Previous Diet
and
Basal Metabolic Rate

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by

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SUMMARY

In recent years, much work has been done regarding basal metabolism and researches on this field have come up with the development of BMR standards. However, there is still a paucity of studies on the effect of minor influences on BMR such as the preceding day's intake. It's cumulative effect over long periods may be an important determinant in differences in daily energy expenditure and if large enough may warrant consideration when defining energy requirements of individuals or population groups.

This study attempts to determine the effect on basal metabolic rate of the preceding day's intake. Results of this study may be able to at least add to existing knowledge in the extent of short-term fluctuations in energy intake and which may possibly serve as background information to other studies.

In this paper are presented some early and recent findings/investigations related to the topic, methods of measurements and how the study was conducted.

The study covered a total of 30 normal women, resident within the Glasgow area, aged 21 to 43 years, and who qualified based on certain criteria set. These included post-doctoral and senior honours students and staff of the Physiology department and some post-graduate students from other departments of the University of Glasgow.

Basal metabolic rate was assessed using the Douglas Bag technique a day after differing levels of energy intake were consumed. Subjects were interviewed on their actual daily energy intake from which a menu was planned for each of the 3 phases of the study. These phases included: the Initial phase, where a day prior to the BMR measurement, energy intake was not controlled - the subject following her normal daily eating habit; the Standard Diet phase, where a day prior to the measurement, the energy consumed was calculated as the requirement of each particular subject based on the measured BMR times 1.4; the Overeating or "40% more" phase, where the diet consumed was 40% more than the average computed from the Standard Diet phase; and the Undereating or "40% less" phase, where the diet plan was based on a deficit of 40% computed from the average intake in the Standard Diet phase.

Results of the study showed no significant changes in the basal metabolic rate in all phases of the experiment. Under conditions of these experiments, the study indicated that the post-absorptive BMR did not show substantial variations on differing levels of intake measured a day after.

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Abbreviations

BMR - Basal Metabolic Rate

RMR - Resting Metabolic Rate

TEF - Thermic Effect of Food

DIT - Dietary-Induced Thermogenesis

ACF - Atmospheric Correction Factor

DB - Douglas Bag

RQ - Respiratory Quotient

STP - Standard Temperature and Pressure

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Declaration

I, Gemma P. Yuchingtat, do hereby confirm that the work presented in this thesis was carried out by me and has not been submitted before to any other university.

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1. INTRODUCTION

The assessment of human energy expenditure on which energy requirements are based is the most significant item in determining the magnitude of an individual's food requirements (Beeghly, 1972). Moreover, estimates of energy expenditure and observations of intake have been considered in drawing up standards of energy requirements; and estimates of energy requirements may be used to assess the adequacy of diets or national food supplies, to plan satisfactory diets and work out national production and consumption policies which aim at equitable distribution of adequate food supplies.

Energy expenditure studies however, involve no small investment in terms of manpower, money and time. Inspite of these, researches on this field have been quite extensive though fragmentary in recent years and the numbered available literature have provided invaluable insights to researchers to do further studies on nutritional requirements so as to be able to arrive at factors to be considered in setting up recommendations.

A recent meeting of the FAO/WHO/UNU Expert Consultation Group (1985) has come up with recommendations for predicting energy and protein requirements. Here, they adopted the principle of calculating all components of total energy requirements as multiples of the basal metabolic rate (BMR). This is because in the great majority of cases, the largest component of energy expenditure is the BMR (FAO/WHO/UNU, 1985), which contributes about 60 - 75% of the total energy output in an average adult individual and which can be measured with accuracy under standardised condition. However, "maintenance requirements" are also indicated by the level of BMR (Blaxter, 1989). This principle though, is said to involve some inconsistencies (FAO/WHO/UNU, 1985) especially when individuals rather than groups of people are considered.

This is because the data used in deriving the equations were from different population groups/studies and that these studies were done under differing conditions and intended to apply to healthy people in any population. The assumption here is that in deriving the energy cost coefficient, it is assumed that a given height, weight, age and sex, corresponds to a given BMR, or in other words, that the equations are valid for all populations. This would also assume that attributing a given coefficient to an activity for two adults of the same sex, the cost of activity expressed as a BMR multiple, will not vary with the weight for height, the experience, the training and other possible factors. This would probably be too presumptuous when individuals are concerned. Hence these equations may not be substitutes for direct measurements when this can be done or when validation studies are needed especially since several factors are known to influence the BMR (Horton, 1983). Moreover, several questions still remain regarding these factors which include muscular exercise, the consumption of food and its subsequent metabolism and the physical environment. Furthermore, several variables have also been assumed to affect BMR, some of which are age, sex, body size, body temperature, time of day and year, nutritional status, body composition and the antecedent diet. In some cases too, whenever there appeared to be much variation in the BMR of supposedly normal individuals, this phenomenon was also considered to be the result of either a carelessly conducted measurement or inadequacies in the measuring equipment (Durnin, 1984; Shils and Young, 1988); or in the potential contribution of a component of large inter- and intra-individual differences observed in BMR and which are termed as inter- and intra-individual variability - the last said to be the result from short-term fluctuations in energy intake and expenditure.

Garrow, 1985, in his report on the "Resting metabolism rate as a determinant of energy expenditure in man", hypothesised that the explanation for the reported variations between individuals on energy requirements must possibly

lie somewhere among the above-mentioned possibilities, alone or in combination. To explain, if the method of measurement is sufficiently wrong, then the whole question disappears since the apparent range in requirements is an artefact of measurement error. However, if the measurement of food intake is correct, then there must be a corresponding range of variation in energy output since anyone who does not change rapidly in weight must have a similar energy intake and output. If the variation is in output, it might be in BMR, or some other component of energy output, i.e., "thermogenesis" which is defined as any increase in metabolic rate above the resting level.

All these possibilities however, are still hardly documented or lack comprehensive study and there is still no satisfactory explanation for the divergence of opinions concerning the reported variations between individuals in energy requirement based on the measurement of the levels of BMR.

Although much work has been done regarding basal metabolism and researches on this field have come up with the development of BMR standards and the quantitative measurements of factors that may affect BMR, still there is a paucity of studies on the effect of minor influences on BMR such as those mentioned above and, as well, the preceding day's diet, physical activity, stress and drugs. Such minor influences often are effective day after day so that over large periods, the cumulative effect is quite large (Van Es, 1984). This could be a most important determinant of differences in daily expenditure and if large enough may warrant consideration when defining energy requirements of individuals or population groups. The study of some minor factors affecting BMR which may be the result of these large differences may be essential to the understanding of the inter- and intra-individual variability in daily energy needs. This has led to an interest in studying the effect on BMR of one of the minor influences - the preceding day's energy intake.

Due to the dearth in published data on this particular topic, it is the sincere hope of the author that results will at least add to existing knowledge. Also the extent of short-term fluctuations in energy intake may possibly serve as extra background information as well, and may stimulate new researches.

2. REVIEW OF LITERATURE

2.1. Early Investigations

The modern era of the science of nutrition was opened by Lavoisier in 1780 (Lusk, 1928). He was the first to apply the balance and the thermometer to the investigation of the phenomena of life. He first published his experiments on the respiration of animals in 1777 with his theory that ordinary air was a mixture of oxygen and nitrogen gases (McCollum, 1957). He showed that during respiration the nitrogen fraction remain unchanged, but the oxygen was diminished, and that which disappeared was replaced by carbonic acid gas. This was also a verification of the discovery by Joseph Black, a professor of medicine in Glasgow who demonstrated that the carbonates of magnesium and calcium could be converted to their oxides with the loss of a gas that was termed "fixed air" and which was later recognised as carbon dioxide (Shils and Young, 1988). Black demonstrated by the use of a balance that his fixed air combined in definite proportion with the metallic element. He used the precipitation of calcium carbonate when fixed air was blown into lime water to demonstrate that air exhaled in respiration contained fixed air.

In 1783, Lavoisier published an account of his studies on the respiratory metabolism of a guinea pig. This was the earliest attempt to determine

quantitatively the magnitude of the combustion involved in respiration, and the amount of heat produced by the body in the process. Then in 1785, together with Sequin, they demonstrated that oxygen was absorbed and carbon dioxide expired in proportion to the mechanical work performed. By these experiments, Lavoisier revealed the basic facts regarding energy metabolism. It was also he, who first made respiration experiments on man and established the fundamental fact that the quantity of oxygen absorbed and of carbon dioxide excreted depends primarily on food intake, work and environmental temperature (Beaton, 1964). A calorimeter devised by him was used to measure the heat production of guinea pigs. Together with the physicist Laplace, they carried out experiments in which they place a guinea pig in a very small closed chamber surrounded by ice. They measured the amount of ice melted over a 10-hour period and at the same time the amount of carbon dioxide given out by the animal. They demonstrated that there was a relationship between the heat produced by the animal and the respiratory exchange. Lavoisier also measured the oxygen consumption of men and showed that it increased after food and exercise (Davidson, 1986).

Boussingault, a French chemist designed a series of experiments in 1839 using a milk cow to prove that nitrogen in the air was not used for nutritional purposes (Shils and Young, 1988). He compared the quantity and nature of the elementary material taken on as food with the quantity and nature of the elementary material eliminated in urinary and digestive products and milk. He then calculated by difference the amount of food eliminated in respiratory products. This was the first introduction of balance experiments in animals and demonstration of the existence of the nitrogen cycle. In 1844, he set out in a massive effort to establish the French view of the source of animal fat despite preliminary evidence that carbohydrate could indeed be transformed into fat in the animal body. By 1845, he had proved both in the goose and in the pig that animals could form fat from other classes of food (Holmes, 1974).

Two outstanding physiologists of the time, Johannes Muller of Germany and Francois Magendie of France, both doubted the adequacy of Lavoisier's theories. It was at this period that many biologists questioned the adequacy of a given chemical process to account for animal heat and even questioned any chemical explanation of similar biologic phenomena. Investigations such as those by Muller did not deny that chemical combustion was a source of a portion of animal heat, but they felt that there was a sufficient experimental evidence to state that chemical processes were the only conceivable source of heat (Shils and Young, 1988). Magendie was the first to differentiate between various form of food protein, carbohydrate and fat and to evaluate them experimentally.

It was a brilliant German contemporary, Justus Liebeg whose critical studies published in 1842 had shown that it was not carbon and hydrogen which burned in the body but protein, carbohydrate and fat (Lusk, 1928). His original theory was that while oxygen caused the combustion of fat and carbohydrate, the breaking down of protein was caused by muscle work. It was shown later that oxygen was not the cause of the decomposition of materials in the body, but that this decomposition proceeds from unknown causes and the products involved unite with oxygen. The sum of these chemical changes of materials under the influence of living cells was later known as "metabolism". Liebeg, later became known to be the father of modern methods of organic analysis (Lusk, 1928). Copying the principle of Boussingault's balance method in order to account for the fate of carbon compounds in the animal economy, he applied to the problems of biology the advantages of the new organic chemistry that he himself was creating. With him began the great accumulation of knowledge concerning the constitution of foods, urine, faeces and even of certain tissues which Lavoisier and his contemporaries had not possessed.

More recent investigations will be further presented in another section.

2.2. The Birth of Calorimeters

Lavoisier has properly been considered the founder of modern science of nutrition (Davidson, 1986). For over a hundred years after his death on the guillotine, ingenious and learned men exercised their talents in designing calorimeters in which laboratory animals and men could live for many hours or even a few days while their metabolism was studied.

Reynault and Reiset in 1849 carried out experiments on small animals and planned to build a human respiration chamber in Paris but unfortunately this did not materialise due to lack of necessary fund. By 1886, Max von Pettenkoffer, constructed the first respiration chamber at Munich in which man could work, eat or sleep without discomfort. He and Carl von Voit, a student, performed many experiments and contributed much to establish the fundamentals of energy metabolism. Voit continued to study the physiology and metabolism related to nutrition. Later on, much credit was given to the school of Carl von Voit due to its tremendous contributions in metabolism and nutrition in Germany in the second half of the 1800's. In 1857, Voit demonstrated that an animal could be brought into what is called "nitrogenous equilibrium" (Leicester, 1974).

