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THE METABOLIC DEMAND FOR ENERGY OF CHILDREN IN HEALTH AND DISEASE

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ABSTRACT

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The body's metabolism exerts a demand for energy which must be fulfilled for normal growth and development. Estimates of basal metabolic rate and energy intake from healthy children are used to determine their energy requirements. The relationship between these components, within the same individual, may indicate the extent to which metabolic demand for energy is satisfied by intake.

Three studies investigated the metabolic demand for energy of children, in health, with Cystic Fibrosis (CF), and receiving chemotherapy during remission. The relationship between metabolic demand and energy intake, as the energy intake to basal metabolic rate ratio (EIN/BMR), was determined for these three groups.

In an age range of 5 to 15 years BMR and EIN varied as much within an age group as between different ages. Body weight and lean body mass were the major contributors towards this variation. Younger children had greater EIN/BMR ratios than older children. The EIN/BMR ratio was higher for the CF group than their healthy control group. In contrast the chemotherapy group and their controls had similar EIN/BMR ratios.

When making recommendations for energy intake in children the ratio of EIN/BMR might be considered because it accounts for differences in body size and composition, and alteration in needs from disease or ill health.

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MAIN ABBREVIATIONS USED IN THE TEXT.

ALL	Acute Lymphoblastic Leukaemia
BMR	Basal Metabolic Rate
CF	Cystic Fibrosis
DRV	Dietary Reference Values
EIN	Energy Intake
HTSDS	Height Standard Deviation Score
LBM	Lean Body Mass
ST	Solid Tumours

INTRODUCTION.

Advice and guidelines regarding what children need to eat is sought by the public and professionals alike. Government policies for schools, institutions and agriculture, as well as overseas food aid, all require standards to ensure food provision is adequate. Recommendations for what children should eat, in order to be healthy and grow and develop normally, are essential [WHO, 1985].

A child's requirement for energy is dictated by genetic and physiological factors. Recommendations to meet the metabolic demand for energy in children have been documented, and continue to be reassessed as new information becomes available and new understanding is reached [Department of Health and Social Security, 1979: Department of Health, 1991]. Recommendations were initially expressed in terms of dietary intake, but this has been superseded, in part, by energy expenditure.

In younger children there is a paucity of data with regard to energy expenditure, and recommendations are still derived from dietary intakes. The ratio of total energy expenditure to metabolic demand for energy at rest has been examined in older children in order to make recommendations for energy intake. The relationship between reported energy intake and metabolic demand for energy at rest in the same child has not been described because of a lack of information. This ratio describes the adequacy with which energy intake meets metabolic demand for energy at rest (energy intake/basal metabolic rate). Multiplied by a child's basal metabolic rate this ratio may be an alternative way of expressing energy requirements. It does not rely upon energy intake alone, and includes an individualized expression of energy expenditure. This would be particularly appropriate for energy intake recommendations in younger children.

Both intake and expenditure of energy may be affected by illness. In long term illness or inherited diseases satisfying metabolic demand for energy may be more complex than in health. This raises the question of whether recommendations for energy requirements in health are appropriate in disease conditions, and if they are not how they should be altered.

The available evidence in the literature upon which recommendations for energy intake were based was explored (chapter 1.4). A series of studies (chapter 3, 4, 5) then investigated the relationship between metabolic demand for energy at rest in children, and simultaneously their energy intake. Both demand and intake of energy were characterized in healthy children, growing normally. The aim of the first study was to determine the adequacy of energy intake in relation to metabolic demand for energy at rest.

The second study investigated the effect of chronic disease (Cystic Fibrosis) upon metabolic demand for energy at rest. In individuals with Cystic Fibrosis there is an altered ion balance leading to respiratory failure and pancreatic exocrine insufficiency. These problems could be associated with a raised metabolic demand for energy and raised faecal energy losses. The relationship between metabolic demand for energy and energy intake was investigated in a group of children with Cystic Fibrosis to determine whether demand was satisfied by intake of energy.

Following these observations in chronic disease, the effect of treatment alone on metabolic demand for and intake of energy was considered. This final study group were oncology patients in remission, receiving monthly chemotherapy. The aim of this final study was to investigate whether treatment influenced the relationship between metabolic demand for energy and energy intake.

CHAPTER 1. REVIEW OF THE LITERATURE.

INTRODUCTION.

Hunger is a recognised drive from within the body which only ceases upon satiety or when metabolism is affected internally by disease or externally/artificially, for example during fasting or anorexia nervosa. This drive to find and consume food appears to be a reflection of the metabolic demand exerted at cell level for substrate and co-factors. Both are based upon common ground, the need for material to replace what has been transformed from being useable to becoming waste.

The metabolic demand for energy must clearly dictate to some extent the energy consumption from the diet. Requirements for energy in children must therefore include energy expenditure and growth. When disease is part of the scenario both demand and intake can be adversely affected. In this review the concept of metabolic demand is explored, followed by energy expenditure and growth. The current level of understanding and present recommendations for energy intake is discussed, and finally the presence of disease in relation to intake and expenditure of energy is reviewed.

1.1 METABOLIC DEMAND FOR SUBSTRATE AND CO-FACTORS.

1.1.1 Defining Metabolic Demand.

Every cell in the body needs energy to exist. The human body has a demand for energy dictated by the collection of cells it is formed from. The sum of the reactions which occur in and between these cells is described as metabolism. The rate at which reactions take place in different cells may vary but all have peremptory demands upon energy supplies.

The essential cellular processes within the body include: substrate turnover, for example of protein; membrane transport, for example the sodium pump; and the mechanical work of ventilation and cardiac rhythm. All require energy to satisfy their unceasing demand.

Throughout childhood part of this metabolic demand is attributed to the energy needs associated with growth. The cellular processes must have a suitable environment of available substrate and co-factors for growth to take place. Only then will the genetically predetermined potential for size and development be achieved by maturity. However, metabolic demand will persist whether growth occurs or not.

Maslow's hierarchy of needs [1970] describes the order in which basic demands must be met - firstly oxygen, then water, then food. These must be fulfilled before more complex communication, and social and spiritual fulfilment can be achieved. Metabolic demand could therefore be described as occupying one of the primary levels of Maslow's pyramidal structure. This is keenly demonstrated during hunger strikes, refugee crises and famine.

1.1.2 Substrate and Co-factors.

To fulfil the demand exerted by metabolism both substrate and co-factors are required in appropriate amounts. The substrate available includes protein, lipid and carbohydrate, and the co-factors are the micronutrients - vitamins and minerals. Potential accessability of substrate is particularly important when considering how metabolic demand can be met, because every process of metabolism has an energy cost. The question arises, where does the supply come from ?

The source of substrate cannot be described as a reservoir which rises and falls without effort, but as a flux of components which themselves require energy to make them accessible to meet metabolic demand. The sources of energy are the diet and body stores. Both diet and body stores can meet the demand for energy separately; the latter for a quick but limited period of time only in the form of glucose. Excess substrate will be dealt with by either storing it as glycogen or lipid, or excreting it.

The source of co-factors is the same as for substrate. Some can be synthesised or stored in the body but the vast majority must be obtained regularly from the diet. Satisfying metabolic demand could not be achieved without co-factors, such is their integral role in metabolic pathways. The water soluble vitamins in particular play a key role in glycolytic pathways to produce energy; for example thiamine, pantothenic acid, and nicotinic acid. The minerals required include sulphur, phosphorous and magnesium. Whilst the quantities required are minimal their presence for satisfactory function is essential.

1.1.3 Factors Affecting Metabolic Demand.

Body size and composition are primary components of metabolic demand. Both will have substrate and co-factor costs and thereby affect requirements.

The most metabolically active organs are the brain, liver, heart and kidneys. As body mass increases during childhood the metabolic rate of each organ will increase, hence inducing an increased demand for substrate. Different body tissues grow at different rates. In the first year of life organ growth is proportional with body weight, but thereafter organ growth slows down. Skeletal muscle mass grows more rapidly after the first year of life, gradually stabilising at maturity. In the first year of life therefore metabolic demand for energy, per kilogram of body weight, is greatest. This demand gradually decreases until growth ceases and metabolic demand stabilises at maturity (see Table 1.1).

AGE (yrs)	Body weight (kg)	Organ weight (% of bdywt)	Muscle mass (% of bdywt)	Body fat (% of bdywt)	BMR/ kgbdywt (kcal/ kg/d)
Low birth weight	1.1	21	<10	3	37
Newborn	3.5	18	20	12	46
0.25	5.5	15	22	11	55
1.5	11.0	14	23	20	54
5	19.0	10	35	15	44
10	31.0	8.4	37	15	37
14	50	5.7	42	12	30
Adult	70	5.2	40	11	26

Table 1.1 Body Composition and Relative Metabolic Demand at Different Stages of Growth [Holliday, 1986].

In addition to the intrinsic factors affecting metabolic demand for substrate in health, there also exist extrinsic factors. If food is not in plentiful supply, the body stores will be drawn on leading to a negative energy balance and weight loss. This would lead to a reduction in metabolic demand initially. However, in a state of chronic energy deficiency when muscle tissue has sacrificed as a source of energy, the metabolic demand per kilogram of body weight may appear to rise because the proportion of metabolically active tissue has increased with the loss of fat and skeletal muscle tissues.

The environment of any cell contains the means to produce a regular supply of substrate. The metabolic pathways which operate in that environment do so within certain boundaries. One of those boundaries is temperature. The normal range of internal body temperature is limited to 36.2-37.2 degrees centigrade, although with exercise this may rise to 40 degrees centigrade [Kinney, 1988]. The state of thermoneutrality under basal conditions, or thermal comfort zone, is also restricted to a narrow band of around 15-25 degrees centigrade [Kinney, 1988]. Crossing temperature boundaries leads to either an increase in body heat production (shivering) or stimulates heat loss processes (sweating) to achieve thermoregulation. Both behaviour (physical activity, dressing or undressing) and metabolism (physiological adaptation) [Waterlow, 1985] act to regulate temperature to ensure an optimum environment for tissue and organ function.

The type of substrate available may also affect metabolic demand. Carbohydrate is the primary source of substrate for energy. If only protein was available, requiring more energy to metabolize it than carbohydrate, metabolic demand would increase because of the additional energy used during its metabolism. Conversely, a high carbohydrate low protein diet would have a lower energy requirement. The energy cost of metabolising the carbohydrate and reduced protein intake would be lower and the outcome might be described as adaptation, an inherent physiological protection for reduced protein availability.

The essentiality of metabolic demand lies on a continuum between life and death. When demand for substrate and co-factors outstrips supply, initially behaviour and metabolism alter to accommodate the situation. When the store of substrate is depleted to a critical level, the cellular events of metabolism are disrupted. There becomes a metabolic precedent for survival: for example growth in children would cease allowing tissue maintenance to continue; followed by specific organs taking the brunt of the stress, for example skeletal tissue relinquished to become a source of energy, protecting visceral organs. Ultimately, the failure of one or more organs to match demand with supply, rather than a complete cellular collapse, would result in death. To prevent this, eating and drinking form a regular pattern of normal daily living.

1.1.4 Metabolic Demand and Disease.

In those disease states where there is abnormal cell activity eg. infection and tumour growth, metabolic demand for substrate may alter. During infection it has been noted that the anorexia experienced by many individuals may be beneficial. The loss of appetite may be a 'specific mechanism of host defence rather than a toxic response to an etiological agent' [Murray, 1978]. Depriving an individual of dietary substrate to replenish body stores, could act to prevent foreign cell activity. The metabolic demand of the foreign antigens would not be satisfied, preventing further proliferation throughout the host.

Tumour growth is abnormal cell activity. The genetic instructions within cancer cells are not those of existing cells, causing conflict in terms of space, size and energy supply. There would be an additional metabolic demand for substrate, which might not be met. The continual stress on the metabolism with the common outward sign of weight loss, used as a diagnostic sign for cancer, would eventually lead to collapse. The adaptation to the stressor cannot continue in the compromised situation, and a stage of exhaustion soon leads to death. This picture of adaption or exhaustion is summed up by Selye's General Adaptation Syndrome [1956].

1.1.5 Summary.

The term metabolic demand implies an unceasing need which requires fulfilling. That need is for substrate and co-factors, in adequate quantities, both to prevent death and enhance life. Substrate is required for synthesis of tissue and fuelling the process of synthesis. Co-factors provide metabolic pathways with essential nutrients. The cost of metabolic demand will vary, both between and within individuals, depending upon size and body composition. Disease appears to upset the balance of supply and metabolic demand.

1.2 ENERGY EXPENDITURE IN CHILDREN.

The word "energy" sums up forces of a very different nature which give matter and radiation the ability to perform work. The flow of energy through the body is continuous, changing in character and function to allow the performance of numerous tasks. If the First Law of Thermodynamics (energy cannot be created or destroyed) is true, then energy has neither a source nor an endpoint. Measuring energy can be carried out directly and indirectly, by studying the changes from one form to another. Altering the natural homeostasis of the body, for example in a disease state, changes the rate of energy exchange. Understanding and overcoming this disruption of energy flux is the aim of those treating disease.

1.2.1 Components of Energy Expenditure.

The body requires energy to replace that lost or expended to keep on functioning. This suggests energy expenditure dictates energy intake. The primary components of energy expenditure are basal metabolic rate, physical activity and in children, growth [FAO/WHO/UNU, 1985; Shürch & Scrimshaw, 1990; British Nutrition Foundation, 1986; James, 1984].

Basal metabolic rate (BMR) has been defined and described by numerous authors. In principle it is the fundamental speed at which the body's essential cellular processes function. Investigating the relationship between oxygen consumption, carbon dioxide production and energy exchange has been seen as important in health and disease. In Dubois's 'Basal Metabolism in Health and Disease' [1936], he discussed the available literature and indicated BMR was the lowest metabolism exhibited by an individual whilst awake, yet motionless. Steady-state conditions included temperature and food consumption. The specific dynamic action or active thermogenesis which occurs post prandially is the result of raised metabolism as food intake is metabolised. Dubois indicated the accepted time for measurement of basal metabolism could be 12-14 hours after a meal. It must be assumed this time period was accepted for both adults and children. The temperature was maintained whereby neither shivering nor sweating occurred, a state of thermoneutrality.

Other terms used in conjunction with BMR are resting metabolic rate, resting energy expenditure, resting metabolic expenditure and fasting metabolic rate. These appear to have arisen because of varied conditions under which BMR has been measured. Some authors considered a true measurement of BMR to be impossible because the individual could never be totally physically relaxed, or would be mentally stimulated above the fundamental rate of their metabolism [Owen, 1988; Stock & Rothwell, 1982]. Others have not adhered to strict fasting and relaxed conditions during measurement, so coined the term resting metabolism to reflect those conditions [British Nutrition Foundation, 1986]. In the early literature, pre-1970s, BMR is usually used. The two most recent documents which reviewed previous work, and suggested the practical use of these measurements to estimate energy requirements, both adhere to the use of BMR [Schofield, 1985;

FAO/WHO/UNU, 1985]. Within the present document the term BMR will also be used, implying when measurements are carried out steady-state conditions would prevail unless otherwise stated.

Age, gender and body size are all known to affect BMR. Much of the variability related to these factors could be attributed to changes in body composition taking place during growth. During childhood and adolescence BMR appears to vary with the growth of the individual. It has been well documented that older children tend to have a higher BMR than younger ones [Robertson & Reid, 1952; Schofield, 1985]. Also, when expressed per kilogram of body weight, BMR in older children tends to be lower than in younger children [Talbot, 1921; Nakagawa, 1934 A, B; Lamb & Michie, 1954]. Tissue activity appears to decrease as its volume increases. Prior to the 20th century it was not possible to assess body composition. Once techniques had been established, the importance of different tissues in terms of metabolic rate could be determined.

At rest the metabolic rate of body tissues ranges from 116 kcal/d for the kidney to 500 kcal/d for skeletal muscle in an adult man. During growth the contribution of the metabolic rate of different tissues towards BMR changes. For example the contribution toward BMR from brain tissue changes from 87% at birth to 23% at maturity. The metabolic rate of brain, liver, heart and kidney together exert 67% of BMR, but only account for 5% of body mass in a 70kg man. Although skeletal muscle has been estimated as 40% of total body weight it is responsible for only 28% of BMR [Holliday, 1986].

During childhood and adolescence skeletal muscle mass increases (from 20% to 35-40% of body weight), organ masses change to a smaller degree (falling from 18% to 4.4-5.2% of body weight), and the overall effect on BMR is one of dilution [Holliday, 1986]. It appears that biological age in childhood may be more important than chronological age, with respect to BMR (Figures 1.2.1 and 1.2.2).

The effect of gender on BMR has similar body composition associations. Garn and Clark [1953] carried out a study examining gender differences in BMR of children. They noted the older the child was, the higher its BMR; and the reverse when BMR was expressed per unit body weight (between the ages of 6 and 18 years). However, the difference in BMR between girls and boys remained, even when matched for lean body mass, especially in the older children.

Other factors which may affect BMR include race [Nakagawa, 1934; Henry & Rees 1988], climate [WHO, 1985], energy intake [Grande et al, 1958], and infection and disease [Kinney, 1988; Vaisman et al, 1985; Kien & Camitta, 1987]. Some of the variability within individuals has been suggested as resulting from circadian rhythms [Aschoff & Paul, 1970] and the menstrual cycle [Solomon et al, 1982]. Neither of the latter studies have been carried out in children and adolescents.

Physical activity is thought to be 20 to 40% of total daily energy expenditure (TDEE). This appears to be an assumption for children, made because the value determined for BMR was 60 to 80% of TDEE for adults [Ravussin et al, 1982]. Only a few studies have been carried out to measure TDEE of children. They suggested physical activity actually formed a larger part of TDEE than for adults, 40 to 50% [Davies et al, 1991].

By its very nature physical activity (PA) is difficult to measure, especially in children. It can be expressed as a

Figure 1.2.1 The contribution of different tissues towards basal metabolic rate during growth.

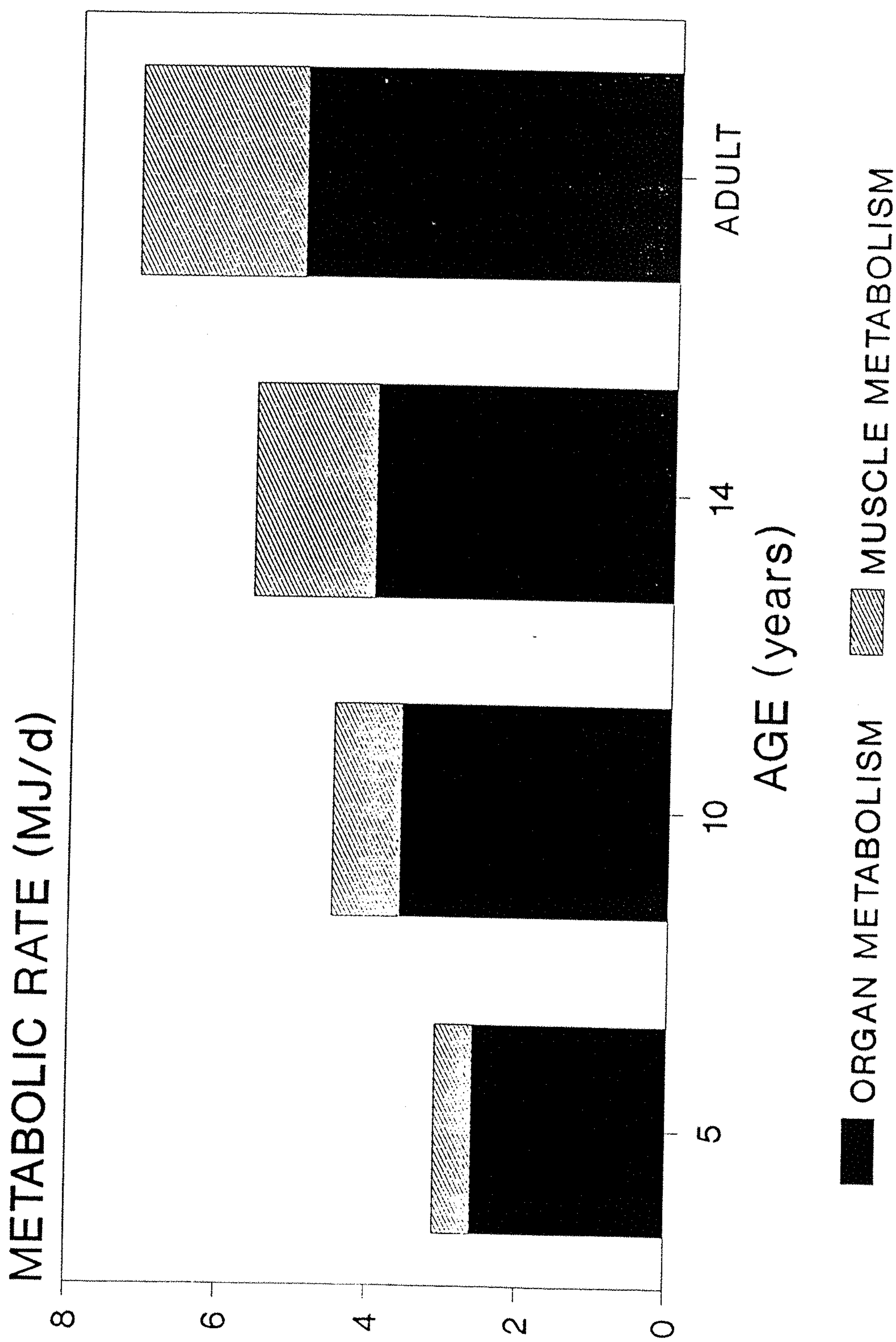
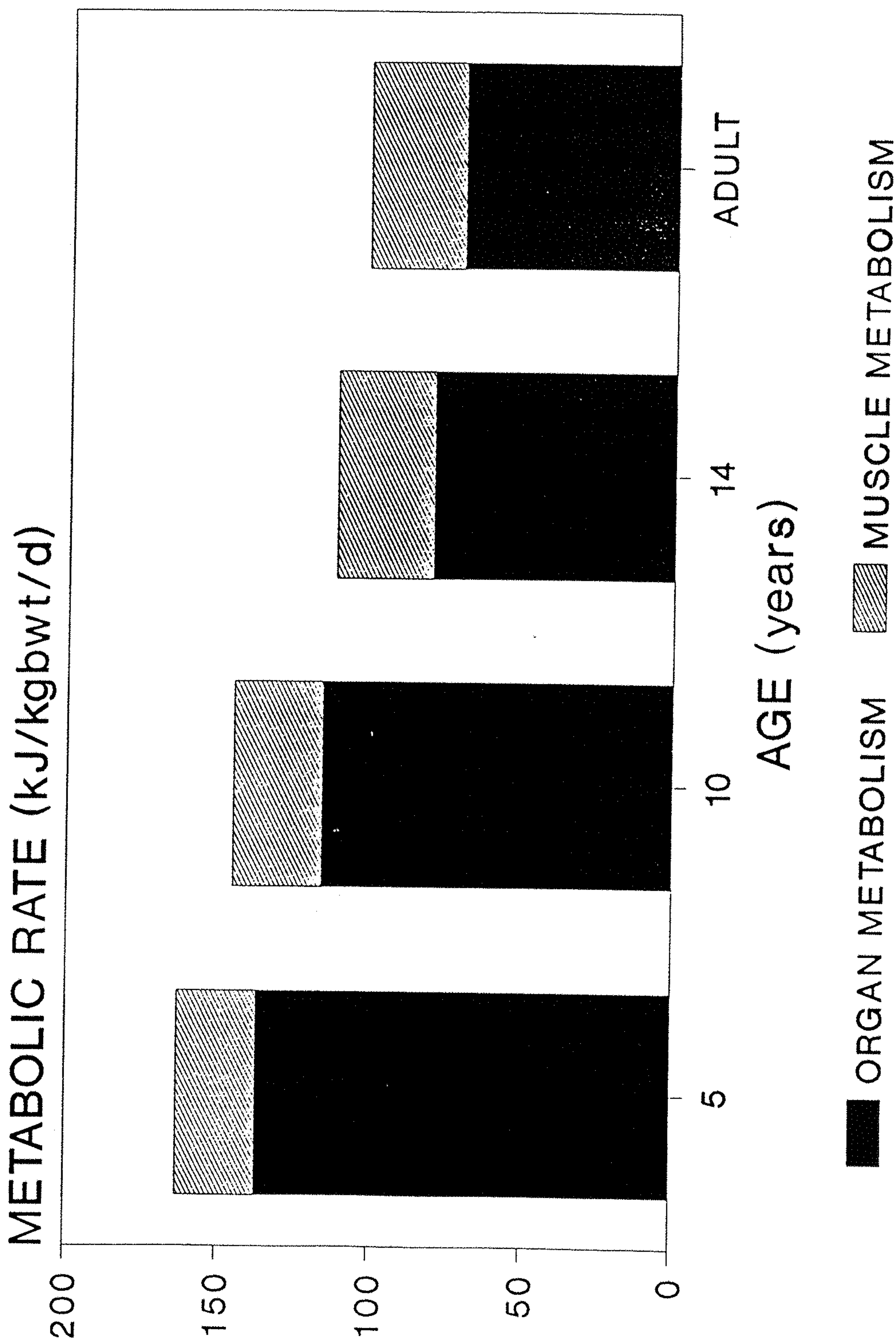


Figure 1.2.2 The contribution of different tissues, per kilogram body weight, towards basal metabolic rate during growth.



multiple of BMR, or a PA ratio:

eg energy cost of cycling = 5.5 x BMR
[James & Schofield, 1990]

Using oxygen consumption values for the energy cost of an activity plus recording time spent at the individual activity gives an estimate of energy expended [Bedale, 1923; James & Schofield, 1990]. James and Schofield [1990] have collated PA ratios for a variety of activities, but the major problem which becomes evident is how few of these relate directly to the energy expenditure of children. The validity of PA data increases substantially if both BMR and energy expenditure during activity are measured in children, rather than estimated from adult results [Torun, 1983]. The amount of PA children take part in is very important when considering how much energy they expend each day, and hence what their energy requirement will be. If relative contributions from BMR and PA towards TDEE are equal, or in different proportions in children compared with adults, there are important implications for long term health in the light of the suggested decline in PA in children [Whitehead, 1982].

Another component of total daily energy expenditure (TDEE) is dietary induced thermogenesis (DIT). This is the loss of metabolisable energy, as a result of digesting and absorbing food. This amounts to about 10% of TDEE [James & Schofield, 1990]. The traditional physiological approach to TDEE was to specify all three components - BMR, DIT and PA - with values in MJ/day. The simplified approach is to incorporate DIT into PA and express TDEE in terms of BMR [WHO, 1985].

1.2.2 Methodology.

Measuring energy expenditure can be carried out in three ways. The first two have been used and validated over the past hundred years - direct and indirect calorimetry. The third is a recent innovation made possible by increasingly sophisticated mass spectrometry - doubly labelled water. Of the components of TDEE, BMR is usually determined by indirect calorimetry, and physical activity by a combination of indirect calorimetry with diary records for time-motion analysis.

Having established energy was lost from the body as heat, and those losses had to be replaced, calorimeters were built to discover how much energy different people expended. These large devices were initially big enough just for a person to sit in, increasing in size to enable exercise performance, for example cycling on rollers or running on a treadmill [Kinney, 1988]. Two types were used, adiabatic and gradient layer calorimeters [Stock & Rothwell, 1982]. The former uses a water cooling system, the latter a temperature gradient. Both are expensive to run and restrictive in reflecting true values of TDEE, especially for children.

Indirect calorimetry determines energy expenditure through understanding that energy is liberated in the body by oxidation. A simple illustration is the oxidation of 1 mole of glucose:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

LIBERATING 21KJ ENERGY FOR
EVERY LITRE OF OXYGEN CONSUMED

The respiratory quotient (RQ) - carbon dioxide produced divided by oxygen consumed - in this case would be one. If this process was repeated, but with fat or protein, the RQ would be 0.7 (19.7kJ) or 0.8 (18.8kJ). It is important to know what mixture of substrate is being oxidised to calculate the energy generated by a reaction.

The RQ can be detrimentally affected by hyper- or hypoventilation, or acidosis and alkalosis, when carbon dioxide acts out its role as a buffer in the blood. RQ can also rise above one if high rates of fat synthesis are taking place. Some of these problems can be overcome if the equation below is used:

Heat production (energy expenditure in kJ) =
$$16.49\ O_2(\text{litres consumed}) + 4.63\ CO_2(\text{litres produced}) - 9.08\ UN(g)$$
UN=urinary nitrogen [Stock & Rothwell, 1982]

Weir [1949] demonstrated how respiratory gas exchange measurements could be used to calculate energy expenditure. He employed changes in percentage oxygen content between inspired and expired oxygen rather than volumes of oxygen consumed. Using constants derived for fat and carbohydrate oxidation gave a value for the RQ, which in turn enabled calculation of volume of oxygen consumed from percentage oxygen content of inspired and expired air. By assuming the proportion of energy production from protein metabolism was constant, which introduced minimal error, Weir's simplified equation was:

$$M = (1.046 - 0.050e)V$$
M = metabolic rate; Oe = oxygen percent in expired air
V = minute volume of expired air

This equation is used specifically for open circuit indirect calorimetry and has an accuracy to within 1% [Mansell & Macdonald, 1990]. Although values for fat and protein oxidation have since altered [Livesey & Elia, 1988], it makes little significant difference.

Many different types of indirect calorimetry apparatus have been invented for determining both BMR and physical activity, [McLean & Tobin, 1987]. Reliability and acceptability of these devices depends heavily upon the investigators making the measurements. Even children appeared able to cope with the cumbersome apparatus used in the 1920s for measuring energy expenditure:

"I have found that children between eight and twelve, wearing the Douglas apparatus, will carry on their affairs with a complete unconcern which is comparatively rare among adolescents and adults. It is necessary, of course, that the apparatus and operator should be familiar to them." [Bedale, 1923].

Present day techniques are similar; particular attention paid toward aesthetic qualities and acceptability of equipment for those being measured.

The doubly labelled water method uses isotopes of oxygen and hydrogen consumed by the subject, and their urine measured to detect the isotopes. This system depends upon carbon dioxide production not oxygen consumption. Its benefit is the ability to assess energy expenditure without inhibiting the individual's daily activity pattern. What it cannot do is determine what activities were carried out, how long for, and how often.

Validation studies have been carried out in adults, summarised by Coward et al [1985], implying although precision and accuracy may be questioned in laboratory studies, in free-living applications there are few alternatives to this method. The problems associated with the doubly labelled water technique include cost of isotope, cost of and technical ability with a highly sensitive mass spectrometer. Analytical errors concerned with possible sources of error include biological variation in isotopic enrichments, calculation of total body water, evaporation water loss and heat equivalent per mole of expired carbon dioxide on the basis of estimated respiratory quotient [Saris, 1986]. This method appears to have potential but remains at present to have limited use both in terms of cost and skills, and ability to answer questions relating to components of energy expenditure [Durnin, 1990; Jackson et al, 1991].

1.2.3 Standards.

Neither methods of assessing TDEE have provided sufficient data to be able to formulate standards of TDEE for children or adults. Conversely, thousands of measurements of BMR have been recorded. This has enabled several authors to produce standards.

"A Biometric Study of Basal Metabolism in Man" [Harris and Benedict, 1919] contains standards worked out from two equations devised to predict BMR.

$BMR = 66 + 13.8W + 5H - 6.8A$ (kcal/24hr)(males)

$BMR = 655 + 9.6W + 1.8H - 4.7A$ (kcal/24hr)(females)

where, W = weight (kg); H = height (cm); A = age (years)

These equations are still widely used to predict BMR. However, they were formed from mostly adult data, and extrapolated backwards when used for children. The lack of data was recognised as not only scientists became interested in BMR but clinicians also, with large numbers of children being measured [Talbot, 1921; Talbot, 1925; Talbot et al, 1935; Talbot; 1937; Talbot, 1938; Lewis et al, 1943].

The majority of publications were from North America , and it was not until 1952 Robertson and Reid published "Standards for the Basal Metabolism of Normal People in Britain". In their study they measured the BMR of 987 males and 1323 females aged between 3 and 80 years. Between 5 and 15 years there were 13-48 boys per year of age measured and, 13-41 girls per year of age measured. Means were given for each age, girls and boys separately.

They also produced a set of standards according to age, with mean, minimum and maximum values for BMR (see Table 1.2).

The most recent publication containing both predictive equations and standards for BMR, and using data collected from all over the world was the work of Schofield [1985]. This review was the most comprehensive work carried out on BMR measurements. The data gathered was checked for invalid results, and only used if collected with standard methodology.

Age last birth-day(yr)	MALES mean	Lower limit	Upper limit	FEMALES mean	Lower limit	Upper limit
5	56.3	47.7	65.0	53.0	44.9	61.1
6	54.2	45.6	62.8	51.8	43.6	59.9
7	52.1	43.4	60.7	50.2	42.1	58.3
8	50.1	41.4	58.7	48.4	40.2	56.5
9	48.2	39.6	56.7	46.4	38.2	54.5
10	46.6	38.6	54.4	44.3	36.3	52.5
11	45.1	37.7	52.2	42.4	35.1	50.6
12	43.8	36.8	50.4	40.6	34.0	47.7
13	42.7	36.0	49.3	39.1	33.2	45.1
14	41.8	35.2	48.4	37.8	32.6	42.7
15	41.0	34.4	47.6	36.8	32.2	41.7

Table 1.2 Expected Mean Heat Output and Limits of Variation(calories per square metre body-surface area per hour)Robertson and Reid [1952].

