2 Energy

2.1 Introduction

An important goal in human nutrition is to ensure that the energy ingested in food is adequate to meet energy demands. The body needs energy for maintaining body temperature, metabolic activity, supporting growth and for physical work. It is also important, particularly in affluent societies, to minimize excess energy intake over expenditure in order to prevent obesity and its complications.

In addition, conceptually, the prevalence of food deprivation, which is termed undernourishment, is based on comparison of usual food consumption expressed in term of dietary energy (kcal) with a minimum requirement level. The part of the population with food consumption below the minimum required level is considered undernourished. The focus on dietary energy in assessing food insufficiency or deprivation is justified from two perspectives. Firstly a minimum amount of dietary energy intake is essential for body-weight maintenance and work performance. Secondly, increased dietary energy, if derived from normal staple foods, brings with it more protein and other nutrients as well, while raising intakes of the latter nutrients without ensuring a minimum level of dietary energy, is unlikely to be of much benefit in terms of improving nutritional status.

The first important principle is that energy requirement must be estimated on the basis of energy expenditure and not of energy intake. It is based on the recognition that it is energy expenditure that drives energy needs rather than intake, which does not necessarily reflect energy needs and may vary independently.

The most recent joint FAO/WHO/UNU Expert Consultation on Energy in Human Nutrition met in October 2001 to review the state of the art of the scientific literature since the 1985 report and to arrive at recommendations for energy requirement throughout the life cycle (FAO/WHO/UNU, 2004). The 2004 report defined energy requirement as "*the amount of food energy needed to balance energy expenditure in order to maintain body size, body composition and a level of necessary and desirable physical activity, consistent with long-term good health*". This includes the energy needed for the optimal growth and development of children, for the deposition of tissues during pregnancy and for the secretion of milk during lactation consistent with good health of the mother and child.

The estimation of energy requirement is based on the factorial approach, which expresses energy requirement/expenditure, as well as its various components, as multiples of basal metabolic rate (BMR). Besides being the largest component of energy expenditure, as high as 70% in sedentary individuals, expressing energy expenditure/requirements in terms of BMR factors make it unnecessary to correct for body weight, thus simplifying the calculation and allowing easier and more meaningful comparisons among diverse population groups. It is however recognized that a residual variability remained of BMR/kg body weight at the diverse weights, with higher values per unit body weight in smaller individuals than in bigger ones. The factorial approach consists of the summation of various activities representing the energy expenses, such as the costs of the diverse types of physical activity, the extra energy allocated for pregnancy and lactation and the energy cost of growth.

2.3 Principles of energy balance and energy requirements

Principles of energy balance

The standard unit of energy is the joule and human energetics are usually expressed in term of kilojoules (i.e. joules x 1000). A megajoule (MJ) is 1000 kJ. One kcalorie or Calorie = 4.184 kJ. It is a fundamental principle of thermodynamics that energy cannot 'disappear'. Food energy eaten has to be either excreted in the faeces, or absorbed by the body. Once absorbed, a small amount of energy is excreted in the urine as the by-product of protein metabolism and the rest of the absorbed fuel has to be metabolized for energy or stored in the tissue as protein, fat or as carbohydrate in the form of glycogen. Metabolized energy supports the making of new chemical compounds within the body, fuels the muscular activity required to breathe, digest food and maintain body posture, and also provides the energy for physical activity (James & Schofield, 1990).

Principles of energy requirements

Energy needs are determined by energy expenditure. Therefore, in principle, estimates of requirements should be based on measurements of energy expenditure. Components of energy expenditure include basal metabolic rate, physical activity, metabolic cost of food and metabolic cost of growth.

Basal metabolic rate

Physiologically, BMR is defined as the lowest rate of energy exchange in the body, which is related to the organization of bodily functions and production of body heat. Technically, it is defined as the rate of energy expenditure of a fasted and fully-rested individual in a thermoneutral environment or can simply be defined as the minimal rate of energy expenditure compatible with life.

Since basal metabolic rate (BMR) is the largest component of energy expenditure, it has been adopted by the FAO/WHO/UNU Expert Committee 1981 as the basis for calculating all components of total energy expenditure. To obtain the total requirement, the estimate of BMR is multiplied by a factor that covers the energy cost of increased muscle tone, physical activity, the thermic effect of food, and where relevant, the energy requirements for growth and lactation (FAO/WHO/UNU,1985).