Lusk, a student of Voit's stated that the discovery of the method of calculating protein metabolism led Voit to suggest to Pettenkoffer that he construct an apparatus with which the total carbon excretion might be measured including that of the respiration, as well as that of the urine and faeces. Voit saw that such data would make it possible to determine how much of each foodstuff was actually burned in the human body. He described the delight that he and Pettenkoffer experienced when their wonderful machine began to explain life processes.

Max Rubner was one of the best known of the investigators trained in the laboratories of Voit. He was one of Voit's most illustrious pupils (McCollum, 1957). He built a self-registering calorimeter that combined measurements of expired carbon dioxide with the nitrogen excreted in the urine and faeces. This became the background for the law of constant heat sums expressed by Hess, namely, that in a chemical reaction the heat produced or absorbed is the same irrespective of the pathway providing the end product. He also measured the varying influence of foods on energy production and found that a difference exists between carbohydrates, fats and proteins that he termed "specific dynamic action". He also introduced the "law of surface area" which states that the energy metabolism of any animal is proportional to the size and the surface area of the animal (Rubner, 1883). This was however seriously challenged year later. He also presented what was termed as the "isodynamic law" wherein he established the fact that the three groups of food are interchangeable in the body in relation to their calorie equivalents. Rubner became known as the leader in the investigation of the metabolism of foodstuffs. In 1928, he contributed a review on metabolism and energy exchange. One of his last experiments was using an animal calorimeter that could accurately measure the amount of heat produced by a dog over 24 hours. The results of these experiments were a dramatic demonstration that the animal body follows the law of conservation of energy (Leicester, 1974).

Zuntz in Switzerland and Johannes in Sweden were others who from 1880 onwards extended the work of the Munich school but it was the American, W.O. Atwater together with E.B. Rosa, a physicist who constructed a human calorimeter which was capable of showing the heat produced by a man with an accuracy of 0.1 per cent (Davidson, 1986). He was the one who established the essential quantitative physiological knowledge on which all assessments of the

energy needs of man are based. Atwater's work was extended by yet others like F.G. Benedict and G. Lusk. The construction of these elaborate and costly devices allowed the establishment and confirmation of the general principles of energy metabolism in animals and in man. In fact they were also used for the determination of energy metabolism in disease conditions and later on, interest in calorimetry became relegated to hospital measurements of the basal metabolic rate (BMR) as an indicator of thyroid function. This was the beginning of the use of basal metabolism studies in clinical work for diagnostic purposes.

As far as fundamental concepts were concerned, respiration and calorimetry studies have made their major contribution to nutrition investigations with the publication of these pioneering investigations of energy metabolism.

2.3. Recent Investigations

In recent decades, the emergence of studies on basal metabolism have been of considerable interest and fascination. Some of them have had an immediate utility and application, while others have been of value in that they have raised new concepts and provided the basis of observations for problems which can be explored using more sophisticated approaches.

The current approaches being made with man represent a continuation of the studies made centuries ago when Lavoisier and Laplace first placed a guinea pig in a calorimeter. Since then there have been quite a number of studies in this field relating them to some factor believed to cause the effect of the large inter- and intra- individual variations to energy expenditure as well as the metabolic effect of diet to energy metabolism. A review of some of the studies is presented.

Durnin (1984), in his report on "Methodological problems of energy expenditure measurements in field conditions, in the assessment of energy balance", stated that although it is possible to assess energy balance solely on the basis of the maintenance of a constant body weight and that such finding will confirm that energy balance will exist, yet it will not tell at what level it is occurring nor whether adjustments in intake or expenditure may have taken place. Hence, measurements of both energy intake and energy expenditure are required to obtain a more informative picture of the situation. However, considerable discrepancies have been found using this method, perhaps due to variability within and between subjects. Recent research has attempted to investigate this and to study its importance when defining energy requirements of individuals.

In his paper, "The variability of dietary energy" (1983), he reported that their findings on a study done on men and women of comparable age, body mass and body composition, basal metabolic rate showed a remarkable difference thus stating that there seems little doubt that the variability in metabolic rate could be considerable and thus necessitates a much more careful look at an individual. He also stated the probable reasons why such differences exist and that it may relate to basic differences in energy conversion within the body, and other mechanisms about which at present little is known in any precise fashion.

Lately though, interest in these "mechanisms" has gained momentum. One important area of research on this pertains to the term "thermogenesis". Garrow (1984) in his paper on "Thermogenesis to small stimuli", defined "thermogenesis " as an increase in metabolic rate above the resting level. The most studied thermogenic stimuli in man are physical activity and exposure to severe cold which cause increases in metabolic rate. Yet, there are other

thermogenic "small" stimuli which have been believed to have an effect, and their magnitude may have relevance to the cause of variability in total energy expenditure. One such "small stimulus" is said to be "food" (Westrate, 1989). It is now generally assumed that in the average sedentary individual, food or energy intake contributes about 10% to total energy expenditure (Danforth, 1985; Sims et al, 1987). This "small stimulus" from food is now termed the "thermic effect of food" (TEF) or better known as "dietary-induced thermogenesis" (DIT).

DIT has been divided into obligatory and adaptive components (Rothwell, 1983; Shils and Young, 1988). Obligatory DIT, formerly known as "specific dynamic action" (SDA), is the energy cost of digestion, absorption and the inner conversion of food substrate and is thought to be due largely to the synthesis of protein and fat from carbohydrate. Adaptive DIT (originally named Luxuskonsumption) represents the dissipation of energy over and above that associated with basal metabolism activity and the obligatory DIT. It is stimulated by the ingestion of a meal, a part of which is oxidised to produce adaptive DIT.

The existence of adaptive DIT is however a controversial subject today (Shils and Young, 1988). The concept that the body is able to control its weight and energy content by disposing of the excess consumed energy (hence the term Luxuskonsumption) comes partly from studies in which individuals have maintained a constant body weight despite different levels of energy intake. The evidence for adaptive DIT from these studies relies upon the demonstration of an apparent discrepancy between estimates of energy intake as food, energy expenditure and the energy storage or change in body fat (Shils and Young, 1988). None of these however, has convinced the sceptic, aware of the difficulties in measuring the energy balance in man over long periods (Passmore et al, 1986). Hence adaptive thermogenesis appears to be an elusive phenomenon perhaps worthy of further investigation (Norgan, 1980).

Although there is much controversy on the subject of dietary-induced thermogenesis and its influence on basal metabolic rate, yet there have been a number of recent studies relating it to energy content of a meal including the effect of overfeeding and underfeeding. Hill et al (1984), in his study, demonstrated that by progressively increasing the energy content of a meal (500-1500 kcal), DIT was found to increase systematically, but not in a linear fashion. Their results also showed that, as the energy content of the meal increased, the magnitude and duration of DIT also increased, but unfortunately, the duration of measurement was not extended for a long enough time to allow the metabolic rate after each meal to return to the basal level.

Early this century also, many investigators believed that nutrient composition of the diet influences energy metabolism. Rubner (1902) and Lusk (1928) have shown that a high protein intake elevated metabolic rate after feeding. Blaxter (1989), in his study showed that the energy expended over 24 hours can also be affected by the nutrient intake. Dauncey and Ingram (1979) noted in their study that not only is the resting metabolism rate (RMR) immediately after a meal influenced by nutrient composition but also the BMR measured between 12 and 20 hours after the last meal (Dauncey et al, 1983). All these studies however, were done on animals. In man, Garrow and Hawes (1972) showed that the increase in RMR after a test meal was independent of nutrient composition. Rosenberg and Durnin (1978) also demonstrated that the composition of the diet is unimportant with respect to energy metabolism. Thomas et al's (1992) study on "Ad-libitum feeding of high fat and higher carbohydrate diets in humans" also failed to show the RMR was influenced by the composition of the diet. However, Dauncey et al's (1983) findings in their study indicated that not only should energy intake be considered as a factor which can

have a potentially significant influence on energy balance in an adult man, but also that the nutrient composition providing the energy be considered.

Because of these differing findings, there still are doubts on whether nutrient composition really can alter metabolic rate. Other than this, the use of meals with mixtures of nutrients, infrequent measurement of oxygen consumption and carbon dioxide expiration, the lack of data regarding changes in resting metabolic rate when nutrient challenge is presented, and the inherent variability of resting metabolic rate data, have all contributed to the uncertainty about the effects of different nutrients on the resting metabolic rate (Welle, 1981). The failure of other investigators to find differences in the thermic response to nutrient composition/energy content of the meal may also be attributable to the fact that thermic response are clearly differentiated only after 2 - 3 hours post-ingestion. It would then appear that the full thermic effect of food on the RMR for longer than four hours may be required for complete quantification of the thermic effect of food (Welle, 1981).

Apart from the acute effects of energy content of the meal on metabolic rate, energy content of a meal may have a long term effect on basal metabolic rate. Overfeeding studies (Dalloso et al, 1982; Schutz et al, 1985) have shown that excess energy intake (overfeeding) affects or causes in increase in BMR especially if overfeeding occurs on the day just prior to BMR measurement (Kinabo, 1990). However this could be related to the prolonged effect of food on metabolic rate since it has been shown that the effect of a large meal on the day prior to BMR measurement could be detected on the following day (Schutz et al, 1985) .

Likewise, RMR was known to show both an adaptive increase to overfeeding (Goldman et al, 1976) and an adaptive fall on starvation (Keys et al,

1952). Dauncey (1980) has reported that RMR was affected by the previous dietary intake so that RMR increased by 10% when energy intake increased by 5400 kJ. However, although RMR may show adaptive changes to dietary intake, there still is no evidence to suggest that the size of the thermic response to a meal is related to previous daily energy intake (Morgan, 1983). Dauncey's (1980) study on the "Metabolic effect of altering 24-hour energy intake in man" showed no marked difference on the effect on 24 hour energy expenditure of overfeeding for only 1 day. He compared this result with those estimated by some other workers after several weeks of increasing energy intake. He also found that the BMR measured at least 14 hours after the last meal can be affected by the previous day's energy intake.

Miller et al (1967) in their report stated that "if there is an increased heat production in subjects who are overeating, it could be explained either by an increase in BMR or by an increased thermic response. In their study however, results showed no consistent elevation of BMR, the changes observed were small and values were within the normal range. Similarly, other groups (Wiley et al, 1931; Gulick, 1922; Strang et al, 1935) have been unable to detect any rise in BMR after overeating. Rose and Williams (1961) found identical results of mean basal oxygen consumption for groups of small eaters and large eaters.

In Norgan and Durnin's (1980) study on the "Effect of 6 weeks of overfeeding on the body weight, body composition and energy metabolism of young men", increases in metabolic rate were associated with increased body size and tissue gain rather than the efficiency of energy utilisation (i.e., Luxuskonsumption).

Many measurements of metabolic rate in overfeeding have been done but these provided no evidence of elevations greater than those expected from the

thermic effect of the quantity of food (Passmore et al, 1955; Passmore et, 1963; Strong et al, 1967). However, these studies were of short duration and it has been proposed that thermogenic processes may take some time to appear (Miller, 1967; Guick, 1977).

The question then arises whether over nutrition really elevates "minimal" metabolism. Garrow's (1978) analysis of many experiments on the effects of overfeeding on the resting metabolism of man failed to reach an unequivocal conclusion but suggested that any increase in minimal metabolism was only apparent following considerable increases in intake. Since resting metabolism was determined after the same length fast in overfed subjects as in control, it is possible that any increase observed reflected failure to reach the true post-absorptive state.

With all these doubts and questions regarding nutrient composition/energy content of the meal or prolonging fasting periods, a critical aspect to be considered then in all studies designed to measure basal metabolism is the length of time man should be fasted to ensure that the continuing effects of metabolism of previous meals are negligible and that the person is in a post- absorptive state.

In man, the controversial post-absorptive period is 10-12 hours after the evening meal. Still this may not be a sufficient interval. Dauncey (1980) has shown that even when the diet supplied 3.7 MJ/d (15480.08 kcal) - about half the normal energy expenditure - an elevation of metabolism of 6% was present 15 hours after the last meal. Her observations did not extend longer.

At present there are quite a number of scientific articles on dietary-induced thermogenesis in man in which most conclude that during 5 hours or so after a meal, metabolic rate increased over the fasting state by about 6-10% of the

energy content of the meal. There are however few reports on the effect of prolonged overfeeding or underfeeding on resting metabolism since this is a more difficult protocol to follow.