This gave information from 7549 individuals, 4937 males and 2616 females, between 0 and 60 plus years. Between 3 and 10 years there were measurements from 338 boys and 413 girls; and between 10 and 18 years there were 734 measurements on boys and 575 measurements from girls. The predictive equations were given with and without height included, because of its importance in relation to predicting BMR in the under three and over 60 age groups. Worldwide standards were therefore established for BMR, and could be used to estimate energy requirements for global populations.

Within the British document for energy requirements of the population [Department of Health, 1991] is included information regarding energy expenditure. For children aged 3 to 10 years insufficient information was available to base requirements upon energy expenditure. Children and adolescents from 10 to 18 years have energy requirements expressed as multiples of BMR, allowing for age, gender and body weight. The Schofield [1985] equations to predict BMR were used. Physical activity was estimated using physical activity ratios. Thus standards for not only BMR were suggested but also TDEE to assess energy requirements. For the younger age group energy intake remained the means to estimate energy requirement.

1.2.4 Summary.

Energy expenditure has been studied intently. In particular the importance of BMR as a major contributor, having greatest influence upon TDEE. Determining BMR for children has been practised both in health and disease. The former provided data from which predictive equations were developed. These can be used in circumstances where equipment for measuring BMR is not available. Standards for energy requirements in the United Kingdom still rely upon energy intake for children of 3 to 10 years, whilst 10 to 18 year olds have standards based upon energy expenditure.

1.3 GROWTH.

1.3.1 Definition of Growth.

Growth may be defined as an increase in form and function resulting from genetically determined physiological changes. Objectively characterizing those changes enables quantitative and qualitative study of growth. Changes in form include increases in stature, mass and weight; and altering body composition. An increase in function is the mental and physical development and refinement leading to increased ability to perform elaborate tasks eg hand/eye co-ordination.

To achieve increases in form, material must be available from which components can be drawn for synthesis and to fuel synthesis. There remains the constant metabolic demand for maintenance of existing tissue, requiring its own supply of substrate and co-factors. The more the existing tissue grows the greater the metabolic demand of maintenance.

Metabolic demand for substrate encompasses a complex array of systems operating at different levels. The cellular level contributes basic units for an overall increase in mass but some cells retain their ability to change in both size and number. Created from the accumulation of specific cells, organs operate on a higher level, enabling function of greater complexity than possible by individual cells. When a collection of organs work together as a system yet more can be achieved. An increase in organ capacity is still required to enable the system to reach its potential by the time growth ceases. The final level of growth is the collection of systems to form an overall living unit - the human body.

The minute changes at cellular level which accumulate and give rise to a general increase in form can be quantified by making measurements of height and weight. More specifically, the speed at which growth has taken place can be assessed by making repeated measurements of height and weight over a period of time. Each variable is used to describe a different dimension of growth. When increases in height cease, growth is said to have stopped. Weight can continue to increase, and decrease, even after maturity has been reached. The composition of increased weight is determined largely by an increase or decrease in physical activity or dietary intake, even before growth stops.

Abnormal growth may be caused by a variety of factors acting from within the body and from the external environment. If conditions are not suitable for growth, either potential body size will not be reached by maturity, or growth will cease until conditions are more favourable. Normal growth is indicative of nutritional needs being met.

Metabolic demand, growth and nutritional status are inextricably linked. Every living cell has a metabolic demand for substrate, which must be met before replication can take place. Substrate availability might reach only maintenance needs, insufficient to allow grow to occur. Increases in height and weight indicate substrate has been available. Comparing those increases with potential growth would illustrate whether substrate had been available in adequate amounts. Thus poor growth implies inadequate substrate and hence poor nutritional status; potential form, and perhaps function, may not be achieved.

1.3.2 The Metabolic Demand of Growth.

Metabolic demand for substrate and co-factors during growth is greater than required for tissue maintenance alone, although the energy requirement for growth is only an additional 5%.

As growth takes place there will be an increase in the energy content and metabolic demand of the body.

Accumulated body tissue will not be uniform in energy density; 35kJ of energy per gram of adipose tissue and 5.6kJ per gram of lean tissue [Jackson, Picou and Reeds, 1977].

During growth, visceral organ and skeletal muscle masses increase. By 5 years total cell mass is about 45% of body weight and does not increase any further [Holliday, 1986]. Muscle mass is estimated as 22% of body weight at 3 months rising to 35-40% at maturity. Organ mass only reaches 5.2% of body weight by maturity. The size of the visceral organs is closely related to stature. The increase in body tissue is predominantly muscle mass, followed by fat (15%), skeleton (15%), extracellular fluid (25%) and organ masses (5.2%) [Holliday, 1976].

1.3.3 Measuring Growth.

The simplest method of identifying increases in body form is by measuring weight and height. Repeated measurements over a period of time, using the same technique, show the pattern of growth and the speed at which it takes place. Abnormalities can also be detected when an individual's measurements are compared with standards eg height, weight and height velocity percentile charts [Tanner et al, 1966].

The largest groups of data upon which standards have been based were of 54,000 Dutch children [van Wieringen et al, 1971], 50,000 Cuban children [Jordan et al, 1975], and 21,000 American children [Hamill et al, 1977]. These were cross-sectional studies which recorded heights, weights, ages and gender revealing the distribution of heights and weights according to age for boys and girls. In a normally distributed reference population 95% of the group would be within two standard deviations of the mean either positive or negative. Measurements consistently above or below two standard deviations for height are signs of either acceleration or cessation of growth from normal.

Standards are used for rate of growth, having been developed from longitudinal studies [Tanner & Whitehouse, 1976]. Time period is critically important because of reliability and time of year at which the measurement was made. The smaller the time interval between measurements the greater the percentage contribution from measurement error. Measurements of less than six months interval are not usually regarded as reliable [Tanner, 1986]. Height growth is markedly slower in autumn and winter than in spring [Marshall, 1975]. Thus even six monthly measurements may be misleading because of the season in which they were made.

Determining changes in body composition during growth requires more complex measuring techniques than used to estimate height and weight. The basis of these techniques relies on an assumption that the body can be divided into fat and fat-free mass. A variety of methods now exist for determining body composition [Lukaski, 1987]. Several of these are contraindicated in children, for example the use of radioactive tracer elements in determining total body water. Skinfolds are a well established technique used to estimate body composition in children. This method is non-invasive, and has a precision of within 5% provided the investigator has appropriate training and experience [Lukaski, 1987]. This is of even greater importance if skinfold measurements are repeated to assess change in body composition during growth. Whichever method is used the investigator requires methodology and derived equations suitable for children, not those used for adults. The reliability of the present equations available for healthy children are questionable, based upon 13 children investigated for obesity and 10 for short stature [Brook, 1971], but are the only ones available for British children at the present time.

1.3.4 Growth as an Indicator of Nutritional Status.

The connection between nutrition and growth has long been recognised, and also that growth status can indicate nutritional status [Waterlow et al, 1977]. Although normal growth has been characterised, optimal growth is an area of some controversy [Durnin, 1984].

The two simple means of measuring growth - height and weight -have been used to describe an individual's nutritional status. Gomez used weight and age to describe mild, moderate and severe malnutrition [1956]. Cut off points of percentage weight for age described either adequate or poor nutrition. However, this classification excluded height as an outcome of growth. Misleading interpretations could arise if a child was the correct weight for age but stunted.

By comparison, Waterlow's classification of malnutrition included both weight and height measurements [1977]. The use of the two measurements overcame the problem of missing stunted children. There can be some idea of whether poor nutrition has been happening for a shorter or longer period of time, depending on the prevalence of stunting. In addition if percentage weight for height was determined there would be a further measure to confirm either wasting or obesity. The greater the degree of poor nutrition identified the more likely it is that substrate and co-factor requirements have not been met over a long period of time.

In disease conditions there will be a variety of causes for raised substrate and co-factor requirements. Infection, surgery, maldigestion and malabsorption will specifically raise energy requirements. In some conditions, for example Cystic Fibrosis, there is a recognised disruption of gastrointestinal function, with implications for altered substrate and co-factor requirements. In other conditions, for example Cancer, both long term treatment and disease may alter nutritional status. In both cases energy required for tissue synthesis is diverted to other uses or simply not available in the quantity required for normal growth.

When growth is halted or interrupted for a period of time regaining the position previously held on a centile chart may not be possible. Two possibilities exist for delayed growth. The first example is a child deficient in growth hormone, whose height remains the same despite age increasing. Energy intake is sufficient but there is no hormonal guide to channel energy into growth. The second example is a child whose energy intake is inadequate to meet its needs, and one of the body's responses is cessation of growth. Replacing the missing links - growth hormone and food - will enable growth to continue, but catch-up growth will only take place if substrate is available for accelerated growth. This process has been described by Prader [1963] and Jackson and Wootton [1990].

1.3.5 Summary.

Growth can be characterised and measured. Specific substrate requirements are dictated by the nature and function of particular tissues. If requirements are not met growth will not take place. Measuring growth may therefore be used to indicate nutritional status. Disease, famine or hormonal stress may induce growth cessation. Overcoming these problems, plus bountiful substrate availability, can allow catch-up growth.

1.4 ENERGY INTAKE IN CHILDREN.

Energy requirements must be met by the dietary intake, hence one of the basic necessities of life is food. The energy required is derived from nutrients in the foods consumed in the daily diet. Although the body is able to store energy, it is a limited store which needs regular replenishing from the diet. Two questions arise, what do children need to eat in order to satisfy their energy requirements, and what do children actually consume ?

1.4.1 British Children's Energy Intakes.

The first major work carried out to examine what children were eating in the United Kingdom was published in 1947. Widdowson compiled information from children between the ages of 1 to 18 years, recording their individual dietary intakes from weighed records of food. She succeeded in accumulating information from over 1000 children, a minimum of 20 boys and 20 girls in each age group. In addition, each child's height and weight was measured. She was able to describe the positive correlations between energy intake and weight, and height in this cross-sectional study.

Despite changing lifestyles and the increase in prevalence of childhood obesity this study has not been repeated. Other studies have gathered similar information but grouped children into age bands or not included anthropometric information (Table 1.4).

Durnin and colleagues [1974] (Table 1.4) attempted a comparison of energy intake over time. They studied a group of 14 year old girls and boys and repeated the measurements seven years later, on another group of the same age. They concludedfrom their data that energy intakes in this age group had decreased, over seven years.

The work by Durnin et al [1974] agreed with a trend of decreasing energy intake since Widdowson's study in 1947. This apparent reduction in energy intake was summarised by Whitehead et al [1982]. Data was reviewed over the age range of one to eighteen years, showing a world wide decline in energy intake despite body weight remaining very similar over the same time period, 1930 - 1955.

Table 1.4 Studies of Energy Intake.

SOURCE	NUMBER	GENDER	AGE (YRS)	MEAN ENERGY INTAKE (kJ/d)	MEAN ENERGY INTAKE (kJ/kg bwt/d)
COOK ET AL (1944)	39	MALE	14-15	9158	NA
WIDDOWSON (1947)	28	MALE	5-6	7240	351
	24		6-7	8109	376
	21		7-8	9104	368
	23		8-9	9071	357
	21		9-10	10212	337
	25		10-11	10454	335
	27		11-12	10538	300
	22		12-13	10993	293
	21		13-14	11520	255
	36		14-15	12812	259
	22		15-16	14379	267
	20	FEMALE	5-6	7139	357
	25		6-7	8297	370
	22		7-8	8339	354
	20		8-9	8719	316
	20		9-10	9050	313
	27		10-11	9802	322
	30		11-12	9581	263
	31		12-13	9907	259
	34		13-14	10467	241
	38		14-15	11023	217
	41		15-16	10818	207
COOK ET AL (1973)	198	MALE	8-11	9522	NA
	124		13-15	11583	
	190	FEMALE	8-11	8381	
	110		13-15	8640	
DARKE ET AL (1980)	92	MALE	14.5	11190	NA
	85	FEMALE	14.5	8640	
DARKE ET AL (1980)	390	MALE	14-15	10249	NA
	401	FEMALE	14-15	8001	

Table 1.4 Studies of Energy Intake cont.

SOURCE	NUMBER	GENDER	AGE (YRS)	MEAN ENERGY INTAKE (kJ/d)	MEAN ENERGY INTAKE (kJ/kg bwt/d)
DURNIN ET AL (1974)	102 90 198 221	MALES FEMALES MALES FEMALES	14.5 14.5 14.7 14.7	11691 9501 10918 8452	229 184 215 167
DURNIN (1984)	93 110 102 125	MALES FEMALES MALES FEMALES	5-6 5-6 10-11 10-11	6918 6111 8498 7800	346 321 250 236
DHSS (1989)	902 821 513 461	MALES FEMALES MALES FEMALES	10-11 10-11 14-15 14-15	8669 7691 10400 7850	272 233 200 148
BLACK ET AL (1976)	26	MALES+ FEMALES	5	6742	NA
HACKETT ET AL (1984)	193 212	MALES FEMALES	11.5 11.5	8899 8101	
MCNEILL ET AL (1991)	18 43	MALES FEMALES	12 12	8962 8138	NA
LIVING-STONE ET AL (1991)	12 12 12 12	MALES+ FEMALES	7 9 12 15	8189 8452 9359 9079	NA
ROBSON ET AL (1991)	251 258 252 254	MALES FEMALES MALES FEMALES	12 12 15 15	11600 9601 13501 9501	NA

NELSON ET AL (1985)	8	MALES	5	7298	NA
	4		6	6650	
	3		7	9760	
	4		8	8201	
	8		9	9142	
	8		10	8481	
	4		11	8381	
	3		12	9171	
	4		13	10801	
	7		14	9790	
	3		15	10270	
	8	FEMALES	5	6040	
	8		6	6550	
	3		7	6579	
	5		8	7420	
	5		9	7842	
	10		10	7700	
	8		11	8941	
	4		12	8598	
	4		13	8481	
	3		14	10509	
	4		15	9660	

Table 1.4 Studies of Energy Intake cont.

Sixteen studies of varying dietary methodology were included, eight of which were conducted outside the United Kingdom. The possibility of varying social and economic status affecting food consumption across countries arose, but the authors stated all countries were industrialised nations. The same problem existed for studies from the United Kingdom, although a description of socio-economic group was included for comparison. The authors' explanation for this downward trend in energy intake, despite lack of change in body weight for age, included the possibility of children's leisure physical activity decreasing.

Other more recent studies [DHSS 1989] undertaken for use in policy making still did not repeat the comprehensive Widdowson study. This despite recognition that studies of food consumption and energy intake were important means were structured. Agricultural targets, school meals, and institutional catering all require information regarding energy requirements for children. Provision of food and financial aid for food also require estimates for adequate provision. When drawing up guidelines for energy requirements all these different avenues could be considered. Attention has also to be paid to child health, whether requirements are for children growing normally, or for those with catch-up growth, or a chronic disease. All possibilities need some basic standard from which to initiate calculations of energy needs, and how much should be recommended to meet those needs.

1.4.2 Methodology.

The amount of food consumed and the nature of its chemical composition are two major components which determine a person's energy intake. In particular the aim of any dietary investigation is to discover what is being habitually eaten [Widdowson, 1947]. A variety of methods have been developed to quantify and qualify the diet of both individuals and groups.

Three important reviews of dietary assessment methodology have been published. These drew together information from which it was possible to select a method most appropriate for the individuals being studied [Pekkarinen, 1970; Marr, 1971; Bingham, 1987]. Bingham [1987] discussed methodology employed, most recent techniques and made recommendations, having established that estimating dietary intake is an essential tool for nutritionists. Measuring the diet requires some degree of skill, and she named nine sources of error which are associated with measurement; food tables, coding errors, wrong weights of food, reporting error, variation with time, frequency of consumption, change in diet, response bias and sampling bias. For the 24-hour recall method, daily variation appeared to be a dominant factor, rather than variation from week to week. The weighed record seemed preferable in terms of accuracy, being sufficient to assess energy intake for an individual with an acceptable degree of precision. During these measurements Bingham emphasised the need for easily understood instructions and avoidance of disrupting normal activities.

Problems associated with accuracy in dietary records were further investigated by Livingstone et al [1990]. They concluded from 31 free living adults (16 mean and 15 women) there was serious bias towards under-reporting of habitual energy intake. They warned of lack of validity of low food intakes. Precision, validity and reproducibility are all demanded for scientific acceptance. When analysing reported dietary intakes these three components must be considered within the nature and limitations of the study.

In the United Kingdom much time has been devoted to food analysis, and how well the body is able to extract nutrients it needs from food consumed. McCance and Widdowson summarised the available literature in 1960. Four subsequent editions of 'The Composition of Foods', latterly edited by Holland, Welch, Unwin, Buss, Paul, and Southgate [1991], have continued to update the number of foods included and implemented new food analysis techniques.

Figures used in 'The Composition of Foods' tables for energy content of foods were based upon chemical analysis of several samples, to allow for a degree of variation between brands and time of year. These British food tables [Holland et al, 1991] multiplied protein, lipid, carbohydrate and alcohol content of foods by energy conversion factors to determine a food's metabolisable energy value [Paul & Southgate, 1978]. The energy conversion factors (modified Atwater factors) derived for protein, fat, carbohydrate and alcohol are 17kJ/g (7kcal), 37kJ/g (9kcal), 16kJ/g (3.75kcal) and 17kJ/g (7kcal). Analysis of foods would give an estimate of quantity of protein, fat and carbohydrate which could then be translated into energy. These factors have been assumed to take into account urinary and faecal energy losses. Research into the validity of these figures continues because of difficulties associated with determining energy availability from foods, in particular with high levels of non-starch polysaccarides [Department of Health, 1991].

Few studies have been carried out looking at faecal energy losses in children. Recent work by Murphy et al [1991] studying a group of 20 healthy children showed an estimated mean faecal energy loss of 3.5%. This was in comparison with Southgate and Durnin [1970], whose mean estimated faecal energy loss in adults was between 3 and 5%. The only other studies which considered faecal energy losses in healthy children were Holt and Fales [1921] and Wang, Kaucher, Wing [1936]. Holt and Fales [1921] concluded about 10% of energy intake was lost in faeces, for all ages after infancy. Both urinary and faecal energy losses were measured by Wang et al [1936], the combined energy loss being 10% of energy intake.

1.4.3 Recommendations for Children's Energy Intake.
Hegstead [1975] argued there were two primary uses for dietary recommendations. For designing, and evaluation of diets. He felt both these activities could not be met by one set of recommendations. This view was echoed by Wretlind [1982] and Truswell [1983]. The former noted Denmark was the only nation at that time which had instituted publication of two sets of recommendations for the two uses suggested above.

When considering the term "energy recommendation" clarification is necessary to understand who the recommendation is being made for, and what framework the recommendation will be used in. It expresses a sense of authority rather than impartiality. Having a choice is seen as being an important feature where food is concerned [British Nutrition Foundation, 1990]. The document entitled Recommended Daily Amounts [Department of Health, 1979] appeared to dictate energy consumption for the population. The data upon which those standards were based was drawn from records of energy intake, according to age and sex. It was in line with comments made by Widdowson [1947], 'over a reasonable period of time and among healthy people, calorie intakes are a measure of calorie requirements provided there is no restriction on the total amount of food.'

However, in 1950 and subsequent FAO Committees on Calorie Requirements it was stated that 'as far as possible, energy requirements should be determined from estimates of energy expenditure.' The latest report in 1985 established the use of multiples of Basal Metabolic Rate (BMR) to calculate total energy expenditure and hence estimate energy requirements.

The United Kingdom has altered its reasons for providing documentation regarding energy recommendations since the 1979 recommendations. The newest government document took into account the positive association with choice, using "reference" rather than recommendation. The Dietary Reference Values for Food Energy and Nutrients for the United Kingdom [Department of Health, 1991] stated DRVs were for:

1) assessing diets of individuals,
2) assessing diets of groups of individuals,
3) prescribing diets or provision of food supplies,
4) labelling purposes.

Included within the report were Estimated Average

Requirements (EAR) for energy. These were clearly described as being mean requirements, 2 standard deviations above and below remaining an adequate level of intake to allow for inter-individual variability in requirements. Energy expenditure data was used to calculate an individual's requirement for energy, in particular basal metabolic rate. Body size was taken into account by including height and weight standards, and BMR prediction equations using weight. It highlighted the deficit of information regarding energy requirements for children under 10 years.

There is now a shift in answers to the two questions posed earlier. Energy intake needs to be determined to find out what children are actually consuming but they do not necessarily reflect what children require. In 1947 one of Widdowson's comments was there appeared to be 'wide individual variations in caloric intake which were compatible with good health and average physical development.' She found in each age group one child who ate about 100% more than another; and one 16 year old appeared to consume less than a one year old. This was despite having accounted for sex, age, bodyweight, height and body surface area. Harries et al [1962] also looked at variation in intake and expenditure of energy in several studies of large groups of children. They suggested for expenditure, coefficient of variation lay between 10 and 20% of the mean value: and for intake, coefficient of variation was between 8 and 32%. Despite taking into account known causes of variation eg age, weight, height, there remained unexplained differences, though less for expenditure than intake.

Recognition of large variation in energy requirements, emphasised by variation in energy intake, has led to difficulty in interpreting dietary intake information. Variability was discussed by two authors to try and understand its sources and effects upon recommendations [Beaton, 1984; Payne, 1984]. Beaton [1984] recommended a probability approach to dietary assessment, based upon assumptions about expected distribution of requirements. Alternatively Payne [1984] implied reliance upon individual intake data for making precise and authoritative statements about requirements was not justified. Neither author was able to make more conclusive statements upon the subject than previously suggested by Harries and colleagues [1962]. Genetic and environmental effects upon energy intake could give rise to variability but why and how remain unclear.

There are also social and behavioral differences which may account for some variability in energy intake data. Cultural and religious periods of fasting could affect energy intake, although children are one of the groups often excused. These types of influence upon energy intake need to be considered when making decisions about energy recommendations [Durnin et al, 1974; Wachs, 1990; Super, 1990].

Making recommendations for energy requirements appears to need clear definition and purpose. Are energy intakes the same as energy requirements, and if not what does a record of dietary intake illustrate ? Also, for what purpose are energy intakes measured and how and who will use any recommendations drawn up from them ? One use which recommendations were mistakenly employed for were in assessing and prescribing diets for children who are unwell. When both intake and expenditure may be altered recommendations for the healthy population might be inappropriate.

1.4.4 Summary.

Collecting information about what and how much healthy children eat is essential even though energy intake will not necessarily reveal energy requirements. Instead, a picture of the range of intake children consume and remain healthy and grow normally becomes apparent. To verify this requires that height and weight are always measured in tandem with dietary intake. It is especially important in a disease state or poor growth.

1.5 ENERGY INTAKE AND EXPENDITURE IN DISEASE.

Symptoms of disease include weight loss, infection and cachexia. These are often associated with altered dietary behaviour. Either disease or its treatment could modify energy availability, energy expenditure and possibly energy requirement.

1.5.1 Energy Requirements for Disease States.

During ill health the disease process commonly includes a period of infection, resulting in raised metabolic demand for energy. Bed-rest is also common during illness and convalescence, reducing time spent being physically active. Raised basal metabolic rate (BMR) plus reduced physical activity (PA) could appreciably cancel out the effect of each other upon total daily energy expenditure (TDEE), which would therefore remain unchanged. It is possible energy requirements in disease are equivalent to those in health, but redistributed under the umbrella of TDEE. Therefore recommendations for energy intake would be the same in health and disease.

In children, as well as the energy required for BMR and PA, energy is required for growth. The energy requirement for children may be raised during disease and convalescence, or alternatively, normal requirements for health may not be met. This could be represented as a rise in TDEE or a decline in energy intake in the energy balance equation.

1.5.2 Acute Illness.

When disease is acute it usually takes place over a short period of time, but is a heavy insult. The child suffering in this way is likely to return to energy balance relatively quickly during recovery. However, younger children with poorer nutritional status prior to becoming ill will suffer more and for longer than previously well nourished children.

Bouts of acute illness may only delay growth, providing the child returns to full health. Recommendations for energy requirements set for healthy children may be sufficient to meet energy needs during short periods of illness in a normally growing child. If the short period of illness was repeated, with insufficient time to recover delayed growth, metabolic demand for energy to recover growth loss would be greater than recommended for healthy children. The condition itself may subsequently be termed chronic because ability to recover was weakened by increased susceptibility to infection.

1.5.3 Chronic Illness.

Serious consequences may arise when acute illness occurs in the midst of an ongoing chronic disease state. Cystic Fibrosis (CF) is a genetically inherited disease which affects a child from birth. The combination of gastrointestinal and respiratory weaknesses, as a result of faulty mucous secretions, ensure CF children are more susceptible to infections and less able to utilize food consumed for metabolizable energy. Parsons [1985] and Hubbard [1982] both recommended figures of between 100-150% of the recommended energy intake for healthy children, for children with CF, to allow normal growth to occur.

Amongst other chronic diseases it has been recognised energy requirements may be altered because of treatment rather than disease itself. Any recommendations suggested must take both into account. In individuals with Cancer it is possible malignancy could alter energy metabolism itself [Young, 1977]. This disruption of normal metabolism would be likely to affect growth [Mauer, 1990]. Arnold et al [1983] concluded from their work with children with chronic renal insufficiency, those consuming less than 75% of recommendations for energy intake for healthy children did not grow. The use of energy supplements led to increased energy intake and growth rate in those children.

1.5.4 Energy Expenditure and Disease.

Infection with fever will raise an individual's BMR. It is also recognised bed rest is associated with fever and infection. BMR was raised and PA lowered, TDEE remained unchanged. One study which investigated these components concluded despite raised BMR, children with CF had similar TDEE to healthy controls [Spicher et al, 1991].

If TDEE was not raised ensuring the individual was not overfed would be more important than underfeeding. Intake of more energy and nutrients than required by metabolic demand would result in raised energy expenditure to cope with digesting and absorbing the extra food. The energy required for these processes may not be readily available, producing an added demand for energy in addition to the stress of an infection.

BMR has been estimated in several different disease conditions. Harris and Benedict [1919] measured diabetics between 14 and 57 years of age, but emphasised the need to measure a large group before drawing any conclusions about the effect of disease upon BMR. Other diseases where BMR of children has been measured recently include measles [Duggan, 1986], diabetes [Muller et al, 1989], leukaemia [Kien & Camitta, 1987; Stallings et al, 1989], and cystic fibrosis [Vaisman et al, 1987; Shepherd et al, 1988; Buchdahl et al, 1988; Pencharz et al, 1988]. Overall these studies suggested BMR of some children with these diseases will be raised. In addition, some drug treatments associated with disease might also raise BMR. Salbutamol, Growth hormone and thyroxine have all been suggested as coming into this category [Vaisman et al, 1987; Bray & Atkinson, 1977].

1.5.5 Energy Intake and Disease.

Literature available centres around diseases which have greatest impact upon growth. The general assumption made is under the impact of disease a child would require a greater energy intake than when in good health. Why should that be ?

Two areas require consideration: appetite, food presentation and availability; and degree of digestion and absorption of nutrients. Firstly both treatment and disease state may cause cachexia [Calman, 1982]. If attention is not paid to skilful food presentation then cachexia could persist for a greater period of time than necessary. In addition changing taste preferences are recognised side effects of some diseases. As soon as appetite returns, energy intake may rise above that of a healthy child to accommodate the period of reduced intake and allow catch-up growth to take place.

The second area which could cause altered energy intake is after food has been ingested. Uptake and utilization of nutrients by the intestine are altered in some disease states eg Cystic Fibrosis, and during treatment in others eg Cancer. This suggests it is not a question of ensuring food is consumed but increasing intake. Actually available metabolizable energy in a disease state would not be the same as that in health. A greater food intake would be necessary to overcome maldigestion and malabsorption.

Several papers have been published looking specifically at these two conditions in childhood. Energy intakes of children with CF have been recorded as 80 [Dodge & Yassa, 1980] to 150% [Hubbard & Mangrum, 1982] of recommendations for healthy children. The variation in figures agrees with those for healthy children growing normally, whose variation in energy intake is substantial [Hubbard, 1985]. In comparative terms Daniels et al [1987] matched CF children (n=40) with healthy children (n=79) for age, receiving a 3 day weighed dietary intake from the 119 children. Results revealed only the under 5 years group consumed significantly more energy with respect to recommended intakes for healthy children. The CF children (aged 0.7 to 23 years) consumed between 92 and 120% of recommendations in comparison with their controls (aged 4.4 to 14.4 years), whose range was 82 to 96%.

When energy intakes were expressed per kilogram of body weight all CF age groups were consuming significantly more energy than their controls, and as one group the CF children's energy intake was 140% of their control group. Similar findings were made by Ellis and Wootton [1989]. It appears to be of paramount importance to establish children's energy intakes with respect to body size in addition to age and gender.

Although an increase in energy intake may seem necessary to overcome raised energy losses, or raised energy requirements in disease, inevitably consumption of higher intakes depends upon whether the child can cope with the raised bulk and energy density of the diet [WHO, 1985].

1.5.6 Summary.

Diseases in children are associated with poor appetite, often the first sign of ill health. In acute illness rise in BMR may be temporary and offset by a period of reduced PA. Overall TDEE would not change and requirement for energy would be the same as during health. In chronic disease states there is evidence of altered BMR in some children even when relatively well. This, coupled with raised energy losses and poor appetite, suggest a need to consider both BMR and intake of energy simultaneously in children with disease.

1.6 CONCLUSIONS.

In the light of the preceding review of literature is it possible to make recommendations for energy intake in children with confidence ? The following conclusions may be drawn :

* Attempts have been made to estimate the metabolic demand of energy at rest and energy intake in healthy children. It is rare to find both measurements from the same individual, with information on body size and composition.

* Energy expenditure data particularly from children aged 5 to 10 years is limited. Thus little is known about relationships between age, gender, body size, composition and metabolic demand with simultaneous energy intake in healthy children.

* The variance in both intake and expenditure of energy in healthy children has not been investigated where both measurements are available from the same child.

* Research into disease has concentrated upon either energy intake or metabolic demand for energy but it is unclear whether these two components, within the same individual, differ from healthy children.

1.7 AIMS OF RESEARCH.

The principle aim of this project was to investigate the relationship between the metabolic demand for energy at rest, and the energy intake from the diet, in healthy children of normal growth and in children with disease. This information could then be considered alongside the present recommendations for energy intake in children. This project addressed the following points.

1) What is the ratio of reported energy intake to basal metabolic rate in healthy children ?

2) What are the determinants of metabolic demand for energy at rest and reported energy intake in terms of age, body size and composition in healthy children ?

3) What is the variance in metabolic demand for energy at rest and reported energy intake in the same children ?

4) How does disease alter metabolic demand and energy intake in the same group of children, expressed by the ratio energy intake/basal metabolic rate ?

CHAPTER 2. METHODS.

This chapter is divided into four sections. The first deals with the children who took part in the three studies, where they came from and what protocols they followed. Secondly the anthropometry and body composition techniques are described, why they were chosen, and what equipment was used. The dietary intake method to estimate energy intake is the third section. Finally, basal metabolic rate measurement is explained, equipment used, and the validity and reliability of measurements.

2.1 SUBJECTS.

All the healthy children who took part in these studies were contacted through local schools in Southampton and Romsey. The first school contact was made through a cousin who was a teacher at a primary school in Romsey. A formal interview with the headteacher followed, during which the nature of the study was outlined and verbal consent was given to contact parents. This was achieved through a letter distributed to all children in the school. Five other schools - one primary, three secondary, and one all ages - were contacted either through suggestion of a parent, or a member of staff. Each headteacher either gave written consent, or verbal consent during an interview, to parental contact being made through a letter given to pupils. There were in addition children of members of university and hospital staff, child-minder groups, and bothers and sisters of all the aforementioned.

All parents received a letter explaining why the study was being carried out and what measurements would be undertaken. Written consent was received from parents of children contacted through a school, and verbal consent from all the rest. Great care was taken to ensure each child was informed of the measurements which would be undertaken.

Racially, the children were predominantly white and caucasian. The only exceptions were a brother and sister whose parents were Afro-Caribbean from Jamaica; and two brothers whose father was Iranian and mother Caucasian. No attempt was made to influence children of different race or background to decline from participation in the studies. The lack of racial mix appeared to be characteristic of this county of Hampshire and the particular schools approached.

The children with Cystic Fibrosis (CF) all belonged to Southampton General Hospital CF clinic. The majority of children were fully cared for by the clinic, the remainder attended on a shared care basis. Each child underwent an annual checkup, their MOT, into which the basal metabolic rate and dietary intake measurements were incorporated. Consent was given by the senior clinician who supervised CF care at this hospital, and verbal consent was given by parents.

The chemotherapy treated children were part of the paediatric oncology clinic at Southampton General Hospital. They were all receiving monthly cycles of drug treatment. They were measured within the cycle, all in the same week of their own cycle; this was the week prior to administration of steroids. The senior clinician gave her permission for all the children to participate, and verbal consent was given by parents.

2.2 ANTHROPOMETRY AND BODY COMPOSITION.

Weight and height were both measured using equipment regularly validated. The former was a balance personal weighing scale reading to 100g; the latter was a wall mounted stadiometer reading to 1mm. A second portable tool was also used to measure height when the stadiometer was not available ;the minimetre was validated using a standard metre rule. When the balance scale was not available a portable balance scale, validated with a standard kilogram weight, was used.

Skinfolds were measured at four sites on each child - biceps, triceps, subscapular and suprailiac as described by Lukaski [1987] and Cameron [1986]. The measurements were made with Holtain callipers, after the design recommended and validated by Edwards et al [1955], and a steel tape measure. Training using adult volunteers was performed before measuring the children in the study.