The FAO/WHO/UNU (2004) report adopted the equations for predicting BMR from body weight as reported in the 1985 report, presented in Table 2.1. Ismail *et al.*,

(1998) has reported predictive equations for adult Malaysians (Table 2.2) and Poh *et al.*, (1999; 2004) for Malaysian adolescents aged 10 to 18 years old (Tables 2.3 & 2.4).

Table 2.1 Equations for predicting basal metabolic rate from body weight (W)[1]

Age range (years)	Kcal /day	Correlation coefficient	SD[a]	MJ /day	Correlation coefficient	SD[a]
Males						
0 - 3	60.9 W - 54	0.97	53	0.255 W - 0.226	0.97	0.222
3 - 10	22.7 W + 495	0.86	62	0.0949 W + 2.07	0.86	0.259
10 - 18	17.5 W + 651	0.90	100	0.0732 W + 2.72	0.90	0.418
18 - 30	15.3 W + 679	0.65	151	0.0640 W + 2.84	0.65	0.632
30 - 60	11.6 W + 879	0.60	164	0.0485 W + 3.67	0.60	0.686
> 601	3.5 W + 487	0.79	148	0.0565 W + 2.04	0.79	0.619
Females						
0 - 3	61.0 W - 51	0.97	61	0.255 W - 0.214	0.97	0.255
3 - 10	22.5 W + 499	0.85	63	0.0941 W + 2.09	0.85	0.264
10 - 18	12.2 W + 746	0.75	117	0.0510 W + 3.12	0.75	0.489
18 - 30	14.7 W + 496	0.72	121	0.0615 W + 2.08	0.72	0.506
30 - 60	8.7 W + 829	0.70	108	0.0364 W + 3.47	0.70	0.452
> 60	10.5 W + 596	0.74	108	0.0439 W + 2.49	0.74	0.452

[1] FAO/WHO/UNU (1985)
[a] Standard deviation of differences between actual BMRs and predicted estimates

Table 2.2 BMR predictive equations for adult Malaysians[1]

Age group	n	Formula	r	SE Mean	%Difference
Male					
18-30	84	0.0550(W) + 2.480	0.644	0.0363	13% WHO[2] 6% HR[3]
30-60	223	0.0432(W) + 3.112	0.501	0.0189	13% WHO 4% HR
Female					
18-30	131	0.0535(W) + 1.994	0.511	0.0263	9% WHO 6% HR
30-60	218	0.0539(W) + 2.147	0.519	0.0200	9% WHO 2% HR

[1] Ismail *et al.* (1998), BMR is expressed in MJ/day, W= body weight in kg.
[2] FAO/WHO/UNU (1985)
[3] Henry & Rees (1991)

Table 2.3 BMR predictive equations for Malaysian adolescents aged 10 – 15 years[1]

Age groups	Regression equations	No. of data points	r^2	s.e.[2]
Boys				
11 years	BMR = 86.42 W + 2097	83	0.62	390
12 years	BMR = 93.45 W + 1899	108	0.64	431
13 years	BMR = 79.75 W + 2377	109	0.66	393
14 years	BMR = 74.65 W + 2487	56	0.54	429
11 – 15 years	BMR = 80.38 W + 2319	360	0.70	417
Girls				
10 years	BMR = 75.29 W + 2118	55	0.62	329
11 years	BMR = 76.66 W + 2124	118	0.66	365
12 years	BMR = 52.46 W + 2846	103	0.47	400
13 years	BMR = 50.86 W + 2736	70	0.43	392
10 – 14 years	BMR = 54.44 W + 2781	353	0.52	405

[1] Poh *et al.* (1999) BMR is expressed in kJ/day, W = Body weight in kg
[2] standard error

Table 2.4 BMR predictive equations for Malaysian adolescents aged 12 – 18 years[1]

Groups	Regression equations	No. of data points	r	s.e.e. [2]
Boys	BMR = 55.8W + 3187	269	0.54	605
Girls	BMR = 53.4W + 2182	303	0.50	498
Combined	BMR = 54.9W + 1119.6S + 2116	572	0.81	551

BMR is expressed in kJ/day, W = Body weight in kg, S = sex: where 1 = female, 2 = male
[1] Poh *et al.* (2004)
[2] standard error of estimate

Physical activity

The level of physical activity must be considered in detail when assessing energy needs. Energy needs may be calculated based on the amount of time spent and the energy cost of various activities. To facilitate the calculations, daily activities are divided into two broad categories, namely occupational activities and discretionary activities (FAO/WHO/UNU, 1985). Occupational activities include those activities that are essential for the individual and the community and can be considered as economic activities that are life-sustaining. The traditional classification of work according to occupation is important, but care must be taken to ensure that there is an adequate description of the occupation. Discretionary activities are additional activities outside working hours that may be of benefit to the community. The requirement to cover these activities should not be considered as dispensable, since it usually contributes to the physical and intellectual well-being of the individual, household or group.