3. METHODS OF MEASUREMENTS

The production of heat or energy by the human body is measured by the use of both direct and indirect calorimetry. The measurement of energy expenditure is referred to as calorimetry, in which energy is measured as heat, heat being one of the most conveniently handled forms of energy. Calorimetry is based on the law of conservation of energy. This law states that "energy can neither be created nor destroyed, and therefore the energy content of any system can be increased or decreased only by the amount of energy that is added or subtracted from the system" (Consolazio, 1963).

Calorimetry, as applied to studies in man. is divided into two types:

3.1. Direct Calorimetry

This is the measurement of energy expenditure in the form of heat. All types of energy are converted to heat and then measured. Since energy is utilised in the human body by means of chemical reactions, it is possible to evaluate energy utilisation from the measurements of the substance consumed and the product formed.

Direct calorimetry is based on the principle that the sum of heat losses - by radiant heat exchange, and convective, conductive and evaporative heat transfer -

equals, in the long run, the heat released by the metabolism in the body (Westrate, 1989).

There are at present three types of calorimeters used for this kind of measurement: the isothermal calorimeter (Atwater and Benedict, 1903), the gradient layer calorimeter (Benzinger and Kitzinger, 1949) and the water-cooled garment (Webb et al, 1972).

Direct calorimetry is considered to be the most accurate measurement of the rate of energy expenditure over prolonged periods of time, say, 24 hours or more. However it is expensive in both time and apparatus and is not well suited for short time observation (Consolazio, 1963).

3.2. Indirect Calorimetry

In this type of calorimetry, energy expenditure is determined from the amounts of oxygen consumed and carbon dioxide produced and is essentially a chemical method in contrast to the purely physical measurements employed in direct calorimetry. This method is also referred to as respiratory calorimetry (Consolazio, 1963).

There are two types of indirect calorimetry:

3.2.1. Open circuit method

In this method, the subject is permitted to breathe air from the outside while his expired air is collected in either a gasometer or metabolimeter for volumetric measurement. This gas volume is corrected for standard conditions

and is analysed for its oxygen and carbon dioxide content, with the subsequent calculation of oxygen consumption and carbon dioxide production.

There are a few open circuit type of calorimeter (McLean and Tobin, 1987) and in this study the Douglas Bag system was used and will be explained further in the succeeding chapter.

3.2.2. Closed circuit method

In this method, the subject is completely cut-off from the outside air and breathes through a closed system. The respirometer originally contains pure oxygen. As the gas is expired by the subject, the carbon dioxide is constantly removed as it passes through soda lime. The decrease in the gas volume in this closed system, is related to the rate of oxygen consumption from which the metabolic rate is then calculated.

4. SUBJECTS AND METHODS

4.1. Subjects

The total number of subjects was 30. Subjects were selected by sequential sampling based on the following criteria:

4.1.1. They were normal women resident within the Glasgow area.

4.1.2. Age was within 20 - 45 years old. They were in good health with no previous history of diabetes mellitus, thyroid disorders or other metabolic disorders.

4.1.3. They were not receiving any medication/drugs and not on a reducing diet regimen.

4.1.4. Subjects must not have had a history of major weight control problems or eating disorders.

4.1.5. They were willing to participate and cooperate all throughout the study.

4.2 Data Collection

Prior to the actual data collection, subjects were interviewed. The objective and other details of the study were explained, emphasising the importance of the study and the subjects' role in the success of the research undertaking.

Data collection was carried out in 4 phases:

4.2.1. Initial Phase

Basal metabolic rate was measured but prior to this, the preceding day's intake was not controlled. The subjects followed their normal eating habit the day before the measurement. Each woman was instructed not to do any strenuous exercise or activity as these might affect the result. Alcoholic drinks were also avoided.

In this phase, interview of the actual dietary intake pattern of the subject was also done. This was to identify the usual eating pattern and kinds of food eaten by the subject from which a menu was planned for the next three phases of the study which were to be carried out.

4.2.2. Standard diet Phase

The first diet plan (considered as an "average" intake) made in this phase covered a computed "maintenance" energy availability for the particular subject. The computation was based on the result of the measured basal metabolic rate computed for 24 hours and multiplied by a factor of 1.4 (based on the FAO/WHO/UNU, 1985, recommendation for a sedentary population). The diet composition planned for each subject provided approximately, 10-15%, 30-35%, and 50-60% energy from protein, fat and carbohydrate respectively. The diet was to be consumed by the subject the day prior to the basal metabolic rate measurement and which has been distributed throughout the day as breakfast, morning snack, lunch, afternoon snack and supper.

4.2.3. Overeating or the "40% more" phase

A similar procedure as in the standard diet phase was followed except that in this stage the amount of the diet/energy intake to be consumed was to be 40% more than the average computed from that in the standard diet phase. Accordingly, the energy distribution of percentage fat, protein and carbohydrate remained the same.

4.2.4. Undereating or the "40% less" phase

Again as in the two other phases, a day prior to the BMR measurement, the energy intake consumed by the subject was based on a diet plan with a deficit of 40% computed from the average intake in the standard diet phase. As usual, the percentage distribution of energy from protein, fat and carbohydrate remained the same.

4.3. Basal metabolic rate measurement

In recent past, the implication that BMR was to be measured before getting out of bed after being admitted to a hospital or a metabolic unit or chamber the night before the test, has become a source of confusion. This however, was not how almost all the fundamental work on BMR was carried out (Benedict, 1915; Du Bois, 1927; Boothby et al, 1936). Rather, in most of these investigations, Du Bois' classical definition of the conditions under which BMR was measured, was followed. The definition states that, "the subject must be instructed to take no food in the evening after 8:00 o'clock; and nothing in the morning except a cup of caffeine-free coffee without milk or sugar. She must be brought to the laboratory without fatigue, must lie quietly for at least one-half hour before the test. The atmosphere of the room should be quiet and confident" (c.f. Kinabo, 1990).

Other investigators (Benedict, 1938; Schutz, 1985), have also defined BMR as the rate of energy production (or energy expenditure) measured by indirect calorimetry in post-absorptive state under highly standardised conditions:

- at complete physical rest (immobile), lying down in a supine position;
- in thermoneutral state;
- 12 - 14 hours after the last meal (viz. post-absorptive);
- awake, at sexual repose and emotionally undisturbed;
- without disease or fever.

All the above conditions were followed in the measurements on the 30 subjects except in two cases where the subjects had their measurements taken earlier in the morning and these were done 10 hours after the last meal.

4.3.1. Procedure (Douglas Bag Technique)

As the subject was supposed to be in a post-absorptive state during the measurement, she was instructed not to eat or drink anything after 9:00 P.M. the day prior to the BMR measurement and to continue fasting (meaning no breakfast or anything to drink or eat) until the following morning.

Upon arrival at the laboratory early in the morning between 7:30 - 9:30 A.M., the subject was requested to lie quietly at rest for 30 minutes before the start of the measurement. The procedure and how the apparatus works were explained carefully. Most of the subjects who were post- doctoral research students and staff of the Physiology department, were already quite familiar with the apparatus as most of them have had experience in this measurement in the past. Hence, it was easier for most of them to adapt to the test immediately. However, to only a few who had no experience with the apparatus, it was explained to them to be as relaxed as possible and absolutely to refrain from movement during the duration of the test.

4.3.2. The apparatus

It consists of a large gas-impermeable plastic bag - better known as the Douglas Bag - of either 100 or 200 liters capacity (Cranlea & Co., Birmingham, U.K.). This bag is connected via a 3- way aluminium tap to a length of flexible corrugated plastic tubing which in turn attaches to a 2-way Rudolph valve (Kansas City, Mo., U.S.A.). A rubber mouthpiece is fitted onto the Rudolph valve.

4.3.3. Collection of expired air

After the thirty-minute rest period, the subject was fitted with a mouthpiece and her nose clamped so that expired air is passed through the mouthpiece which has been connected to a respiratory valve, corrugated plastic tubing, aluminium 3-way tap and an airtight bag. The 3-way tap allowed either of 2 circuits for the subject's expired air to be passed to either the outside air or to the Douglas Bag. In the first 5 minutes of the test, to allow the subject to become acquainted and used to the apparatus before the actual collection began, a "run-in" period was done. Thus the tap was directed to the outside air position at this time. After the appropriate "run-in" period, the tap was changed and directed to the other circuit so that expired air collected this time passed into the Douglas bag for a specified time (10 minutes). The tap was then closed off and the bag disconnected from the system for gaseous analysis. Two 10-minute determinations were done except in some cases where a third collection was made when results of either of the first 2 measurements or both were questionable.

4.3.4. Analysis of expired air

The subject's expired air was analysed using a paramagnetic oxygen analyser (Servomex Model 570 Sybron, Servomex Lt., Cambridge, Sussex, England) and an infrared carbon dioxide analyser (PK Morgan Ltd., Chatham, Kent, England). A sample of expired air from the Douglas Bag was introduced into the analysers and oxygen and carbon dioxide readings were recorded after an interval of about 1 minute. (This was to allow readings on the analysers to stabilise and was equivalent to about 0.5 liters of gas passing from the bag. This 0.5 liters was taken into account in the computation of the volume of expired

air). The volume of the expired air was measured using a gas meter (Parkinson-Cowan Ltd., London, England) and temperature of the air passing through the meter was likewise recorded by an attached thermister. The correction of the volume of expired air to standard temperature, pressure and saturation (STP) using an appropriate "atmospheric correction factor" (ACF), was read using a nomogram on the basis of barometric pressure and temperature (Consolazio et al, 1963).

4.3.5. Calibration of gas analysers

Before the tests were started, the oxygen and carbon dioxide analysers were calibrated using oxygen-free nitrogen and standard gas mixtures with known concentrations: 6.17% CO_2 ; 15.52% O_2 . The O_2-free nitrogen was used for the zero calibration of both analysers while the standard gas mixtures were for the span calibration. Likewise, the span of the oxygen analyser was checked to be 20.93% using atmospheric air.

To check whether both zero and span calibrations were correct, other gas mixture of known concentration were introduced: 16.68% O_2 and 4.09% CO_2.

4.4 Calculation of the metabolic rate (Weir, 1949)

4.4.1. Principle:

Weir (1949) emphasised that the usual methods for calculating the metabolic rate were cumbersome, that the effect of protein metabolism were commonly ignored, and that the total respiratory quotient (RQ) was used to

assign a caloric value for oxygen consumption which is appropriate strictly only for the non-protein respiratory quotient.

Weir showed by computation that the energy expenditure can be approximated closely from only 2 measurements; the volume of expired air and its oxygen content. Formulae have been constructed to calculate the caloric value of oxygen based on the assumption of a fixed percentage of the total energy of the diet being for protein intake. (c.f. Consolazio, 1963)

4.4.2. Calculation

After the gas volume had been measured and analysing an aliquot for oxygen and carbon dioxide, the energy cost in kcal/min was calculated.

Based on the recorded barometric pressure and temperature of expired air, the atmospheric correction factor (ACF) was read from a line chart or nomogram (Appendix 1) prepared by R.C. Darling (c.f. Consolazio et al, 1963) for determining the factor to reduce saturated gas volume to dry volumes at 0°C and 760mm Hg.

The pulmonary ventilation was then computed as follows:

$$PV = V_2 - V_1/Time \times STP\ factor$$

where:

PV (Pulmonary ventilation) = liters of gas expired/minute, reduced to 0°C and 760mm Hg., dry.

P_1 = first reading of the volume from the gas meter, liters

P_2 = second reading of the volume from the gas meter, liters

STP factor = value for reducing gas at any temperature and pressure, wet. to 0°C and 760mm Hg., dry.

Time is expressed in minutes and decimal fractions.

4.4.3 Respiratory Exchange Ratio or Respiratory Quotient (RQ). (Consolazio, 1963)

The RQ is defined as the volume ratio of carbon dioxide production and the oxygen consumption ie;

$$CO_2 \text{ production}/O_2 \text{ consumption}$$

and was utilised in the following:

"True oxygen" and Respiratory Quotient (RQ). The "true oxygen" represents the number of millilitres of oxygen consumed for every 100ml of air expired. It is based on the following consideration: One desires to know the quantity of oxygen that is removed from the inspired air, but the only measurements made are the volume of air expired and its oxygen, carbon dioxide and nitrogen content. The volume of inspired air usually does not have the same value as that of expired air.

