52	250	355	320	315	320	61 ^a	71	59	58	82	120	96	98		
EN	46	56	90	471	538	498	333	246	77	76	81	65	73	59	66	67		
RD	43	43	60	420	547	475	355	190 ^a	18	19	22	33	50	40	31 ^b	29 ^b		
NM	25	27	55	283	305	410	390	403	28	32	60	61 ^b	43	26	37	39		
YK	106	101	110	309	566	605	441 ^a	401	60	62	70	67	70	77 ^b	75	84		
RL	11	14	281	459	465	410	259	200	39	41	38	39	40	73	58	27		
RK	98	101	287	442	743	477	557	285	157	160	149	126	130 ^a	81	126	172		
EL	108	111	332	385	495	480	393	225	25	57	59	46	71	49	52	43		
NL	--	73	170	420	665	407	359	237	--	90	89	112	76	58	48	56		

^a Duplicates differ by >10%

^b Single aliquot

TABLE XXXVII
FASTING SERUM CHOLESTEROL CONCENTRATIONS
ON TWO TEST DAYS

Subject	Total Cholesterol	
	Milligrams per 100 Milliliters	
RM	228	233
SM	178	201
HM	211	222
HT	282	242
RT	258	311
MR	207	221
YL	198	196
GN	300	353
LP	253	210
NH	396	362
RW	235	238
SL	176	196
NS	247	235
EN	171	169
RD	235	283
NM	158	164
YK	242	246
RL	264	269
RK	174	151
EL	204	218
NL	---	177

TABLE XXXVIII
FASTING SERUM LIPOPROTEIN CONCENTRATIONS¹
(Milligrams per 100 Milliliters)

Subjects	Lipoprotein Classes				
	S _f 0-11	S _f 12-20	S _f 21-35	S _f 35-100	S _f 100-400
RM	---	100	47	96	---
SM	---	45	13	28	---
	---	52	11	18	---
HM	---	19	10	24	---
	---	25	10	27	---
HT	---	19	2	6	---
	---	28	10	20	---
MR	---	29	11	31	---
YL	---	16	2	0	---
	---	28	10	33	---
GN	---	22	16	33	---
	---	18	8	18	---
LP	---	24	7	18	---
RW	---	6	3	1	---
SL	---	29	21	34	---
NS	---	16	3	3	---
EN	---	14	13	41	---
RD	---	25	14	49	---
	---	19	8	21	---
NM	120	51	21	21	5
YK	---	51	29	64	---
	---	55	31	61	---

TABLE XXXVIII continued

Subject	Lipoprotein Classes				
	S _f 0-11	S _f 12-20	S _f 21-35	S _f 35-100	S _f 100-400
RL	---	21	7	16	---
RK	---	12	3	5	---
	140	2	2	4	---
EL	---	43	13	21	---

¹Analyses were obtained on two days for some subjects and on one day for others; no lipoprotein analyses were obtained for subjects RT, NH and NL.

TABLE XXIX

BLOOD PYRUVIC ACID CONCENTRATIONS AT INTERVALS ON TWO TEST DAYS

(Milligrams per 100 Milliliters)