Equations devised by Brook [1971] (1-11 years), and Durnin and Rahaman [1967] (12-16 years) were used to calculate body density. At the time of the studies these were the only equations available for British children. Their adequacy is questionable because the Brook [1971] equations were based upon data collected from children being investigated for obesity and short stature (total number 23); and the Durnin and Rahaman [1967] equations although derived from a larger nonclinical group of children, still consisted of only 48 boys (12 to 15 years) and 38 girls (13 to 16 years).

Siri's equation [1956] was used to calculate percentage body fat, and lean body mass was determined using body weight. All these measures were based on the assumption a child reaches chemical maturity at around four years of age, and constants developed for adults can be applied to children using the two component system (fat and fat-free body) established by Siri [1956]. Lohman [1986] provided evidence for the need to replace Siri's constants with age- and sex-appropriate values for children. The skinfold method of estimating body fat was readily accessible, and appeared to be appropriate for not only healthy children but also those with disease. Alternative methods, such as bioelectrical impedance, have been deemed inappropriate in clinical situations [Roubenoff et al, 1991] because of possible variation in state of hydration.

2.2.1 Reproducibility and Validity.

Although the use of skinfold callipers is advocated in larger studies, the degree of confidence in the results must take into account several issues. These were summed up by Lohman et al [1986] - the pubertal mixture of children upon which the equations were based; the bias of regression equations depending upon the technique used for data collection; the lack of cross-validation of regression equations; and variation in selection of sites and measurement procedures for skinfolds. Therefore in these studies the degree of error associated with skinfold measurements, and its affect upon the estimate of lean body mass were considered. Repeated measures were carried out on four children (two boys and two girls) to study the reproducibility of the measurements and of calculated lean body mass (LBM).

Each child was measured on four occasions using the same pair of callipers. Percentage body fat values ranged from: 8.8 to 10.2%; 10.9 to 12.1%; 23.3 to 26.0%; 26.6 to 27.4%. This led to differences in LBM of: 22.2 to 22.99kg; 21.7 to 21.9kg; 26.9 to 27.5kg; 25.1 to 25.8kg. Thus for the child with the largest difference in percentage body fat (14%), the actual difference in LBM was only 0.8 kg. The difference between the four sum of four skinfolds which gave rise to this difference in LBM was 5.8mm. This shows the degree with which skinfold measurements can alter yet still produce LBM values differing by less than one kilogram.

Within the framework of the technique used to assess LBM reproducibility was demonstrated by these repeated measurements. No other technique was available to validate the LBM determinations, but comparisons were made with groups of children from other studies in chapter three which showed similar results using similar standardised methods.

2.3 DIETARY ASSESSMENT.

The methodologies associated with measurement of dietary intake have been reviewed in depth [Pekkarinen, 1970; Marr, 1971; Bingham, 1987]. The weighed inventory method was deemed most suitable for the present studies. Validity and variability associated with this method were discussed by Marr [1971] and Bingham [1987]. A seven day period was used for weighing all food and drink. This length of time was shown to be adequate to estimate metabolisable energy in children by Bingham [1987], Nelson et al [1989] and Miller et al [1991].

A food diary and digital kitchen scales were provided for each child. The food diary was a notebook with typed instructions inserted, and pages ruled to indicate time when food eaten, description of food consumed, its weight and food code.

The scales were battery operated (6*1.5V); either Soehnle with a 1000g capacity, measuring in 1g divisions over the first 64g and 2g divisions over the remainder; or Hanson with a maximum weight of 2000g with 1g resolution. Both types of scale possessed a tare facility. The child and one or both parents received a full explanation and demonstration of how to weigh and record food and drink consumed. Emphasis was placed on keeping the diary with the child at all times, and collecting wrappers from items for ease of identification. Both work and home telephone numbers were made available and the family encouraged to use them if any problems arose. When the seven day period was finished the diary was checked with the child and/or parent for accuracy and clarity.

Dietary assessment is recognised as a method fraught with difficulties. Livingstone et al [1990] and Schoeller [1990] both used studies of doubly labelled water compared against weighed and recorded intakes in adults to demonstrate the degree of error in the latter. In particular they suggested the expected day-to-day variations in dietary intake could not account for the differences between intake and expenditure of energy. It was noted by both authors that the prevalence of under-reporting was greatest in the obese. In the present studies special care was taken to ensure supervision and checking of dietary records.

Foods and drinks were coded using McCance and Widdowson Food Tables [Paul & Southgate, 1978] with additional supplements to the food tables [Tan et al, 1985; Holland et al, 1988; 1989]. Those foods which did not appear in the tables were assessed from labels and manufacturers' information. Analysis was performed using a computerised composition database [Microdiet, University of Salford]. It was assumed modified Attwater factors used to calculate metabolisable energy of the foods were satisfactory for the subjects measured.

2.3.1. Reproducibility and Validity.

The reliability of diary contents depends very much upon the motivation and attitude of the recorder. All the children in the studies were volunteers, and particularly the younger children received considerable support from one or both parents, even extended family members and friends, throughout the week of recording. The possibility of under- or overestimation seemed less likely in the younger children than the older children because of adult supervision. Incomplete records were not included in the study.

Ideally repeated dietary intakes and comparison with other methods would have been employed to validate the dietary intakes. The latter was not possible within the constraints of the present studies. Validation methods have been discussed further in the Energy Intake section of the review chapter. Improved techniques for determining and verifying energy intake in children are needed; in the meantime, reported energy intakes must be interpreted with caution.

2.4 INDIRECT CALORIMETRY.

The gas analysis system used to determine BMR for all the children was open circuit indirect calorimetry with a ventilated hood system. Conditions specified by Dubois [1936] for BMR were adhered to, rather than a resting measurement. Thermoneutral conditions were achieved by having the room at 20-22 degrees centigrade, with a fan heater to adjust the temperature when necessary. The children were asked to fast overnight and not eat breakfast before the test; 12 hours was specified on their pre-measurement instructions. Lack of movement and relaxation was emphasised, and helped by listening to a cassette on a Walkman during measurement.

The initial instrument for determining BMR was a respiratory mass spectrometer. Expired air and room air were pumped into the machine through capillary tubes. Air was sampled from each tube for 10 seconds, three times in a minute, alternating between each tube.

The whole system was described as a quadrupole mass spectrometer which included an SX200 control unit (VG), interfaced with an Apple II microcomputer using Spectralab software. Two 5*1/4 disc drives were used for the software. A larger VDU screen was installed in addition to that provided by VG. The system was connected to a printer which typed out results every minute.

The calibration procedure took approximately five minutes to complete. Temperature and Barometric pressure were entered from a wall hanging barometer. Gases used for calibrating the mass spectrometer were oxygen free nitrogen, and a span gas of 20% oxygen, 1% carbon dioxide and the remaining percentage made up of nitrogen. The system was calibrated at least once before each measurement was carried out.

The printout recorded inspired and expired gases, respiratory quotient (RQ), energy expenditure and flow rate. Mean energy expenditure was calculated from the number of measurements recorded over a period of 35 minutes.

A pump with a range of 5 to 80 litres per minute was used to pump air through the hood and allow sampling to take place. During measurements the pump operated between 40 and 50 litres per minute. The flow range could be controlled by a tap, depending on size of subject being measured. For example, a small five year old girl would require values of 35 litres per minute in comparison with a large 15 year old boy, requiring 45 litre per minute flow.

The hood was made of perspex with a sheet of heavy plastic attached at the front, to make it air tight. Between hood and pump a disposable filter (Pall Biomedical Ltd.) was fitted. The filter was used for infection control with a 99.999% bacterial/viral efficiency. In addition Hibispray was used in the hood after each subject had been measured.

The Deltatrac Metabolic Monitor (Datex) was used to determine energy expenditure when the original equipment was no longer viable. This self contained unit incorporated a mixing chamber, oxygen and carbon dioxide analyzers and a microcomputer with VDU screen. The unit was used in tandem with a Hewlett Packard Thinkjet printer. The principles of open circuit indirect calorimetry were followed, using a ventilated hood.

Gas and pressure calibration were carried out for each measurement. Barometric pressure was obtained from the wall hanging barometer and the calibration gas mixture was 95% oxygen and 5% carbon dioxide. A result was printed out each minute and the computer averaged energy expenditure values over the period of measurement. An artifact option allowed the first five minutes as settling time for subjects, and discounted these values from the final energy expenditure figure.

The equation both pieces of equipment employed for calculating energy expenditure was Weir's, also incorporating the Haldane transformation, stating the relationship between inspiratory and expiratory volumes.

2.4.1. Reproducibility and Validity.

If the BMR values were truly standardised then repeated measurements would not uniformly decline or increase. The coefficient of variation for the within measurement value would be expected to be small to reflect the stability of the measurement, the child resting throughout. These points were investigated with a sample of 10 children (five boys and five girls). BMR was measured in each child on the same day and time for four consecutive weeks. The results are shown in Table 2.1.

SUBJECTS	WEEK 1	WEEK 2	WEEK 3	WEEK 4
FEMALES: A (8yr)	5.3 (4.8)	5.0 (6.8)	5.0 (5.0)	5.0 (4.3)
B (9yr)	4.8 (7.0)	4.9 (4.1)	4.7 (2.8)	4.8 (4.8)
C (6yr)	4.8 (5.2)	4.8 (5.8)	5.0 (6.8)	4.7 (8.1)
D (7yr)	4.3 (4.2)	4.4 (4.8)	4.8 (5.9)	4.5 (6.3)
E (8yr)	5.0 (2.6)	5.0 (5.0)	5.2 (3.4)	5.1 (3.7)
MALES: A (8yr)	5.4 (6.9)	4.7 (6.7)	4.6 (4.3)	4.7 (4.3)
B (8yr)	4.8 (2.7)	4.6 (6.1)	4.7(12.6)	4.9 (4.2)
C (8yr)	5.1 (3.3)	5.1 (5.0)	5.1 (5.2)	5.2 (4.8)
D (6yr)	4.3 (2.8)	4.3 (3.8)	4.3 (2.7)	4.3 (4.2)
E(12yr)	6.0 (4.9)	6.1 (5.3)	6.3 (7.9)	6.6 (6.8)

Table 2.1 Repeated measurements of BMR (MJ/d) for ten children with percentage coefficient of variation on parenthesis.

The differences in BMR between the four weeks ranged from 4 to 10% for the girls and 0 and 15% for the boys. For each child the within measurement variation of one minute values over 30 minutes gave coefficients of variation (CV) ranging from 2.6 to 8.1% for the girls, and 2.7 and 12.6% for the boys. These were representative of the whole group of 148 children in the study whose CVs ranged from 2.6 to 15.2%. The pattern of values, as a group, showed no tendency toward a training effect: the CV neither fell continuously, nor rose continuously over four weeks of measurement.

Validity of both mass spectrometer and Deltatrac were checked by burning ethanol in a chamber for periods of 40 minutes to an hour, and comparing weight of ethanol burnt against energy expenditure calculated by the equipment. Values for the mass spectrometer ranged from plus or minus 10%; whilst values for the deltatrac ranged from plus or minus 6%.

When the two pieces of equipment were used to measure the same patient simultaneously the deltatrac appeared to be overestimating BMR by up to 23%, but having checked flow rates the overestimate was the result of connections between the two systems. When they were rectified the two systems measuring ethanol burning showed only a difference of 1% between them, the mass spectrometer having the higher value. Consistency of deltatrac measurements, and its reliability meant when the mass spectrometer became unavailable the deltatrac was used for 75% of the children measured. The system was checked regularly by Datex technical staff.

Ethics.

Ethical approval for these studies was provided by the Southampton Ethical Committee. All procedures were explained both to parents and their children, with telephone contact available throughout the study period.

Statistics.

All statistical analysis was carried out by computer software called SPSS. The data was contained within one file and accessed by the software to perform appropriate analysis. Correlation analysis was carried out to investigate relationships between variables; and the Student t-test was used when considering whether differences between variables were statistically significant. Regression analysis was performed to generate equations to examine the relationship between BMR and highly correlated variables.

CHAPTER 3. CHARACTERISING METABOLIC DEMAND FOR ENERGY AND ENERGY INTAKE IN A GROUP OF HEALTHY CHILDREN.

3.1 INTRODUCTION.

When energy intake and expenditure are determined in the same child it is possible to estimate to what extent demand could be satisfied by intake. This ratio of energy intake (EIN) to basal metabolic rate (BMR) could be used as a factor in calculating energy requirements. The method was suggested first by Wang and colleagues [1936]; its advantage was it took into account both size and shape of the child. No other studies have been conducted to investigate the potential of this method.

This chapter is devoted to observations of healthy children of normal growth. Measurements of EIN and BMR, anthropometry and body composition were collected from children between the ages of 5 and 15 years. The aims of the study were, to characterise BMR and energy intake; thus enabling calculation of the ratio of energy intake to BMR.

3.2 METHODS.

3.2.1 Subjects.

This study was part of an ongoing project investigating EIN and BMR of healthy children. In total, 63 girls and 85 boys between 5 and 15 years took part in this study. Parental consent was obtained for each child, as explained further in the methods chapter. The children were all in good health at the time of the study, and no medication was being taken. Any child who was subsequently found to be unwell during the measurement, eg raised temperature, was automatically excluded. The study was approved by Southampton Hospitals and South West Hampshire Health Authority Ethical Subcommittee.

3.2.2 Data Collection.

Each child was given an appointment for BMR measurement. They were advised to fast for 12 hours and arrived for measurement in the morning, between 7.00am and 8.30am. During BMR measurement the child listened to either a story or music tape on a Walkman. After anthropometric and body composition measurements were recorded the child and parent were instructed in how to keep a seven day weighed food diary. Each family was closely monitored and given support throughout the subsequent week of measurement. Upon return of the diary it was analyzed as described in the methods chapter.

3.2.3 Statistical Analysis.

All results were given as means (plus or minus standard error of the mean) with ranges. Computed variables included body mass index, EIN expressed per kilogram body weight and per kilogram lean body mass, BMR expressed per kilogram body weight and per kilogram lean body mass, and ratio of EIN to BMR. Correlation analysis was performed to investigate the strength of relationships between variables. Regression analysis was performed to determine the nature of that relationship, and to generate prediction equations for BMR.

Girls and boys were divided into two age groups - 5 to 10 years and 11 to 15 years. This produced groups approximating to prepuberty and during puberty, without actual pubertal ratings being available. Growth normality was assumed if height fell within plus or minus 2 standard deviation scores.

3.3 RESULTS.

3.3.1 Anthropometry and Body Composition.

Children aged 5 to 10 years.

The 34 boys had a mean age of 8.82 years. Their weights ranged from 19.0 to 38.1kg, and heights from 109.7 to 148.8cm. Mean percentage body fat (%BF) was 17%, mean lean body mass (LBM) was 24kg, and mean body mass index (BMI) was 16kg/m^2 (Table 3.1, p64).

There were 38 girls who had a mean age of 8.07 years. Their weight range was larger than the boys', 17.2 to 40.2kg; but height range was smaller, 108.2 to 142.5cm. Mean %BF was the same as the boys' at 17% and LBM 2kg lower at 22kg. Mean BMI was 16kg/m^2, the same as the boys' (Table 3.2, p65).

Children aged 11 to 15 years.

In this group 51 boys had a mean age of 14.31 years. Their weights ranged from 33.4 to 79.5kg; and heights from 142.3 to 179.0cm. Mean %BF was 18% and mean LBM was 44kg. BMI for the group was a mean of 20kg/m^2 (Table 3.1).

The smaller group of 25 girls had a mean age of 12.80 years. Their weights ranged from 31.2 to 70kg; and heights from 138.5 to 169.7cm. Mean %BF was 27%, and mean LBM was 35kg. Mean BMI was 20kg/m^2 (Table 3.2).

3.3.2 Basal Metabolic Rate.

Children aged 5 to 10 years.

The 34 boys had a mean BMR of 5.00 MJ/d; the 38 girls a mean BMR of 4.44 MJ/d. The values for BMR for boys and girls are presented in Tables 3.3 and 3.4. There was a tendency for the older children to have higher values than the younger ones, but there was often a wide range of values within each age group (Figure 3.1 and 3.2, p66 and 67).

Table 3.1 The characteristics of the boys divided into two age groups; 5 to 10 years (n = 34), and 11 to 15 years (n = 51). Values are means, with standard error of the mean (SEM) in parenthesis. The range of values is displayed below the mean and SEM. Height is also expressed as standard deviation scores (SDS).

VARIABLES	5 - 10 YEARS	11 - 15 YEARS
AGE (yr)	8.82 (0.28) 5.54 - 10.87	14.31 (0.16) 11.58 - 15.72
WEIGHT (kg)	28.9 (0.9) 19.0 - 38.1	53.5 (1.6) 33.4 - 79.5
WEIGHT CENTILE	62 (3) 17 - 90	53 (4) 1 - 100
HEIGHT (cm)	133.4 (1.6) 109.7 - 148.8	165.1 (1.1) 142.3 - 179.0
HEIGHT CENTILE	66 (4) 9 - 96	55 (4) 3 - 97
HEIGHT SDS	0.50 (0.13) (-1.32) - 1.77	0.08 (0.14) (-1.97) - 1.93
BODY FAT (%)	17 (1) 11 - 26	17 (1) 11 - 32
FAT FREE MASS (kg)	24 (1) 16 - 36	45 (1) 29 - 63
BODY MASS INDEX (kg/m^2)	16 (0.2) 13 - 18	20 (0.3) 15 - 25

Table 3.2 The characteristics of the girls divided into two groups by age, 5 to 10 years, (n = 38) and 11 to 15, (n = 25). Values are means, with standard error of the mean (SEM) in parenthesis. The range of values is displayed below the mean and SEM. Height is also expressed as a standard deviation score (SDS).

VARIABLES	5 - 10 YEARS	11 - 15 YEARS
AGE (yr)	8.07 (0.27) 5.00 - 10.8	12.80 (0.29) 11.04 - 15.39
WEIGHT (kg)	26.7 (0.8) 17.2 - 40.2	48.7 (2.1) 31.2 - 70.0
WEIGHT CENTILE	55 (4) 7 - 95	62 (6) 7 - 97
HEIGHT (cm)	128.0 (1.5) 108.2 - 142.5	154.2 (1.8) 138.5 - 169.7
HEIGHT CENTILE	66 (4) 6 - 97	56 (6) 3 - 97
HEIGHT SDS	0.50 (0.13) (-1.58) - 1.88	0.23 (0.21) (-1.96) - 1.87
BODY FAT (%)	17 (1) 5 - 33	27 (1) 16 - 40
FAT FREE MASS (kg)	22 (1) 15 - 29	35 (1) 25 - 47
BODY MASS INDEX (kg/m^2)	16 (0.3) 13 - 21	20 (1) 16 - 24

Figure 3.1 Basal Metabolic Rate (MJ/d) of boys aged 5 to 15 years expressed as individual values ⊡ , and the mean for each age group ✳ .

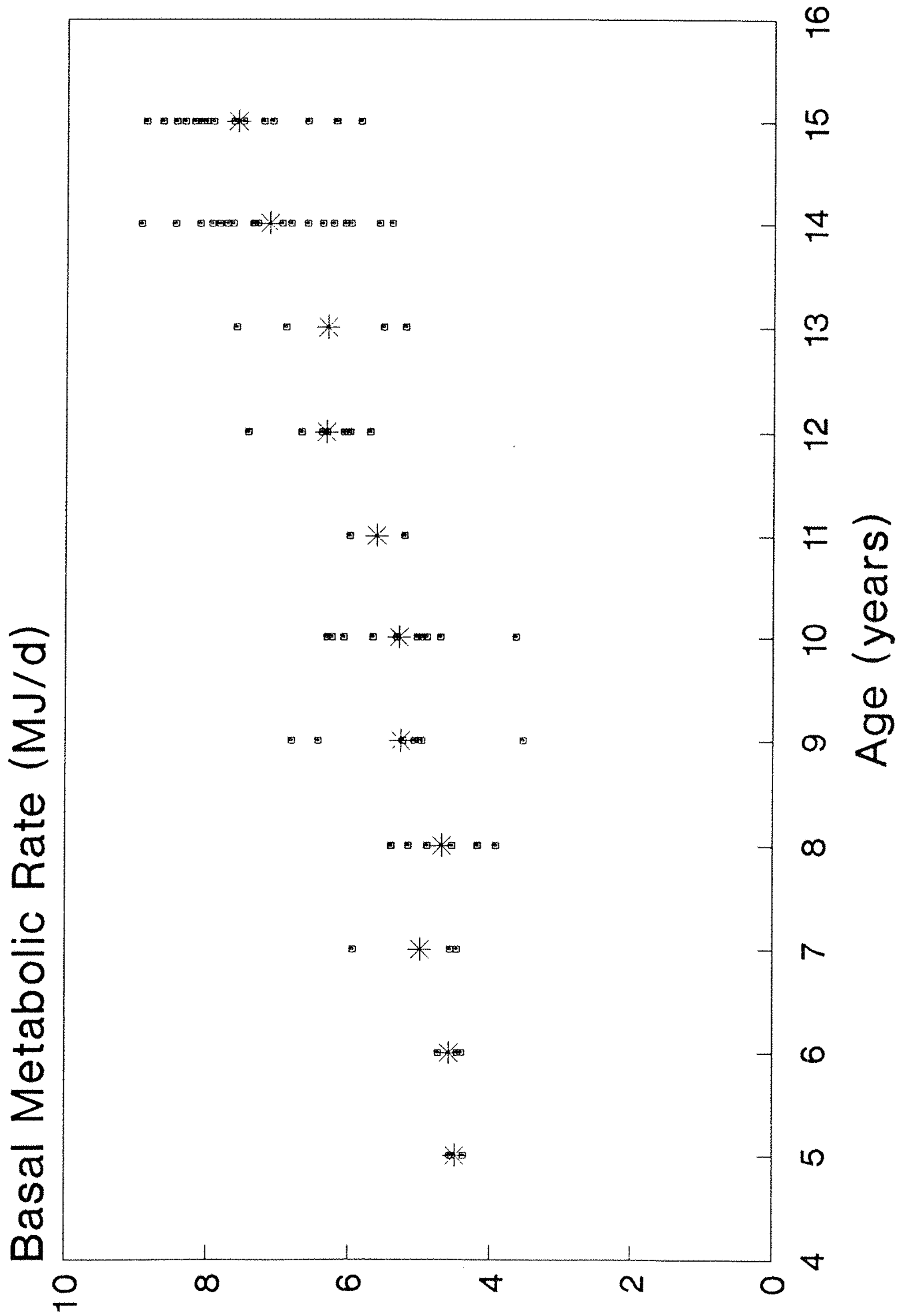
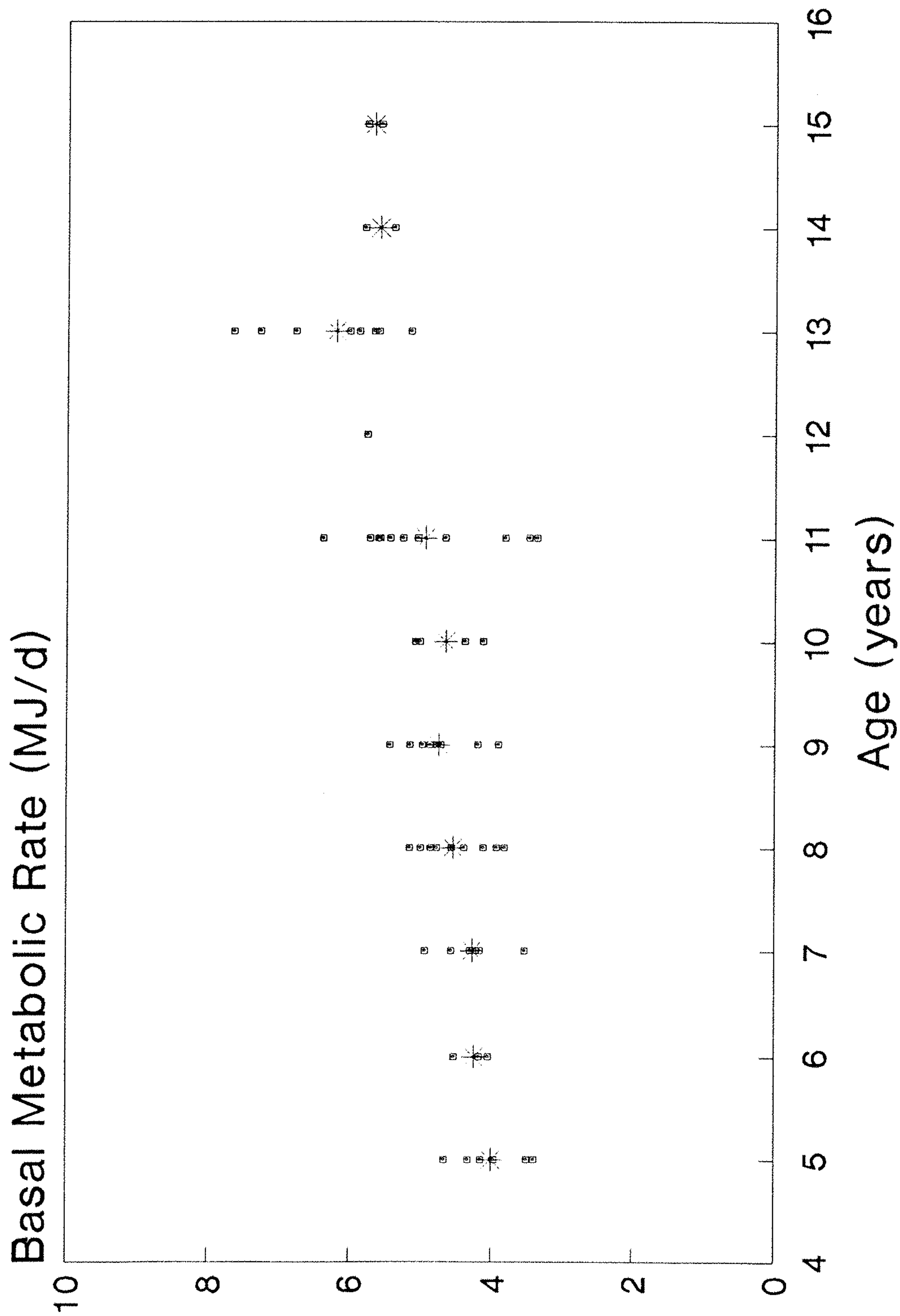


Figure 3.2 Basal Metabolic Rate (MJ/d) of girls aged 5 to 15 years expressed as individual values ⊡ , and the mean for each age group ✳ .



When BMR was expressed per kilogram body weight (BMR/kgbwt) or lean body mass (BMR/kglbm) both data from boys (Figure 3.3, p69) and girls (Figure 3.4, p70) showed the opposite tendency, the older children tending to have lower values than the younger girls and boys. In Figures 3.3 and 3.4 the boys and girls in the present study had very similar values for BMR/kgbwt in comparison with predicted values. When expressed as BMR/kglbm, the wide range of values at each age group remained for boys (Figure 3.5, p71) and girls (Figure 3.6, p72).

Children aged 11 to 15 years.

Values for BMR can be found in Tables 3.3 and 3.4 (p73 and 74). The boys mean BMR was 7.04 MJ/d, and the girls was 5.54 MJ/d. Like the younger children BMR for both boys and girls tended to be greater for the older boys and girls than the younger ones. Also, there is still the wide variation in BMR in this age group for both boys and girls (Figures 3.1 and 3.2).

When expressed per kilogram body weight (Figure 3.3 and 3.4) the 11 year olds tended to have higher values for BMR than the 15 year olds, continuing the declining trend seen in the younger group. The values from the present study and predicted values were similar. The lower BMR/kglbm in the 15 year olds compared with the 11 year olds echoed the lower BMR/kgbwt, for both boys (Figure 3.5) and girls (Figure 3.6).

Relationships between variables.

To investigate the association between BMR and other variables correlation analysis was performed. There was a strong relationship between BMR and age, weight, height and lean body mass (LBM) for boys and girls. When the children were separated into age groups associations were not as strong. In the 5 to 10 year old boys there was a relationship between BMR and weight ($r = 0.57$, $p<0.001$),

Figure 3.3 Basal Metabolic Rate expressed per kilogram body weight (kJ/kg/d) of boys aged 5 to 15 years, from the present study ┼ , and from predicted values [Schofield, 1985] using 50th centile weight for age [Department of Health, 1991] ✳ . Values are the mean for each age group.

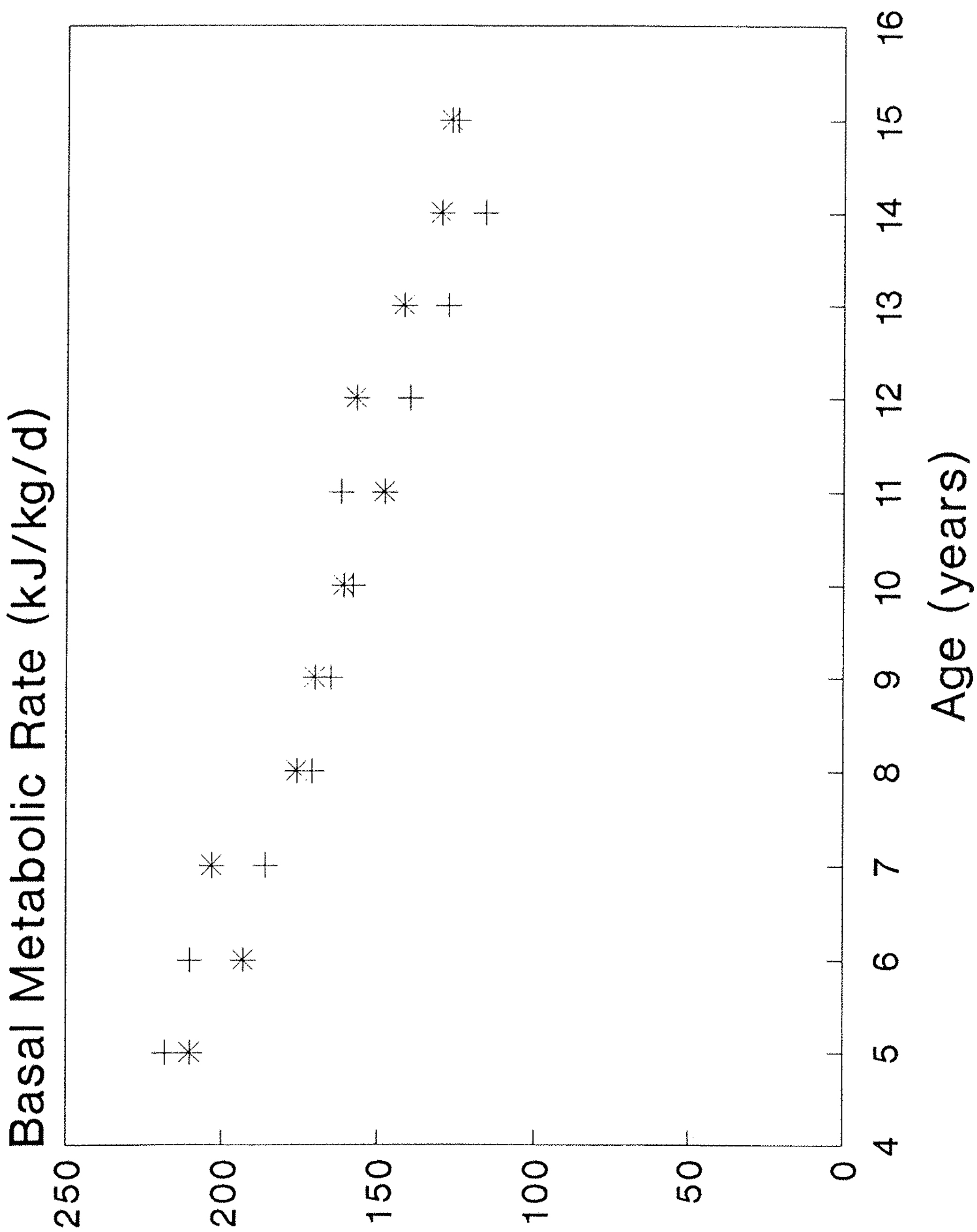


Figure 3.4 Basal Metabolic Rate expressed per kilogram body weight (kJ/kg/d) of girls aged 5 to 15 years, from the present study + , and from predicted values [Schofield, 1985] using 50th centile weight for age [Department of Health, 1991] ✳ . Values are the mean for each age group.