This is because RQ has to be exactly 1.00 for inspired to equal expired air. If the RQ is less than 1.00, as is usually the case in rest or moderate exercise, then the oxygen removed from the inspired air is only partially replaced by carbon dioxide; and if 1 litre has been inspired, less than 1 litre will be expired. The nitrogen concentration in this case will be higher in expired than in inspired air. The concentration of nitrogen and other inert gas in outdoor air is 79.04 % , and the concentration in the expired air is determined by analysis. Based on this principle, "true oxygen" and the respiratory quotient can then be calculated. However, to facilitate the computation of true oxygen and the RQ, a line chart or nomogram (Appendix 2) was constructed by Dill and Fohling., 1928. (c.f. Consolazio, 1963)

4.4.4. Oxygen consumption

O_2 consumption = "true oxygen" x ventilation rate

4.4.5. Metabolic rate

Metabolic rate = O2 consumption x calorific equivalent O2

(kcal/min) (l/min) (kcal/l)

4.5 Anthropometric measurements

4.5.1. Height

This is measured using a wall stadiometer (Holtain Ltd. Grymych, Dyfed, U.K.) and readings were taken to the nearest mm.

4.5.2. Weight

Subjects' weight were recorded to the nearest 0.1 kg using an Avery beam balance (model no. 3302).

4.5.3. Skinfold thickness measurements

Next to combinations of height and weight , skinfolds are probably the most widely used method to measure body composition in epidemiological

studies (Willet, 1990). This method has conceptual appeal because it provides a direct measure of body fat. Over half of the fat in the body is deposited under the skin (Brozek and Keys, 1955) and the distribution and amount of subcutaneous fat change with age and sex. The thickness of this subcutaneous fat can be measured at various sites with the use of standardised skin clippers. In this study a Harpenden cal iper - Holtain Ltd. Grymych, Dyfed, U.K., calibrated to exert constant pressure of 10 g/mm^2 was used.

At present, Durnin and Womersley's (1974) equations for the prediction of body fat from 4 sites of skinfold thickness has been widely used (Appendix 3).

4.5.3.1 Skinfold measurement sites

4.5.3.1.1. Biceps skinfold thickness

It is the skin fold on the anterior aspect of the upper arm, directly above the centre of the cubital fossa, at the same level as the triceps skin fold and mid-arm circumference.

4.5.3.1.2. Triceps skinfold thickness

It is between the skin and subcutaneous tissue, 1 cm, above the mid-point between the tip of the acromial process of the scapula and the olecranon process of the ulna. The measurement is made in the mid-line posteriorly while the arm hangs relaxed and vertical.

4.5.3.1.3. Subscapular skinfold

The skin is lifted 1 cm under the inferior angle of the scapula with the shoulder and arm relaxed. The fold should run parallel to the natural cleavage lines of the skin; this is usually a line about 45 degrees from the horizontal extending medially upwards.

4.5.3.1.4. Supra-iliac skinfold

It is the skin fold 2 cm above the iliac crest in the mid-axillary line. The crest of this fold should run horizontally.

4.5.3.2. Method of measuring skinfolds:

4.5.3.2.1. Locate the anatomic site.

4.5.3.2.2. Lift the skin and fat layer from the underlying tissue by grasping the tissue with the thumb and forefinger.

4.5.3.2.3. Apply cal iper about 1 cm distal from the thumb and forefinger, mid-way between the apex and base of the skinfold.

4.5.3.2.4. Continue to support the skin fold with the thumb and forefinger for the duration of the measurement.

4.5.3.2.5. After 2 to 3 seconds of caliper application, read skinfold to the nearest 0.5 mm.

4.5.3.2.6. Measurements are then made in triplicate until readings agree within +/- 1.0 mm; results are averaged.

4.5.3.2.7. Using Durnin and Womersley's (1974) table (Appendix 3), the percentage body fat is recorded.

5. RESULTS

Table 1 shows the physical characteristics of the 30 female subjects. The mean age, weight, height and percentage body fat were 28 +/- 6 years, 57 +/- 8kg, 163 +/- 7cm and 26 +/- 4% respectively.

Table 2 shows the basal metabolic rate (BMR) in kcal/min of the 30 female subjects after consuming different levels of energy intake a day prior to the test. In the initial phase where the energy intake was not controlled on the day prior to the BMR measurement, the mean and standard deviation (SD) were 0.897 +/- 0.109 kcal/min with BMR values ranging from 0.676 to 1.150 kcal/min. In the standard diet phase where energy intake consumed was calculated as the requirement of each particular subject based on BMR x 1.4, the mean and standard deviation were 0.880 +/- 0.134 kcal/min with BMR values ranging from 0.668 to 1.150 kcal/min. In the overeating or "40% more" phase where energy intake consumed the day prior to the test was increased by 40% of the diet in standard phase, the mean and standard deviation were 0.877 +/- 0.113 with BMR values ranging from 0.709 to 1.147 kcal/min. In the undereating or "40% less" phase, the mean and standard deviation were 0.870 +/- 0.118 with BMR values ranging from 0.596 to 1.110 kcal/min.

Examination of Table 2 shows that there was a slight change (-0.016 kcal/min) from the initial phase to the standard diet phase. Likewise, from the standard diet phase to the overeating or "40% more" phase (-0.003 kcal/min); and the undereating or the "40% less " phase (-0.010 kcal/min). Figures 1a, 1b, and 1c show plots of the changes between the initial phase and the standard diet phase as well as between the standard diet phase and the "40% more" or overeating and the "40% less" or undereating phase and which suggest the "slight falls".

Table 1. Physical Characteristics of Subjects

Subject No.	Age (yr)	Weight (kg)	Height (cm)	Body Fat* (%)
1.	37	41	145	26
2.	25	44	156	22
3.	31	44	145	28
4.	31	45	156	27
5.	26	49	163	22
6.	25	51	160	26
7.	27	51	158	25
8.	24	52	163	26
9.	31	52	175	23
10.	25	53	166	17
11.	34	53	157	32
12.	24	53	168	28
13.	21	54	165	22
14.	24	55	165	26
15.	21	57	157	25
16.	21	57	168	26
17.	28	57	165	22
18.	29	57	159	27
19.	25	58	171	22
20.	42	60	159	33
21.	30	62	162	29
22.	26	63	161	28
23.	26	63	174	25
24.	25	63	164	24
25.	21	65	169	22
26.	43	65	159	38
27.	20	69	171	25
28.	25	70	168	26
29.	32	73	163	32
30.	39	74	171	33
Mean	28	57	163	26
SD	6	8	7	4
Range:				
Min	20	41	145	17
Max	43	74	175	38

*Based on sum of four skinfold thicknesses (Durnin and Womersley, 1974) and expressed as percentage of body weight.

Table 2. Mean basal metabolic rate (in kcal/min) day after consumption of different diets.

Subject No.	Initial phase	Standard diet phase	Overeating or "40% more" phase	Undereating or "40% less" phase
1.	0.717	0.717	0.709	0.718
2.	0.676	0.668	0.748	0.649
3.	0.721	0.695	0.747	0.596
4.	0.878	0.746	0.749	0.750
5.	0.789	0.688	0.752	0.760
6.	0.828	0.729	0.826	0.810
7.	0.903	0.900	0.939	0.926
8.	0.753	0.703	0.761	0.742
9.	1.028	0.952	0.920	0.971
10.	0.909	0.900	0.915	0.869
11.	0.821	0.774	0.803	0.883
12.	0.849	0.845	0.836	0.852
13.	0.912	0.934	0.947	0.810
14.	0.808	0.848	0.893	0.827
15.	0.901	0.951	0.866	0.918
16.	0.945	0.913	0.917	0.894
17.	0.978	0.913	0.863	0.978
18.	0.979	0.948	0.842	0.886
19.	0.948	0.983	0.947	0.954
20.	0.902	0.785	0.749	0.732
21.	1.030	0.955	0.820	0.857
22.	1.055	1.139	1.068	1.012
23.	0.828	0.762	0.767	0.820
24.	0.970	1.009	0.997	0.900
25.	1.093	1.055	1.147	1.110
26.	0.778	0.787	0.828	0.868
27.	1.069	1.150	1.102	0.993
28.	0.939	0.955	0.914	1.003
29.	0.970	1.004	1.006	1.024
30.	0.917	0.997	0.943	0.987
Mean	0.897	0.880	0.877	0.870
SD	0.109	0.134	0.113	0.118
Range:				
Min	0.676	0.668	0.709	0.596
Max	1.093	1.150	1.147	1.110

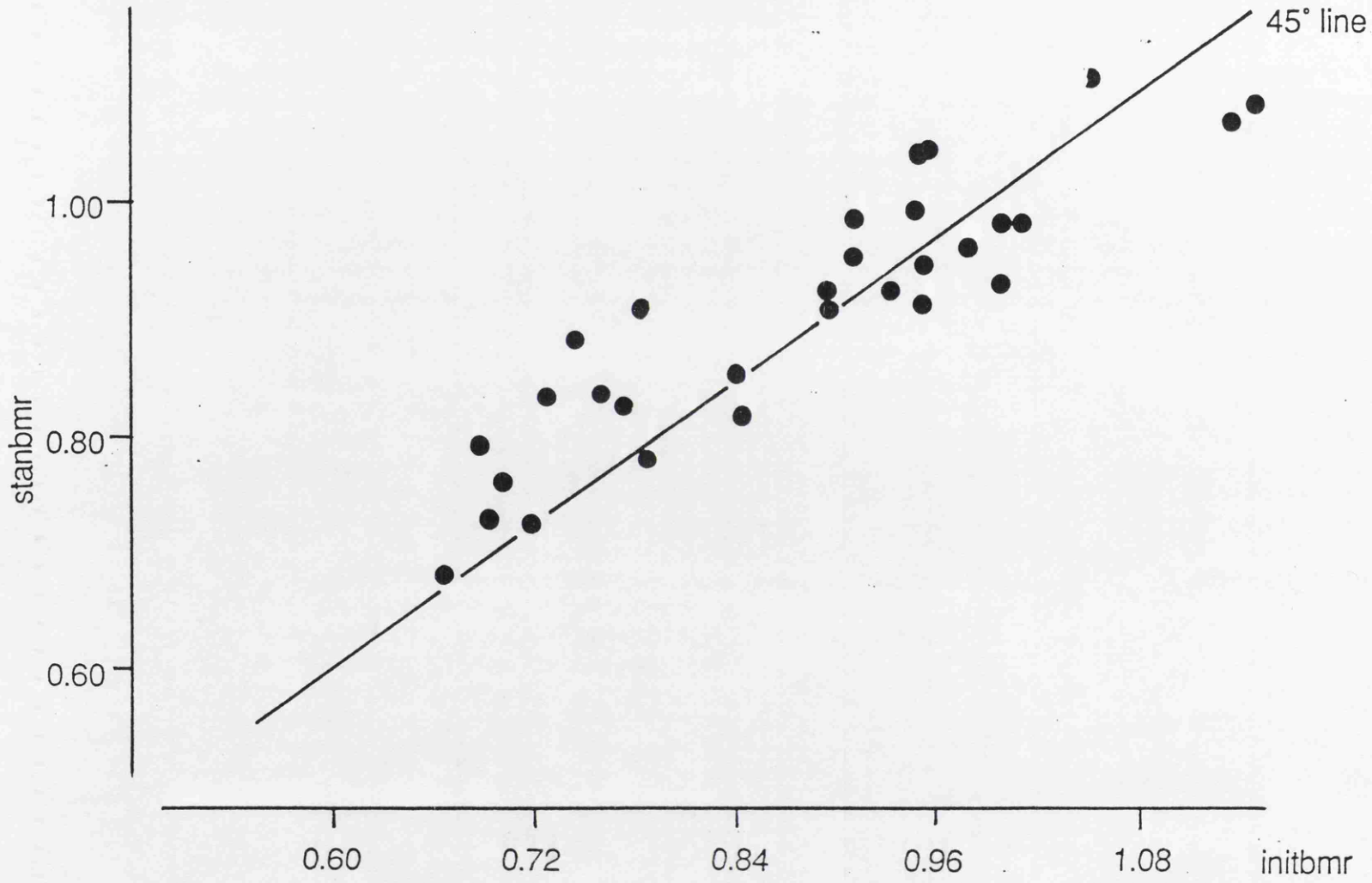

Figure 1a. Plot of initial BMR (initbmr) against BMR on standard diet (stanbmr).