Subject	Fast- ing	Hours After High Fat Test Meal			Fast- ing	Hours After High Carbohydrate Test Meal		
		1	3	5		1	3	5
BM	0.90	0.93	0.80 ^a	1.01 ^a	0.98 ^b	1.04	0.82 ^b	0.77
SM	1.58	1.98	1.86	1.44	0.88 ^a	1.66	1.31	1.47
HM	0.94 ^c	0.85 ^c	0.78 ^c	0.69 ^c	0.99 ^c	1.05 ^c	0.85 ^c	0.94 ^c
HT	0.89	1.07	0.79	0.97	1.29	1.48	1.01	0.97
RT	1.20	1.37	0.88	1.10	1.58	2.02 ^b	1.03	1.32
MR	1.64	1.40	1.21	1.57	1.40	1.97 ^a	1.21	1.06 ^a
YL	1.23	1.30 ^a	1.08	1.42	1.55	1.60 ^a	1.38	1.40
GN	0.96 ^b	1.10 ^a	1.31	1.28	1.07	1.97 ^a	0.80	1.21
LP	0.99	0.68	0.71	0.99	0.77 ^a	1.24	0.70	0.80
NH	1.13	1.10	1.08	0.99 ^a	0.98 ^a	2.25	0.94	1.18
RW	1.12 ^b	0.94 ^b	--	1.13	1.05	2.27	1.12	1.16
SL	1.14	1.21 ^b	0.82 ^b	1.25	0.93	0.89	0.43	0.75
NS	1.00	1.11 ^a	0.94	0.91	1.12 ^a	1.88	0.82	0.87
EN	0.96	0.88	0.77	0.83 ^a	1.10	2.91	1.26	0.90
RD	0.89	1.57	0.87	0.90 ^a	0.80	1.57	0.98 ^a	1.20
NM	0.91	1.05	1.21	0.90	0.95	1.59 ^a	0.93	1.17
YK	1.25	1.29	0.95	1.03	1.03	1.86 ^b	--	0.94
RL	0.76	1.33	0.85	0.98	0.73	1.15	0.40 ^b	0.74
RK	0.82	0.82 ^a	0.77	0.74	0.91 ^b	1.37 ^a	1.15	0.78
EL	0.73 ^a	0.98	0.77	1.10	1.00 ^b	1.28	1.14	0.70
NL	0.50 ^b	0.71	0.58 ^b	0.74	0.61	1.03 ^a	0.68	0.91

^a Duplicates differ >10%^b Single aliquot^c Samples stood 4 hrs; no duplicate determinations

TABLE XL
FASTING SERUM ALKALINE PHOSPHATASE
CONCENTRATIONS ON TWO TEST DAYS

Subject	Serum Alkaline Phosphatase	
	Nitrophenol units	
RM	1.35	1.80
SM	1.60	1.50
HM	1.25	1.65
HT	1.16	1.10
RT	1.90	1.84
MR	1.50	1.65
YL	0.92	1.12
GN	0.65	0.80
LP	0.95	0.90
NH	2.25	2.05
RW	1.29	0.86
SL	1.15	0.90
NS	1.45	1.20
EN	1.60	1.45
RD	0.90	1.07
NM	0.84	0.85
YK	1.65	1.45
RL	1.00	0.92
RK	1.36	1.48
EL	1.20	2.12
NL	--	1.40

TABLE XLI
HOURLY AND CUMULATIVE URINARY NITROGEN EXCRETIONS AT INTERVALS ON TWO TEST DAYS
(Milligrams)

Subject	Test Meal: High Fat					Test Meal: High Carbohydrate				
	Fast- ing	1st Hour	1st-3rd Hours	3rd-5th Hours	Cumulative Excretions 5 Hours	Fast- ing	1st Hour	1st-3rd Hours	3rd-5th Hours	Cumulative Excretions 5 Hours
RM	674	570	544	402	2462	782	515	447	404	2217
SM	660	227	652	537	2605	588	593	536	515 ^a	2695
HM	425	337	396	296	1721	430	437	347	346	1823
HT	858	531	549	295	2219	1049	610	434	393	2264
RT	246	565 ^a	336	304	1845	364	289	366	294	1609
MR	417	314	402	303	1724	515	558	588	470	2674
YL	281	219	447	317	1747	417	567	518	284	2171
GN	401	313 ^a	310	248	1429	513 ^a	402	437	357	1990
LP	531	618	443	405	2314	560	444	491	375	2176
NH	509	515	629	521	2815	443	509	512	441	2415
RW	517 ^a	390	426	302 ^a	1846	530	332	366 ^a	361	1786
SL	445	457	432	358	2037	628	395	364	402	1927
NS	489	484	360	315	1834	388	412	426	423	2110
EN	367	281	351	271	1525	459	331	424	405	1989
RD	498	519	332	289	1761	432	399	431	349	1959
NM	294	435	281	261	1519	99	331	309	270	1489
YK	346	301	283	291	1449	285	388	355	265	1628
RL	291	312	304	249	1418	343	326	367	287	1634
RK	395 ^a	285 ^a	391	291	1649	572	533	411	299	1953
EL	398	329	371	213	1497	481	370	248	293	1452
NL	197	269	212	209	1111	296	378	320	297	1612

^aDuplicates differ > 5%

CASE HISTORIES

Subject RM.