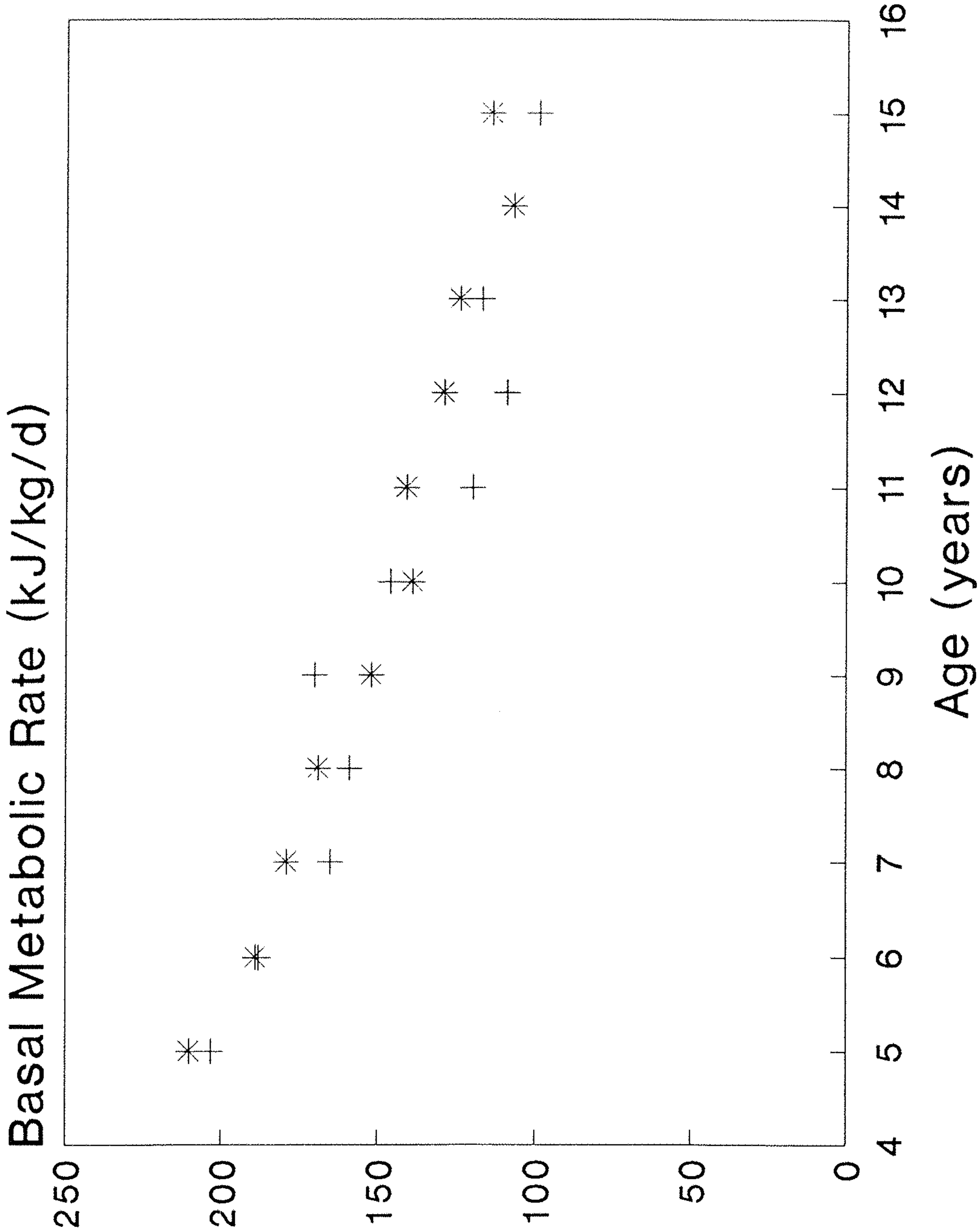


Figure 3.6 Basal Metabolic Rate expressed per kilogram lean body mass (kJ/kg/d) of boys aged 5 to 15 years expressed as individual values ▫ , and the mean for each age group ✳ .

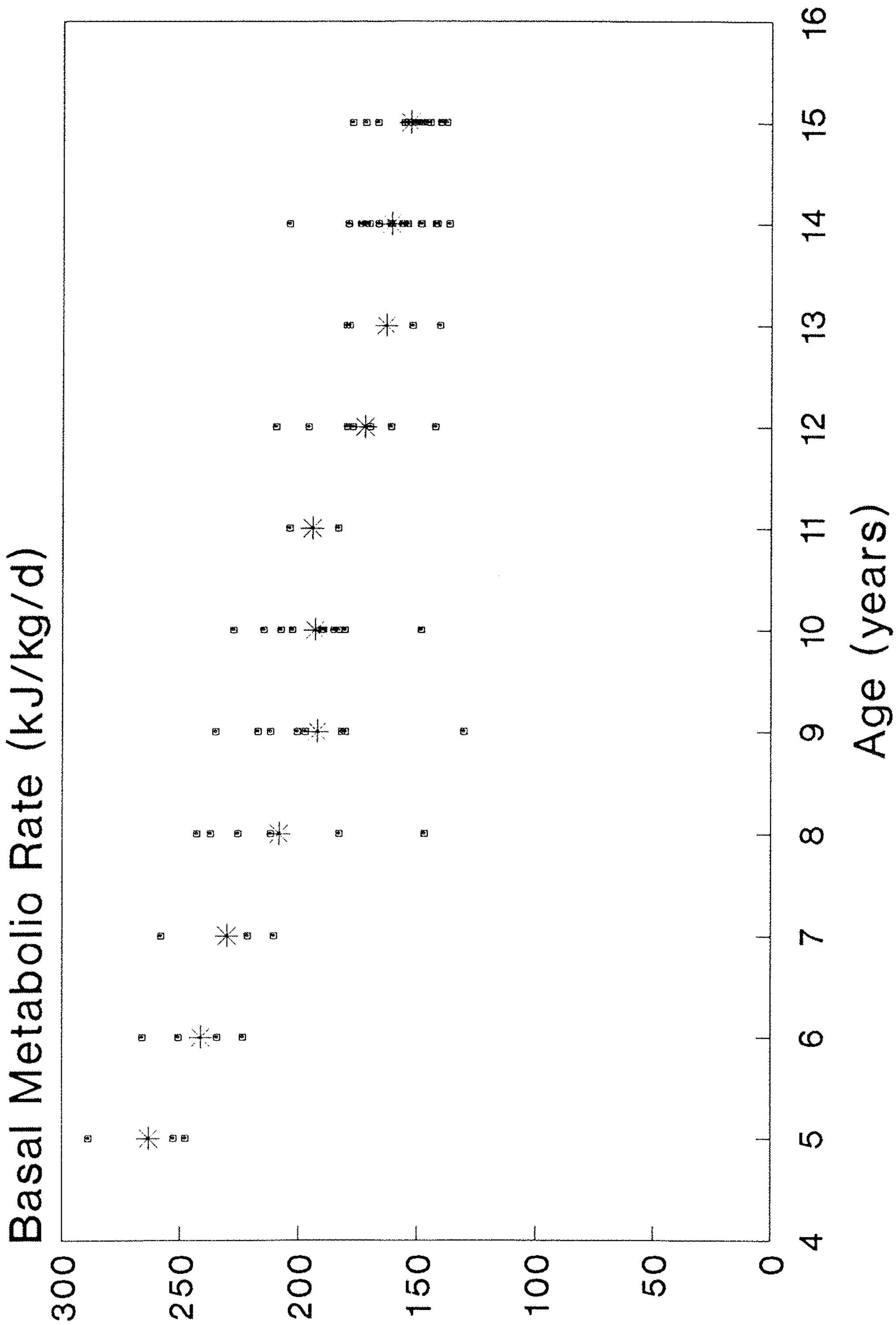


Figure 3.6 Basal Metabolic Rate expressed per kilogram lean body mass (kJ/kg/d) of girls aged 5 to 15 years expressed as individual values ⊡ , and the mean for each age group ✳ .

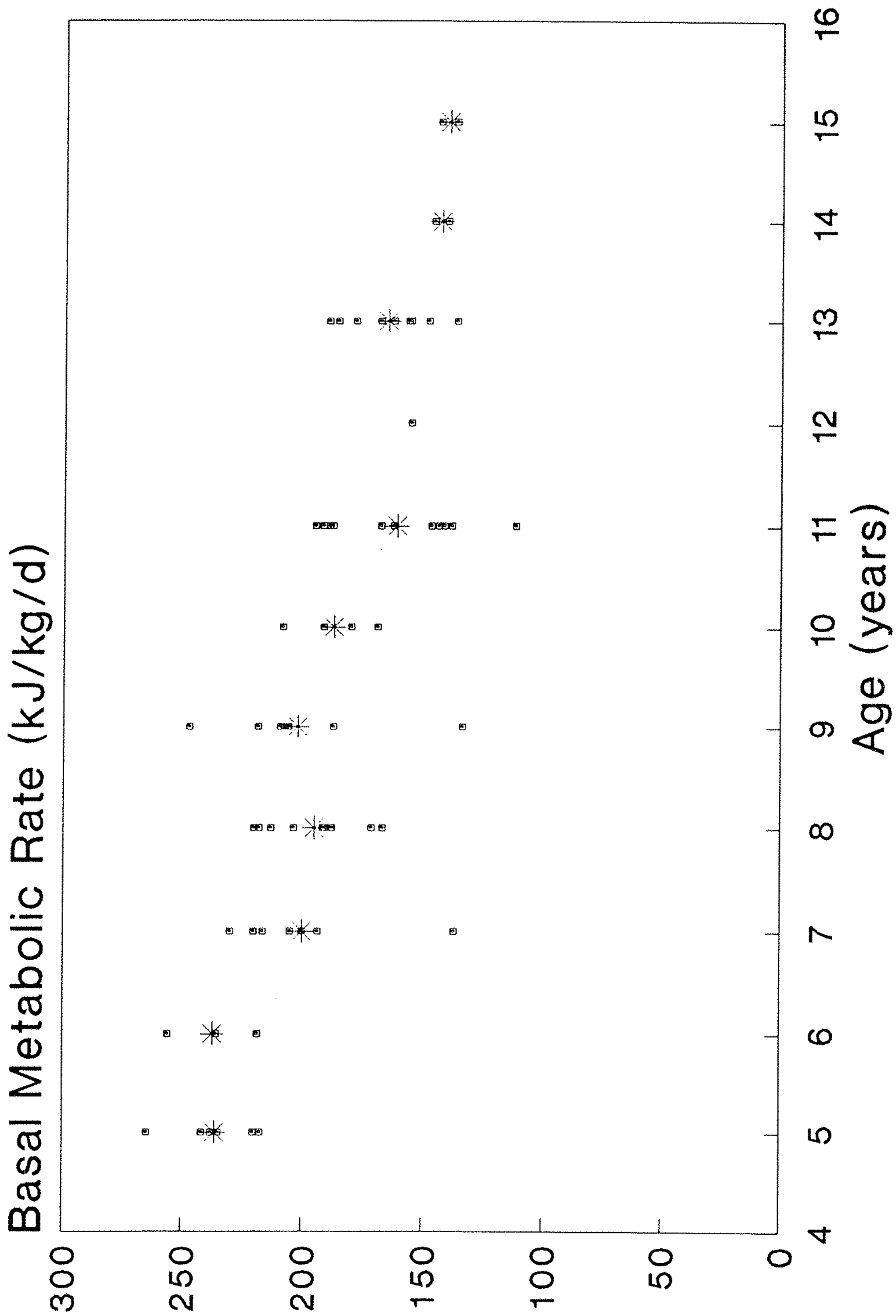


Table 3.4 Energy intake (EIN) and basal metabolic rate (BMR) values of the girls divided by age, 5 to 10 years (n = 38), and 11 to 15 years (n = 25). Values are expressed per kilogram body weight and per kilogram lean body mass. Plus values for percentage of predicted BMR [Schofield, 1985], and ratio of EIN to BMR. All values are means with standard error of the mean (SEM) in parenthesis, and range displayed below.

VARIABLES	5 - 10 YEARS	11 - 15 YEARS
BMR (kJ/d)	4439 (81) 3390 - 5430	5537 (198) 3365 - 7647
PREDICTED BMR (%)	103 (1) 81 - 115	99 (3) 65 - 123
BMR (kJ/kgbwt/d)	170 (4) 120 - 231	116 (4) 88 - 162
BMR (kJ/kglbm/d)	206 (5) 133 - 264	159 (4) 111 - 195
EIN (MJ/d)	7.05 (0.20) 5.14 - 11.23	7.92 (0.36) 5.14 - 11.52
EIN (kJ/kgbwt/d)	270 (9) 148 - 400	169 (10) 86 - 255
EIN (kJ/kglbm/d)	327 (10) 213 - 457	231 (12) 128 - 363
EIN/BMR	1.60 (0.04) 1.11 - 2.18	1.48 (0.10) 0.74 - 2.57

Table 3.3 Energy intake (EIN) and basal metabolic rate (BMR) values of the boys aged 5 to 10 years (n = 34), and 11 - 15 years (n = 51); expressed per kilogram body weight and per kilogram lean body mass. Plus values for percentage of predicted BMR [Schofield, 1985], and the ratio of EIN to BMR. All values are means with standard error of the mean in parenthesis, and the range is displayed below.

VARIABLES	5 - 10 YEARS	11 - 15 YEARS
BMR (kJ/d)	5039 (126) 3538 - 6810	7130 (126) 5210 - 9030
BMR PREDICTED (%)	104 (2) 68 - 126	105 (1) 85 - 120
BMR (kJ/kgbwt/d)	178 (5) 106 - 240	135 (2) 100 - 177
BMR (kJ/kglbm/d)	212 (6) 130 - 289	162 (2) 137 - 209
EIN (MJ/d)	8.14 (0.20) 5.55 - 10.82	9.92 (0.31) 5.13 - 15.77
EIN (kJ/kgbwt/d)	286 (7) 195 - 352	191 (6) 79 - 336
EIN (kJ/kglbm/d)	342 (8) 228 - 423	231 (87) 92 - 394
EIN/BMR	1.65 (0.05) 1.10 - 2.47	1.42 (0.04) 0.57 - 2.15

height ($r = 0.54$, $p<0.001$) and LBM ($r = 0.58$, $p<0.001$). When expressed per kilogram body weight or LBM the association became negative and slightly stronger with height ($r = -0.64$, $p<0.001$), ($r = -0.63$, $p<0.001$), as described in the text above.

In the girls group the strongest associations were between BMR and weight ($r = 0.63$, $p<0.001$) and height ($r = 0.60$, $p<0.001$). When BMR was expressed per kilogram body weight there were stronger negative associations with height ($r = -0.68$, $p<0.001$), and LBM ($r = -0.81$, $p<0.001$): or per kilogram LBM with height ($r = -0.78$, $p<0.001$), also as described in the text above.

In the 11 to 15 year groups there were slightly stronger associations within the older girls than within the younger ones; between BMR and weight ($r = 0.73$, $p<0.001$), height ($r = 0.76$, $p<0.001$) and LBM ($r = 0.73$, $p<0.001$). When expressed per kilogram body weight or LBM there was only association between weight and BMR per kilogram body weight ($r = -0.51$, $p<0.01$).

There were stronger relationships between BMR and weight ($r = 0.81$, $p<0.001$), height ($r = 0.80$, $p<0.001$) and LBM ($r = 0.85$, <0.001) in the boys group. These were very much weaker when expressed per kilogram body weight or LBM.

Regression Analysis.

Multiple regression analysis was performed generating predictive equations for BMR. Initially all variables (age, weight, weight centile, height, height centile, height standard deviation score (HTSDS), %BF, LBM, mid-arm circumference, energy intake, BMR and gender) were entered into the analysis and all three methods of regression performed (Table 3.5, p76).

METHOD		R	se	n
STEPWISE	BMR = 0.099L + 0.467G + 0.004HC + 1.510	0.91	0.563	148
BACKWARD	BMR = 0.582G - 0.009WC - 0.279A +0.030 + 0.114L + 0.035HT - 0.0965	0.92	0.549	148
FORWARD	BMR = 0.099L + 0.467G + 0.003HC +1.510	0.91	0.563	148

Table 3.5 Regression equations for a group of healthy boys and girls using three different methods of analysis. (L: lean body mass; HC: height centile; G: gender; WC: weight centile; A: age).

Forward regression analysis did not add any information, and backward analysis included some very weakly associated variables. Neither was therefore used in further analysis. The presence of gender in the equations, and evidence of gender differences in BMR led to separation of boys' and girls' data when performing further stepwise regression analysis (Table 3.6, p78).

In order to compare this information with previous studies girls' and boys' data was further divided by age. The groups were those used clinically and in previous publications: 5 to 10 years (usually 3.01 to 10.00 years) and 10.01 to 15.99 years (normally 10.01 to 18.00 years).

The majority of previously published regression equations to predict BMR have been generated using weight, body composition details not being available for inclusion within the analysis. In Table 3.6 the present study data was compared with standard equations [Schofield, 1985]. R values particularly for the younger children were lower than the Schofield equations. In the present study group numbers were lower and standard errors higher than those for the Schofield equations.

Table 3.7 (p79) shows regression equations generated using weight, height and LBM, and those generated using only weight, or only LBM. R values were higher for LBM in the younger and older boys. The younger girls had higher R values for weight; the older girls had equivalent R values for both LBM and weight.

3.3.3 Energy Intake.

Children aged 5 to 10 years.

Values for energy intake (EIN) are in Tables 3.3 and 3.4 (p73 and 74). The boys' mean EIN was 8.14MJ/d, and the girls' was 7.05 MJ/d. There was a tendency for 10 year olds to have higher EINs than 5 year olds (Figure 3.7

PRESENT STUDY 5.00 - 10.00 YEARS		R	se	n
BOYS	BMR = 0.068W + 3.028	0.46	0.65	25
GIRLS	BMR = 0.075W + 2.473	0.66	0.38	34
SCHOFIELD [1985] 3 - 10.00 YEARS				
BOYS	BMR = 0.095W + 2.110	0.83	0.28	338
GIRLS	BMR = 0.085W + 2.033	0.81	0.29	413
PRESENT STUDY 10.01 - 15.99 YEARS				
BOYS	BMR = 0.080W + 2.720	0.86	0.61	60
GIRLS	BMR = 0.065W + 2.394	0.75	0.66	29
SCHOFIELD [1985] 10.01 - 18.00 YEARS				
BOYS	BMR = 0.074W + 2.754	0.93	0.44	734
GIRLS	BMR = 0.056W + 2.898	0.82	0.47	575

Table 3.6 Regression equations for a group of healthy children compared with standard equations to predict basal metabolic rate. (W; weight).

AGE AND GENDER		R	se	n
BOYS: 5 - 10 YEARS	BMR = 0.08L + 2.99	0.51	0.63	25
	BMR = 0.08L + 2.99	0.51	0.63	25
	BMR = 0.07W + 3.03	0.46	0.65	25
GIRLS: 5 - 10 YEARS	BMR = 0.08W + 2.47	0.66	0.38	34
	BMR = 0.07L + 2.99	0.46	0.46	34
	BMR = 0.08W + 2.47	0.66	0.66	34
BOYS: 11 - 15 YEARS	BMR = 0.12L + 2.35	0.88	0.56	60
	BMR = 0.12L + 2.35	0.88	0.88	60
	BMR = 0.08W + 2.72	0.86	0.89	60
GIRLS: 11 - 15 YEARS	BMR = 0.11L + 1.69	0.75	0.66	29
	BMR = 0.11L + 1.69	0.75	0.75	29
	BMR = 0.07W + 2.39	0.75	0.75	29

Table 3.7 Regression equations for a group of healthy boys and girls; equations were generated firstly using weight, height and lean body mass, then with lean body mass alone, finally with weight alone. (L: lean body mass; W: weight).

boys, Figure 3.8 girls, p81 and 82). Figures 3.9 and 3.10 (p83 and 84) illustrate EIN per kilogram body weight for boys and girls; and in Figures 3.11 and 3.12 EIN per kilogram LBM is illustrated (p85 and 86). Like BMR above, the slope of EIN with age was negative when expressed per kilogram of body tissue.

Children aged 11 to 15 years.
The boys had a mean EIN of 9.92 MJ/d, and the girls a mean EIN of 7.72 MJ/d. When expressed per kilogram body weight or per kilogram LBM, EIN was clearly higher for the 11 year olds than 15 year olds (Figures 3.9 and 3.11 boys, 3.10 and 3.12 girls).

Relationships between variables.
When considering association between EIN and other variables correlation analysis was performed for girls (n = 63) and boys (n = 85). Amongst the girls were strong relationships between, age and EIN expressed per kilogram body weight ($r = -0.80$, $p<0.001$), and EIN expressed per kilogram LBM ($r = -0.76$, $p<0.001$); height and EIN expressed per kilogram body weight ($r = -0.77$, $p<0.001$), and EIN expressed per kilogram LBM ($r = -0.71$, $p<0.001$): and, BMR and EIN per kilogram body weight ($r = -0.61$, $p<0.001$), and EIN per kilogram LBM ($r = -0.53$, $p<0.001$). Despite a weak association between EIN and BMR ($r = 0.32$, $p<0.01$), when both were expressed per kilogram bodyweight ($r = 0.77$, $p<0.001$) and per kilogram LBM ($r = 0.63$, $p<0.001$) the relationship was stronger.

The boys also exhibited strong relationships between the same variables: age and EIN expressed per kilogram body weight ($r = -0.81$, $p <0.001$), and EIN per kilogram LBM ($r = -0.81$, $p<0.001$); height and EIN expressed per kilogram body weight ($r = -0.81$, $p<0.001$), and EIN expressed per kilogram LBM ($r = -0.81$, $p<0.001$): BMR and EIN per kilogram body weight ($r = -0.72$, $p<0.001$), and EIN per

Figure 3.7 Energy intake (MJ/d) of boys aged 5 to 15 years expressed as individual values ⊡ , and the mean for each age group ✳ .

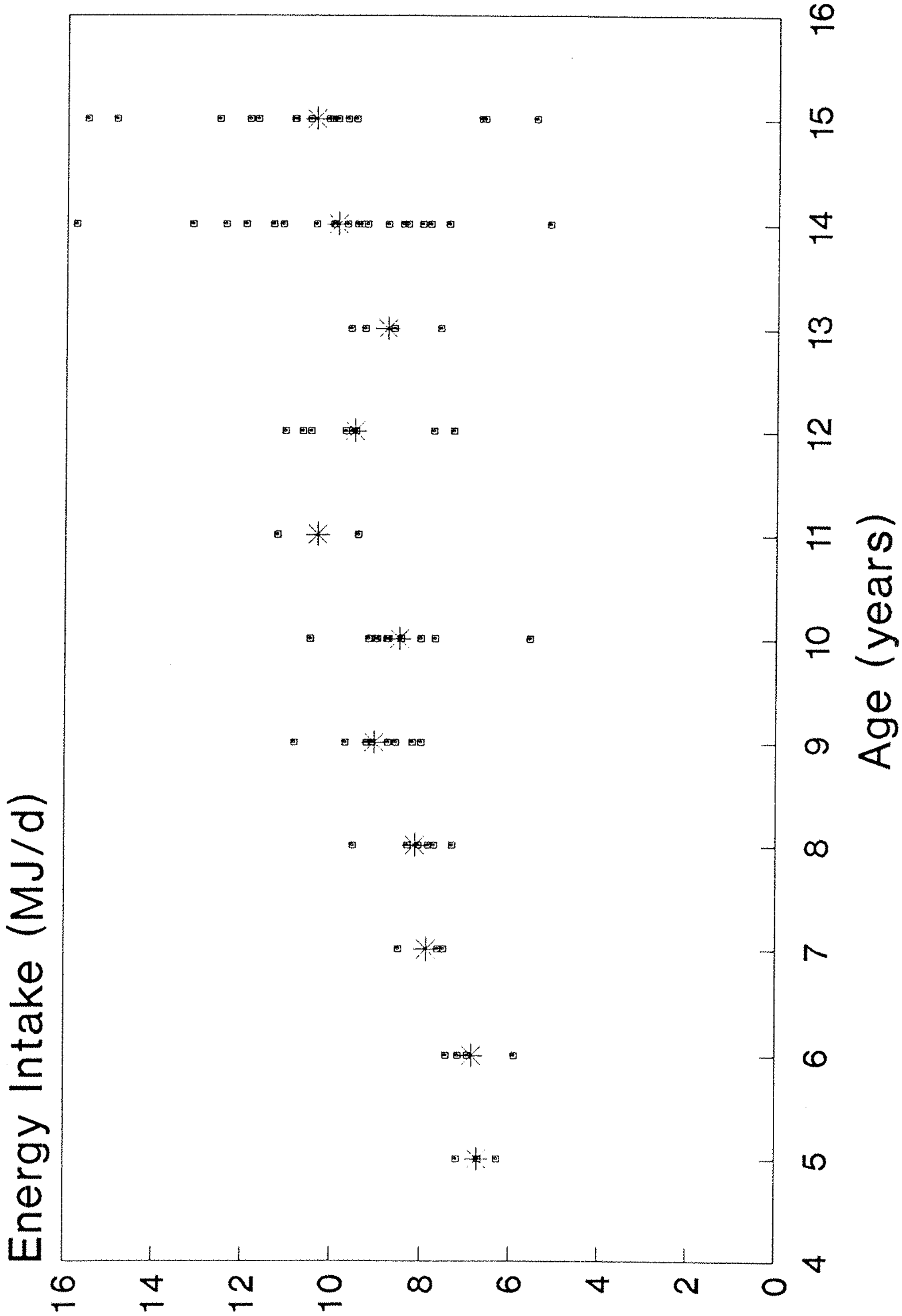


Figure 3.8 Energy intake (MJ/d) of girls aged 5 to 15 years expressed as individual values ▣ , and the mean for each age group ✳ .

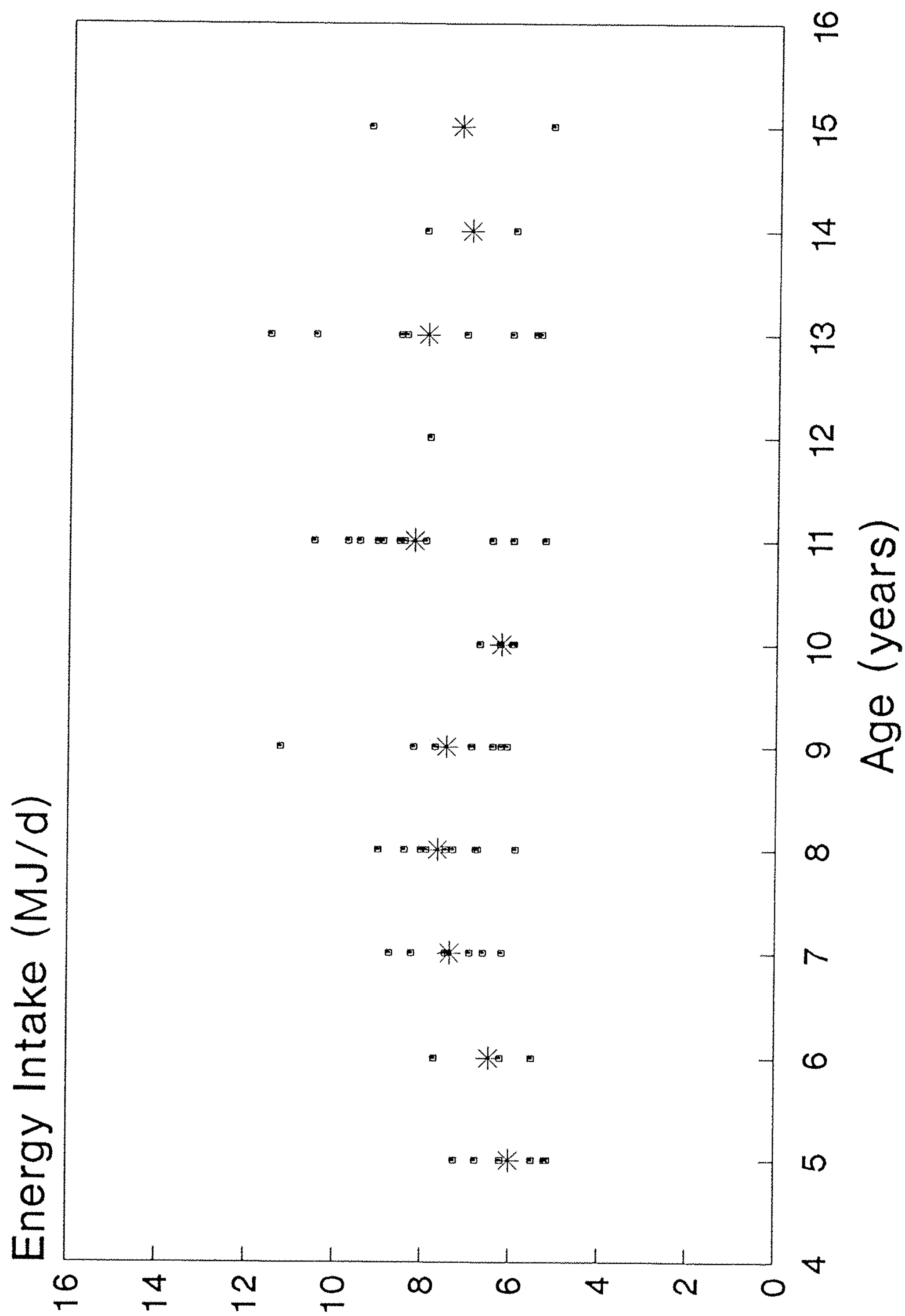


Figure 3.9 Energy intake expressed per kilogram body weight (kJ/kg/d) of boys aged 5 to 15 years, from the present study + , and from Widdowson [1947] ✳ . Values are the mean for each group.

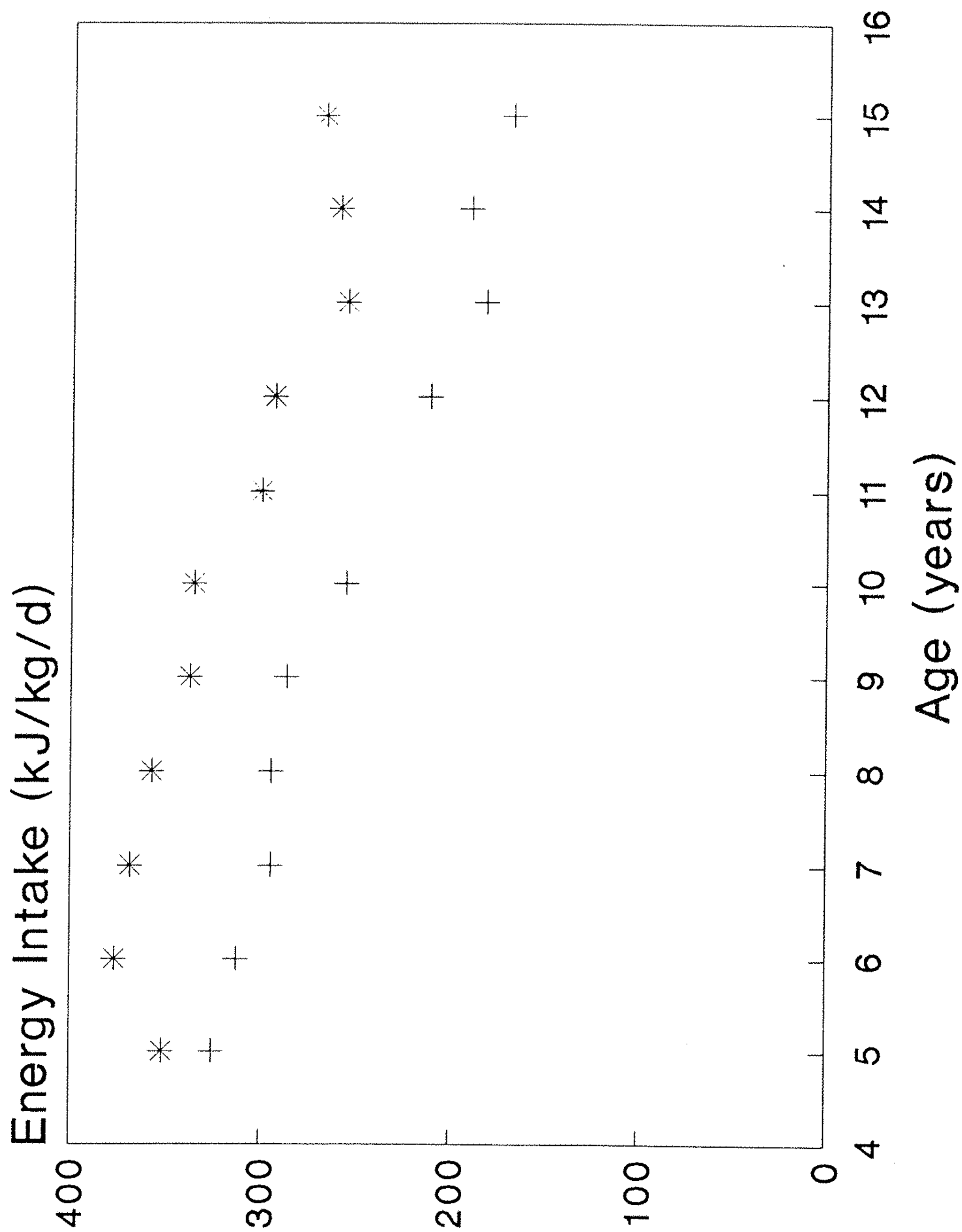


Figure 3.10 Energy intake expressed per kilogram body weight (kJ/kg/d) of girls aged 5 to 15 years, from the present study +, and from Widdowson [1947] ✳. Values are the mean for each group.