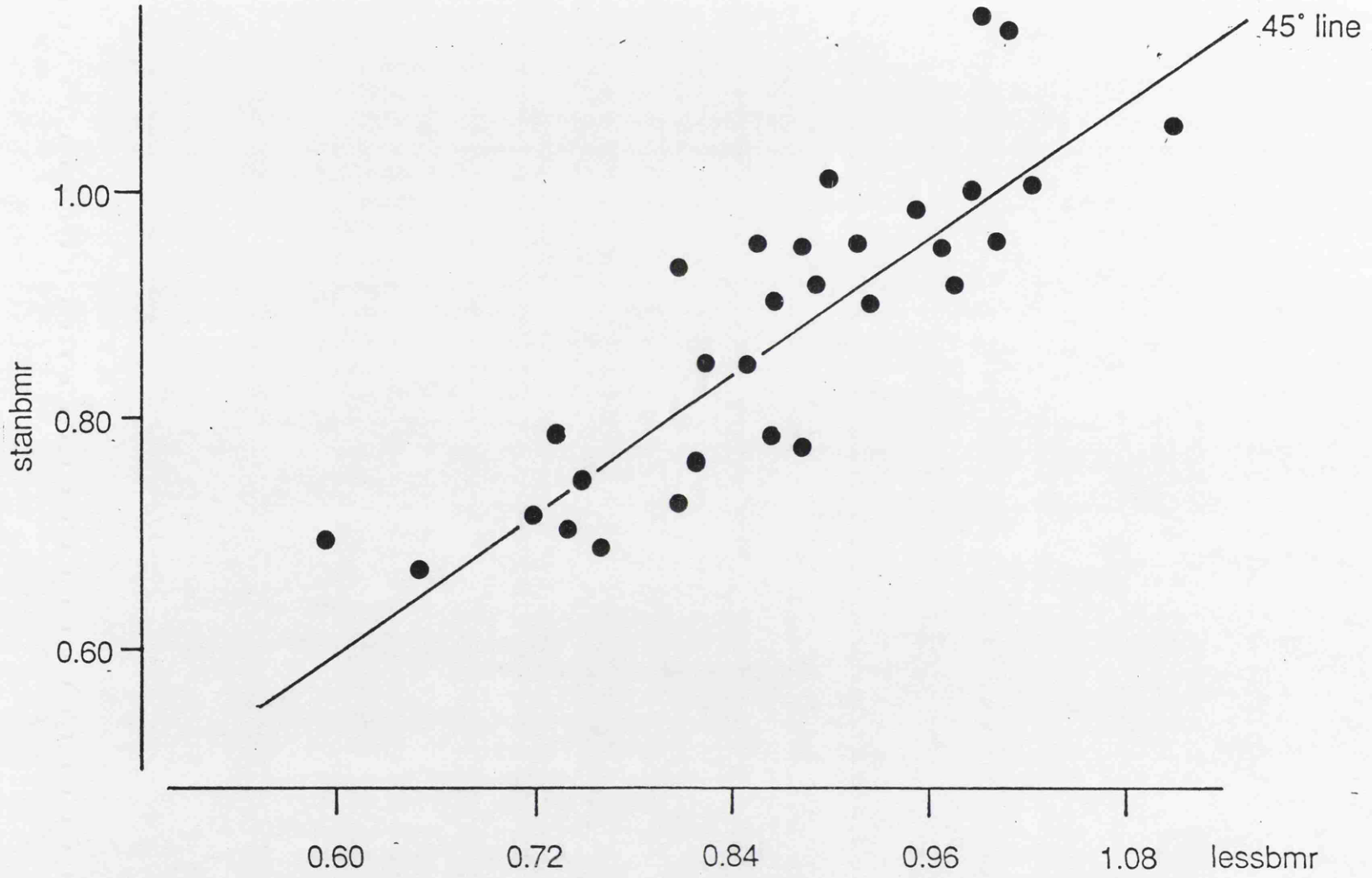

Figure 1b. Plot of BMR on standard diet (stanbmr) on "40% less" diet (lessbmr).

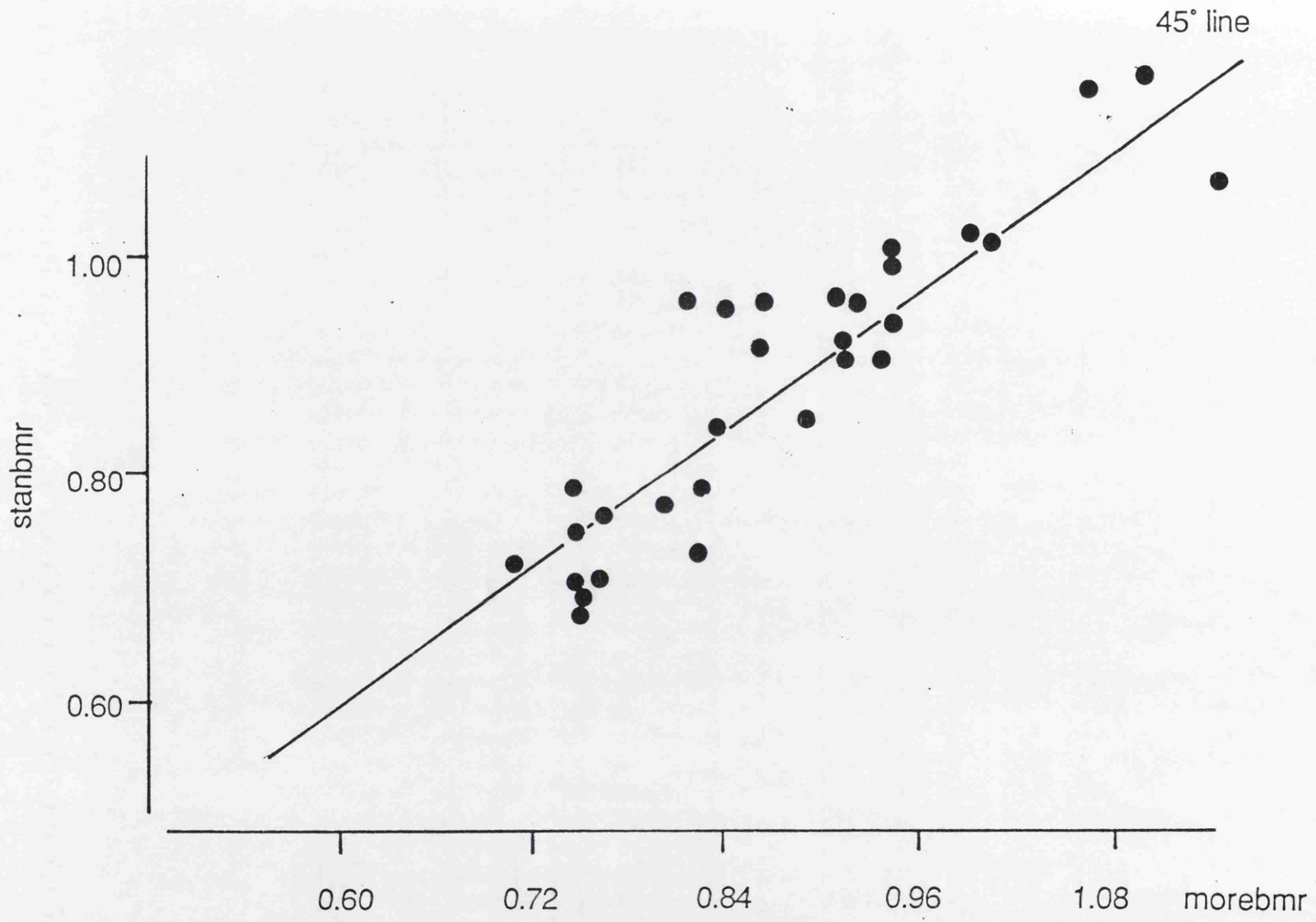

Figure 1c. Plot of BMR on standard diet (stanbmr) on BMR on "40% more" diet (morebmr).

In all these cases though, the fall or changes were small and were not statistically significant when a paired t-test was done (Tables 3a and 3b).

Table 3a. T-test [Differences between BMR in the Initial phase minus BMR in the Standard diet phase (C13)].

	C13
Mean difference	-0.0163
t	-1.51
p value	0.14

Table 3b. T-test [Differences between BMR in the Standard diet phase minus BMR in the Overeating or "40% more" phase (C11) and; Standard diet phase minus the Undereating or "40% less" phase (C12)].

	C11	C12
Mean difference	-0.0028	-0.0102
t	-0.27	-0.80
p value	0.79	0.43

It was also noted that when weight was taken as a normalising factor (that is, BMR values were expressed in terms of kcal/kg/min to allow for differences in body size between subjects), still the differences between phases were not statistically significant.

6. DISCUSSION

The study was carried out to determine the influence on basal metabolic rate of increasing or decreasing the usual energy intake on the previous day of 30 women subjects, while maintaining constant the percentage of energy supplied by protein, fat and carbohydrate in the diet. Findings in this study have indicated that the previous day's diet had no effect on BMR. These confirm previous reports by Miller et al. 1967, Strong et al, 1967, Rosenberg and Durnin, 1978, Norgan and Durnin, 1980 and Westrate, 1989. Miller et al (1967), in his paper "Gluttony 2. thermogenesis in overeating man", reported that it is unlikely that an increase in BMR may result if there is an increase in heat production in subjects who are overeating because the influence of diet is deliberately excluded in the measurement of BMR which is made after a 12-hour fast. There are other reports confirming this (Wiley and Newburgh, 1931; Munro, 1950; Passmore et al, 1955 and Passmore et al, 1963).

It was interesting to note however that, although there were some changes in the BMR from the initial to the standard diet phase, yet when the group was taken as a whole, the t-test showed no significant statistical differences between the phases. This could mean that there seems to be no clear evidence of a relationship between the BMR in all phases. However, even if the differences were not statistically significant, the test does not imply that there is really no effect. But rather that it may simply mean that the results could either be real or the study could have failed to demonstrate the existence of an effect.

Although the group as a whole showed no significant changes in their BMR on differing levels of intake, yet when taken individually, it can be noted that 18 subjects had a fall from the initial to the standard phase, and 3 subjects had about a 13% fall or change (subjects 4, 5 and 20). This could possibly be attributed to the subjects trying to adjust to the apparatus during the test in the initial phase, this being the first measurement. Although the BMR measurements were performed as much as possible under standardised conditions following the definition of basal metabolic rate, still there was the possibility of some variations in conditions under which the BMR was assessed. Chances are, there could have been variations among the repeated measurements within a subject like for instance, in the subject's behaviour during the measurement. That is, for example during the initial phase, this being the first measurement and the subject still trying to adjust to the apparatus, she may have been restless (this was observed in some of them) thus have had many spontaneous movements and changes in positions; she may have breathe irregularly with alternating periods of hyper- and hypo-ventilation (this was observed in one subject so much so that only 1 out of the 3 measurements was considered); or that, she may also have dozed off frequently (this was observed in 4 subjects for which 3 measurements had to be done). While in the succeeding measurements (changes here were observed to be small), it was observed that since most of the subjects have adapted or have had experience in how the test was done, they adhered to the conditions of the test, that is to say, that they were lying down in the supine position calmly, awake, motionless as much as possible and breathing regularly.

These observations then seem to suggest that variations in the subject's behaviour and in measurement circumstances may have a greater source of within subject variation in BMR rather than the diet or energy intake of the previous day.

This was also observed by Westrate (1989) in his study on "The assessment of BMR, DIT and in vivo fuel utilisation using a ventilated hood system: methodological considerations".

The with-in person coefficient of variation for repeated measurements on differing levels of intake and days were in general about 5% with a range from 1 - 10%; while the between person coefficient of variation ranged from 12 - 15% in all phases.

7. Conclusion

This study indicates that the post-absorptive BMR does not show substantial variation even when the preceding day's intake was altered which means that a diet of differing levels does not seem to have marked effects on BMR measured 12 - 14 hours after the last meal.