RM was 39 years of age and was evaluated to be sixty-six percent above desirable weight. The rate of fasting energy expenditure was significantly lower than that predicted by the calculated line of regression, although the actual rate of energy expenditure was the highest of all subjects. Fasting non-protein respiratory quotients were higher than the mean of the overweight subjects, while fasting blood pyruvic acid concentrations were lower than the group mean. Fasting serum lipoprotein fraction S_f12-20 and S_f35-100 concentrations were greater than 80 and 50 milligrams per 100 milliliters, respectively. Following the high fat test meal, responses were generally typical of the overweight group; serum total lipids were increased from fasting at all hours measured. Following the high carbohydrate test meal, the one-half hour blood glucose concentration was low and deviated markedly from the rest of the group; blood pyruvic acid concentrations showed no increase from fasting values; serum total lipids were increased above fasting through the third hour and then decreased markedly at the fifth hour; chylomicron concentrations, however, showed almost no hour to hour variation. Total urinary nitrogen excretion was higher following high fat than high carbohydrate test meal.

Subject SM.

SM was 53 years of age and was evaluated to be fifty-eight percent above desirable weight. The rate of fasting energy was slower than that predicted by the calculated line of regression; the concentration of S_f12-20 fraction of serum lipoproteins was greater than 50 milligrams per 100 milliliters; other fasting values were typical of the overweight group but between day variation in blood pyruvic acid concentration was very high. Following the high fat test meal, the increase in rate of energy expenditure was high, serum total lipids showed a marked increase in concentration to the third hour, and blood pyruvic acid was increased to the greatest extent of the overweight subjects. Following the high carbohydrate test meal, energy expenditure and non-protein respiratory data were not obtained for the fifth hour; at the first hour the non-protein respiratory quotient was 1.01; chylomicron concentrations showed little hour to hour variation; and serum total lipid concentrations were decreased from fasting value at the first and third hour, but were increased above fasting at the fifth hour.

Subject HM.

HM was 30 years of age and was evaluated to be thirty-one percent above desirable weight. Fasting values were generally typical of those of the overweight group; chylomicron concentrations were the highest of any subject, however; pyruvic acid concentrations were somewhat low, but only single determinations were made; between day variation for all values was very slight. Following the high fat test meal, the increase in energy

expenditure was low; the fifth hour serum sample was extremely creamy and the chylomicron count at that hour was extremely high; serum lipid concentrations were not changed. Following the high carbohydrate test meal, responses were generally typical; HM had a very marked increase in serum total lipids and erratic changes in serum chylomicron concentrations; blood pyruvic acid concentrations showed no increase from fasting value.

Subject HT.

HT was 45 years of age and was evaluated to be twenty-nine percent above desirable weight; she was in a period of active weight gain. Fasting values were generally typical of the overweight group means; fasting hourly urinary nitrogen excretions were, however, extremely high and fasting cholesterol concentrations were 282 and 242 milligrams per 100 milliliters for the two test days, respectively. Following the high fat test meal, responses were generally typical of the group; non-protein respiratory quotient showed a marked elevation at one-hour, however; serum total lipid concentration was markedly reduced at the first hour; and the change in serum chylomicron concentration was the least of any subject. Following the high carbohydrate test meal, hourly energy expenditure was markedly decreased from the first to third hours, maximum non-protein respiratory quotient measured was at the third hour, serum chylomicron concentrations were highly erratic, while serum total lipids were increased at the first hour and then gradually were decreased. Cumulative calorie increments measured for five hours were greater after the high fat test meal but low following either.

Subject RT.

RT was 57 years of age and was evaluated to be twenty-two percent above desirable weight. Fasting values were typical of the overweight subjects, except that fasting hourly urinary nitrogen excretions were low and serum chylomicron concentrations were low for the overweight group; fasting serum total lipid concentrations were greater than 1000 milligrams per 100 milliliters and fasting cholesterol concentrations were 258 and 311 milligrams per 100 milliliters. Following the high fat test meal, hourly energy expenditures continuously decreased from fasting value, blood glucose showed a definite one-half hour peak concentration, the chylomicrograph was typical of overweight subjects and hourly urinary nitrogen excretion was markedly increased at first hour. Following the high carbohydrate test meal, responses were generally typical of the overweight group; chylomicron concentrations, however, showed no hour to hour irregularity, although serum total lipid concentrations were markedly increased. Total urinary nitrogen excretion for five hours was greater following high fat test meal.