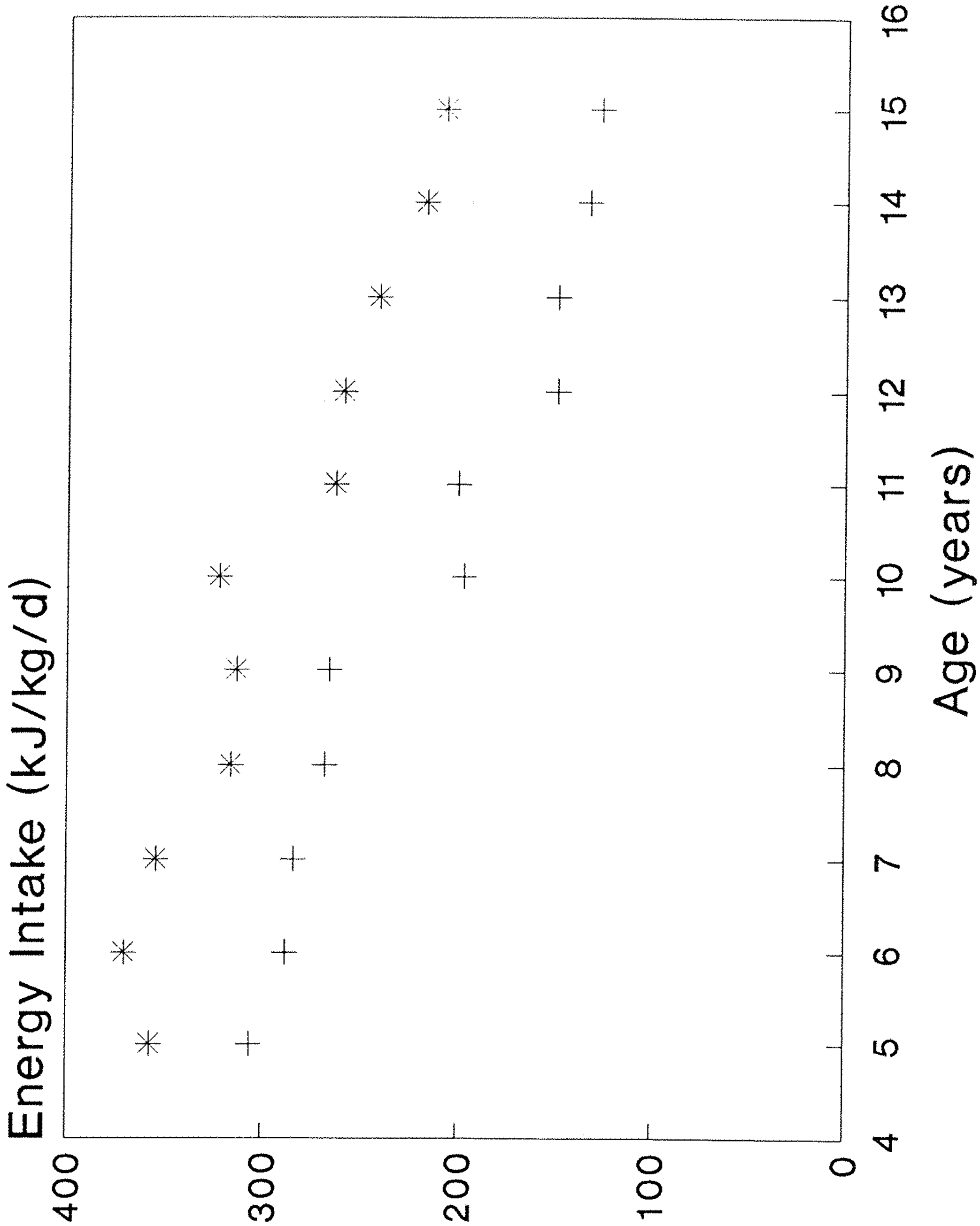


Figure 3.11 Energy intake expressed per kilogram lean body mass (kJ/kg/d) of boys aged 5 to 15 years, expressed as individual values ◘ , and the mean for each age group ✳ .

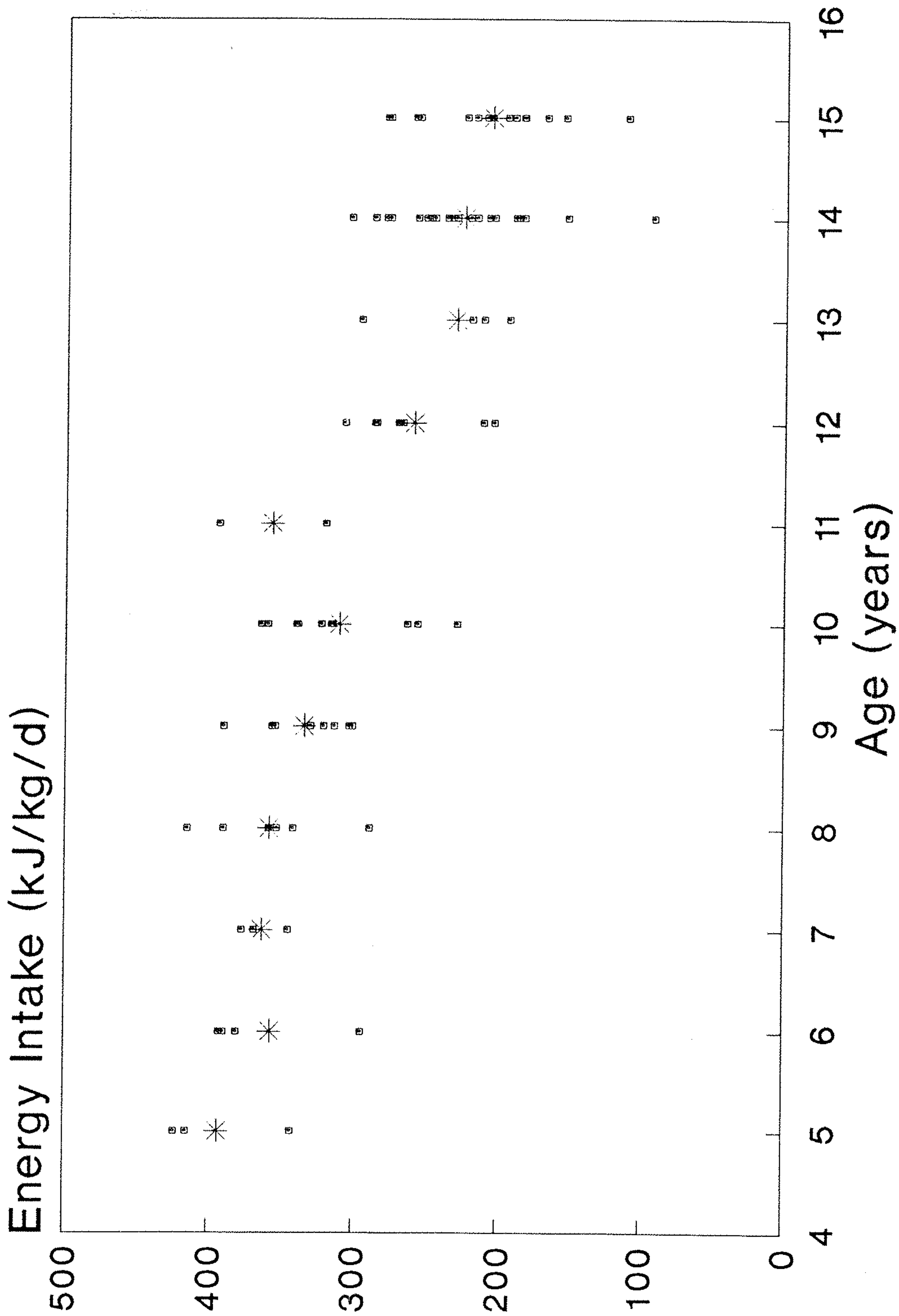
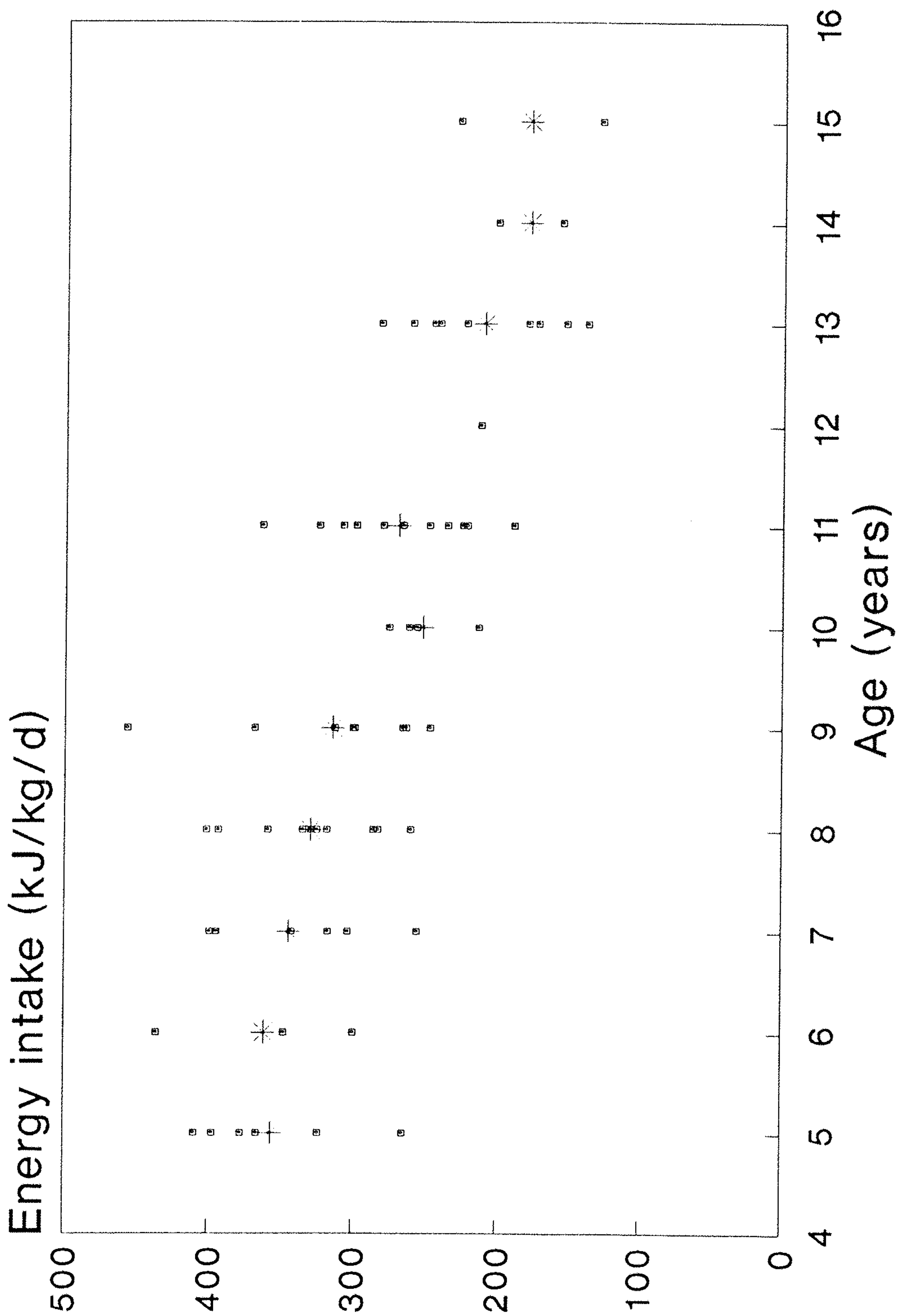


Figure 3.12 Energy intake expressed per kilogram lean body mass (kJ/kg/d) of girls aged 5 to 15 years, expressed as individual values ⊡ , and the mean for each age group ⁎ .



kilogram LBM ($r = -0.71$, $p<0.001$). In addition, there was a degree of association between EIN and BMR ($r = 0.54$, $p<0.001$), greater than for girls; but the relationship was stronger, like the girls' data, when both were expressed per kilogram body weight ($r = 0.74$, $p<0.001$), or per kilogram LBM ($r = 0.73$, $p<0.001$).

When boys and girls were split into their two age groups and correlation analysis performed with the same variables, the younger girls (5 to 10 years) retained an association between EIN and age and height, but to a lesser degree, but no relationship existed between EIN and BMR. The relationship between EIN and BMR per kilogram body weight and kilogram LBM was weaker ($r = 0.58$, $p<0.001$: $r = 0.51$, $p<0.001$). The older girls (11 to 15 years) also retained an association between EIN and age, and to a lesser degree height, but not with BMR. There was no association between EIN and BMR when expressed either per kilogram body weight or LBM for the older girls.

The younger boys (5 to 10 years) displayed associations between EIN and age ($r = 0.63$, $p<0.001$), height ($r = 0.67$, $p<0.001$), and weight ($r = 0.68$, $p<0.001$), stronger before they were expressed per kilogram body weight or LBM. There was only a weak association between EIN and BMR ($r = 0.46$, $p<0.01$), slightly stronger when expressed per kilogram body weight ($r = 0.55$, $p<0.001$), or per kilogram LBM ($r = 0.53$, $p<0.001$). Another variable which did associate more strongly with EIN was LBM ($r = 0.71$, $p<0.001$).

Associations within the older boys (11 to 15 years) were much weaker. There were no longer associations between EIN and age, height and weight, and only weak associations when EIN was expressed per kilogram body weight or LBM. The relationship between EIN and BMR was very weak ($r = 0.35$, $p<0.01$), becoming stronger when expressed per kilogram body weight ($r = 0.48$, $p<0.001$), or per kilogram LBM ($r = 0.45$, $p<0.001$).

3.3.4 The Energy Intake to Basal Metabolic Rate Ratio.
Children aged 5 to 10 years.
In Figures 3.13 (boys) and 3.14 (girls) the ratio of EIN to BMR (EIN/BMR) was plotted for each child (p89 and 90), with mean values indicated where appropriate. There was no clear pattern for boys or girls in this group. There were no EIN/BMR values less than 1, but two boys and one girl had values greater than 2. When a Student t-test was carried out to determine whether EIN/BMR ratio was similar for both sexes, there was no statistically significant difference between boys (1.65) and girls (1.60) (Table 3.3 and 3.4, p73 and 74).

Children aged 11 to 15 years.
The plotted values for the older children revealed a tendency for EIN/BMR to be less in the older group than the younger group. Unlike the younger children, two boys and one girl had EIN/BMR values of less than one; and three girls had values greater than two. A Student t-test again revealed no statistically significant difference between the mean value for girls (1.48) and boys (1.43). When the same test was carried out to investigate differences between age groups there were statistically significant differences between the two age groups for boys ($p<0.001$), and between the younger children and the older ones (1.62 v 1.44, $p<0.001$).

Figure 3.13 Energy intake to basal metabolic rate ratio (EIN/BMR) for boys aged 5 to 15 years, expressed as individual values ⊡ , and the mean for each age group*.

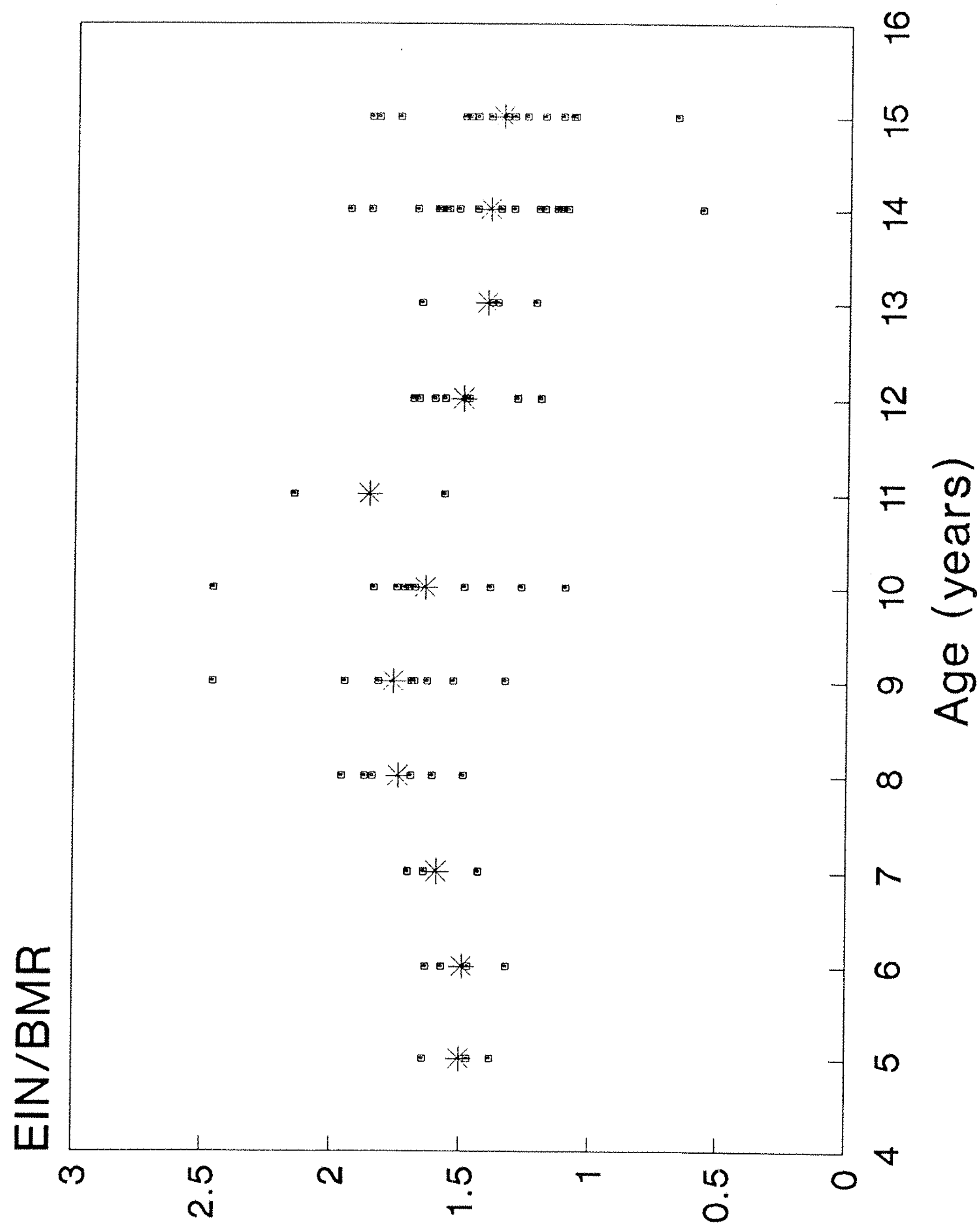
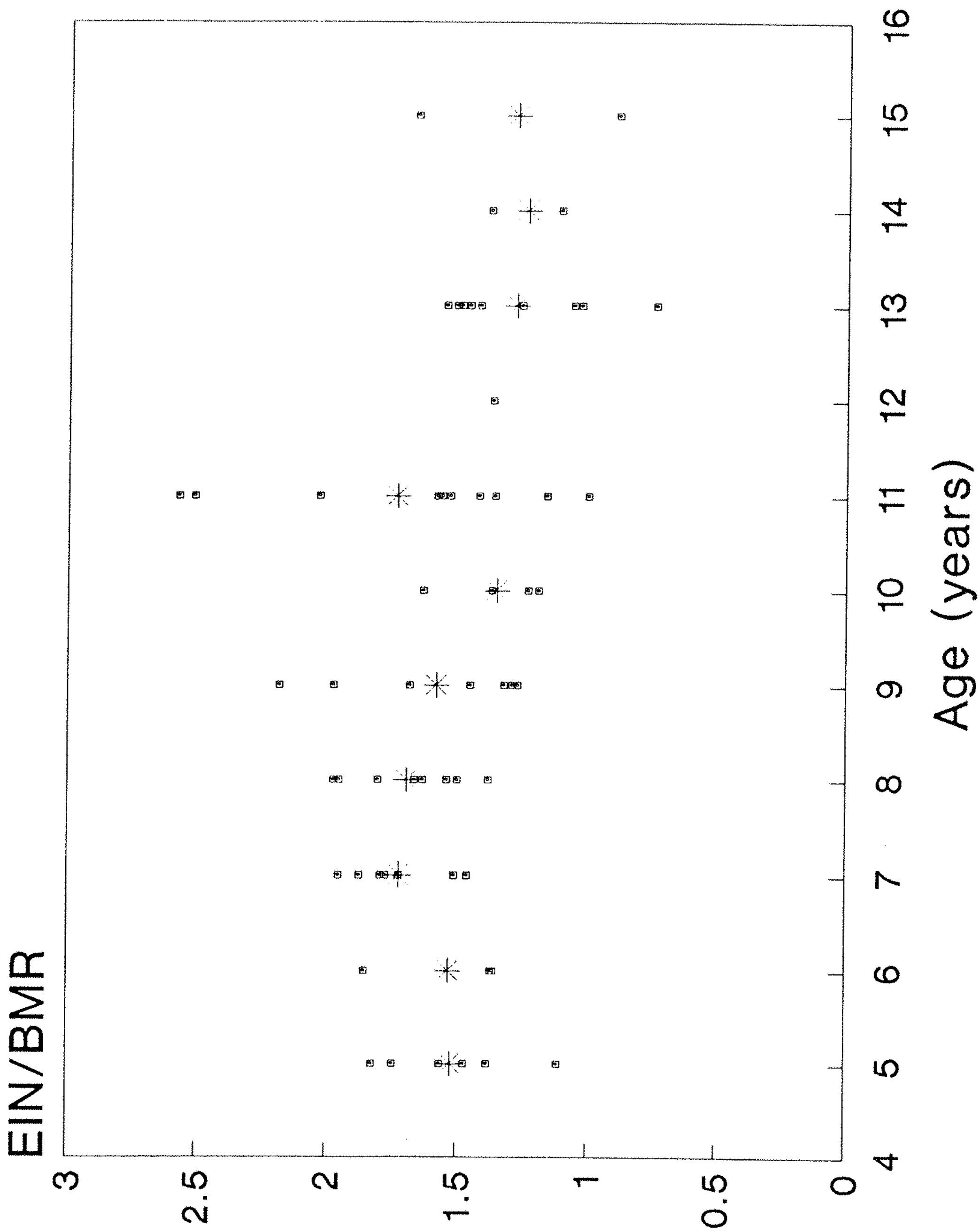


Figure 3.14 Energy intake to basal metabolic rate ratio (EIN/BMR) for girls aged 5 to 15 years, expressed as individual values ▣ , and the mean for each age group*.



3.4 DISCUSSION.

The aims of this chapter were to investigate the association between metabolic demand for energy and body size and composition and energy intake; and investigate the relationship between metabolic demand and energy intake expressed as a factor, EIN/BMR. These were both carried out in healthy children of normal growth. Normal growth was identified by comparison of anthropometric and body composition data with appropriate standards and ensuring every child was within plus and minus two standard deviation scores for height.

The British dietary standards include the most recent tables of weight and height centiles for children [Department of Health, 1991]. To make a comparison between figures from the present study with those aforementioned, mean values were taken over similar age groups for boys and girls. The results are presented in Table 3.8 (p92). The younger boys in the present study were heavier (by 3.2kg) and taller (by 6.1cm) than the standards. Using the same comparison for the younger girls, present study children were of similar weight and shorter (by 2cm) than the standards. The differences could be attributable to comparison of two groups with dissimilar distributions in age.

Differences appeared to be less for the older groups of children, shown in Table 3.9 (p93). Boys in the present study were similar weight and taller (by 7.3cm), but their mean age was greater than the standards. Girls in the present study were younger, but heavier and shorter, by 3.2kg and 1cm. As with the younger children, disparate age distributions may be the cause of differences in weight and height. Centile comparisons agreed with work by Voss and colleagues [1990] suggesting that children from Wessex were on average 1cm taller than Tanner and

Table 3.8 Characteristics of the boys (n = 37) and girls (n = 44), aged 5 to 10 years (n = 37), compared with the current British standards [DH, 1991], expressed as means and standard deviations.

VARIABLE: BOYS	MEAN AND RANGE	DRV 1991
AGE (yr)	8.83 (5.54 - 10.87)	8.0 (5.5 - 10.5)
WEIGHT (kg)	28.9 (19.0 - 38.1)	25.7 (19.3 - 32.7)
WEIGHT CENTILE	62 (17 - 90)	50 (3 - 97)
HEIGHT (cm)	133.4 (109.7 - 148.8)	126.9 (112.4 - 140.5)
HEIGHT CENTILE	59 (3 - 97)	50 (3 - 95)
VARIABLE: GIRLS		
AGE (yr)	8.83 (5.54 - 10.87)	8.5 (5.5 - 10.5)
WEIGHT (kg)	28.9 (19.0 - 38.1)	26.8 (15.3 - 46.6)
WEIGHT CENTILE	62 (17 - 90)	50 (3 - 97)
HEIGHT (cm)	133.4 (109.7 - 148.8)	130.0 (103.4 - 152.1)
HEIGHT CENTILE	66 (9 -96)	50 (3 - 97)

Table 3.9 The characteristics of the boys (n = 64) and girls (n = 23), aged 11 to 15 years, compared with centile standards for the British population.

VARIABLE: BOYS	MEAN AND RANGE	DRV 1991
AGE (yr)	14.44 (11.58 - 15.72)	13.5 (11.5 - 15.5)
WEIGHT (kg)	53.6 (33.4 - 79.5)	52.3 (35.9 - 56.5)
WEIGHT CENTILE	53 (1 - 100)	50 (3 - 95)
HEIGHT (cm)	165.1 (142.3 - 179.0)	157.3 (145.5 - 170.3)
HEIGHT CENTILE	55 (3 - 97)	50 (3 - 95)
VARIABLES: GIRLS		
AGE (yr)	12.86 (11.04 - 15.39)	13.5 (11.5 - 15.5)
WEIGHT (kg)	48.1 (31.2 - 70.0)	45.5 (36.7 - 52.5)
WEIGHT CENTILE	58 (7 - 97)	50 (3 - 95)
HEIGHT (cm)	153.4 (138.5 - 169.7)	155.2 (145.9 - 161.9)
HEIGHT CENTILE	51 (3 - 97)	50 (3 - 95)

Whitehouse standards [1966]; mean height centile for boys and girls being between 56 and 66, rather than 50.

No standards were found for body composition measurements of British children, but data was available from American children in a publication by Fomon and colleagues [1982]. The American children had a lower mean age of 7.5 versus 8.8 years for boys, and 8.2 years for girls in the present study (Table 3.10, p95). Boys in the present study had greater percentage body fat (%BF) and lean body mass (LBM) than the Americans. Younger girls in the present study had similar %BF and greater LBM than American girls.

Like the younger children 11 to 15 year olds had to be compared with information from similarly aged American children [Slaughter et al, 1987]. Boys in the present study were slightly older, had similar %BF but greater LBM than Americans. This suggested the older boys in the present study were further ahead in stage of puberty than the younger Americans, as might be expected by age difference. Girls in the present study were slightly younger but had greater %BF and less LBM than their American counterparts. The same factors may be true for the girls as the boys, differing body composition because of difference in puberty in the younger British girls than the older Americans.

When comparing body composition data the use of American children introduced possible error in terms of environment, heredity and gene pool. However, the figures appeared to reflect similarity between the two populations rather than major differences.

It is difficult to make a true comparison between groups because of the way the data is skewed toward older ages. In addition, children in the present study were from

Table 3.10 Body composition of the 5 - 10 year old girls and boys in comparison with Fomon et al [1982]; and of the 11 - 15 year old girls and boys in comparison with Slaughter et al [1987]. Values are means with standard deviations in parenthesis.

VARIABLES: 5-10yr	PRESENT STUDY	FOMON ET AL
GIRLS: AGE (yr)	8.19 (5.00 - 10.80)	7.5 (5 - 10)
BODY FAT (%)	17.6 (5.4 - 32.9)	17.5 (16.4 - 19.4)
LEAN BODY MASS (kg)	22.1 (15.0 - 29.3)	19.9 (14.7 - 26.2)
BOYS: AGE (yr)	8.83 (5.54 - 10.78)	7.5 (5 - 10)
BODY FAT (%)	16.5 (11.2 - 25.9)	13.5 (12.8 - 14.6)
LEAN BODY MASS (kg)	24.2 (15.8 - 35.7)	21.2 (16.0 -27.1)
VARIABLES: 11-15yr	PRESENT STUDY	SLAUGHTER ET AL
GIRLS: AGE (yr)	12.86 (11.04 - 15.39)	13.5
BODY FAT (%)	27.6 (16.0 - 40.0)	24.1
LEAN BODY MASS (kg)	34.8 (24.6 - 47.0)	36.3
BOYS: AGE (yr)	14.44 (11.58 - 15.72)	13.1
BODY FAT (%)	17.0 (10.8 - 32.0)	17.9
LEAN BODY MASS (kg)	44.5 (28.5 - 62.7)	40.7

predominantly middle class caucasian families, whilst the nationally collected data included ethnic minorities as a representative sample of the population.

The comparisons highlight the lack of available information regarding body composition of British children. This deficit should also be recognised as caused partly by limited available methodologies for estimating body composition in children [Boileau et al, 1985].

The most recent BMR standards set out for British children [Department of Health, 1991] are those suggested for use worldwide [Schofield, 1985]. When results from the present study were compared with those worldwide standards, plus older standards of Harris and Benedict [1919], boys' BMR values were closest to Schofield's predicted values, Harris Benedict values being the lowest of the three (Figure 3.15, p97). By comparison, girls in the present study also had BMR values closest to Schofield's predicted values but Harris Benedict values were higher than the other two sets of values (see Figure 3.16, p98). Harris Benedict equations appear less appropriate for predicting BMR in children than Schofield equations.

Patterns of EIN with age were consistent with previous studies [Widdowson, 1947; Whitehead et al, 1982; Nelson, 1985] as described in Figures 3.17 and 3.18 (p99 and 100). The apparent reduction in EIN when expressed per weight of body tissue reflected a similar pattern in metabolic demand. EIN increased to meet raised metabolic demand, but the increased metabolic load was distributed over increasing amounts of tissue. The proportions of tissue altering from higher visceral organ tissue/lower skeletal muscle tissue to lower visceral organ tissue/higher skeletal muscle tissue. This describes the

Figure 3.15 Basal metabolic rate (MJ/d) of boys aged 5 to 15 years from the present study + , and their predicted values using Schofield equations [1985] ✳ , and Harris Benedict equations [1919] × . Values are expressed as the mean for each age group.

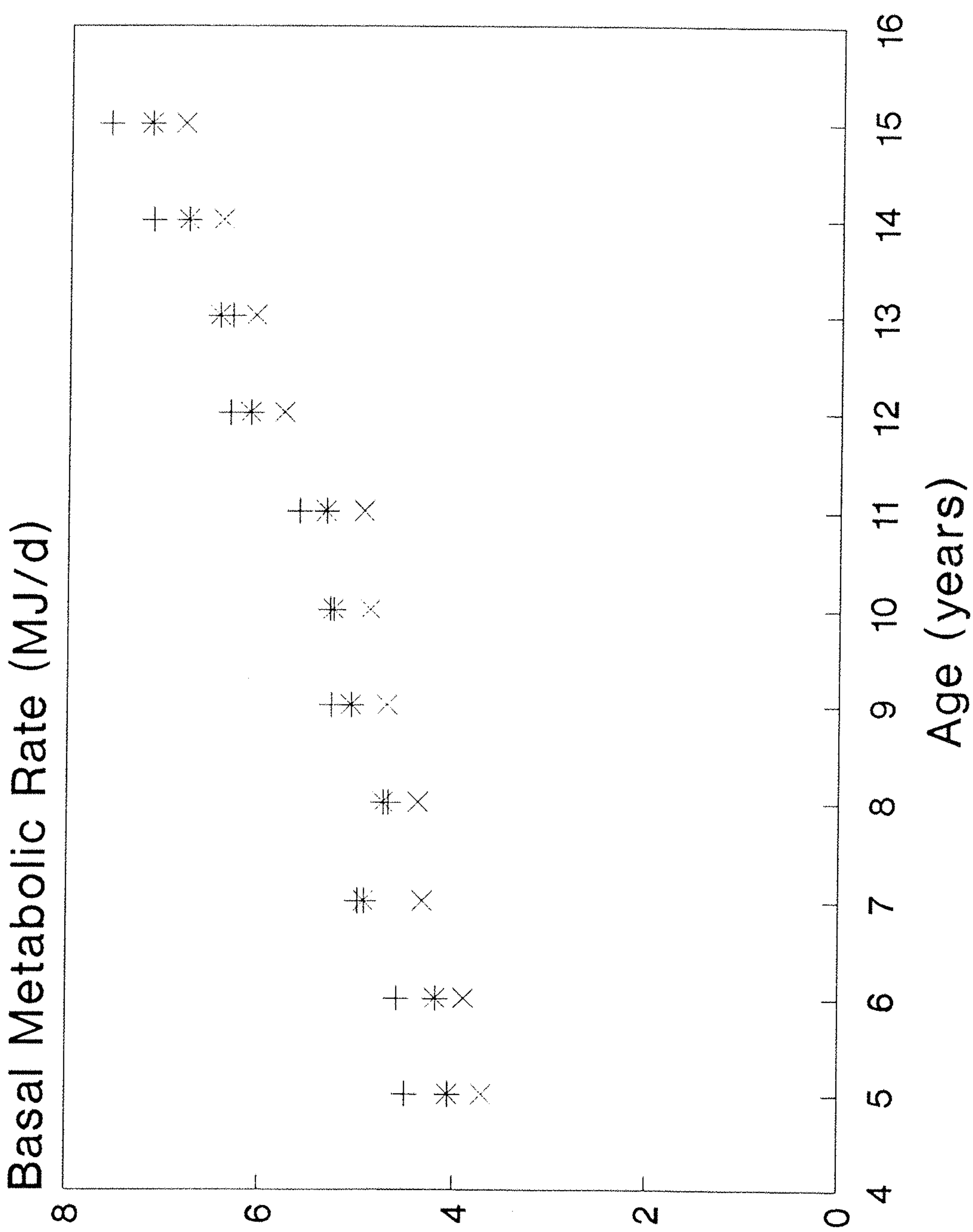


Figure 3.16 Basal metabolic rate (MJ/d) of girls aged 5 to 15 years from the present study ┼ , and their predicted values using Schofield equations [1985] ✳ , and Harris Benedict equations [1919] ✕ . Values are expressed as the mean for each age group.