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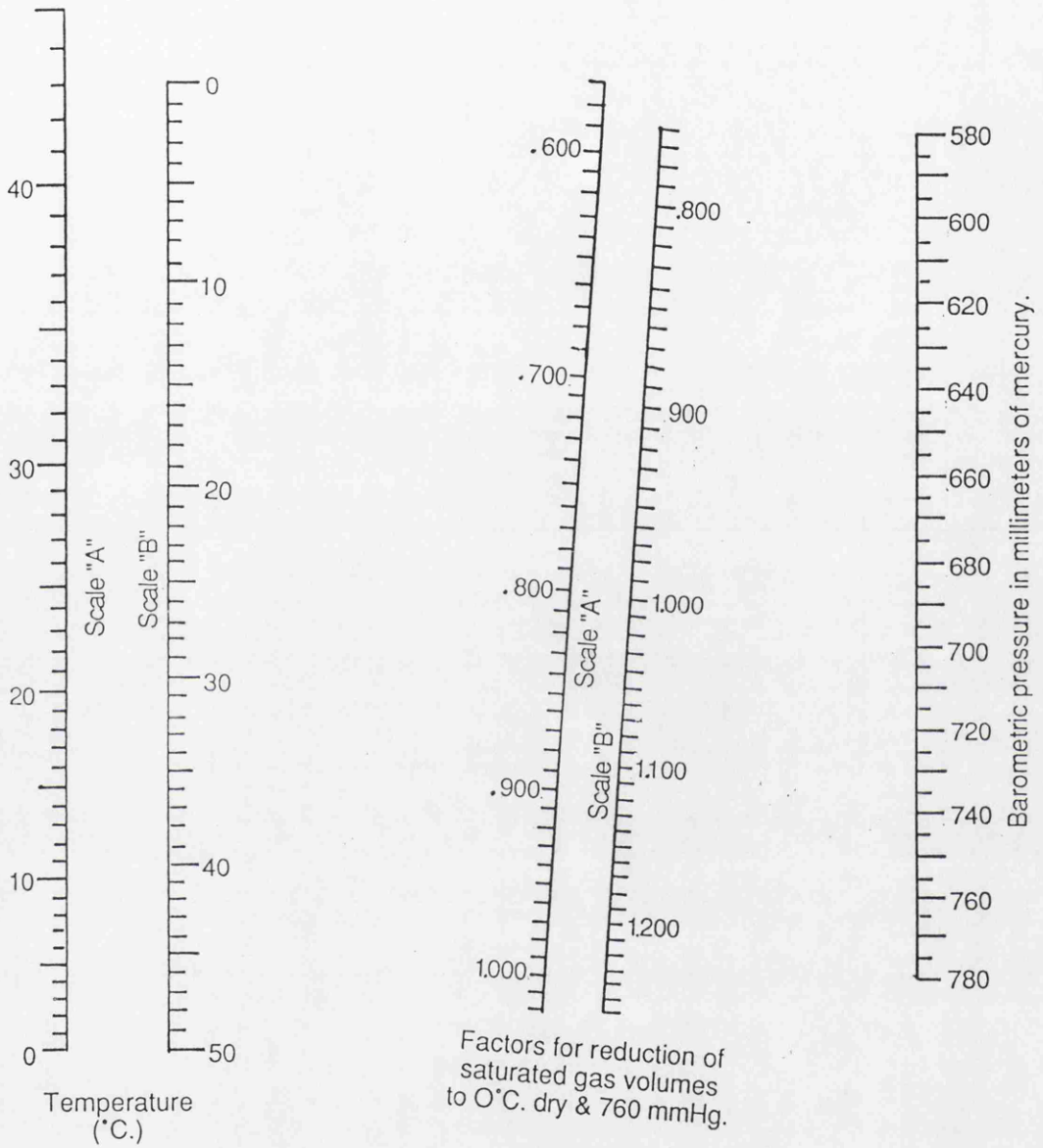
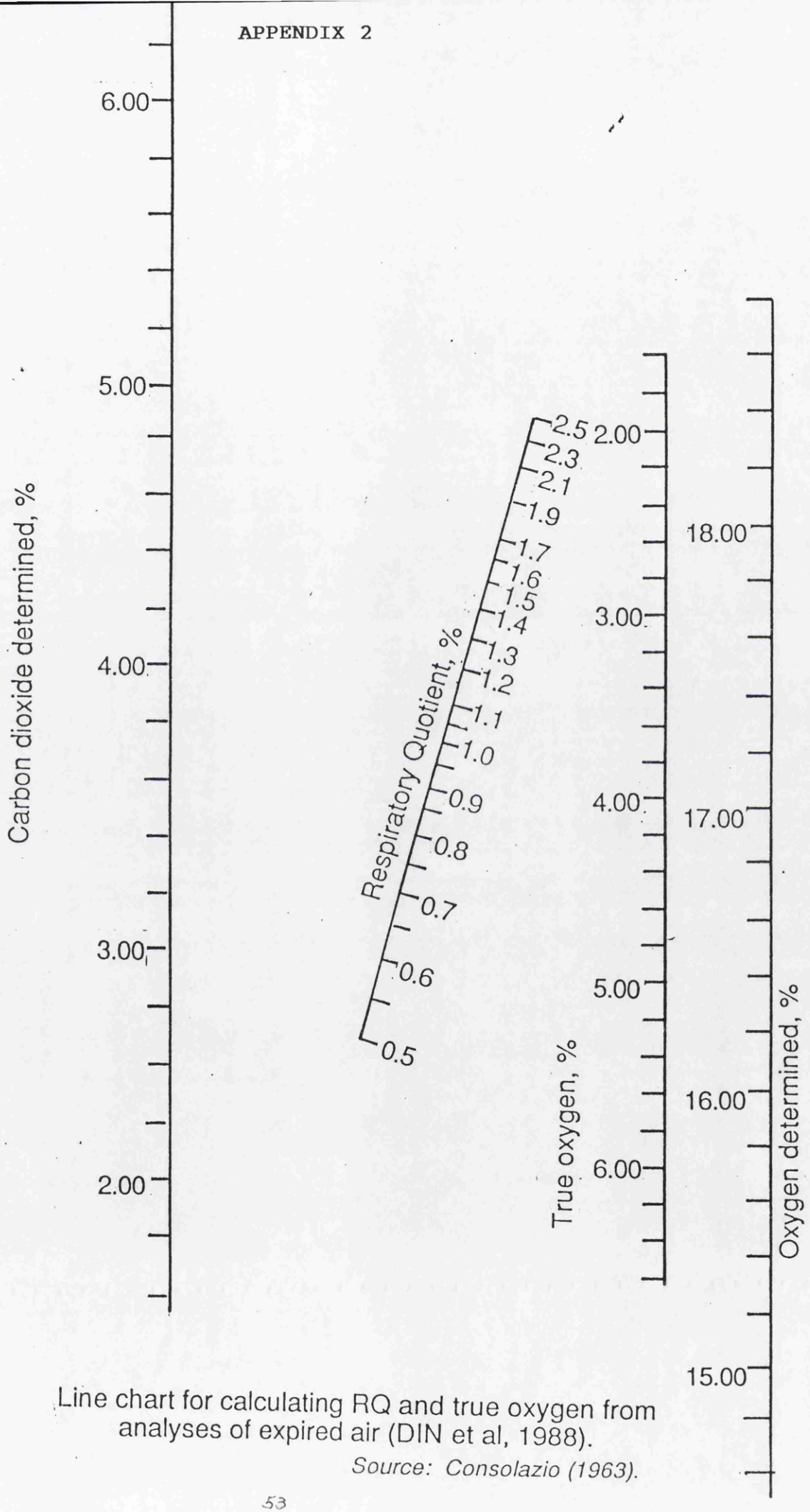
APPENDIX 1



Line chart for determining factors to reduce saturated gas volumes to dry volumes at O°C and 760 mmHg. (Chart prepared by R C Darling).

Source: Consolazio (1963)



Line chart for calculating RQ and true oxygen from analyses of expired air (DIN et al, 1988).

Source: Consolazio (1963).

APPENDIX 3

Equivalent Fat Content, as a Percentage of Body Weight, for a Range of Values for the Sum of Four Skinfolds*

Skin-folds (mm)	Males (age in years)				Females (age in years)			
	17-19	30-39	40-49	50+	16-29	30-39	40-49	50+
15	4.8	-----	-----	----	10.5	-----	-----	----
20	8.1	12.2	12.2	12.6	14.1	17.0	19.8	21.4
25	10.5	14.2	15.0	15.6	16.8	19.4	22.2	24.0
30	12.9	16.2	17.7	18.6	19.5	21.8	24.5	26.6
35	14.7	17.7	19.6	20.8	21.5	23.7	26.4	28.5
40	16.4	19.2	21.4	22.9	23.4	25.5	28.2	30.3
45	17.7	20.4	23.0	24.7	25.0	26.9	29.6	31.9
50	19.0	21.5	24.6	26.5	26.5	28.2	31.0	33.4
55	20.1	22.5	25.9	27.9	27.8	29.4	32.1	34.6
60	21.2	23.5	27.1	29.2	29.1	30.6	33.2	35.7
65	22.2	24.3	28.2	30.4	30.2	31.6	34.1	36.7
70	23.1	25.1	29.3	31.6	31.2	32.5	35.0	37.7
75	24.0	25.9	30.3	32.7	32.2	33.4	35.9	38.7
80	24.8	26.6	31.2	33.8	33.1	34.3	36.7	39.6
85	25.5	27.2	32.1	34.8	34.0	35.1	37.5	40.4
90	26.2	27.8	33.0	35.8	34.8	35.8	38.3	41.2
95	26.9	28.4	33.7	36.6	35.6	36.5	39.0	41.9
100	27.6	29.0	34.4	37.4	36.4	37.2	39.7	42.6
105	28.2	29.6	35.1	38.2	37.1	37.9	40.4	43.3
110	28.8	30.1	35.8	39.0	37.8	38.6	41.0	43.9
115	29.4	30.6	36.4	39.7	38.4	39.1	41.5	44.5
120	30.0	31.1	37.0	40.4	39.0	39.6	42.0	45.1
125	31.0	31.5	37.6	41.1	39.6	40.1	42.5	45.7
130	31.5	31.9	38.2	41.8	40.2	40.6	43.0	46.2
135	32.0	32.3	38.7	42.4	40.8	41.1	43.5	46.7
140	32.5	32.7	39.2	43.0	41.3	41.6	44.0	47.2
145	32.9	33.1	39.7	43.6	41.8	42.1	44.5	47.7
150	33.3	33.5	40.2	44.1	42.3	42.6	45.0	48.2
155	33.7	33.9	40.7	44.6	42.8	43.1	45.4	48.7
160	34.1	34.3	41.2	45.1	43.3	43.6	45.8	49.2
165	34.5	34.6	41.6	45.6	43.7	44.0	46.2	49.6
170	34.9	34.8	42.0	46.1	44.1	44.4	46.6	50.0
175	35.3	----	----	----	-----	44.8	47.0	50.4
180	35.6	----	----	----	-----	45.2	47.4	50.8
185	35.9	----	----	----	-----	45.6	47.8	51.2
190	----	----	----	----	-----	45.9	48.2	51.6
195	----	----	----	----	-----	46.2	48.5	52.0
200	----	----	----	----	-----	46.5	48.8	52.4
205	----	----	----	----	-----	----	49.1	52.7
210	----	----	----	----	-----	----	49.4	53.0

*Biceps, triceps, subscapular, and suprailiac of males and females of different ages.
From Durnin, J.V.G.A., Womersley,J.: Br.J.Nutr.32:77-97, 1974 (with permission).