Subject MR.

MR was 29 years of age and was evaluated to be twenty-two percent above desirable weight. Fasting non-protein respiratory quotients were very low and fasting blood glucose concentrations were both near 100 milligrams per 100 milliliters of blood; other values were typical of the overweight group. Following the high fat test meal, the non-protein respiratory quotient increased to the third hour, but was never greater than 0.79; blood

pyruvic acid was decreased from fasting value at the first and third hours; cumulative calorie increments for five hours were higher following the high fat test meal than the high carbohydrate meal; the chylomicrograph was typical of the underweight subjects. Following the high carbohydrate test meal, non-protein respiratory quotient was 1.10 at one hour and still elevated above fasting value at the fifth hour; the one-half hour blood glucose concentration was the highest of all subjects; serum total lipids were decreased at one hour but then increased at the third and fifth hours, while chylomicron concentration displayed erratic increases and decreases.

Subject YL.

YL was 25 years of age and was evaluated to be twenty-one percent above desirable weight; she was in a period of active weight gain. Fasting values were all typical of the overweight group; fasting energy expenditure and non-protein respiratory quotients showed marked day to day variation. Following the high fat test meal, responses were generally typical of the overweight group, although cumulative calorie increments for five hours were similar after both the high fat and high carbohydrate test meals. Following the high carbohydrate test meal, responses were again generally typical of the overweight group: serum total lipids and chylomicron concentrations both showed marked increases at the third hour; hourly urinary nitrogen excretion was increased from fasting value at the first and the first to third hours; there was no change in blood pyruvic acid concentration.

Subject GN.

GN was 38 years of age and was evaluated to be thirteen percent above desirable weight. Basal energy expenditure was slightly below that predicted by the regression line; the fasting serum total lipid concentration was high and serum total cholesterol concentration was greater than 300 milligrams per 100 milliliters; other fasting values were within average weight group range and showed very minimum day to day variation except for basal energy expenditures. Following the high fat test meal, non-protein respiratory quotient was above fasting value at the fifth hour; the chylomicrograph was of the overweight pattern; blood pyruvic acid concentration showed a gradual increase at each hour; other responses were typical of the average weight subjects. Following high carbohydrate test meal, one-half hour blood glucose concentration was low and third, fourth and fifth hour values were below fasting value. Total urinary nitrogen excretion for five hours was higher following high carbohydrate test meal than following high fat test meal.

Subject LP.

LP was 40 years of age and was evaluated to be six percent above desirable weight. Fasting values were typical of those of the average weight group, but between day variation was high for basal energy expenditure, fasting non-protein respiratory quotients and serum total lipids. Following the high fat test meal, cumulative calorie increment above fasting was the highest of any subject and greater than that following high carbohydrate meal; non-protein respiratory quotient showed little change from fasting; the chylomicrograph was typical of the overweight subjects.

Following the high carbohydrate test meal, all responses were generally typical of the average weight group, but non-protein respiratory quotient was below fasting value at fifth hour. Total urinary nitrogen for five hours was higher after high fat than high carbohydrate test meal.

Subject NH.

NH was 52 years of age and was evaluated to be about two percent above desirable weight. Her fasting energy expenditure was slightly below that estimated by the regression line; fasting serum total lipids and serum total cholesterol were the highest of all subjects; other fasting values were within group ranges. Following the high fat test meal, non-protein respiratory quotient showed no change at the first hour, then decreased continuously at the third and fifth hours; chylomicron concentration changes were typical of the overweight subjects; serum total lipids showed marked and continuous increase throughout the five hours; and hourly urinary nitrogen excretions showed no decrease from fasting value. Following the high carbohydrate test meal, the one-half hour glucose concentration was highest of average weight group, fifth hour non-protein quotient was decreased from fasting value; serum total lipids increased markedly from the first to the third hours and then decreased, and hourly urinary nitrogen excretions showed no decrease from fasting value. Total urinary nitrogen excretions for five hours were higher following high fat than high carbohydrate test meal.