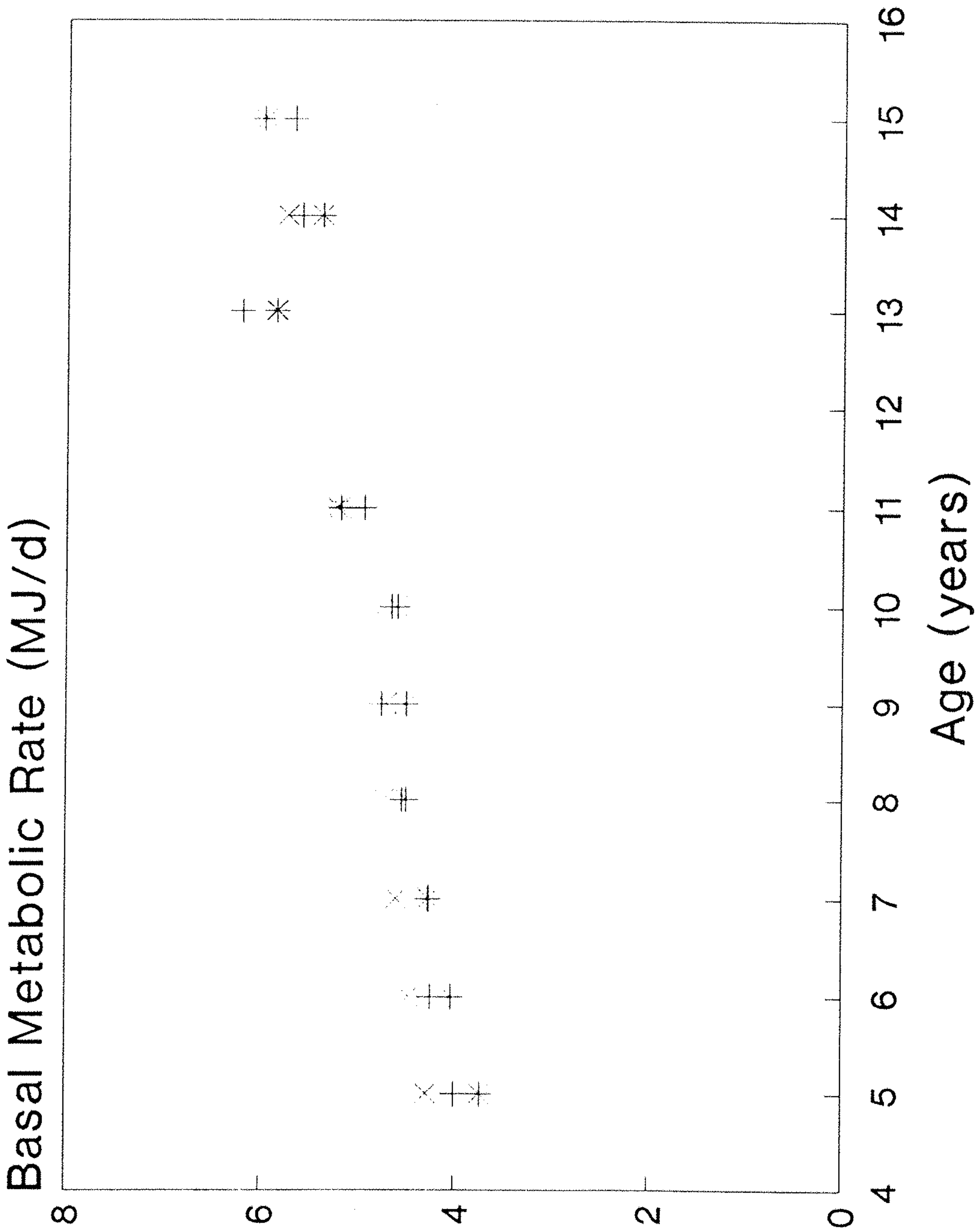


Figure 3.17 Energy intake (MJ/d) of boys aged 5 to 15 years, from the present study + , Widdowson [1947] ✳ , and Nelson [1985] × . Values are expressed as the mean for each age group.

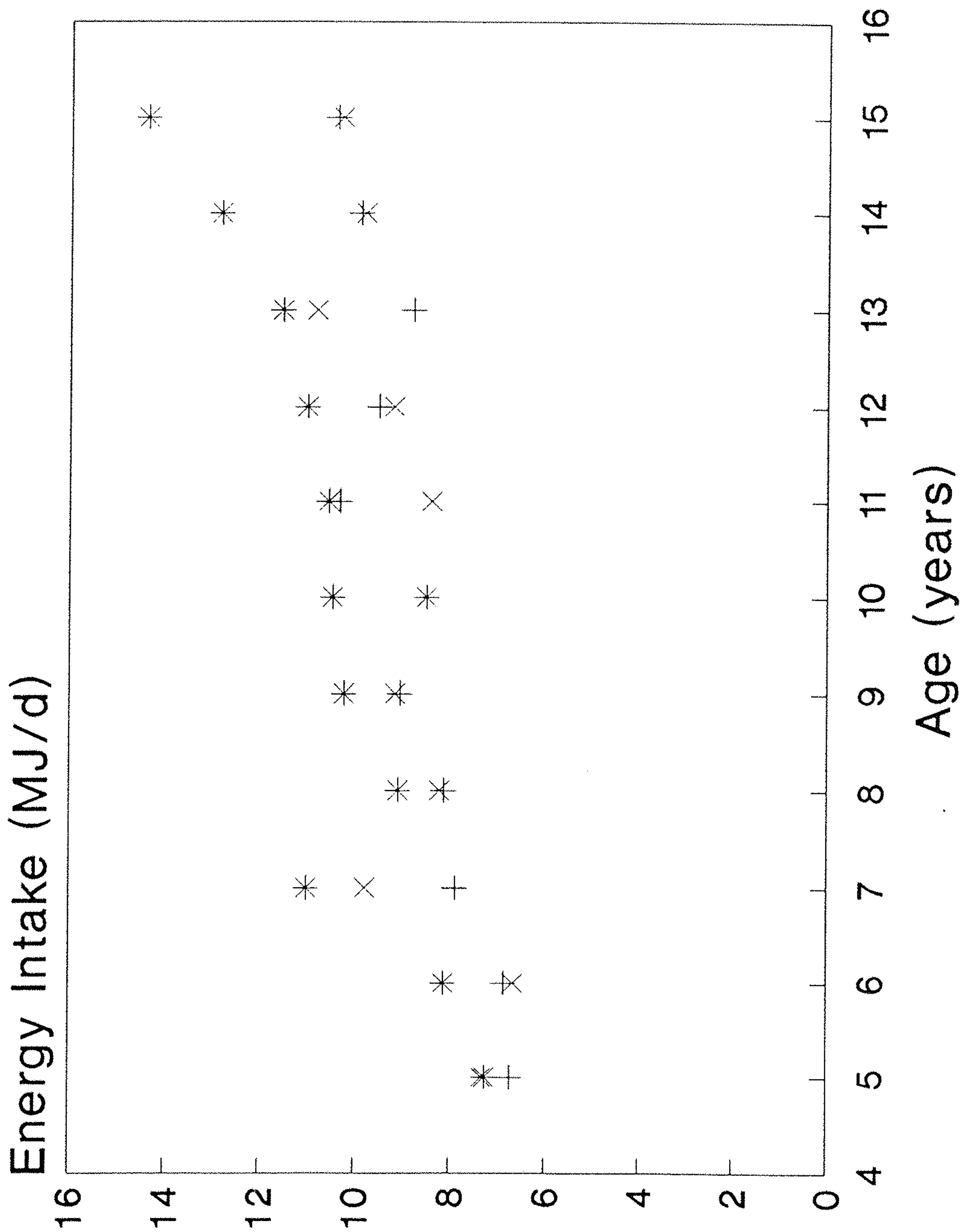
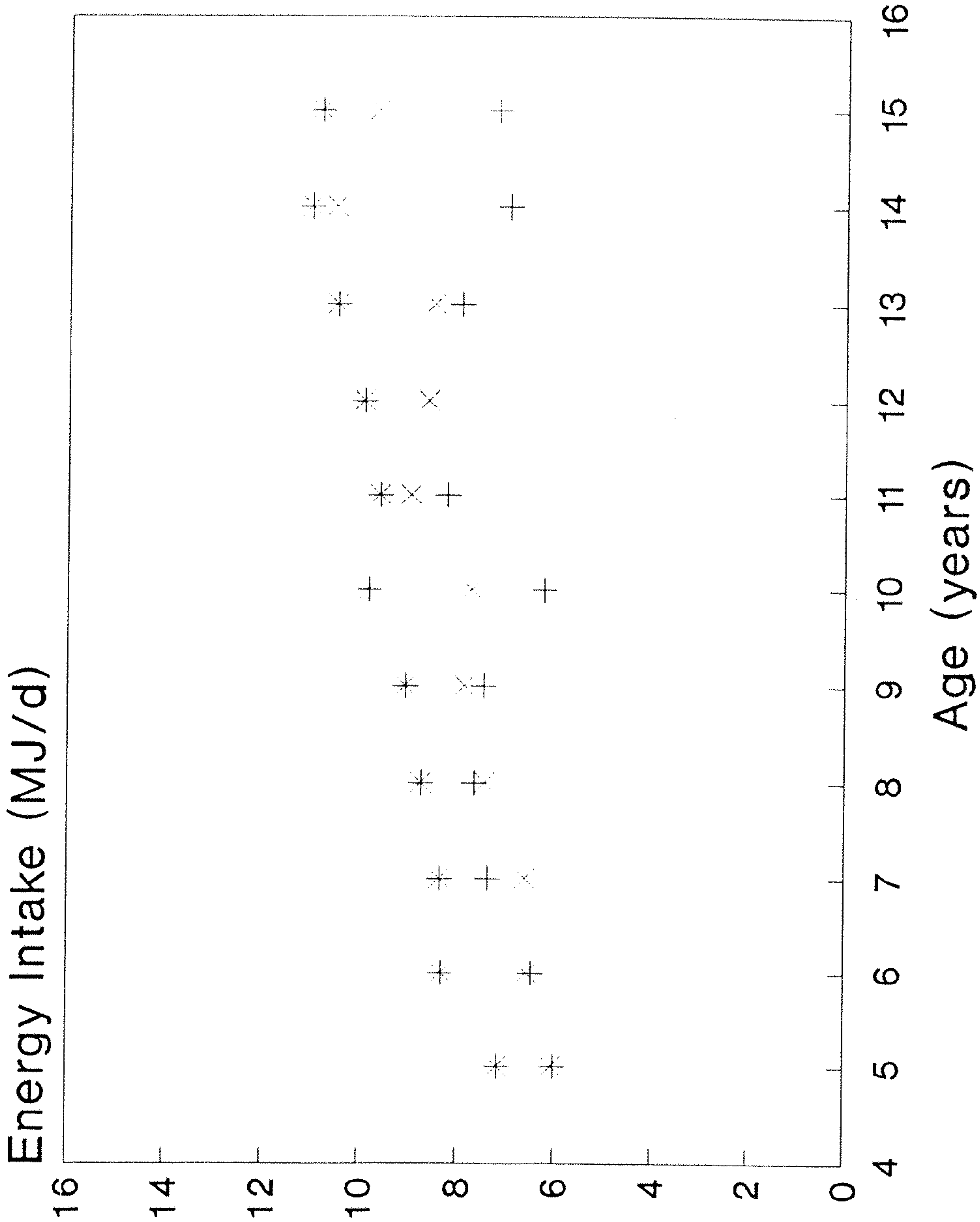


Figure 3.18 Energy intake (MJ/d) of girls aged 5 to 15 years, from the present study +, Widdowson [1947] ✳, and Nelson [1985] ×. Values are expressed as the mean for each age group.



insidious but essential alteration in body composition during growth which dictates changes in metabolic demand and energy intake.

The anomaly between the present study and those of Widdowson [1947] and Nelson [1985] when comparing mean energy intake (Figure 3.17, boys; 3.18, girls) agreed with the review by Whitehead et al [1982]. These studies appear to show children consuming less but remaining the same weight over a period of 40 years. The suggestion was that physical activity is in decline. The implications of reduced physical activity from childhood into adulthood are greater health risks associated with lack of physical fitness in the population. These include coronary heart disease, non-insulin-dependent diabetes, deteriorating bone mass in postmenopausal women, psychological wellbeing and possibly cancer.

The Estimated Average Requirements (EAR) [Department of Health, 1991] for energy were comparable with this study: girls, 7.28MJ/d (EAR) versus 7.03 MJ/d (this study); boys, 8.24 MJ/d (EAR) versus 8.14 MJ/d (this study). In the older age group girls had a lower mean EIN than their EAR: 8.83 MJ/d (EAR) versus 7.71 MJ/d (this study); whilst boys had a higher mean EIN than their EAR: boys, 9.27 MJ/d (EAR) versus 9.95 MJ/d (this study).

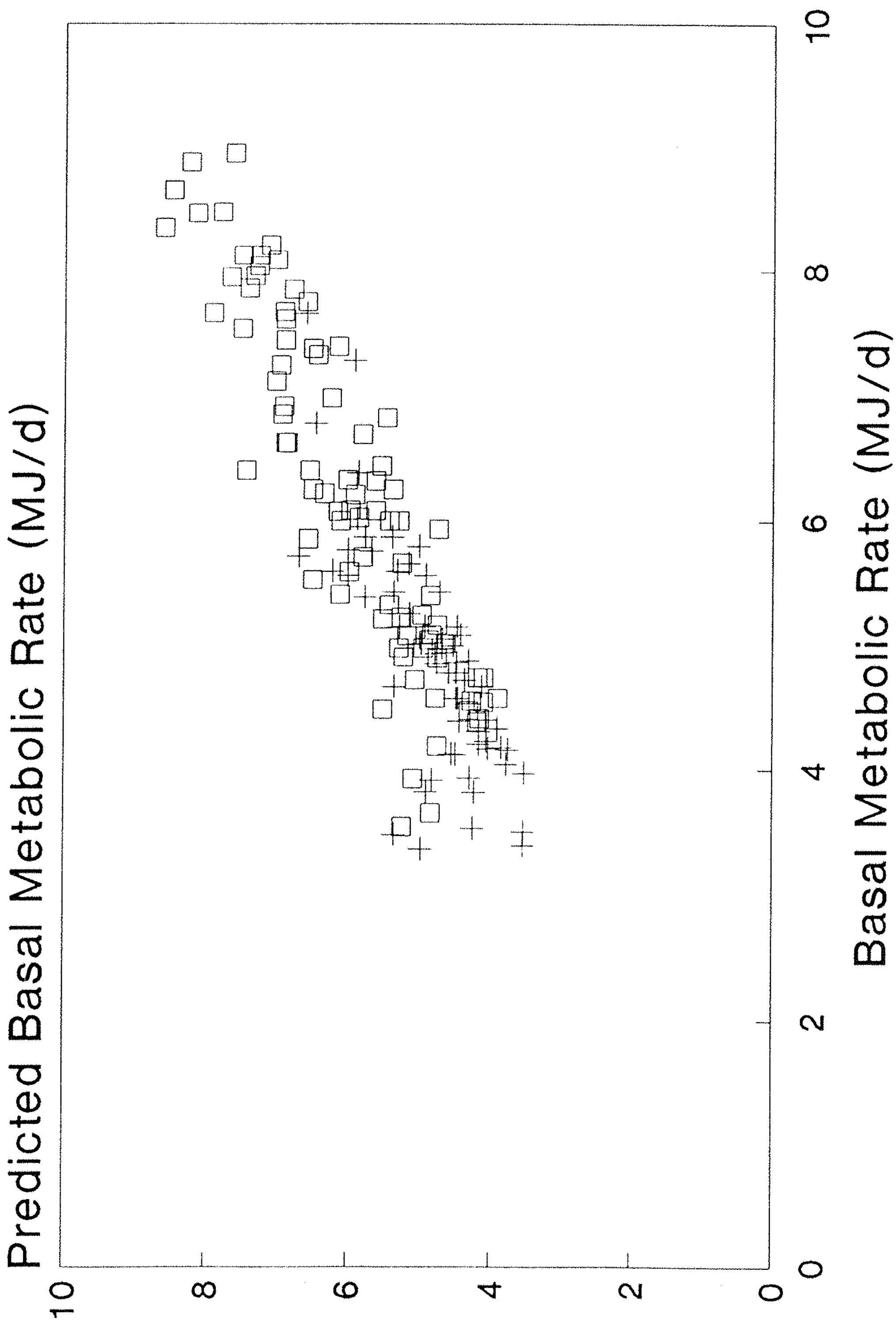
The strongest association was between BMR and weight, height and LBM. These variables also featured prominently in regression equations formed to predict BMR. Usually considered the most thorough method of regression analysis, the stepwise procedure was chosen in preference to both backward and forwards methods for further analysis. Height and weight centile were initially included but the slope of the line was so small it was barely statistically significant. Neither body size nor relative body size appeared as significant as body composition, specifically LBM.

On splitting the data into boys and girls (Table 3.6, p78) and comparing with Schofield equations [1985] the R value was lower for the present study and standard errors higher. The graph of BMR and Predicted BMR (Figure 3.19, p103) illustrates the close association between prediction and measurement (R_2 = 0.81). However for lower values there is less agreement, suggesting that prediction equations are less reliable for smaller or younger children.

In Table 3.7 (p79) each gender age group had three equation generated for it. These highlighted the importance of LBM in predicting BMR. Only the younger girls showed weight being more highly associated with BMR than LBM. It should also be noted as the group of children were divided by gender and age, numbers within each group were considerably reduced and standard error appeared to be simultaneously rising. Overall these equations suggested both body size and composition were important in predicting BMR, though gender and age also needed to be taken into consideration. These findings agreed with Schofield [1985], but it must also be noted the Schofield equations have differing age bands which would be associated with different weight ranges and possibly body composition.

Both correlation and regression analysis were performed under the assumption that linearity existed. Growth charts and all other assessments of growth strongly indicate that this is not the case. Care must therefore be taken when interpreting the results of this study and others where linearity has been assumed. When dealing with statistical formulae it is important to remember these are physiological measurements not simply mathematical ideas [Klieber, 1950].

Figure 3.19 Basal metabolic rate and predicted basal metabolic rate [Schofield, 1985] of boys□and girls+aged 5 to 15 years from the present study.



Although energy expenditure was suggested by the recent Dietary Reference Values [Department of Health, 1991] as the preferred method for estimating energy requirements, only children from 10 years had predictive equations for BMR. The 5 to 10 year requirements were derived from energy intake data alone because of the paucity of data available. The suggestion made by Wang et al [1936] 50 years previously, to use the energy intake to basal metabolic rate ratio to estimate requirements did not appear to have been considered. She suggested a blanket figure of 2 * BMR for energy requirements for children. In contrast the Physical Activity Level (total energy expenditure/BMR) for 10 to 18 year olds was suggested as 1.48 for girls and 1.56 for boys [Department of Health, 1991]. In the present study the EIN/BMR ratios for girls and boys were 1.48 and 1.43.

The younger children in the present study had significantly higher EIN/BMR ratios suggesting a higher proportion of metabolically active tissue with consequently higher demand for energy. Also, this might reflect the greater underestimation of dietary intake by the older children [Livingstone et al, 1992]. The use of the EIN/BMR ratio might be employed to estimate requirements in younger children, instead of solely EIN data, and may be used to assess under-reporting of dietary intakes.

3.5 SUMMARY AND CONCLUSIONS.

In a group of healthy children growing normally EIN and BMR both showed substantial variation within age groups. Patterns of BMR and EIN were consistent with previous studies, but EIN appeared to be less than the values typically reported 40-50 years ago. The highest degree of association with BMR came from weight, height and LBM. Both weight and lean body mass were prominent in regression equations generated to predict BMR. EIN/BMR ratios were created for each age group and gender.

In conclusion:

1) the ratio of reported energy intake to metabolic demand for energy at rest was, 1.65 and 1.60 for boys and girls aged 5 to 10 years; and 1.43 and 1.48 for boys and girls aged 11 to 15 years. Thus older children had lower EIN/BMR ratio than the younger children.

2) the metabolic demand for energy at rest and energy intake were both clearly related to body weight and lean body mass. There was greater variation in energy intake, likely to be related more to the physical activity component of energy expenditure than BMR. Lean body mass appeared to be important in determining BMR.

3) metabolic demand for energy at rest and reported energy intake were similar over the range of ages of girls and boys. However, there could be a 40% difference within a given age group.

CHAPTER 4. METABOLIC DEMAND FOR ENERGY AND ENERGY INTAKE IN DISEASE.

4.1 INTRODUCTION.

During childhood infections are commonplace. The fever which occurs is known to raise basal metabolic rate, but is often accompanied by a diminution in physical activity [Scrimshaw, 1977]. Balance between intake and expenditure of energy will therefore be maintained to prevent weight loss. If bouts of infection are common recovery time may not be long enough to allow growth to take place. If a negative energy balance exists [WHO, 1985] then the normal growth channel cannot be re-established.

An example of a disease associated with recurring infections is Cystic Fibrosis (CF). It has been shown that energy expended at rest or basal metabolic rate (BMR) is raised in groups of children with CF [Buchdal et al, 1988; Vaisman et al, 1987; Shepherd et al, 1988]. In addition, energy intakes (EIN) of these children have been shown to be higher than those of children without the disease [Ellis & Wootton, 1989]. It is uncommon for these two variables to be assessed in the same group of children.

With the possibility of having permanently or recurrently raised BMR, and a known tendency toward higher faecal energy losses [Murphy et al, 1991] how adequate is the EIN of these children to meet their metabolic demand for energy ?

The aim of this study was to determine the adequacy with which metabolic demand for energy was met by EIN in a group of children with CF in comparison with a group of healthy children of normal growth.

4.2 METHODS.

4.2.1 Subjects.

The 37 children with CF who took part in this study were part of a large CF clinic further described in chapter two. Their participation was voluntary but measurements were included within a clinical framework. The healthy children were a subsample from the group of healthy children in the previous study.

4.2.2 Data Collection.

Standard procedures were followed to measure each child's BMR, their EIN for seven days, and height, weight and body composition. BMR was estimated by indirect calorimetry using a ventilated hood as described in chapter 3. Dietary intake was recorded using digital electronic scales explained in detail in the methodology section. Body composition was estimated from skinfold calliper measurements also found in more detail in the section covering methodology. All children were closely monitored and given support throughout the study. After completing the dietary record the families were interviewed to ensure there were no omissions or errors regarding both food and dietary supplements.

4.2.3 Statistical Analysis.

Values are presented as means with standard error of the mean and range. Correlation analysis was used to determine whether relationships existed between measured variables. Linear regression was carried out to generate predictive equations for BMR using weight and lean body mass (LBM).

4.3 RESULTS.

4.3.1 Anthropometry and Body Composition.

The characteristics of girls and boys with and without CF are shown in Table 4.1 (p109). Mean values show how closely the two groups were matched for LBM, and the similarities in age, weight and height. Relative height and centiles for both weight and height revealed the children with CF had a tendency to be both shorter and lighter for their age. The shift toward negative height standard deviation scores in the CF group is illustrated in Figure 4.1 (p110).

Height for age and weight for height were determined as percentages to compare the two groups in terms of estimated nutritional status. According to the Waterlow classification [Jackson & Golden, 1988; Waterlow, 1987] neither group mean indicated poor nutritional status. Within the CF group 4 children were less than 90% height for age or stunted, and three different children were less than 80% of weight for height or wasted; one of the healthy children was also less than 80% weight for height.

4.3.2 Basal Metabolic Rate.

BMR mean values for the two groups are displayed in Table 4.2 (p111). BMR was also expressed per kilogram body weight and LBM. In addition, BMR as a percentage of predicted using gender, age, weight and height [Schofield, 1985] was also calculated. The CF values were 4% higher than their healthy matches when expressed in kilojoules per day or expressed per kilogram LBM per day; this figure rose to 9% when BMR was expressed per kilogram body weight. Both groups had higher BMRs than predicted, the controls by 2% and the CF group by 8%.

The correlation of BMR with age, weight, height and LBM

Table 4.1 The characteristics of a group of children with Cystic Fibrosis matched for lean body mass and gender with healthy children (n = 37). Values are expressed as means with standard error of the mean, and the range in parenthesis. Height is also expressed as a standard deviation score (SDS).

VARIABLES	CONTROL	CYSTIC FIBROSIS
AGE (yr)	9.27 (0.41) 5.08 - 14.31	10.29 (0.49) 5.47 - 15.27
WEIGHT (kg)	30.7 (1.5) 17.2 - 55.9	29.1 (1.5) 14.5 - 53.2
WEIGHT CENTILE	55 (4) 7 - 95	27 (4) 1 - 94
HEIGHT (cm)	134.2 (2.3) 108.8 - 160.5	134.2 (2.5) 108.5 - 166.9
HEIGHT CENTILE	60 (4) 3 - 95	30 (4) 1 - 88
HEIGHT SDS **	0.28 (0.14) (-1.96) - 1.63	-0.78 (0.16) (-2.99) - 1.17
BODY FAT (%)	18 (1) 7 - 35	14 (1) 4 - 26
LEAN BODY MASS (kg)	25 (1) 15 - 41	25 (1) 14 - 42
BODY MASS INDEX (kg/m^2)	17 (0) 13 - 22	16 (0) 12 - 21
HEIGHT FOR AGE (%)	101 (1) 93 - 107	96 (1) 87 - 105
WEIGHT FOR HEIGHT (%)	99 (2) 75 - 130	98 (2) 74 - 135

** $p<0.001$

Figure 4.1 The values for height standard deviation score (HTSDS) plotted against age for the children with Cystic Fibrosis X and their healthy controls ⊡ .

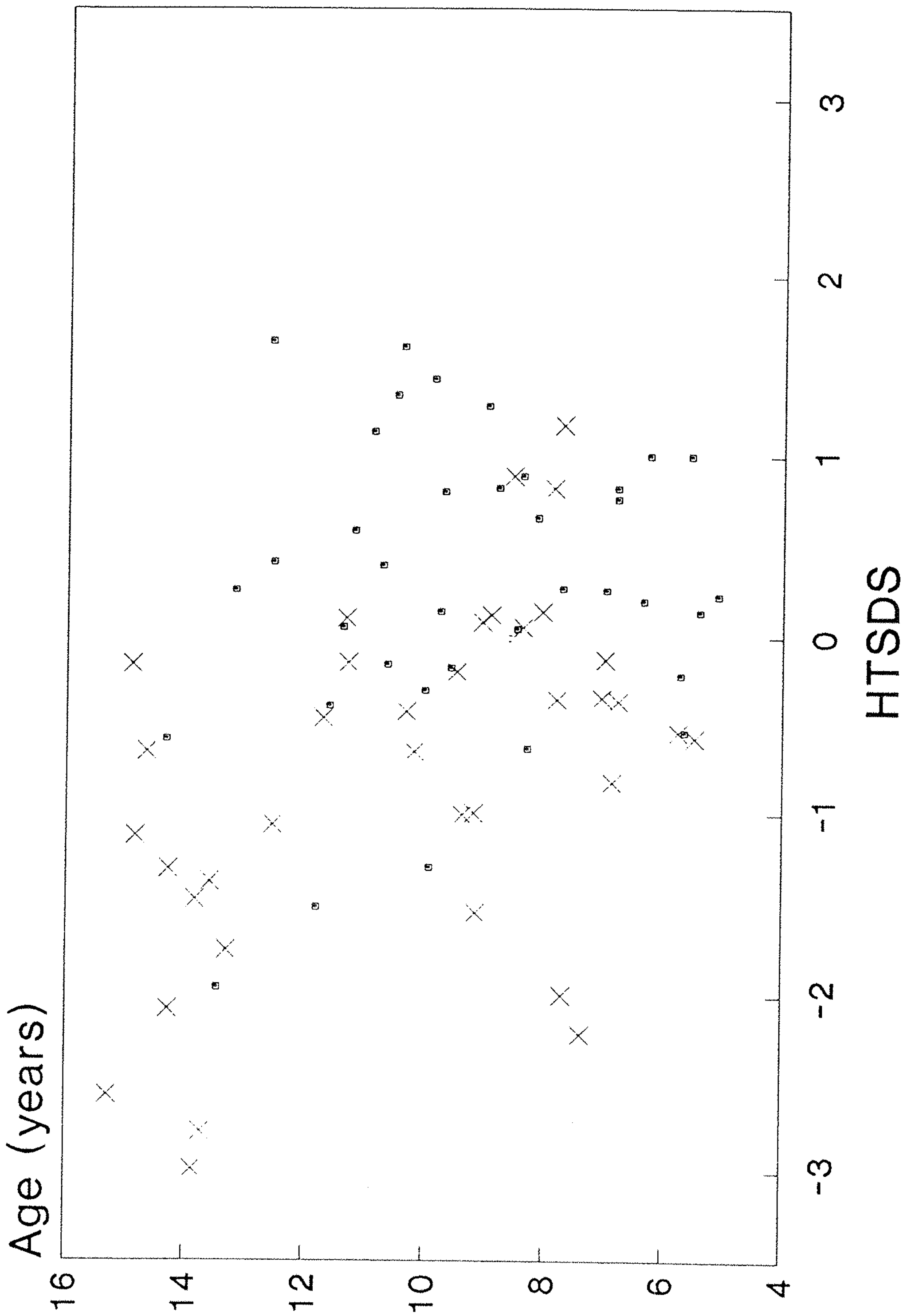


Table 4.2 The energy intake (EIN) and basal metabolic rate (BMR) of children with Cystic Fibrosis and their lean body mass matched healthy controls (n = 37). Plus values for the percentage of predicted BMR [Schofield, 1985], and ratio of EIN to BMR. Values are expressed as means with standard error of the mean in parenthesis, and the range displayed below.

VARIABLES	CONTROL	CYSTIC FIBROSIS
BMR (kJ/d)	4869 (143) 3390 - 7430	5078 (188) 2893 - 8672
BMR predicted (%)	102 (2) 68 - 125	108 (2) 76 - 161
BMR (kJ/kgbwt/d)	167 (6) 98 - 240	182 (6) 129 - 266
BMR (kJ/kglbm/d)	203 (6) 130 - 289	212 (7) 147 - 300
EIN (kJ/d)	7695 (237) 5244 - 11218	8487 (338) 4872 - 13710
EIN (kJ/kgbwt/d) *	265 (10) 123 - 363	305 (13) 202 - 553
EIN (kJ/kglbm/d) *	321 (10) 189 - 400	356 (14) 239 - 604
EIN/BMR	1.60 (0.05) 1.00 - 2.46	1.71 (0.07) 1.03 - 2.90

* $p<0.05$

appeared to be good for the group with CF (R = 0.57, 0.82, 0.64, 0.80; all at $p<0.01$). The strength of association between those variables and BMR was comparable with the healthy children (R = 0.59, 0.68, 0.70, 0.73; all at $p<0.01$). Thus 67% or 64% of the variance in BMR could be explained by weight or LBM respectively in the CF group. By comparison only 46% or 53% of the variance in BMR could be explained by weight or LBM in the healthy group.

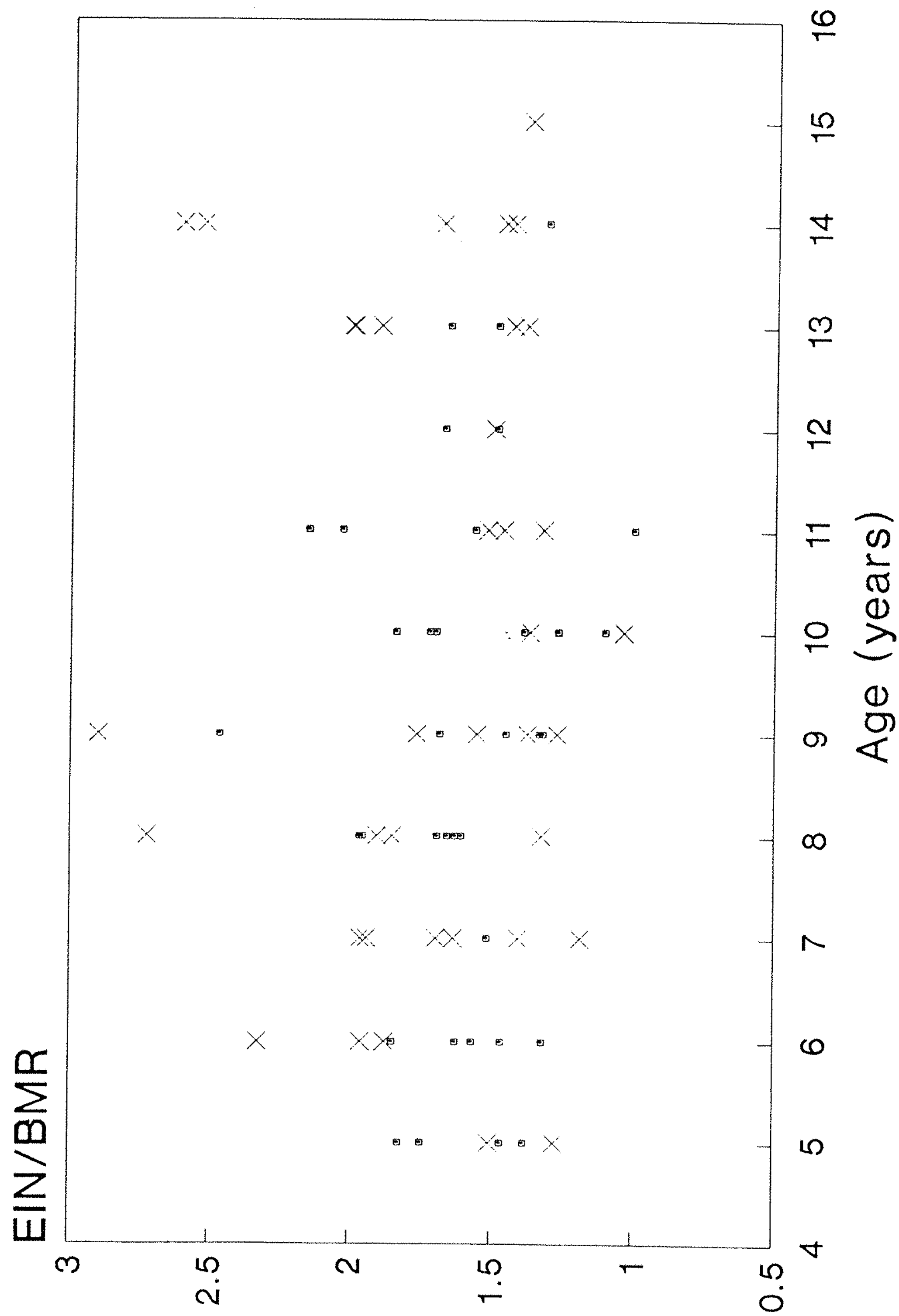
Regression equations were generated for BMR for each group including either weight or LBM. The four equations are illustrated in Table 4.3. The standard errors for each equation were slightly less for the healthy children than for the CF group.