The FAO/WHO/UNU (2004) consultation endorsed the proposition that recommendations for dietary energy intake must be accompanied by recommendations for an appropriate level of habitual physical activity.

Metabolic response to food

The increased oxygen uptake after a meal depends on the nutrient composition of the food consumed and the amount of energy ingested. The measurement of the energy cost of digesting, absorbing and storing ingested nutrients is not easy. It is difficult to separate the energy expended in excess of the basal rate after eating a meal, from the energy cost of the physical activity involved in sitting, eating and digesting (FAO/WHO/UNU, 1985).

Growth

The energy cost of growth includes two components: the energy value of the tissue or product formed and the energy cost of synthesizing it. Although the energy requirement for growth relative to maintenance is small, except for the first months of life, satisfactory growth is a sensitive indicator of whether needs are being met. To determine the energy cost of growth, the energetics of growth must be understood and satisfactory growth velocities must be defined. Except in the case of young infants and during lactation, the estimates of energy cost are not very critical, since human growth is a slow process, taking up a small proportion of the energy requirement (FAO/WHO/UNU, 1985).

2.4 Energy deficiencies and excesses

Inadequate energy intake

By comparing the distribution of dietary energy supply (DES) with per caput energy requirements in different countries, two types of food inadequacy measures are provided, namely the *prevalence* and the *intensity* of food inadequacy. The prevalence measure is concerned with the proportion and number of people who have inadequate access to food, i.e. whose access falls short of a specified cut-off point while the estimates of intensity, is to assess by how far access to food falls short of requirement (FAO, 1996).

Energy deficiency can be acute or chronic. *Acute energy deficiency* (AED) is by nature “episodic”, and characterized by a state of negative energy balance, in which the energy expenditure is greater than energy intake. Under these conditions, there is a progressive loss of body weight, along with changes in the pattern of energy expenditure, in an attempt by the body to achieve a new but lower plane of energy equilibrium. If the energy deficiency persists, further weight loss occurs along with deterioration in health ultimately leading to death.

On the other hand, *chronic energy deficiency* (CED) is a “steady state”, due to inadequate food energy over a lifetime. Individuals with CED could be in energy balance, although their anthropometric parameters, may be less than desirable. This state is achieved by the presence of low body weight and fat stores, but the individual’s health is normal and the body’s physiological function is not compromised to the extent that the individual is unable to lead an economically productive life. There is good evidence to show that individuals with CED are less productive and that the CED state is associated with higher morbidity and mortality. In addition, the steady state referred to above must be appreciated as a theoretical one, subject to periodic fluctuations of physiological and environment, such as the menstrual cycle and seasons. A high incidence of LBW babies has been reported in mothers with low pre-pregnant BMI. Milder energy-nutrient deficiency leads to stunting, and is also associated with several functional and behavioral consequences. From a population viewpoint, it is CED that is important to prevent and address.

Excess energy intake

Excessive energy intake and positive energy balance are conditioned by adequate availability of food energy and a sedentary lifestyle, accompanied by marketing strategies which stimulate over-consumption of highly palatable energy dense foods. Development in many societies in transition is associated with the adoption of a “western” lifestyle. This process is shifting the nutrition related disease burden away from under-nutrition and towards death and disability related to energy excess and positive energy balance. Social factors such as income, education, access to information and cultural beliefs, biological factors associated to a genetic predisposition and metabolic changes associated to diet and physical activity are the main conditioning factors linked to the rising prevalence of positive energy balance and excessive energy stores. The non-fatal but debilitating health problems associated with chronic energy excess and obesity include respiratory difficulties, chronic muscle-skeletal problems, skin problems and infertility. The more life-threatening, chronic health problems fall into four main areas: (a) condition associated with insulin resistance, namely Non-Insulin Dependent Diabetes Mellitus (NIDDM), (b) cardiovascular problems including hypertension, stroke and coronary heart disease, (c) certain types of cancers mainly the hormonal-related and large bowel cancers, and (d) gallbladder disease.