Subject RW.

RW was 37 years of age and was evaluated to be at desirable weight. Fasting non-protein respiratory quotients were low and fasting chylomicron counts were low for the average weight group; other fasting values were typical. Following the high fat test meal, expired gas samples were lost for the first hour and serum total lipids were not determined; the chylomicrograph was typical of the underweight subjects; the non-protein respiratory quotient was markedly above fasting value at the fifth hour. Following the high carbohydrate test meal, serum total lipids were determined at the second, fourth and fifth hours; both the second and fifth hour samples showed serum total lipid concentrations elevated from fasting. Non-protein respiratory quotient was similar to fasting value by the third hour following carbohydrate meal. Total urinary nitrogen excretions were similar following both test meals.

Subject SL.

SL was 25 years of age and was evaluated to be seven percent below desirable weight. Subject SL had the lowest calorie per hour expenditure of the average weight subjects; hourly energy expenditure slightly below that estimated by regression line; other fasting values were typical. Following the high fat test meal: the non-protein respiratory quotient was below fasting value at the fifth hour; the chylomicrograph showed no change at one-half hour and then the highest one-hour peak concentrations. Serum total lipids were not determined. Following the high carbohydrate test meal: the non-protein respiratory quotient peak above 1.0 was delayed until the third hour; there was the most pronounced decrease of

blood glucose concentration below fasting of average weight subjects; pyruvic acid concentrations were depressed below fasting at all hours measured; serum total fats increased and the chylomicron concentrations were slightly elevated from fasting. Total urinary nitrogen excretion for five hours was higher following high carbohydrate than high fat test meal.

Subject NS.

NS was 29 years of age and was evaluated to be seven percent below desirable weight. Fasting values were all typical of the average weight group. Following the high fat test meal, the chylomicrograph was typical of overweight subjects; the non-protein respiratory quotients, blood glucose and pyruvic acid concentrations, serum total lipids and hourly urinary nitrogen excretions were typical of average weight group, though highest non-protein respiratory quotient was at third hour. Following the high carbohydrate test meal serum total lipids were not determined; responses measured were typical of the average weight group, except that hourly urinary nitrogen excretions showed little decrease from fasting values. Total urinary nitrogen excretion for five hours was higher following high carbohydrate than high fat test meal.

Subject EN.

EN was 32 years of age and was evaluated to be ten percent below desirable weight. Fasting values were typical of the average weight pattern. Following the high fat test meal, no increased calorie response to the test meal was measured until the fifth hour; the chylomicrograph was typical of the underweight subjects; other responses were typical of average weight subjects. Following the high carbohydrate test meal: calorie expenditures, non-protein respiratory quotients, blood glucose and serum chylomicron concentrations were typical of those of the average weight group; blood pyruvic acid changes were typical of those of the average weight group, but the peak concentration was the maximum value determined for any subject; serum lipid concentrations decreased. Total urinary nitrogen excretion for five hours was higher following high carbohydrate than following high fat test meals.

Subject RD.

RD was 51 years of age and was evaluated to be twelve percent below desirable weight. Fasting values were all typical of the group pattern except serum total cholesterol concentrations which were 235 and 283 milligrams per 100 milliliters on the two days. Following the high fat test meal, peak glucose concentration was delayed to the first hour; the blood pyruvic acid concentration increase at one hour was the greatest of the underweight subjects. Following the high carbohydrate test meal, the blood glucose concentration increased to 185 milligrams per 100 milliliters of blood at one-half hour, decreased slowly until the second hour, then decreased sharply to below fasting concentrations at the third hour; the non-protein respiratory quotient increased to 1.15 at the first hour. Other metabolic responses to the test meals were typical of the underweight group.

Subject NM.

NM was 40 years of age and was evaluated to be thirteen percent below desirable weight. Fasting values of all constituents measured were typical of the underweight group, except fasting hourly urinary nitrogen excretions, which were low and lipoprotein fraction S_f12-20 concentrations which were somewhat high. Following the high fat test meal, the chylomicrograph of NM was typical of the overweight rather than that of the underweight subjects; peak concentration was delayed and there was no decrease toward fasting concentrations during the five hour period. Following the high carbohydrate test meal, the blood glucose concentration was 182 milligrams per 100 milliliters at one-half hour; the renal threshold for glucose of the subject was exceeded during the first hour and during the first to third hours. Following the high carbohydrate test meal, the serum total lipid concentration showed the most marked decrease from fasting of that of any subject and total urinary nitrogen excretion for five hours was slightly less than following high fat meal. Total cumulative calorie increments above fasting for the five hours after feeding were higher following the high carbohydrate test meal than following the high fat test meal.