4.3.3 Energy Intake.
Mean values for EIN are displayed in Table 4.2 (p111). The CF group had a mean EIN which was 10% higher than the healthy group. When expressed per kilogram LBM the difference was 11%. Similarly with BMR, EIN when expressed per kilogram body weight showed the largest difference between the two groups, 15%. Both the latter were statistically significant differences at $p<0.05$.

EIN was less well correlated with age, weight, height and lean body mass than BMR. The CF group had values of 0.52, 0.58, 0.59 and 0.61 at $p<0.001$; whilst the healthy group had values of 0.51, 0.57, 0.61 and 0.64 at $p<0.001$ respectively. Lean Body mass accounted for 37% of the variance in EIN for the CF group and 41% in the healthy group.

4.3.4 Energy Intake to Basal Metabolic Rate Ratio.
The range of values for the two groups is illustrated in Figure 4.2 (p113). The CF group mean of 1.71 was higher than the healthy group at 1.60 but the difference was not

Figure 4.2 Values for the energy intake to basal metabolic rate ratio (EIN/BMR) in age groups of the children with Cystic Fibrosis X and their healthy controls ⊡ .



statistically significant. The CF children had a wider range of values than their healthy controls (Table 4.2).

4.4 DISCUSSION.

The aim of this study was to ascertain how a chronic disease condition, Cystic Fibrosis, affected metabolic demand and energy intake in the same group of children, with a view to the adequacy of intake to meet demand. By observation alone, children with CF are often smaller than healthy children of the same age. Matching the two groups illustrated this tendency, having the same mean LBM and height, but weight and %BF greater in the healthy children by 5% and 22%. The group of CF children were smaller and lighter for their age (mean, 10.29yr) than the healthy group (mean, 9.27yr).

The importance of comparing children by body size and composition as well as by age can be illustrated by an example from within this study. One girl aged 13.84 years with CF exhibited both stunting and wasting. Her LBM matched control was aged 8.38 years. If the girl with CF was compared with healthy girls of 13 years, her BMR would have been considered low and her EIN above average but by no means outside the normal range. If expressed per kilogram body weight or LBM, BMR would have been considered very hight when compared with healthy 13 year olds. However, when BMR and EIN were compared with healthy 8 year old girls, the 13 year old with CF appeared to have both within the expected range of values. The legacy of insufficient EIN to meet metabolic demand may be the explanation for her high EIN/BMR ratio of two, or raised faecal energy losses. Neither healthy 8 or 13 year old girls normally exhibit a figure as high as two (see previous chapter). Using LBM to match these children may help to detect whether the difference in BMR between the two groups results from altered genetically programmed tissue or metabolically altered tissue caused by environmental changes.

Previous studies have reported between 9% [Buchdal et al, 1988] and 22% [Wootton et al, 1991] difference in BMR when expressed per kilogram body weight; or 7% and 22% respectively per kilogram LBM when comparing children with CF and those without the disease. The present study showed the CF group had a mean BMR per kilogram body weight 9% greater than controls, and 4% difference when comparing BMR expressed per kilogram LBM. Neither 4% or 9% differences were significantly different from the controls using statistical comparisons.

Values for EIN suggested a tendency toward higher EIN for the CF children which agreed with previous studies [Ellis & Wootton, 1989; Daniels et al, 1987]. Although mean EIN was 10% higher for the CF group it was not statistically significant. When expressed per kilogram body weight EIN was 15% higher, and 11% higher when expressed per kilogram LBM, neither were statistically significant differences. The increased EIN was greater than the rise in BMR found in the CF group. Raised faecal energy losses [Murphy et al, 1991] might account for the excess EIN of the CF group, 6% greater than BMR when expressed per kilogram body weight.

Correlations for the two groups underlined the importance of weight and LBM in relation to BMR, and to a lesser extent EIN. Regression equations generated using either body weight or LBM showed a high degree of association but also high standard errors. The latter perhaps caused by being small groups. When groups were divided by age and gender into prepubertal and pubertal sections and regression analysis was performed, equations could no longer be generated.

Recommendations for EIN of children with CF have recently been set out alongside those for healthy children [The Hospitals for Sick Children, 1991] to complement the

Dietary Reference Values [1991]. These recommendations have not altered from between 120 to 150% of EAR for children with CF older than one year of age. Wootton et al [1991] questioned the suitability of this approach. The feasibility of consuming this amount of energy as food, the possibility of pancreatic enzyme replacement therapy not being adequate to prevent high energy losses, and large variability in BMR combined to indicate the need for recommendations which have a more individual approach.

The Dietary Reference Values [1991] advocated using recommendations based upon energy expenditure, although they could only do so for children of ten years and older. The regression equations produced (Table 4.3, p117) suggest predicting BMR from CF generated equations would be similar to predicting from healthy children generated equations. The relatively small group upon which the equations were based could not be divided into gender or age based equations, both shown to be important when considering BMR of children.

Another method of estimating energy requirements for these children could be using EIN/BMR ratios. This would be personalised to the child rather than a percentage times an estimated figure based upon information prescribed for healthy children. The EIN/BMR ratio for the group of children with CF in this study was a mean of 1.7 versus 1.6 for the healthy group. It suggests within the children with CF were individuals whose energy needs were substantially greater than the healthy group, both for their age and with respect to catch-up growth, and raised faecal energy losses.

Table 4.3 Regression equations for the Cystic Fibrosis group and the healthy controls. W: body weight in kilogams; F: lean body mass in kilograms. The equations are presented for 37 children in each group with their respective R value and standard error (se). Basal metabolic rate is calculated in megajoules per day.

GROUP		R	se	n
CONTROL	BMR = 0.064W + 2.90	0.68	0.652	37
CYSTIC FIBROSIS	BMR = 0.105W + 2.00	0.82	0.668	37
CONTROL	BMR = 0.100F + 2.39	0.73	0.604	37
CYSTIC FIBROSIS	BMR = 0.136F + 1.72	0.80	0.693	37

4.5 SUMMARY AND CONCLUSIONS.

Two groups of children, one with a chronic disease Cystic Fibrosis (CF) and the other free of disease, were matched for gender and LBM. Mean BMR and EIN tended to be higher for children with CF than healthy children but differences did not reach statistical significance. The elevation in EIN was greater than that in BMR, possibly to account for increased faecal energy losses.

In conclusion:

1) equations used to predict BMR for a group of children with Cystic Fibrosis (CF) were comparable with those for their controls. The equations used to predict BMR for healthy children would be satisfactory for predicting BMR in groups of CF children. When determining energy requirements for children with CF, it would be unwise to use only energy expenditure data.

2) the significantly greater reported energy intake per unit of body tissue in the group with CF, compared with their controls, may be explained by raised faecal energy losses which led to reduced metabolizable energy availability. Thus children with Cystic Fibrosis may have elevated requirements, but not necessarily because of a raised metabolic demand for energy at rest.

3) the reported energy intake to metabolic demand for energy at rest (EIN/BMR) was greater for the Cystic Fibrosis group than their controls. This ratio might be used to make recommendations for energy intake in Cystic Fibrosis (CF) because it appears to account for altered requirements.

CHAPTER 5 METABOLIC DEMAND FOR ENERGY AND ENERGY INTAKE IN MAINTENANCE CHEMOTHERAPY.

5.1 INTRODUCTION.

One of the major problems for children with cancer is malnutrition [Van Eyes, 1979]. Two studies of children with cancer [Kien & Camitta, 1987; Stallings et al, 1989] have shown that although at diagnosis energy expenditure at rest was greater than predicted, within seven days the difference disappeared. A further study by Merritt and colleagues [1981] described a rise in predicted basal metabolic rate (BMR), persisting 30 days after diagnosis. There appeared to be a raised metabolic demand during the disease process, which continued during treatment.

It is known that chemotherapy treatment can potentiate severe nausea, vomiting and anorexia. The resulting malabsorption will perpetuate poor nutritional status [Van Eyes, 1985]. Growth deficits have been recorded in a large group of children with a diagnosis of acute lymphoblastic leukaemia (ALL) over a period of 10 years but it was unclear whether the deficit was attributable to the disease process itself or the therapy received [Clayton et al, 1988].

The purpose of this study was to investigate the metabolic demand for energy and simultaneous energy intake of children during maintenance chemotherapy, and determine whether they remained comparable with healthy children not receiving treatment.

5.2 METHOD.

5.2.1 Subjects.

The subject group included twenty five children (aged 5 to 15 years) receiving chemotherapy. Fifteen had a diagnosis of ALL and were on Medical Research Council UK acute lymphoblastic leukaemia (UKALL) trials (three girls and twelve boys). The other ten children (seven girls and three boys) included one with chronic granulocytic leukaemia and nine with various solid tumours (ST). They were all on UK Children Cancer Study Group (UKCCSG) trials or related studies. Before participating in this study each child received a minimum of three courses of chemotherapy, in addition to initial diagnostic or therapeutic surgery. Diagnosis was made a minimum of six months before this study. All children were clinically well and afebrile throughout the study period.

5.2.2 Data Collection.

The methods of determining EIN and BMR have been described in chapter two. They were estimated in the week prior to monthly chemotherapy treatment. Anthropometry and body composition measurements were also carried out as described earlier. The chemotherapy treated children were matched from the large group of healthy children detailed in the methodology chapter. These controls were matched by gender and lean body mass (LBM).

5.2.3 Statistical Analysis.

All data gathered was analyzed using SPSS software. The treated children were investigated as a group, and also divided into two diagnosis groups described (ALL and ST). Association between variables was assessed from correlation analysis. Regression equations were generated for BMR from either body weight or LBM. The unpaired Student's t-test was used to assess significance of differences between groups.

5.3 RESULTS.

5.3.1 Chemotherapy Treated and Controls.
The characteristics of these two groups are described in Table 5.1 (p122). Both had a mean age of 9 years and similar mean values for weight, height and LBM. Mean weight and height centiles were greater for the control group than the treated group, by 13% and 8% respectively. Mean height standard deviation score (SDS) was also greater for the control group, by 22%. The range of values is illustrated in Figure 5.1 (p123). Body composition and body mass index (BMI) values were similar.

Mean values for percentage height for age and weight for height were comparable. One of the treated group was less than 90% height for age, considered stunted; and three of the treated group were less than 80% weight for height, considered wasted [Jackson & Golden, 1987; Waterlow et al, 1977]. These values were from four different children.

Mean values for BMR and EIN were similar for the treated group and their controls. All results are shown in Table 5.2 (p124). The controls were 107% of predicted BMR, but the treated group were only 98% of predicted BMR. None of the differences between the two groups were statistically significant.

The treated group variables most closely associated with BMR were age, weight, height and LBM, all at $p<0.001$; ranging from $r = 0.85$ for age to 0.88 for LBM. EIN was also associated with BMR but not as strongly at $r = 0.53$ ($p<0.01$). By comparison, in the control group, there were strong associations between BMR and the same variables ranging between $r = 0.76$ for age to 0.89 for LBM ($p<0.001$). EIN had a stronger association with BMR,

Table 5.1 The characteristics of the group of chemotherapy treated children (both Acute Lymphoblastic Leukaemia:ALL and solid tumour:ST) and their healthy controls (n = 25). Height is also expressed in standard deviation scores (SDS). Values are means plus standard error of the mean in parenthesis, with the range below.

VARIABLES	CONTROLS	CHEMOTHERAPY (ALL + ST)
AGE (yr)	9.70 (0.61) 5.54 - 15.20	9.84 (0.62) 5.61 - 15.84
WEIGHT (kg)	32.2 (2.3) 19.0 - 67.3	31.8 (2.3) 18.3 - 59.1
WEIGHT CENTILE	54 (6) 7 - 95	47 (7) 1 - 95
HEIGHT (cm)	137.1 (3.3) 109.7 - 169.7	137.6 (3.8) 108.8 - 173.8
HEIGHT CENTILE	62 (6) 3 - 96	57 (6) 1 - 100
HEIGHT SDS	0.32 (0.21) (-1.95) - 1.72	0.25 (0.26) (-3.21) - 3.16
BODY FAT (%)	18 (1) 7 - 35	18 (1) 3 - 29
LEAN BODY MASS (kg)	26 (2) 16 - 44	26 (2) 15 - 45
BODY MASS INDEX (kg/m^2)	17 (0) 13 - 24	16 (0) 13 - 20
HEIGHT FOR AGE (%)	101 (1) 94 - 111	101 (1) 88 - 114
WEIGHT FOR HEIGHT (%)	102 (2) 82 - 118	94 (3) 66 - 125

Figure 5.1 The values for height standard deviation score (HTSDS) plotted against age for the children receiving chemotherapy X and their controls ▣ .

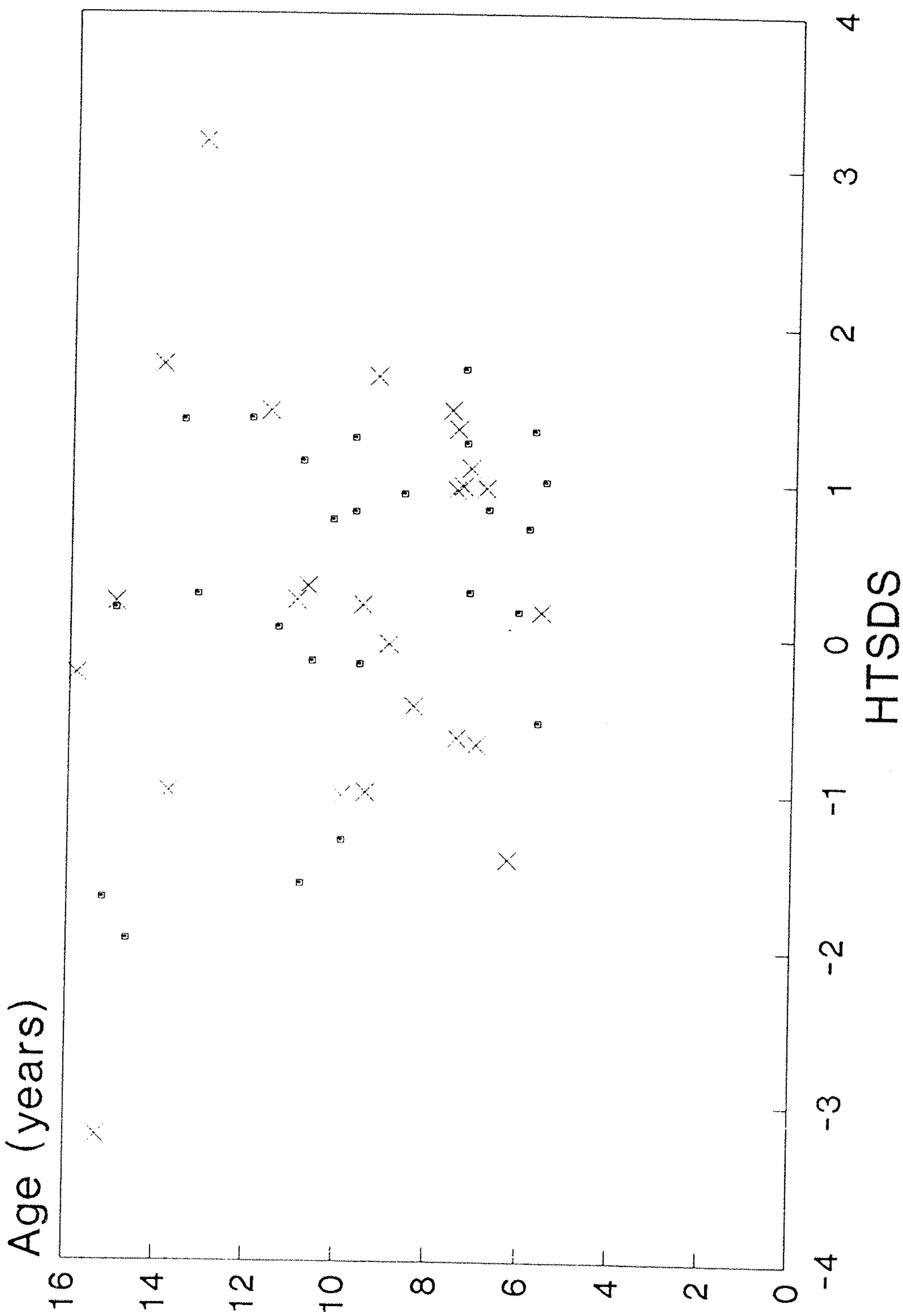


Table 5.2 Basal metabolic rate (BMR) and energy intake (EIN) of the chemotherapy treated group and their matched controls (n = 25). BMR and EIN are expressed per kilogram body eight and lean body mass. BMR is also expressed as a percentage of predicted [Schofield, 1985]; EIN is also expressed as a percentage of the estimated average requirement (EAR) [DH, 1991].

VARIABLES	CONTROLS	CHEMOTHERAPY (ALL + ST)
BMR (kJ/d)	5220 (174) 4040 - 6969	4838 (213) 3222 - 7245
BMR PREDICTED (%)	107 (2) 94 - 126	98 (2) 78 - 113
BMR (kJ/kgbwt/d)	172 (7) 101 - 240	160 (6) 101 - 210
BMR (kJ/kglbm/d)	211 (8) 149 - 289	196 (7) 133 - 250
EIN (kJ/d)	7734 (344) 5187 - 11124	7636 (473) 4398 - 13247
EIN/EAR (%)	97 (3) 58 - 132	96 (5) 60 - 149
EIN (kJ/kgbwt/d)	256 (12) 123 - 352	252 (14) 140 - 391
EIN (kJ/kglbm/d)	313 (14) 168 - 423	307 (14) 174 - 449
EIN/BMR	1.48 (0.05) 1.00 - 1.84	1.59 (0.08) 0.96 - 2.73

r = 0.72 ($p<0.001$), in the control group than the treated group. EIN for both groups showed similar associations with the same variables but no relationship was as strong as had been with BMR.

Regression equations, generated for BMR, used either weight or LBM as dependent variable. These are shown in Table 5.3 (p126). In the treatment group 73% of the variance in BMR could be explained by weight; only 69% in the control group. When LBM was dependent variable it could explain 77% of the variance in BMR for the treatment group, and 79% in the control group. Mean EIN/BMR ratios were 1.6 for the treated group and 1.5 for their controls.

5.3.2 Acute Lymphoblastic Leukaemia and Controls.
The characteristics of these two groups are displayed in Table 5.4 (p127). The three girls and 12 boys had a mean age of 9 years in both groups. Mean weight and height were similar but mean weight and height centiles were 17% and 31% less in the ALL group than their controls. Relative height was also less for the ALL group than their controls; the range of values showed the lowest height SDS was -3.21. Mean percentage body fat, LBM and BMI of the two groups were comparable.

When considering nutritional status mean height for age and mean weight for height were adequate for both groups. One child in the ALL group was below 90% height for age, regarded as being stunted [Jackson and Golden, 1987; Waterlow et al, 1977].

Values for BMR and EIN were lower in the ALL group than their controls, whichever way they were expressed. Controls mean BMR was 7% greater than predicted [Schofield, 1985] whilst ALL group BMR was 2% less than predicted (Table 5.5, p128). Differences between mean BMR

Table 5.3 Regression equations for the chemotherapy group and their controls. W: body weight in kilograms; F: lean body mass in kilograms. The equations are presented for 25 children in each group with their respective R value and standard error (se). Basal metabolic rate is calculated in megajoules per day.

GROUP		R	se	n
CONTROL	BMR = 0.062W + 3.218	0.83	0.493	25
CHEMOTHERAPY	BMR = 0.082W + 2.248	0.86	0.547	25
CONTROL	BMR = 0.092F + 2.834	0.89	0.408	25
CHEMOTHERAPY	BMR = 0.108F + 2.063	0.88	0.512	25

Table 5.4 The characteristics of the children with Acute Lymphoblastic Leukaemia (ALL) and their matched controls (n = 15). Height is also expressed as a standard deviation score (SDS). Values are means plus standard error of the mean in parenthesis, and the range below.

VARIABLES	CONTROLS	ALL
AGE (yr)	9.42 (0.72) 5.64 - 15.20	9.72 (0.83) 5.61 - 15.84
WEIGHT (kg)	30.4 (2.1) 19.0 - 48.0	30.5 (2.3) 18.3 - 49.2
WEIGHT CENTILE	54 (7) 10 - 89	45 (9) 1 - 95
HEIGHT (cm)	136.1 (3.8) 109.7 - 158.5	134.1 (4.3) 108.8 - 170.5
HEIGHT CENTILE	65 (8) 5 - 96	45 (8) 1 - 93
HEIGHT SDS	0.44 (0.27) (-1.68) - 1.72	-0.25 (0.32) -3.21) - 1.45
BODY FAT (%)	18 (1) 13 - 24	19 (1) 13 - 29
LEAN BODY MASS (kg)	25 (2) 16 - 40	25 (2) 15 - 40
BODY MASS INDEX (kg/m^2)	16 (0) 13 - 19	17 (0) 14 - 20
HEIGHT FOR AGE (%)	102 (1) 94 - 111	99 (1) 88 - 107
WEIGHT FOR HEIGHT (%)	99 (2) 82 - 112	100 (3) 85 - 125

Table 5.5 Basal Metabolic Rate (BMR) and energy intake (EIN) of the Acute Lymphoblastic Leukaemia group (ALL) and their matched controls. EIN and BMR are expressed per kilogram body weight and per kilogram lean body mass. BMR is also expressed as a percentage of predicted [Schofield, 1985]. EIN is also expressed as a percentage of the estimated average requirement (EAR) [DH, 1991]. Values are means plus standard error of the mean in parenthesis, with the range below.

VARIABLES	CONTROLS	ALL
BMR (kJ/d)	5217 (195) 4160 - 6680	4794 (264) 3570 - 7245
BMR PREDICTED (%)	107 (3) 94 - 126	98 (2) 83 - 113
BMR (kJ/kgbwt/d)	178 (8) 129 - 240	163 (6) 118 - 208
BMR (kJ/kglbm/d)	217 (10) 156 - 289	201 (7) 150 - 250
EIN (kJ/d)	7940 (318) 6248 - 10466	7496 (610) 4829 - 13247
EIN/EAR (%)	98 (4) 58 - 115	91 (6) 66 - 143
EIN (kJ/kgbwt/d)	273 (15) 140 - 352	256 (18) 140 - 391
EIN (kJ/kglbm/d)	334 (18) 168 - 423	314 (20) 174 - 449
EIN/BMR	1.54 (0.06) 1.08 - 1.84	1.58 (0.11) 0.97 - 2.73

values were not statistically significant when the Student t-test was applied. Neither group EIN mean was 100% of the estimated average requirement for energy, the controls 2% less and the ALL group 9% less.

There were good associations between BMR and age (r = 0.80), weight (r = 0.89), height (r = 0.88) and LBM (0.91), all at $p<0.001$ for the ALL group. The same was true for the controls except that age was only at $p<0.01$. The ALL group had a weaker association between EIN and height (r = 0.63) and LBM (r = 0.60) both at $p<0.01$; there were no associations between EIN and other variables in the control group. Mean EIN/BMR for the two groups were similar at 1.5 for controls and 1.6 for the ALL group.

5.3.3 Solid Tumour and Controls.

The ten children (seven girls and three boys) in the ST group and their controls both had a mean age of 10 years. Their characteristics are together in Table 5.6 (p130). The ST group were lighter and taller than their controls, reflected in mean weight and height centiles. Height SDS was greater for the ST group than the controls, the former range included one girl with a height SDS of 3.16. Mean LBM, BMI and percentage body fat were similar for the two groups.

The mean values for percentage height for age and weight for height did not indicate poor nutritional status in either of the groups. However, within the ST group were two boys and one girl whose weight for height was less than 80%, or were wasted [Waterlow et al, 1977; Jackson and Golden, 1987].

The mean BMR of the ST group was 100% of that predicted, but control mean was 7% greater than predicted (Table 5.7, p131). Mean EIN was 4% less for controls and 3%

Table 5.6 Characteristics of the children with solid tumours (ST) and their matched controls (n = 10). Values are expressed as means plus standard error of the mean in parenthesis, with the range below. Height is also expressed as a standard deviation score (SDS).

VARIABLES	CONTROLS	ST
AGE (yr)	10.11 (1.12) 5.54 - 14.98	10.02 (0.96) 6.99 - 14.99
WEIGHT (kg)	34.9 (4.9) 20.4 - 67.3	33.7 (4.5) 20.6 - 59.1
WEIGHT CENTILE	53 (11) 7 - 95	49 (11) 6 - 91
HEIGHT (cm)	138.5 (6.4) 114.9 - 169.7	142.9 (6.7) 115.5 - 173.8
HEIGHT CENTILE	57 (10) 3 - 92	75 (8) 25 - 100
HEIGHT SDS	0.15 (0.34) (-1.95) - 1.39	0.99 (0.35) (-0.69) - 3.16
BODY FAT (%)	19 (3) 7 - 35	17 (2) 3 - 24
LEAN BODY MASS (kg)	28 (3) 16 - 44	28 (3) 16 - 45
BODY MASS INDEX (kg/m^2)	17 (1) 13 - 24	16 (1) 13 - 20
HEIGHT FOR AGE (%)	98 (1) 94 - 103	104 (2) 97 - 108
WEIGHT FOR HEIGHT (%)	106 (4) 95 - 132	85 (3) 66 - 102

Table 5.7 Basal metabolic rate (BMR) and energy intake (EIN) of the solid tumour group (ST) and their matched controls (n = 10). BMR and EIN are expressed per kilogram body weight and lean body mass. Also BMR is expressed as a percentage of predicted [Schofield, 1985]; and EIN expressed as a percentage of the estimated average estimate (EAR) [DH, 1991]. Values are means plus standard error of the mean in parenthesis, with the range below.

VARIABLES	CONTROLS	ST
BMR (kJ/d)	5224 (335) 4040 - 6969	4907 (372) 3222 - 7131
BMR PREDICTED (%)	107 (2) 96 - 113	100 (3) 78 - 108
BMR (kJ/kgbwt/d)	163 (12) 101 - 216	156 (11) 101 - 210
BMR (kJ/kglbm/d)	202 (12) 149 - 256	189 (13) 133 - 250
EIN (kJ/d)	7425 (731) 5187 - 11124	7846 (782) 4398 - 11785
EIN/EAR (%)	96 (7) 66 - 132	103 (9) 60 - 149
EIN (kJ/kgbwt/d)	229 (19) 123 - 321	246 (21) 169 - 363
EIN (kJ/kglbm/d)	281 (18) 189 - 368	296 (21) 206 - 425
EIN/BMR	1.40 (0.07) 1.00 - 1.68	1.61 (0.12) 0.96 - 1.93

higher for the ST group than the estimated average requirement for energy. The mean EIN/BMR ratio was greater for the ST group at 1.6 than controls at 1.4.

5.4 DISCUSSION.

Poor nutritional status is a contributory factor toward poor prognosis in children with cancer [Donaldson et al, 1981]. At diagnosis nutritional status is likely to be good, thus deterioration occurs during treatment [Carter et al, 1983]. Poor growth in the long term has been indicated by several studies of children in remission [Shalet et al, 1976; Swift et al, 1978; Kirk et al, 1987]. The factors associated with side effects of chemotherapy, poor dietary intake, raised faecal losses and the nature and magnitude of metabolic demand, could all upset the balance between intake and expenditure of energy sufficient to limit growth.

Several adult studies of patients with cancer have shown an increase in basal metabolic rate (BMR) [Warnold et al, 1978; Bozetti et al, 1980; Arbeit et al, 1984]. This was not the case in another larger study of 200 cancer patients by Knox et al [1983] where 33% were hypometabolic, 41% were within the normal range and 26% were hypermetabolic. Two studies have measured energy expenditure at rest in children with cancer. Both were undertaken from diagnosis. Kien and Camitta [1987] reported a limited series of observations in eight children with acute lymphocytic leukaemia. BMR was measured by indirect calorimetry for a five minute period during which time some of the children slept. Results were expressed as a percentage of published values for normal children and revealed the mean increase in BMR was 50% above normal. Apart from potential errors associated with such a brief period of measurement, no attempts were made to compare these results with BMR determined in a control group. It was also not possible to determine whether these measurements were made before or after treatment was initiated.

In a subsequent study by Stallings et al [1989] greater attention was paid to technical detail. Measurements of BMR were conducted in nine children with newly diagnosed ALL before and during the first two weeks of chemotherapy. Energy expenditure at rest was determined in the patients who were subdivided into two groups with differing tumour burden. They found the three patients with a high white cell count at diagnosis exhibited a BMR that was 13 to 45% greater than that predicted from age, size and gender. The other six children with low tumour burden exhibited BMR values comparable with those predicted. The raised BMR of the high tumour burden group rapidly returned to normal with treatment.

In the present study of 25 children receiving chemotherapy each child had a LBM and gender matched control. They had been receiving treatment for a minimum of six months, the longest up to 11 years during which time several relapses had occurred. The children who had been receiving treatment for greater than five years (three boys and one girl) all had minus height standard deviation scores (SDS), all had weight centiles of less than 50 and two had height centiles of less than 10. The one boy who had been receiving treatment for 11 years had a height SDS of -3.21 and both his weight and height centiles were less than one. He showed signs of stunting, being less than 90% of height for age, but was not classified as wasted. In comparison with their controls the girls were the same age, but the boys were between one and three years older than their LBM matched controls. The length of time of treatment appeared to relate to poor growth.

When the chemotherapy group was separated into the two diagnosis groups (Acute Lymphocytic Leukaemia and Solid Tumour) the children with poor growth, in terms of height, were in the ALL group (one child) whilst those who were wasted were confined to the ST group (three children). Although both were receiving chemotherapy, their initial treatments differed. The impact of surgery and radiotherapy, followed by chemotherapy, may have compounded to cause an energy deficit sufficient to lead to wasting in the children in the ST group.

Despite the presence of children presenting with stunting and wasting in the treatment group, mean EIN for the group was only 2% less than their controls'. Both groups also consumed energy only 3 - 4% less than the estimated average requirement [Department of Health, 1991]. These findings agreed with a large American study of 277 children with cancer who had EIN assessed at diagnosis and six months later. EIN was a comparable with the general American population for that age group, as a percentage of the RDA. The authors expressed concern for individuals at the extremes of the range of EIN, and foresaw problems for some children receiving treatment for a longer period of time [Carter et al, 1983]. Within the present study were three children with EIN lower than 70% of their EAR, none exhibiting poor nutritional status but two having EIN/BMR ratios less than one. Like the American study there were individual children in this present study whose EIN was a potential problem.

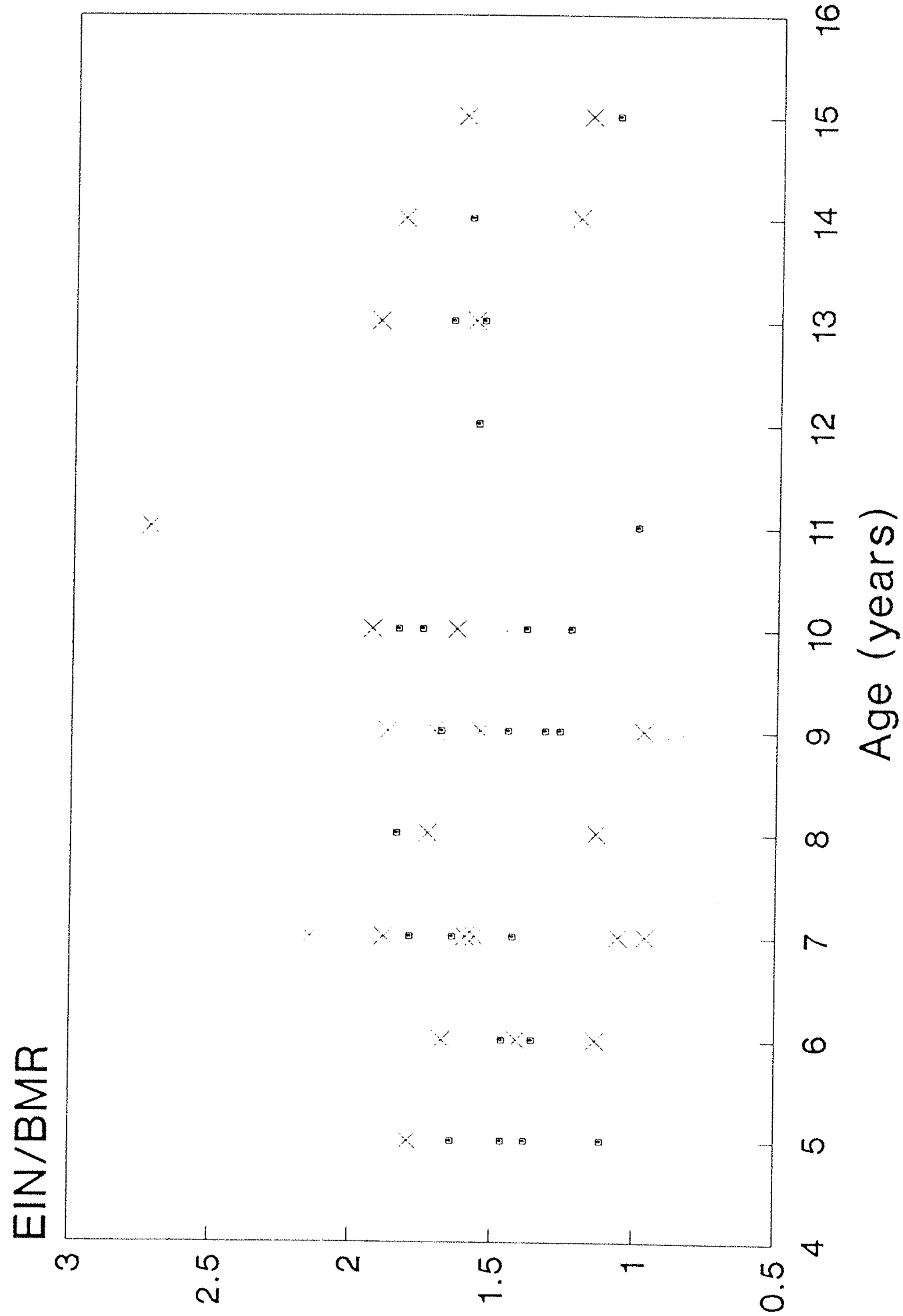
Looking at the two sub groups of treated children individually the 2% difference in EIN with the control children increased. In the ALL group the 6% difference in EIN was significantly lower than the controls when expressed in kilojoules per day. Values for the ST group ranged between 5 and 7% but were not statistically significant, and EIN was greater than controls'. The two treatment groups differed in EIN from their controls in opposite directions but when considered together as a group they cancelled the differences out to a large extent.