APPENDIX 4

Sample No. _____

NAME _____ PLACE _____

AGE _____ HEIGHT _____ WEIGHT _____

DATE _____ TIME _____ AIR TEMP. _____

ACTIVITY OBSERVER

Bar Press. _____ Temp. Expired Air _____ Atmos. Corr. Factor _____

SP METER: Final Reading (2) _____ Difference (2-1) _____

Initial Reading (1) _____

Respirometer No. _____ Corr. Factor _____

Duration of Sample _____

Pulmonary Ventilation (BTPS) _____ (Gas analysis:

(Analyst: _____

(

(CO_2 =

(3) (STP) _____ (

(O_2 =

(_____

True Oxygen (4) _____ RQ _____

Caloric Value Exp. Air:

$$\frac{(20.93 - \_\_\_\_\_)}{(\quad 20 \quad)}$$

$$\frac{\_\_\_\_\_}{20} \qquad (5)\ \_\_\_\_\_$$

OXYGEN CONSUMPTION: $\frac{(\ 3\ X\ 4\ )}{100}$ =

CALORIES PER MINUTE: (3 X 5) =

APPENDIX 5

Raw data of BMR Measurements during the Initial Phase

Subj. No.	Diff (Vol)	CO2	O2	PV (STPD)	True O2	RQ	O2 Cons	kcal/ min	Mean BMR
1.	36.4	3.62	16.70	3.40	4.40	0.81	0.150	0.721	
	34.4	3.54	16.50	3.21	4.66	0.75	0.150	0.713	0.713
2.	32.9	3.92	16.70	3.07	4.32	0.89	0.133	0.651	
	33.7	3.92	16.48	3.14	4.61	0.84	0.151	0.700	0.676
3.	32.4	4.29	15.90	2.95	5.24	0.81	0.155	0.743	
	32.1	4.04	16.20	2.92	4.93	0.81	0.144	0.692	
	33.3	4.05	16.10	3.02	5.06	0.79	0.153	0.729	0.721
4.	44.0	3.58	16.75	4.02	4.35	0.81	0.175	0.840	
	53.7	3.46	17.20	4.91	3.82	0.89	0.188	0.916	0.878
5.	41.1	3.75	16.64	3.64	4.45	0.03	0.162	0.783	
	41.4	3.67	16.60	3.67	4.51	0.80	0.166	0.795	0.789
6.	43.9	3.56	16.67	3.96	4.45	0.79	0.176	0.843	
	40.7	3.47	16.50	3.67	4.68	0.73	0.171	0.813	0.828
7.	50.4	3.58	16.89	4.52	4.16	0.85	0.188	0.913	
	49.1	3.44	16.87	4.40	4.23	0.81	0.186	0.893	0.903
8.	38.2	4.02	16.62	3.53	4.40	0.91	0.155	0.762	
	37.9	3.90	16.70	3.51	4.34	0.89	0.152	0.744	0.753
9.	39.2	3.76	15.10	3.52	6.32	0.58	0.222	1.028	1.028
10.	50.5	3.55	17.05	4.67	3.97	0.88	0.185	0.906	
	51.5	3.57	17.10	4.76	3.91	0.90	0.186	0.911	0.909
11.	33.7	4.26	15.55	3.08	5.70	0.74	0.176	0.828	
	32.1	4.47	15.37	2.93	5.87	0.76	0.172	0.184	0.821
12.	57.4	3.09	17.75	5.32	3.21	0.95	1.171	0.846	
	42.8	3.11	16.92	3.96	4.26	0.72	0.169	0.796	0.821
13.	49.3	3.65	16.78	4.40	4.30	0.84	0.189	0.913	
	49.3	3.60	16.80	4.40	4.22	0.83	0.186	0.911	0.912
14.	43.0	3.86	16.90	3.98	4.08	0.93	0.154	0.804	
	44.5	3.85	17.00	4.12	3.96	0.96	0.154	0.812	0.808
15.	41.8	4.33	16.14	3.78	4.95	0.87	0.187	0.905	
	44.4	4.18	16.46	4.01	4.56	0.91	0.183	0.896	0.901

APPENDIX 5 (Continuation)

Raw data of BMR Measurements during the Initial Phase

Subj. No.	Diff (Vol)	CO2	O2	PV (STPD)	True O2	RQ	O2 Cons	kcal/ min	Mean BMR
16.	38.3	4.22	15.60	3.54	5.63	0.74	0.199	0.945	
	37.5	4.34	15.50	3.47	5.74	0.75	0.199	0.944	0.945
17.	48.9	3.71	16.50	4.44	4.62	0.79	0.205	0.986	
	49.2	3.58	16.60	4.47	4.53	0.78	0.202	0.970	0.978
18.	49.3	3.47	16.50	4.41	4.70	0.73	0.207	0.977	
	49.4	3.48	16.50	4.42	4.70	0.73	0.208	0.980	0.979
19.	54.1	3.81	16.96	4.71	4.02	0.93	0.189	0.935	
	53.1	3.76	16.78	4.63	4.26	0.87	0.197	0.961	0.948
20.	51.9	3.71	16.78	4.75	4.28	0.86	0.203	0.986	
	37.7	3.91	16.20	3.45	4.97	0.78	0.171	0.818	0.902
21.	49.5	3.83	16.40	4.54	4.72	0.81	0.214	1.028	
	52.0	3.71	16.60	4.77	4.50	0.81	0.215	1.032	1.030
22.	49.8	3.73	16.20	4.47	5.01	0.74	0.224	1.057	
	51.7	3.59	16.40	4.64	4.78	0.75	0.222	1.053	1.055
23.	39.8	3.75	16.40	3.65	4.75	0.82	0.173	0.829	
	40.0	3.71	16.40	3.67	4.71	0.82	0.173	0.826	0.828
24.	42.0	4.00	15.80	3.75	5.47	0.73	0.205	0.968	
	42.7	3.90	15.80	3.81	5.42	0.71	0.206	0.972	0.970
25.	38.5	4.82	15.00	3.65	6.25	0.77	0.228	1.084	
	39.9	4.87	15.10	3.78	6.11	0.79	0.231	1.102	1.093
26.	41.4	3.40	16.80	3.70	4.34	0.78	0.161	0.766	
	42.5	3.40	16.80	3.80	4.36	0.77	0.166	0.789	0.778
27.	46.3	4.00	15.90	4.18	5.30	0.75	0.222	1.054	
	50.3	3.82	16.10	4.54	5.11	0.74	0.232	1.096	
	46.6	3.89	15.90	4.19	5.35	0.72	0.224	1.056	1.069
28.	44.0	4.02	16.15	3.90	5.00	0.80	0.195	0.932	
	44.1	4.05	16.10	3.91	5.06	0.79	0.198	0.946	0.939
29.	43.8	3.54	16.05	3.94	5.25	0.69	0.207	0.961	
	45.3	3.62	16.11	4.06	5.15	0.70	0.209	0.978	0.970
30.	39.2	4.00	15.66	3.49	5.62	0.71	0.196	0.921	
	39.0	3.80	15.67	3.47	5.65	0.67	0.196	0.912	0.917

APPENDIX 6

Raw Data of BMR Measurements during the Standard Diet Phase

Subj No.	Diff (Vol)	CO2	O2	PV (STPD)	True O2	RQ	O2 Cons	kcal/ min	Mean BMR
1.	33.2	4.00	16.10	2.97	5.06	0.78	0.150	0.719	
	33.0	4.01	16.20	2.95	4.93	0.81	0.145	0.699	0.709
2.	35.2	3.57	16.79	3.23	4.30	0.82	0.139	0.669	
	34.4	3.61	16.71	3.16	4.37	0.82	0.138	0.667	0.668
3.	30.7	3.90	16.10	2.85	5.10	0.76	0.145	0.690	
	35.6	3.45	16.70	3.30	4.44	0.77	0.147	0.700	0.695
4.	33.6	4.30	15.96	2.99	5.17	0.83	0.155	0.745	
	34.5	4.27	16.07	3.07	5.05	0.84	0.155	0.746	0.746
5.	39.2	3.75	17.03	3.53	3.95	0.94	0.140	0.688	
	40.4	3.66	17.15	3.64	3.81	0.95	0.139	0.688	0.688
6.	39.4	3.70	16.93	3.65	4.08	0.89	0.149	0.730	
	38.8	3.79	16.90	3.60	4.11	0.88	0.148	0.727	0.729
7.	45.4	3.68	16.61	4.10	4.48	0.81	0.183	0.886	
	50.0	3.53	16.89	4.52	4.18	0.83	0.189	0.913	0.900
8.	32.7	3.88	16.32	3.03	4.82	0.80	0.146	0.700	
	31.9	4.00	16.16	2.95	4.99	0.81	0.147	0.705	0.703
9.	47.2	3.43	16.40	4.25	4.82	0.71	0.205	0.965	
	45.9	3.52	16.40	4.13	4.80	0.73	0.198	0.938	0.952
10.	51.2	3.57	16.71	4.56	4.39	0.81	0.200	0.962	
	50.8	3.55	16.95	4.53	4.09	0.86	0.185	0.901	
	48.3	3.65	16.75	4.30	4.32	0.84	0.186	0.899	0.900
11.	35.4	3.89	16.04	3.15	5.18	0.86	0.163	0.772	
	36.3	3.97	16.12	3.23	5.05	0.78	0.163	0.776	0.774
12.	47.4	3.68	17.01	4.35	3.99	0.91	0.174	0.853	
	47.6	3.63	17.09	4.36	3.91	0.92	0.170	0.837	0.845
13.	49.0	3.51	16.77	4.50	4.35	0.80	0.196	0.936	
	47.1	3.57	16.63	4.33	4.51	0.79	0.195	0.931	0.934
14.	42.0	3.91	16.60	3.89	4.45	0.87	0.173	0.844	
	41.5	3.78	16.50	3.84	4.60	0.83	0.177	0.852	0.848
15.	43.0	4.06	16.31	4.09	4.76	0.84	0.195	0.941	
	53.1	3.82	16.76	4.60	4.27	0.88	0.209	0.961	0.951

APPENDIX 6 (Continuation)

Raw Data of BMR Measurements during the Standard Diet Phase

Subj. No.	Diff (Vol)	CO2	O2	PV (STPD)	True O2	RQ	O2 Cons	kcal/ min	Mean BMR
16.	39.9	3.90	16.01	3.69	5.10	0.76	0.188	0.908	
	41.0	3.80	16.10	3.79	5.12	0.74	0.176	0.917	0.913
17.	42.0	3.70	16.26	3.85	4.94	0.74	0.190	0.901	
	42.6	3.80	16.20	3.90	4.97	0.78	0.194	0.924	0.913
18.	57.3	3.50	16.56	4.28	4.61	0.75	0.197	0.937	
	49.6	3.50	16.62	4.44	4.53	0.76	0.201	0.959	0.948
19.	57.1	3.49	17.12	5.15	3.92	0.88	0.202	0.981	
	57.5	3.49	17.13	5.19	3.89	0.89	0.202	0.986	0.983
20.	41.0	3.61	16.53	3.73	4.64	0.77	0.173	0.821	
	40.5	3.56	16.89	3.68	4.17	0.84	0.153	0.743	
	39.5	3.68	16.53	3.59	4.61	0.79	0.165	0.790	0.785
21.	31.2	3.60	16.37	2.76	4.82	0.74	0.133	0.629	
	29.9	3.80	16.05	2.60	5.18	0.73	0.135	0.634	0.632
22.	53.0	3.50	16.50	4.84	4.67	0.74	0.226	1.074	
	56.1	3.63	16.40	5.12	4.72	0.75	0.242	1.157	
	52.8	3.71	16.00	4.80	5.27	0.70	0.253	1.186	1.139
23.	40.0	3.75	16.65	3.56	4.42	0.83	0.157	0.762	
	40.5	3.70	16.60	3.61	4.50	0.81	0.162	0.783	0.773
24.	49.4	3.69	16.40	4.49	4.77	0.77	0.214	1.019	
	49.8	3.74	16.40	4.40	4.75	0.78	0.209	0.999	1.009
25.	40.5	4.68	15.10	3.64	6.15	0.76	0.224	1.063	
	42.0	4.59	15.40	3.78	5.80	0.79	0.219	1.047	1.055
26.	42.0	3.50	16.80	3.86	4.31	0.80	0.166	0.799	
	41.4	3.50	16.85	3.80	4.24	0.82	0.161	0.775	0.787
27.	54.0	3.50	16.13	4.76	5.16	0.67	0.245	1.142	
	53.8	3.50	16.06	4.74	5.25	0.66	0.249	1.157	1.150
28.	43.2	4.27	15.99	3.88	5.15	0.82	0.200	0.958	
	42.2	4.29	15.89	3.78	5.26	0.81	0.199	0.952	0.955
29.	48.1	3.67	16.34	4.40	4.81	0.76	0.212	1.010	
	51.1	3.63	16.67	4.68	4.43	0.81	0.207	0.997	1.004
30.	53.4	3.45	16.80	4.80	4.32	0.79	0.207	0.994	
	50.1	3.57	16.50	4.50	4.66	0.76	0.210	0.999	0.997