Subject YK.

YK was 51 years of age and was evaluated to be fourteen percent below desirable weight; YK was "actively" losing weight. The lowest measured basal energy expenditure was that of YK, 42 calories per hour. Only single basal energy expenditure and respiratory quotient values were obtained for each experimental day; the between day variations were marked. Fasting blood pyruvic acid concentrations were the highest of the underweight group; fasting serum lipoprotein fractions S_f12-20 and S_f35-100 concentrations were relatively high. Other fasting values were typical. Following the test meals, certain responses were atypical of the underweight group. Non-protein respiratory quotients following both test meals increased to a greater extent than those of any other underweight subject; peak quotients also occurred at later hours. The chylomicrograph following high fat feeding was typical, but peak concentration was delayed to the third hour. Total cumulative calorie increments above fasting for the five hours after feeding were higher following the high carbohydrate test meal than following the high fat test meal. Blood glucose concentrations of one-half hour following high fat test meal was not changed from fasting value; one hour blood glucose value following high carbohydrate test meal was below fasting concentration.

Subject RL.

RL was 34 years of age and was evaluated to be fifteen percent below desirable weight. Fasting respiratory quotients were low for the underweight group. RL responded with the lowest non-protein respiratory quotients following both test meals. In both cases acetone bodies were excreted in the third to fifth hour urine collections; traces of acetone substances were indicated in the first to third hour urine collection following the high fat test meal. Other fasting values and metabolic responses measured showed no unique pattern. Fasting serum total cholesterol concentrations were relatively high, however, 264 and 369 milligrams per

100 milliliters. Following the high carbohydrate test meal, serum total lipids were decreased markedly at the first hour; subsequent measurements were made at the second, fourth and fifth hours and showed consistent increases toward fasting concentrations.

Subject RK.

RK was 25 years of age and evaluated to be seventeen percent below desirable weight. Fasting glucose and fasting chylomicron concentrations were in the upper range of the underweight group; fasting serum total lipid concentrations were the lowest. Following the high fat test meal: the energy increment response was low; blood pyruvic acid concentration showed no change; chylomicrograph was generally typical, but the peak serum chylomicron concentration was the highest measured for any subject, and the maximum total blood lipid response was quantitatively low but typical in terms of percent of fasting concentration. Following the high carbohydrate test meal responses were generally typical, except that the rate of energy expenditure was the most erratic of the group; chylomicron counts were relatively erratic and the decrease in hourly urinary nitrogen excretion was the most marked of the underweight subjects.

Subject EL.

EL was 27 years of age and evaluated to be seventeen percent below desirable weight. One fasting non-protein respiratory quotient of 0.79 was low for the underweight group. The high fasting chylomicron count measured on the first experimental day appeared to be the result of the ingestion of two doughnuts by the subject late in the evening prior to that experimental day. Following the high fat test meal, EL had the highest increase in serum total lipids of all underweight subjects; other responses conformed to group pattern. Following the high carbohydrate test meal: serum total lipid values were not determined; urinary nitrogen excretion was slightly lower than following the high fat test meal; and blood glucose concentration was maximum at one-half hour, decreased at the first hour, increased again at the second hour and then decreased below fasting at the fifth hour.

Subject NL.

NL was 27 years of age and evaluated to be twenty-one percent below desirable weight. Her fasting energy expenditure deviated from the rest of the underweight group; the hourly rate of calorie expenditure was significantly higher than that estimated by the regression line. Hourly fasting urinary nitrogen excretions were low. Other fasting values conformed to the group pattern. Following the high fat test meal, chylomicron concentrations reached a high peak concentration at the second hour; the serum sample was visibly milky. Serum total lipids showed the smallest increase in concentration of all underweight subjects and then fell below fasting concentrations; serum total lipids were determined at the one-half, first, second, fourth and fifth hours because sufficient serum was not available at the regular intervals. The third hour calorie increment was greater than that of the first hour. Other responses following the high fat test meal were typical of the underweight group. Following the high carbohydrate test meal, metabolic responses generally conformed to the group pattern; however, a positive qualitative sugar test was found for the first hour urine collection (estimated, 0.1%) whereas the one-half hour blood glucose value was relatively low.