There was a 7% difference in BMR whether expressed in kilojoules, per kilogram body weight, or per kilogram LBM. When the two treatment groups were separated it was the ALL group who appeared to have an 8% lower BMR than their controls, whilst the ST group were lower by 6%. None of these differences were statistically significant. Four of the 25 treated children (16%) had BMRs which were less than 90% of their predicted values [Schofield, 1985], indicating hypometabolism in comparison with the control group.

The regression equations generated for BMR with weight or LBM had high R values though standard errors were large, probably the result of small numbers. These equations may be more appropriate for children being treated for cancer whose BMR may be altered. They also support the importance of LBM when determining BMR.

Although EIN/BMR ratio was higher for the treated group than their controls, it did not reach statistical significance. When the two treatment groups were separated it was the ST group whose EIN/BMR ratio (1.61) was higher than either the control group (1.48) or ALL group (1.58). Despite the tendency toward lower BMR the treated groups were consuming similar EIN to their controls. This may be one reason why the evident stunting and wasting in the group were not seen in the same children. The stunted child was adequately nourished for his height. The three children who were wasted may have had a recent growth spurt and were eating now to make up for the weight discrepancy to height, as shown by their EIN/BMR ratios of 1.87, 1.91 and 1.73.

Figure 5.2 Values for the energy intake to basal metabolic rate ratio (EIN/BMR) in age groups of the children receiving chemotherapy X and their controls ▫ .



5.5 SUMMARY AND CONCLUSIONS.

In a group of 25 children receiving chemotherapy, in remission from cancer, four were classified as being either stunted or wasted. The metabolic demand and EIN was similar in the treated and untreated groups. Although there was no significant difference between EIN/BMR ratio for treatment groups and their controls there were some individuals with much greater and much smaller values than the controls. The range of values appeared to be larger for the treated children.

In conclusion:

1) at this particular stage of chemotherapy there was no significant difference in metabolic demand for energy at rest nor in energy intake between the treated children and their controls.

2) the children diagnosed as Acute Lymphoblastic Leukaemia had comparable EIN/BMR values with their controls, although one individual was 0.97 suggesting either inadequate energy intake or under-reporting. The children diagnosed as Solid Tumours had higher values for EIN/BMR ratio than their controls, again one value was 0.96 with the possibilities suggested above. The two groups appeared to have EIN/BMR values which are comparable with healthy children.

3) the equations to predict BMR for the treated children were similar to those for the untreated children. Recommendations for healthy children would appear to be appropriate for this group of chemotherapy treated children. However, there were individuals whose nutritional status suggested energy requirements had not been met in the past, and needed nutritional support.

CHAPTER 6. GENERAL DISCUSSION.

The relationship between metabolic demand and energy intake (EIN) during childhood is intriguing and complex. Children either grow and develop because dietary intake meets metabolic demand, or a myriad of dysfunctions result in poor growth and development. The nature of metabolic demand for energy has been investigated in this thesis, and considered with regard to the adequacy of energy intake to meet that demand.

6.1 METABOLIC DEMAND, ENERGY INTAKE AND HEALTH.

In seeking to estimate metabolic demand in children the concept of basal metabolic rate (BMR) was used and measurements were carried out in a post absorptive state, in a thermoneutral environment by indirect calorimetry. Although conditions were fulfilled for each child by carrying out the measurement after a 12 hour fast and at constant temperature, the underlying principle of even these guidelines has been questioned. In a review by Blaxter [1985] he suggested the post absorptive state is not reached until after at least 14 hours, with the possibility of an even longer period. In this context Benedict [1938] advised the previous diet should be standardised. Blaxter [1985] contended any evidence of over- or undernutrition would also not give a true estimate of BMR.

These questions present a greater problem for making estimates of BMR in children than adults. Although cooperation from an adult is usually straightforward, the fasted state for many children was barely acceptable at 12 hours overnight. Keeping children awake and quiet was a further hurdle which had to be overcome. Many studies of children do not give details about fulfilling this condition of measurement. In one large study [Lewis et al, 1943] children were kept quiet by the operator drawing pictures on the glass window of the calorimeter. In the present study, using a Walkman cassette player with a choice of tapes appeared to satisfy this condition. In a previous study variation in BMR in a large group of adults and children was calculated to be plus or minus 7.5% [Mitchell, 1962]. In the present study of healthy children variation was calculated as plus or minus 5.4%. This appeared to vindicate problems mentioned for the group, and substantiate the use of this data for comparative purposes in other studies.

The relationship between BMR and body size has been generally recognised, and used to generate predictive equations for BMR [Schofield, 1985]. With the development of body composition techniques, the last decade has seen the generation of predictive equations for BMR of adults using lean body mass (LBM)[Cunningham, 1991]. The use of LBM appeared to explain 85 to 90% of variance in BMR. In the present study equations were also generated for BMR using LBM. A wealth of potential errors exists in formulating these equations for children.

The lack of discreet measurements for estimating LBM in healthy children, especially within the United Kingdom, makes reliability doubtful except that all errors involved will be consistent. Measurement of BMR in children is, as mentioned previously, more difficult practically than in adults. Additionally, the continuous changing nature of body composition because of growth and development may possibly mean variation within BMR is higher during childhood than in adults. Variation with age was demonstrated in chapter three of this thesis. Even within an age group there could be up to a 40% variation in BMR. The importance of body size and composition in relation to BMR was also demonstrated when BMR was expressed per weight and LBM. Metabolic demand for energy per kilogram of tissue appeared to be less in the older children. Thus suggesting as the ratio of visceral organ tissue to skeletal tissue changed from the younger to older children, metabolic demand also changed. The relationship between growth and demand depended primarily upon physiological age, chronological age being simply a marker of change.

With EIN and BMR data from the same children meant the pattern of the two measurements could be compared and their similarity noted. It indicated, cross-sectionally, metabolic demand for energy in this group of children dictated their intake. Although this has been tacitly assumed in the past this present information is documented evidence supporting that assumption.

Although the pattern of EIN was similar to BMR there appeared to be greater variation in intake within age groups. Since BMR does not represent total energy expenditure, but about 30% is habitual physical activity (PA), wider variation in intake is likely to be a response to the variation in PA. In addition, environmental factors would affect EIN; not a response to metabolic demand but to social and psychological interactions.

Recognising limitations in determining BMR, uncertainty regarding EIN information is even more of a problem. The need to estimate metabolizable energy to find out how much healthy children consume has led to reliance upon the weighed dietary record method. Although Livingstone et al [1992] demonstrated that the diet history may be more representative of habitual intake than the weighed diet record, especially in adolescents. In the present study having parents helping particularly the younger children meant ensuring the whole family was involved, with the possibility of a higher standard of recording.

Nevertheless there remained the accuracy of the database itself, with its own drawbacks in foods analyzed, and increases in the use of prepared items. Ensuring consistency of intake analysis and the longest reasonable period for recording used [Nelson et al, 1989], intakes can only be accepted with reservations common to all studies of EIN [Bingham, 1987].

6.1.1 The Ratio of Energy Intake to Basal Metabolic Rate. Having considered the stability of and relationship between both estimates of intake and BMR, these two variables appeared to have a bearing upon each other. Is there value in using the relationship between BMR and EIN to predict energy requirements of children as was suggested in the past [Wang et al, 1926; Wang et al, 1936], when BMR and EIN were measured in the same children ? The authors measured 52 boys and girls between the ages of 4 and 13 in one study, and 18 prepubertal girls aged 11 to 15 years. Some children in the first study were underweight; overall they had a mean EIN/BMR ratio of 1.7 (range 1.4 - 2.2). In the second study 18 girls had a mean EIN/BMR ratio of 1.8 (1.3 - 2.2), and a factor of 2 multiplied by BMR was suggested as appropriate for energy requirements of healthy girls of this age. The benefit of using a ratio like EIN/BMR multiplied by BMR was because it took into account "size and build and various abnormal conditions which influence" BMR.

Values for EIN/BMR were lower in the present study. When mean values for EIN and BMR were considered separately in the Wang et al [1936] study by comparison, mean EIN was over 20% higher and mean BMR over 20% lower than in the present study. These differences led to the older study ratio being about 40% higher than the present study. To isolate which variable was less reliable in the present study both EIN and BMR were compared with present standards. The mean value for BMR of 11 to 15 year old girls was 100% of predicted [Schofield, 1985]. When EIN was compared with the estimated average requirement for 11 to 14 years [Department of Health, 1991], it was only 97%. Of the two variables it appeared EIN was more likely to have brought the value down. This agreed with the less reliable methodology for estimating EIN, and the possibility of slimming diets used by the girls measured in the present study.

There were far fewer values available for boys in the earlier study, only six between 5 and 10 years. Mean EIN/BMR ratio was 1.6, closer to the mean value in the present study of 1.65 for boys of that age. The boys in the older study were described as "normal in weight, but not vigorous", having been underweight at the start of the study but reached normal weight by the time BMR was determined.

No other studies of this nature have been discovered to date. How pertinent is this EIN/BMR ratio for estimating energy requirements in children ? The methods which have been declared most appropriate to predict energy requirements were energy expenditure or EIN. The former used the ratio of total energy expenditure to BMR, or PAL (physical activity level), multiplied by personal BMR. The latter used solely EIN values. These were for children under 10 years because of paucity of data on energy expenditure for this group. The mixture of two methods inevitably led to mismatches at the overlap between the two groups, as evidenced in the recommendations [Department of Health, 1991].

Requirements for the 3 to 9 year group were based upon EIN with, for example, 8 year old boys at 8.24MJ/d and 9 year old boys at 8.55MJ/d. If the energy expenditure method was applied using predictive equations with the

PAL value suggested for 10 to 18 year old boys of 1.56, plus weight at the 50th centile for a 10, and an 11 year old boy, energy requirements were calculated as 8.07MJ/d (10 years) and 8.44MJ/d (11 years). The same was true for girls of these ages; the expenditure method gave lower values for 10 and 11 year olds than the intake method gave for 8 and 9 year olds. The table of estimated average requirements (EAR) for 7 to 10 year olds hides this discrepancy because it uses mean values over a range of ages. It does suggest caution when deciding which method to use for requirements at these ages.

Comparison between EIN/BMR ratios from the present study (PS) and values estimated using EAR and predicted BMR, using 50th centile weights [Department of Health, 1991] are illustrated in the table below. It also includes BMR factors estimated from total energy expenditure to BMR ratio.

AGE AND GENDER	EIN/BMR (PS)	EIN/BMR (DRV)	TEE/BMR (DRV)	TEE/BMR (WHO)
5-10 years MALE	1.65	1.79	-	-
FEMALE	1.60	1.91	-	-
11-15 years MALE	1.43	1.62	1.56	1.69
FEMALE	1.48	1.38	1.48	1.59

Table 6.1 Values derived from the present study (PS), the Dietary Reference Values [Department of Health, 1991], and WHO [1985] values, for ratios of energy intake to basal metabolic rate and total energy expenditure to basal metabolic rate.

The table highlights how varied these ratios can be. Although EIN/BMR ratios (DRV) were higher than the present study for the first three groups, the older female group has a lower figure. When values for the older groups were compared, estimated TEE/BMR ratios appeared closer to present study EIN/BMR ratios than DRV values. Although WHO values were highest they included an extra 5% for physical activity, excluded from DRV recommendations. If deducted from WHO values males were 1.61 and females 1.51, closer to the other ratios.

Several points must be considered, lest conclusions are drawn inappropriately. The DRV estimate of EIN/BMR ratios were formed using measurements from different groups of children. Despite a comparatively smaller sample used in the present study, all measurements were collected from the same children simultaneously. For younger children, using a combination of determined EIN and BMR may be more reliable for estimating requirements for EIN than relying upon estimates of intake alone. The figures for the older children suggest the EIN/BMR ratio may be a marker of the validity of the dietary intake, rather than to estimate requirements.

6.2 THE RATIO OF ENERGY INTAKE TO BASAL METABOLIC RATE IN DISEASE.

In the CF group studied mean EIN/BMR ratio was higher than their controls. The range of values showed individuals who had much greater EIN/BMR ratios, outside the control range. One explanation could be, during infection with a simultaneous rise in BMR and decrease in EIN the ratio for those children would be low; once infection subsided the two variables switched leading to a very high ratio during the period without infection, as the child ate more to make up for the past anorexia. None of these children were suffering from infection at time of measurement.

The metabolic harmony normally achieved, giving ratio values seen in healthy children, would swing between high and low in an effort to satisfy metabolic demand for energy. Growth would inevitably suffer in those individuals. CF children who had ratios of two or more included one who was stunted, and two who were wasted, and two out of the six had height SD scores less than minus 2.

The component which might also account for a raised EIN/BMR ratio was elevated faecal energy losses, common to children with CF. The children within the present study represented CF children who were relatively healthy at the time of measurement. Their increase in EIN/BMR ratio was most likely the result of not raised metabolic demand for energy, but the consequence of reduced metabolizable energy caused by maldigested/malabsorbed dietary intake.

6.3 THE RATIO OF ENERGY INTAKE TO BASAL METABOLIC RATE WITH MAINTENANCE CHEMOTHERAPY.

The introduction of chemicals into the body to destroy or moderate a disease inevitably upsets further the disrupted homeostasis already present. The symptoms, like weight loss, may be overcome in adults. In childhood weight loss, or simply lack of weight gain, could lead to irretrievable losses in height, and possibly weight. Cancer treatment often demands heavy doses of chemotherapy over a protracted period of time. This can occur during the most prominent time for growth.

In the present study a concerning feature was evidence of poor growth in children who had received the longest periods of treatment. There was also a tendency for reduced BMR in the whole group. This was still the case when groups were separated by diagnosis. If long term treatment is related to poor growth then monitoring nutritional status throughout treatment is imperative.

It seems likely that metabolic demand, if raised, would be so earlier on during treatment possibly leading to an energy deficit. The reasons for some children appearing to have raised EINs may result from several compounding factors: previously raised metabolic demand from the disease, plus raised demand from periods of infection, plus energy deficits from periods of anorexia, plus possibly a drug interaction unknown at present. Catch up growth demands a high intake, which is suggested by the high EIN/BMR ratios. The highest ratio for healthy children was 1.84, but there were four treated children higher than that, ranging from 1.88 to 2.73. These figures underline the importance of specifying individual needs, to ensure demand is adequately met by intake, avoiding the possibility of poor growth during treatment.

6.4 SUMMARY AND CONCLUSIONS.

In healthy children patterns of BMR, or metabolic demand for energy a rest, appeared to be similar to those of EIN. Both BMR and energy intake demonstrated large variation. The contribution played by body composition, in particular lean body mass, was highlighted and considered as of at least equal value as body weight when generating predictive equations for BMR in children. More information is necessary for body composition data in the United Kingdom to improve the standing of these equations. The ratio of EIN/BMR described how metabolic demand was met by intake of energy, and older children appeared to have lower ratios than younger children.

Cystic Fibrosis appeared to affect metabolic demand and also energy intake, causing an overall rise in EIN/BMR ratio compared with healthy children. Chemotherapy treatment did not seem to change the components of EIN/BMR ratio. Having established the possibility of an alternative method of estimating energy requirements in children by using the EIN/BMR ratio, its use may be most helpful in determining individual rather than group requirements.

In conclusion:

1) energy expenditure data was considered a better reflection of energy requirements than energy intake data, and was used in preference when making recommendations for energy intake [Department of Health, 1991]. Using a combination of the largest, least variable component of total energy expenditure - BMR - with energy intake might be a better alternative than energy intake alone when total energy expenditure is not available, for example when making recommendations for the energy intake of groups of 5 to 10 year old children.

2) the use of the ratio EIN/BMR describes the extent to which metabolic demand for energy is satisfied by reported energy intake. It could also be evidence of how valid reported energy intake is, especially in older children.

3) the variation seen in both metabolic demand for energy at rest and energy intake was explained partially by changes in body weight and lean body mass. This is consistent with the findings in adults.

4) despite having a similar BMR to the control group the energy intake of the Cystic Fibrosis group was greater then the controls' energy intake. Using total energy expenditure to calculate energy requirements and make recommendations for energy intake would not therefore account for faecal energy losses. The EIN/BMR ratio did appear to reflect raised energy needs, despite their altered requirements.

5) the healthy children and those receiving chemotherapy appeared to have similar demands and intakes of energy. However the nutritional status of some individuals with growth deficiency suggested there might have been demand and intake imbalances in the past. The treated children had the highest EIN/BMR ratios but also the lowest. This might only represent similar variation as seen in the healthy children (chapter 3) in a smaller more heterogeneous group.

When making recommendations for energy intake in children using the ratio of EIN/BMR might be considered because it accounts for differences in body size and composition, and alteration in needs from disease or ill health. This view is supported by Wang and colleagues [1926, 1936]. A child's own measured BMR multiplied by the EIN/BMR ratio could make the estimation of energy needs more appropriate than either energy intake or total energy expenditure by doubly labelled water. This may be applicable especially for an individual instead of using group recommendations, particularly at present for the 5 - 10 year old age group.

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MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
1	1	8.72	29.6	135.7	24.6	4719	.
2	1	7.36	27.9	126.8	22.0	4433	7069
2	1	7.48	31.0	129.6	22.0	5038	5319
3	1	9.69	25.6	139.0	22.3	4870	8205
2	1	7.20	24.4	126.5	19.1	3222	6060
2	1	7.62	25.8	131.1	20.2	4526	4398
2	2	7.50	26.3	128.7	22.9	4801	10284
2	2	10.97	30.7	143.3	26.2	5457	8917
2	2	15.84	49.2	170.5	39.7	7245	8514
2	2	11.61	41.2	154.4	32.4	4859	13247
2	2	6.27	18.3	108.8	15.2	3800	5368
2	2	13.76	41.4	151.7	34.4	6403	10108
2	1	10.73	29.9	142.0	27.4	4989	9636
2	2	15.28	35.9	148.8	29.2	5067	8206
2	2	14.99	51.3	170.0	42.1	7131	8662
2	1	6.99	20.6	115.5	16.3	4067	4613
2	1	9.92	32.0	129.5	24.3	4161	7111
2	1	9.24	25.9	141.6	25.1	4031	7551
2	2	13.13	51.0	173.8	40.3	6158	11785
2	2	9.39	24.6	128.5	21.0	3964	6143
3	2	10.25	28.1	133.8	24.6	3646	8967

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
3	1	7.63	25.8	131.5	25.8	3529	6590
3	1	9.65	32.7	142.5	29.3	3910	7716
3	2	9.75	33.5	136.4	27.2	3538	8720
3	2	8.63	27.7	135.0	22.9	5160	9491
3	1	8.13	25.5	129.5	22.3	3817	7456
3	1	8.45	28.6	134.1	24.7	4117	8023
3	1	11.04	35.4	138.7	24.6	3476	8736
3	1	11.18	47.3	146.4	31.7	4656	9452
3	2	10.49	38.1	147.7	30.0	6073	7684
3	2	10.38	35.1	148.8	29.1	5322	9164
3	2	9.65	30.4	132.0	26.6	5240	7996
3	1	13.14	41.4	153.8	30.6	5145	5477
3	2	9.97	36.3	145.3	35.7	6427	10318
3	1	8.07	28.9	128.6	22.9	4994	8995
3	2	10.08	35.0	140.9	29.1	6241	10468
3	1	5.79	24.9	118.8	19.6	4656	5187
3	1	11.12	36.4	142.0	30.2	3365	8445
3	1	8.84	26.5	127.4	20.6	3929	5680
3	2	6.25	23.1	121.3	20.0	4463	5981
3	2	13.80	50.9	151.5	39.3	5525	7596
3	1	14.98	53.6	156.0	39.7	5795	7979

LIST /VARIABLES CODE SEX AGE WEIGHT HEIGHT LBM REE EIN. MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
1	1	13.70	32.5	143.0	27.8	5162	10290
1	1	6.86	21.0	114.0	18.0	2893	5660
1	1	7.50	24.6	118.8	19.4	4602	.
1	1	10.92	32.1	139.5	28.7	5613	.
1	1	9.61	24.6	132.0	22.3	4476	.
1	1	7.86	28.1	128.9	22.2	3938	7715
1	1	8.04	24.5	126.0	22.3	4187	7970
1	1	12.93	23.3	138.6	20.9	5990	.
1	1	6.99	20.4	118.6	16.2	3917	9100
1	1	7.71	31.3	130.0	25.3	4788	9280
1	2	14.82	35.4	160.0	30.9	4557	11530
1	2	9.36	22.5	127.4	19.1	4364	7700
1	2	13.56	31.5	147.2	28.4	4935	9370
1	2	13.28	41.7	142.6	35.0	7598	10500
1	2	11.69	40.2	141.6	33.7	6258	9500
1	2	14.19	31.9	143.2	27.9	6100	.
1	2	11.31	35.9	144.2	30.9	5670	8298
1	2	8.37	27.3	128.5	24.4	4603	8510
1	2	9.13	22.6	123.0	19.1	4217	6550
1	2	7.79	21.4	123.0	19.1	5019	5940
1	1	13.84	26.5	142.0	23.2	4565	9129

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
1	1	10.17	21.8	133.0	20.4	4714	4872
1	2	14.26	33.7	149.3	30.2	4810	12540
1	2	8.90	34.2	131.8	25.3	6284	8308
1	1	5.96	19.2	111.8	.	5563	5905
1	2	9.47	29.5	132.9	25.8	5981	7589
1	1	9.04	28.0	131.2	24.9	5303	7291
1	2	14.89	53.2	166.9	41.8	8672	12678
1	2	5.47	17.5	108.5	15.1	4474	5698
1	1	11.27	32.0	142.7	28.8	5955	7860
1	2	11.21	30.1	137.6	26.0	4463	.
1	2	10.44	30.8	137.9	25.6	5639	8069
1	1	8.54	24.8	133.2	22.7	5036	13710
1	1	5.75	18.0	109.1	15.0	4230	6364
1	1	15.21	37.2	160.1	30.9	5025	.
1	2	7.69	19.5	117.5	17.7	4364	7128
1	2	9.17	27.2	128.3	23.5	3749	10870
1	1	9.46	28.4	133.8	25.4	5159	.
1	1	6.39	20.0	114.2	16.6	4263	.
1	1	7.37	14.5	107.1	13.9	3627	6150
1	2	10.39	23.7	127.6	21.6	4880	.
1	2	9.30	33.9	135.0	25.1	5112	.

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
3	1	7.71	29.0	124.9	22.8	4562	6909
3	1	6.58	26.7	125.7	20.7	4522	6193
3	1	15.39	59.9	157.2	40.2	5767	5143
3	2	8.28	22.5	124.0	18.7	4538	7291
3	1	9.56	27.0	132.5	25.2	4714	6214
3	1	14.66	51.1	160.9	38.4	5390	5963
3	1	9.91	24.6	127.8	20.4	4196	6088
3	1	13.62	70.0	169.7	47.0	7647	11521
3	1	11.35	31.2	141.0	25.9	5047	7956
3	1	11.27	35.0	146.1	29.1	5570	6442
3	1	11.39	41.1	155.6	34.5	5599	8548
3	1	11.36	42.7	144.5	27.8	5253	5244
3	1	8.62	28.8	129.8	25.9	4857	6723
3	1	13.52	67.3	167.4	43.5	6768	10485
3	1	11.55	56.7	156.0	34.0	6378	9043
3	1	13.58	42.8	156.4	32.9	5867	8552
3	1	13.89	51.0	161.1	39.6	5868	6025
3	1	13.57	58.0	156.3	39.2	7270	5381
3	1	13.72	63.5	162.0	41.1	5600	7063
3	2	8.73	29.2	130.0	22.8	5400	8051
1	2	15.27	49.3	153.0	38.5	7260	9969

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
1	2	14.26	33.6	154.4	27.1	4910	8268
1	2	13.81	37.2	149.0	30.8	5990	8571
3	1	10.30	27.7	135.0	22.9	4380	5985
1	1	12.52	33.2	147.3	26.4	5740	8590
1	2	6.76	19.8	117.1	17.1	4912	9200
1	2	10.98	35.5	144.0	31.2	6400	.
1	1	14.64	40.3	157.5	31.4	5694	8141
1	2	7.04	19.3	118.8	17.1	5136	7209
2	2	9.50	34.6	135.6	27.7	4980	4827
2	2	8.37	31.3	125.6	23.0	4880	5540
2	1	14.00	59.1	171.1	44.9	5960	10915
2	1	6.86	22.3	123.7	18.9	3990	6680
2	2	7.42	19.7	119.3	16.3	3690	5767
2	2	8.92	21.4	130.8	18.3	4490	7775
2	2	5.61	18.8	113.0	15.4	3370	6405
3	2	8.15	27.6	128.8	22.9	4181	7827
3	2	5.89	22.0	117.5	17.3	4370	7175
3	1	8.38	34.9	132.3	23.4	5150	8391
3	2	5.64	19.0	109.7	15.8	4560	6683
3	1	7.06	23.6	122.7	20.6	4220	3220
3	1	5.39	20.5	110.3	17.7	4150	7239

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
3	1	9.23	28.1	135.9	24.6	5150	11231
3	2	11.58	33.4	142.3	28.5	5220	11218
3	2	12.02	40.3	156.1	34.1	6680	10466
3	1	9.60	30.8	139.8	24.1	4970	6401
3	2	12.60	42.6	157.3	35.8	6080	7289
3	2	5.54	21.0	116.7	18.3	4530	6264
3	1	6.11	20.4	114.9	15.8	4040	5488
3	2	8.97	31.5	139.0	26.7	3920	7700
3	2	12.47	64.0	159.5	44.9	6390	9470
3	2	11.98	35.6	146.1	29.4	5990	9402
3	2	12.70	43.3	155.6	37.2	6320	10659
3	2	6.79	20.5	123.7	17.8	4730	6931
3	2	6.79	21.2	123.4	18.8	4400	7151
3	2	13.65	55.9	164.5	45.4	6900	9578
3	2	14.46	60.4	170.5	48.8	8120	9240
3	2	14.31	44.5	159.6	38.4	5990	7846
3	2	6.98	21.6	121.8	18.9	4730	7413
3	1	8.78	30.0	134.1	24.9	4770	7904
3	1	7.10	25.2	123.0	18.7	4300	7377
3	1	7.84	23.5	124.0	19.5	4220	6175
3	2	15.51	57.1	168.7	48.6	7100	9500

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
3	2	14.98	49.4	169.7	42.0	6240	9950
3	2	15.72	74.6	173.9	59.9	8880	15528
3	2	14.34	54.4	172.2	48.4	6610	7412
3	2	15.40	51.1	160.0	39.0	5850	10877
3	2	14.89	55.0	174.5	42.8	7660	11958
3	2	10.71	30.5	143.0	24.8	4710	8002
3	2	12.14	41.1	154.9	34.0	6020	9701
3	2	7.71	24.4	121.7	20.2	4470	7608
3	1	6.34	21.2	116.5	17.7	4170	7706
3	2	13.17	36.1	155.1	29.2	5210	8637
3	2	14.08	53.7	167.6	45.1	7840	11346
3	1	8.98	28.4	135.4	22.4	4560	8965
3	1	7.18	23.3	121.9	18.9	4160	7449
3	2	9.96	28.5	136.8	24.0	5080	8563
3	2	12.53	40.4	152.3	35.5	5710	9558
3	2	12.58	55.9	160.5	41.4	7450	11052
3	1	7.97	32.6	135.6	25.5	4930	8722
3	2	13.55	55.7	163.5	42.3	7600	9276
3	2	10.19	33.8	142.5	27.6	4970	8722
3	2	7.29	28.4	129.1	21.7	4560	7485
3	1	13.44	41.4	147.0	29.9	5660	8418

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
3	1	10.80	29.4	131.1	24.4	5080	6248
3	1	5.71	17.2	110.5	15.0	3965	5483
3	2	7.34	27.7	132.0	23.0	5930	8476
3	1	5.08	17.5	108.2	15.9	3500	5138
3	2	14.39	50.4	165.0	40.9	6390	12403
3	2	10.62	33.2	139.0	26.5	4900	9012
3	2	8.47	28.1	129.0	23.1	4890	8283
3	1	10.20	40.2	139.9	27.9	5010	5945
3	2	12.02	33.8	142.5	28.6	5990	7734
3	2	9.68	32.6	138.5	27.9	5070	9205
3	1	15.20	54.9	166.2	40.7	5570	9269
3	2	9.79	29.9	139.0	24.8	4970	9670
3	1	10.05	32.0	133.0	24.4	4120	6718
3	1	9.61	28.5	134.0	23.0	4770	6896
3	2	10.50	33.7	139.0	24.9	5660	8442
3	1	5.08	17.6	108.8	15.6	3390	6182
3	1	11.78	39.0	138.5	26.6	3820	5966
3	1	5.00	21.8	119.0	17.9	4320	6747
3	1	8.11	23.2	128.0	20.6	4390	6771
3	2	14.82	48.5	168.5	42.9	7310	8018
3	2	15.05	60.5	172.0	53.1	8030	10106

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
3	2	15.40	70.0	171.0	54.5	7650	10014
3	2	15.40	63.5	177.0	51.0	7520	10514
3	2	14.64	67.5	179.0	54.9	8470	15773
3	2	14.64	45.5	154.4	36.2	7380	8346
3	2	15.20	48.0	158.5	39.9	6210	6696
3	2	14.68	50.0	163.5	42.8	7360	9994
3	2	15.12	63.5	175.0	53.7	8120	14877
3	2	15.40	55.0	169.5	47.2	6610	9907
3	2	10.87	38.1	148.5	33.3	6308	8760
3	1	8.58	32.1	135.9	25.8	4850	7290
3	1	13.80	51.2	166.5	38.4	6010	8549
3	1	9.72	28.4	142.0	22.0	5430	6873
3	2	9.65	26.7	127.0	23.1	5010	8184
3	2	9.87	35.7	145.0	29.0	6810	9079
3	2	15.14	66.0	175.5	54.8	7940	11883
3	2	15.09	58.5	167.0	49.2	8200	5456
3	2	14.70	45.0	154.5	38.2	5410	8442
3	2	14.72	45.0	159.5	37.6	6070	9683
3	2	14.86	43.0	155.0	35.7	5590	8771
3	2	14.66	47.0	153.5	40.2	6969	11124
3	2	14.62	62.0	178.0	52.9	7850	13152

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
3	2	15.39	78.0	175.5	62.7	8650	9685
3	2	14.60	45.1	166.0	45.1	7740	9377
3	2	15.08	79.5	179.0	54.1	8340	9918
3	2	15.50	73.0	175.0	56.2	8460	12561
3	2	15.02	57.0	169.0	45.6	8080	11701
3	2	14.86	61.5	169.0	51.5	7950	9450
3	2	15.28	55.5	177.0	48.5	7230	10855
3	2	15.40	41.5	158.7	36.1	6200	6627
3	2	14.60	55.5	172.0	48.0	6840	10381
3	2	14.97	65.0	178.0	55.7	8950	5133
3	2	10.00	28.4	135.0	24.3	5040	5547
3	1	12.04	53.0	152.7	37.1	5760	7874
3	1	11.92	51.1	158.8	41.4	5719	9730
3	1	11.49	43.5	153.8	32.4	5430	10498
3	1	9.72	33.5	140.6	26.4	4710	6993
3	1	11.59	33.6	145.2	27.1	5240	6878
3	1	11.13	30.5	141.8	27.1	4240	6450
3	1	11.07	39.3	143.8	29.0	4740	6451
3	1	11.53	36.1	144.6	26.8	4690	7468
3	1	7.11	19.0	111.0	16.5	4210	6765
3	2	9.56	28.9	133.9	24.9	4670	8731

MORE

CODE	SEX	AGE	WEIGHT	HEIGHT	LBM	REE	EIN
3	2	12.39	43.8	154.6	37.9	6420	10782
3	2	8.61	29.9	139.2	26.3	5050	9030
3	1	9.84	27.2	132.2	24.5	4090	7595

Number of cases read = 234 Number of cases listed = 234

NO EIN (DIETARY RECORDS) n = 13

NO LBM n = 1

NEW ENTRIES n = 10

TOTAL IN THESIS n = 210

SEX FEMALE = 1
MALE = 2