APPENDIX 7

Raw Data of BMR Measurements during the Overeating or "40% More" Phase

Subj. No.	Diff (Vol)	CO2	O2	PV (STPD)	True O2	RQ	O2 Cons	kcal/ min	Mean BMR
1.	31.3	3.69	16.50	2.85	4.64	0.79	0.132	0.633	
	29.2	3.75	16.30	2.65	4.88	0.76	0.129	0.615	0.624
2.	39.8	3.50	16.90	3.75	4.18	0.83	0.157	0.758	
	41.8	3.39	17.10	3.94	4.06	0.82	0.160	0.749	0.748
3.	31.8	4.08	15.80	2.94	5.42	0.75	0.159	0.756	
	31.9	4.15	15.90	2.93	5.27	0.78	0.154	0.738	0.747
4.	40.2	3.79	16.90	3.70	4.09	0.91	0.151	0.747	
	39.4	3.90	16.79	3.63	4.22	0.92	0.153	0.751	0.749
5.	38.6	3.71	16.59	3.48	4.51	0.81	0.157	0.755	
	36.8	3.83	16.44	3.33	4.67	0.81	0.156	0.749	0.752
6.	44.1	3.63	16.52	3.96	4.62	0.82	0.183	0.875	
	44.8	3.74	16.92	4.02	4.09	0.90	0.164	0.808	
	43.3	3.75	16.84	3.88	4.19	0.88	0.163	0.795	0.826
7.	50.6	3.44	16.91	4.60	4.18	0.81	0.192	0.925	
	51.2	3.54	16.83	4.65	4.25	0.82	0.198	0.953	0.939
8.	38.2	3.91	16.63	3.58	4.42	0.88	0.158	0.770	
	36.9	3.82	16.57	3.45	4.51	0.84	0.156	0.752	0.761
9.	39.7	4.09	15.80	3.57	5.42	0.75	0.193	0.917	
	40.0	4.09	15.80	3.59	5.42	0.75	0.193	0.923	0.920
10.	50.1	3.36	16.97	4.63	4.12	0.81	0.191	0.917	
	50.9	3.31	17.06	4.70	4.02	0.81	0.189	0.912	0.915
11.	31.2	4.32	15.39	2.89	5.87	0.73	0.170	0.801	
	32.1	4.55	15.52	2.97	5.62	0.80	0.167	0.805	0.803
12.	45.8	3.69	17.07	4.27	3.93	0.93	0.168	0.824	
	40.4	3.96	16.42	3.75	4.67	0.84	0.175	0.848	0.836
13.	45.9	3.72	16.50	4.25	4.65	0.79	0.198	0.944	
	45.0	3.85	16.38	4.17	4.76	0.80	0.198	0.950	0.947
14.	43.0	3.75	16.50	4.02	4.62	0.80	0.186	0.892	
	44.0	3.86	16.60	4.12	4.46	0.85	0.184	0.894	0.893
15.	44.5	3.76	16.79	4.18	4.26	0.87	0.178	0.865	
	44.6	3.77	16.79	4.19	4.26	0.88	0.178	0.867	0.866

APPENDIX 7 (Continuation)

Raw Data of BMR Measurements during the Overeating or the "40% More" Phase

Subj. No.	Diff (Vol)	CO2	O2	PV (STPD)	True O2	RQ	O2 Cons	kcal/ min	Mean BMR
16.	39.1	4.08	15.90	3.59	5.28	0.77	0.190	0.905	
	42.8	3.96	16.20	3.92	4.96	0.79	0.194	0.929	0.917
17.	44.5	3.90	16.67	4.03	4.38	0.88	0.177	0.858	
	44.8	3.80	16.65	4.05	4.42	0.85	0.179	0.867	0.863
18.	45.5	3.40	16.87	4.13	4.24	0.79	0.175	0.838	
	46.1	3.40	16.88	4.18	4.24	0.79	0.177	0.846	0.842
19.	51.7	3.50	17.07	4.85	3.99	0.87	0.194	0.936	
	51.8	3.54	17.00	4.86	3.44	0.87	0.167	0.957	0.947
20.	39.4	3.62	16.72	3.50	4.37	0.82	0.153	0.739	
	39.7	3.76	16.63	3.53	4.45	0.83	0.157	0.759	0.749
21.	34.3	4.02	15.70	3.10	5.56	0.72	0.172	0.812	
	39.6	4.11	16.30	3.57	4.78	0.85	0.171	0.828	0.820
22.	49.3	3.87	16.20	4.47	4.97	0.77	0.222	1.059	
	52.5	3.72	16.40	4.75	4.75	0.78	0.226	1.076	1.068
23.	42.0	3.81	16.96	3.81	4.02	0.94	0.153	0.758	
	43.0	3.80	16.96	3.90	4.02	0.94	0.157	0.776	0.767
24.	45.3	3.85	16.10	4.11	5.11	0.75	0.210	0.995	
	44.5	3.86	16.10	4.04	5.22	0.73	0.211	0.998	0.997
25.	44.2	4.54	15.30	4.04	5.93	0.76	0.240	1.139	
	45.6	4.48	15.40	4.17	5.70	0.78	0.238	1.155	1.147
26.	43.1	3.45	16.70	3.88	4.44	0.77	0.172	0.823	
	44.6	3.49	16.80	4.02	4.30	0.80	0.173	0.832	0.828
27.	51.7	3.93	16.20	4.66	4.96	0.79	0.231	1.104	
	52.6	3.91	16.30	4.74	4.74	0.81	0.229	1.100	1.102
28.	38.7	4.33	15.73	3.48	5.45	0.79	0.190	0.905	
	40.0	4.33	15.80	3.59	5.36	0.80	0.192	0.923	0.914
29.	52.4	3.62	16.67	4.65	4.43	0.81	0.206	0.990	
	53.6	3.53	16.64	4.75	4.50	0.78	0.214	1.021	1.006
30.	48.8	3.49	16.60	4.40	4.56	0.76	0.201	0.950	
	49.0	3.55	16.70	4.41	4.42	0.80	0.195	0.935	0.943

APPENDIX 8

Raw Data of BMR Measurements during the Undereating or the "40% Less" Phase

Subj No.	Diff (Vol)	CO2	O2	PV (STPD)	True O2	RQ	O2 Cons	kcal/ min	Mean BMR
1.	33.6	3.64	16.20	3.06	5.03	0.72	0.154	0.725	
	35.2	3.50	16.50	3.20	4.69	0.74	0.150	0.711	0.718
2.	31.5	3.51	16.43	2.90	4.76	0.73	0.138	0.653	
	33.8	3.27	16.63	3.11	4.58	0.71	0.142	0.669	
	33.2	3.49	16.84	3.05	4.26	0.81	0.130	0.625	0.649
3.	31.1	3.53	16.60	2.79	4.55	0.77	0.127	0.605	
	32.3	3.32	16.90	2.90	4.23	0.78	0.123	0.586	0.596
4.	35.3	4.06	16.36	3.27	4.70	0.86	0.154	0.749	
	36.4	4.02	16.47	3.37	4.59	0.87	0.155	0.751	0.750
5.	41.1	3.62	16.85	3.72	4.21	0.84	0.157	0.759	
	40.3	3.66	16.76	3.65	4.31	0.84	0.157	0.761	0.760
6.	43.2	3.71	16.80	3.85	4.26	0.86	0.164	0.797	
	50.1	3.39	17.25	4.47	3.72	0.89	0.166	0.822	0.822
7.	57.3	3.09	17.37	5.19	3.70	0.82	0.192	0.924	
	51.7	3.28	16.97	4.68	4.15	0.78	0.194	0.927	0.926
8.	34.7	3.86	16.36	3.19	4.78	0.80	0.153	0.731	
	37.2	3.96	16.54	3.42	4.52	0.87	0.155	0.752	0.742
9.	45.7	3.40	16.18	4.08	5.12	0.65	0.209	0.971	
	45.8	3.35	16.18	4.08	5.12	0.65	0.209	0.971	0.971
10.	50.6	3.35	17.15	4.59	3.90	0.85	0.179	0.868	
	51.6	3.31	17.21	4.68	3.84	0.85	0.180	0.870	0.869
11.	40.7	4.16	15.65	3.67	5.60	0.74	0.206	0.969	
	36.9	3.90	16.13	3.32	5.05	0.77	0.168	0.797	0.883
12.	44.1	3.43	16.62	4.04	4.55	0.75	0.184	0.873	
	43.4	3.42	16.62	4.00	4.56	0.74	0.182	0.864	
	43.0	3.26	16.79	3.96	4.39	0.74	0.174	0.820	0.852
13.	40.2	3.73	16.50	3.65	4.62	0.80	0.169	0.810	
	40.6	3.72	16.65	3.68	4.44	0.83	0.163	0.788	0.810
14.	41.0	3.84	16.50	3.77	4.60	0.83	0.173	0.837	
	40.0	3.82	16.50	3.68	4.61	0.82	0.170	0.817	0.827
15.	50.3	3.59	16.95	4.63	4.09	0.87	0.189	0.921	
	48.9	3.70	16.50	4.12	4.63	0.79	0.191	0.915	0.918

APPENDIX 8 (Continuation)

Raw Data of BMR Measurements during the Undereating or the "40% Less" Phase

Subj. No.	Diff (Vol)	CO2	O2	PV (STPD)	True O2	RQ	O2 Cons	kcal/ min	Mean BMR
16.	39.1	3.98	15.90	3.50	5.32	0.74	0.186	0.882	
	39.4	4.17	15.80	3.52	5.40	0.77	0.190	0.905	0.894
17.	47.2	3.67	16.40	4.25	4.76	0.76	0.202	0.972	
	49.0	3.56	16.50	4.41	4.67	0.76	0.206	0.979	0.978
18.	51.4	2.90	17.20	4.67	3.96	0.73	0.185	0.873	
	49.8	3.10	16.95	4.52	4.21	0.73	0.190	0.899	0.886
19.	49.2	3.49	16.79	4.60	4.23	0.81	0.195	0.952	
	49.5	3.58	16.79	4.62	4.30	0.82	0.199	0.956	0.954
20.	43.6	3.51	16.74	3.54	4.38	0.79	0.155	0.743	
	38.7	3.45	16.76	3.46	4.51	0.76	0.156	0.721	0.732
21.	44.9	3.20	16.80	4.08	4.29	0.72	0.175	0.845	
	51.4	3.40	17.22	4.67	3.79	0.89	0.177	0.869	0.857
22.	52.0	3.50	16.78	4.82	4.33	0.80	0.209	1.003	
	50.5	3.50	16.58	4.68	4.58	0.76	0.214	1.020	1.012
23.	38.0	3.73	16.20	3.46	5.01	0.74	0.173	0.820	
	40.5	3.71	16.50	3.69	4.62	0.79	0.170	0.819	0.820
24.	40.3	3.98	16.00	3.65	5.20	0.76	0.190	0.902	
	40.1	3.92	16.00	3.63	5.22	0.75	0.189	0.897	0.900
25.	43.5	4.35	15.40	3.96	5.86	0.74	0.232	1.097	
	44.5	4.40	15.40	4.05	5.85	0.75	0.237	1.122	1.110
26.	45.2	3.57	16.70	4.07	4.42	0.80	0.180	0.863	
	45.7	3.65	16.70	4.12	4.39	0.82	0.181	0.873	0.868
27.	43.8	3.50	16.08	4.03	5.22	0.67	0.210	0.979	
	46.4	3.50	16.18	4.27	5.10	0.68	0.218	1.006	0.993
28.	41.2	4.41	15.55	3.72	5.66	0.78	0.210	1.001	
	41.1	4.49	15.52	3.71	5.67	0.79	0.210	1.005	1.003
29.	49.6	3.62	16.42	4.55	4.75	0.76	0.216	1.028	
	51.2	3.56	16.58	4.69	4.58	0.84	0.215	1.020	1.024
30.	47.6	3.71	16.40	4.30	4.76	0.78	0.205	0.976	
	48.6	3.80	16.40	4.39	4.74	0.79	0.208	0.997	0.987