Directions for Subjects

We should like to request your cooperation for two separate days from early morning until approximately 2:00 P.M.

On the day preceding an experiment, no food should be consumed after 7 P.M. and supper should be as low in fats as possible. (Do not eat fats as butter, mayonnaise and salad dressing, cream, gravies, or rich desserts.)

Eight hours sleep should be obtained on the night preceding an experiment.

On arising in the morning, the bladder should be emptied as completely as possible and the time noted. (This should preferably be by 6:45 A.M.) Please drink a glass of water and then do not urinate again until after you come to the laboratory.

Please arrive at the laboratory by 7:15 A.M. Be leisurely in activity!

You will be asked to rest quietly (lying or sitting) during the experimental period. Bring reading matter or hand-work, if you desire.

A test meal breakfast will be served. Basal metabolism tests and collections of blood and urine samples will be made during the course of the experiment.

DIET HISTORY

Name _____ Date _____

Address _____

Birth date _____ Age _____ Sex _____

Place of birth _____

Nationality _____ Are you a citizen of the U.S.? _____

Father's birthplace _____

Mother's birthplace _____

How many generations has your family lived in the U.S.? _____

How many members are there in your family? _____

Do you live in a) Country _____ b) Small town _____ c) City _____

Have you always lived here? Yes _____ No _____. If not, where have you
lived most of your life? _____

Do you eat vegetables? _____ Fresh? _____ Canned? _____

Do you usually eat vegetables? _____ Yes _____ No _____

(a) Once per day? _____ Twice per day? _____ More? _____

(b) What vegetables do you dislike? _____

(c) Favorite vegetables _____

Do you eat potatoes? _____ Yes _____ No _____

(a) Once per day? _____ Twice per day? _____ More? _____

(b) Favorite method of preparation _____

Do you eat any vegetables raw? _____ Yes _____ No _____

How often? Once or twice per day? _____ Several times per week? _____

Do you eat fruits? Yes _____ No _____ Fresh _____ Canned _____ Dried _____

Do you usually use some fruits in your diet? Yes _____ No _____

(a) Once per day? _____ Twice per day? _____ More? _____

(b) What fruits do you dislike? _____

(c) Favorite fruits _____

Do you eat meat? Yes _____ No _____

How often do you plan meat in your diet? Once per day _____

Twice per day? _____ Several times per week? _____

Do you buy (a) liver? Yes _____ No _____

(b) kidney? Yes _____ No _____

(c) brains? Yes _____ No _____

(d) sweetbreads? Yes _____ No _____

How often do you eat:

(a) liver? Once per week? _____ Once per month _____ Less _____

(b) brains? Once per week? _____ Once per month _____ Less _____

(c) kidney? Once per week? _____ Once per month _____ Less _____

(d) sweetbreads? " " _____ Once per month _____ Less _____

What meats do you dislike? _____

Favorite meat _____

Do you eat fish? Yes _____ No _____

Once per week? _____ Several times per week? _____

Do you drink milk? (a) Yes _____ No _____

How many glasses per day? _____

Do you use cream? (a) Yes _____ No _____

(b) Liberally _____ Sparingly _____

Do you eat eggs every day? Yes _____ No _____ No. per week(average) _____

Do you eat cheese regularly? Yes _____ No _____

Kind of cheese _____

Do you eat cereals regularly? Yes _____ No _____

Kinds most often used _____

Average number of slices of bread used per day _____

Do you eat many home-baked products? _____

How many servings of butter and/or margarine do you estimate you eat
per day _____

Do you eat nuts regularly? (a) Yes _____ No _____

(b) Favorite nuts _____

How often do you eat:

(a) Pie? Once per day? _____ Twice per week? _____ Once per month? _____
Other? _____

(b) Cake? Once per day? _____ Twice per week? _____ Once per month? _____
Other? _____

(c) Cookies? Once per day? _____ Twice per week? _____ Once per month? _____
Other? _____

(d) Milk puddings? Once per day? _____ Twice per week? _____ Once per month? _____
Other? _____

(e) Ice Cream? Once per day? _____ Twice per week? _____ Once per month? _____
Other? _____

(f) Other desserts? _____

What is your favorite dessert? _____

How often do you drink:

(a) Cocoa? _____ Servings per day _____ Servings per week _____

(b) Coffee? _____

(c) Tea? _____

(d) Soft drinks? _____

(e) Alcoholic beverages? _____

What foods not listed above do you dislike: _____

Do you have any food allergies? Yes _____ No _____

If so, what are they _____

What method is used most in preparing meats? Deep Frying _____
Roasting _____ Broiling or _____
Stewing _____ Panbroiling _____

Do you wash your meats before cooking? Yes _____ No _____

Do you cook vegetables (a) in large amounts of water? Some _____ All _____
(b) in small amounts of water? Some _____ All _____

How long do you usually cook vegetables? Until well done? _____
Until tender? _____

Do you use the stock from canned or home cooked vegetables?

Yes _____ No _____ How used (a) With vegetable? Yes _____ No _____
(b) In soups or gravies? Yes _____ No _____

Do you use soda in vegetables? Yes _____ No _____

Do you boil such vegetables as potatoes in the skin? _____ Peeled? _____

Do you commonly add fat for seasoning in cooking?

(a) Yes _____ No _____

(b) Liberally _____ Sparingly _____

Do you take vitamin preparations? _____ What kind? _____

Do you take other medication? _____ What kind? _____

Do you take laxatives? _____ How often? _____ What kind? _____

How many glasses of water do you drink daily? _____

What foods do you usually eat for breakfast?

Dinner?

Supper?

Do you eat between-meal snacks? _____ Often? _____ Seldom? _____
Regularly? _____

What are some typical snacks? _____

Do you eat at bedtime? _____ Often _____ Seldom _____ Regularly? _____

What are some typical examples _____

MEDICAL HISTORY

Name _____ Date _____

Check once the conditions which you have had and give approximate dates.
Check twice those you now have.

Arterio sclerosis _____ Jaundice _____

High blood pressure _____ Arthritis or Gout _____

Other heart conditions _____ Ulcers _____

Measles _____ Colds, frequent _____

Whooping Cough _____ Pneumonia _____

Diarrhea _____ Migraine headaches _____

Diphtheria _____ Diabetes _____

Scarlet Fever _____ Smallpox _____

Tuberculosis _____ Gall Bladder disturbances _____

Typhoid fever _____ Mumps _____

Rheumatic Fever _____ Other (specify) _____

Joint pains _____

Have you ever had any surgical operations? _____
Explain _____

Have you ever had any broken bones? _____
Explain _____

Have you ever been confined to bed for longer than 2 weeks? _____

If so, why and how long? _____

Do you have a family doctor? _____ Dentist? _____

When did you last see a dentist? _____

When were you last under the care of a doctor? _____

Are you taking any medications now? _____

Is any member of your family now under doctor's care? _____

Why? _____

Do you ever have:

Loss of appetite _____	Chest pain _____	Swellings _____
Nausea or vomiting _____	Fainting spells _____	Boils _____
Cramps _____	Shortness of breath _____	Sore mouth _____

Has either of your parents or any brother or sister had:

Tuberculosis _____	Diabetes _____
Epilepsy _____	Cancer _____
Gout _____	Heart Disease _____

Any significant loss or gain in weight last year? _____

Approximate range in body weight during adulthood: _____

Have you had children? _____ How many and what ages? _____

Menstrual history:

Age of menarche _____

Length of cycle _____

Duration of period _____

Is medication necessary _____

Have you completed the menopause? Yes _____ No _____ In progress _____

How long did it last? _____ Years.

How long ago was the menopause completed? _____ Years.

Did you have?

(a) Hot flashes	_____	How long?	_____	Years
	Yes No			
(b) Nervousness	_____	How long?	_____	Years
	Yes No			
(c) Other Ills	_____			

Were any of these symptoms serious enough to consult a doctor? Yes _____ No _____

List the ones that were severe enough to call a doctor _____