2.5 Sources of dietary energy

Energy for metabolic and physiological functions of humans is derived from the chemical energy bound in food carbohydrates, fats, proteins and alcohol, which act as substrates or fuels. Each of these macronutrients has numerous sub-types with specific attributes in terms of energy delivery and potential health effects. The gross and metabolizable energy contents of the macronutrients in their natural forms are well established. The sources of energy is carbohydrates, fat and protein with physiological fuel values of 4, 9, 4 kcal/g (16.7kJ, 37.7kJ, 16.7kJ/g), respectively. Ethanol has a caloric value of 7kcal/g (29.3kJ/g). The energy value of a food or diet is calculated by applying these factors to the amount of substrates determined by chemical analysis, or estimated from appropriate food composition tables (FAO/WHO/UNU, 2004).

The Joint WHO/FAO Expert Consultation on diet, nutrition and the prevention of chronic diseases (WHO, 2003) recommends that contribution of macronutrients to total daily energy intake should be within these ranges: total carbohydrate 55 – 75%, total fat 15 – 30% and protein 10 – 15%. The Technical Subcommittee on Energy and Macronutrients decided to adopt the WHO (2003) recommendation with slight modifications. The TSC recommends that total carbohydrate should contribute 55 – 70%, total fat 20 – 30%, and protein 10 – 15% to total daily energy intake for the Malaysian adult population.

2.6 Factors affecting energy requirement

In view of the fact that energy requirement is determined from energy expenditure, it is therefore affected by the factors that affect basal metabolic rate and physical activity, which are the major components of energy expenditure. The FAO/WHO/UNU (1985) report has provided details of these factors.

Age

The most important component of energy expenditure, the basal metabolic rate, depends on the mass of metabolically active tissue in the body, the proportion of each tissue in the body, and the contribution of each tissue to the energy metabolism of the whole body. The changes in body composition with age, therefore, markedly affect energy requirements, since some organs of the body are much more metabolically active than others. These changes in body composition in children and adults have to be taken into account when calculating the energy requirement of a particular section of the population. There are also altered activity patterns with age. Children become progressively more active once they are able to crawl or walk while the physical activity pattern of adults are usually dominated by the nature of their work.

Gender

Men have a relatively greater muscle mass than women, which would tend to reduce their BMR when expressed in terms of lean body mass, since muscle has a low metabolic rate. However, the greater body fat content of women means that the observed BMR per unit total body weight is somewhat lower in women. The energy demand for physical activity will often depend on the different types of employment for men and women. In children, basal energy expenditure on a weight basis differs little between pre-adolescent boys and girls, but since there are differences in body weight and composition from the first few months of life, and different physical demands is made on boys and girls, their energy requirements are considered separately.

Individual variations

In any assessment of the average requirement, both intra- and inter-individual variability must be recognized. The former results from short-term fluctuations in energy intake and expenditure. It has been suggested that within individual variations in intakes are more important than between-individual variations, and that the observed inter-individual variations can largely be explained in terms of the intra-individual variations. However, later evidence supports the conclusion that within-subject variations in BMR are small and insignificant, even when energy intake and physical activity are uncontrolled. It is also generally recognized that in a group of apparently comparable people, there is much inter-individual variation in habitual energy expenditure.

Population variations

The differences in BMR between populations of the world are equivocal. Some studies showed 8-10% lower in the tropics while others suggested no difference in BMR between Indians and Europeans provided the subjects were well nourished. Other evidence suggest that the relationship between BMR and standard independent variables such as age, sex and body size may vary among populations including seasonal variations in BMR corresponding with diet and/or temperature changes.

2.7 Setting requirements and recommended intakes of energy

The proposed recommended energy intake for Malaysia is based on the 2004 Interim Report on Human Energy Requirements. Although the basic principles set forth in the 1985 report have withstood the test of time, several modifications were proposed in the FAO/WHO/UNU 2004 report. The IOM (2002) report on Dietary Reference Intakes for Energy was also used as a reference by the Technical Sub-Committee (TSC) on Energy and Macronutrients. The energy intakes recommended by the TSC for each group are given below in bold and summarised in Appendix 2.1.

Infants

Whitehead, Paul & Cole (1981) compiled energy intakes of infants from the literature between 1940 up to 1980. These data were later used by the FAO/WHO/UNU 1985 consultation to estimate energy requirement of infant set at 5% higher than observed intakes to compensate for underestimation of intake.

Since the 1980's, even though information on the BMR of infants were available, to estimate requirements from multiples of BMR was not appropriate because reasonable allowance for physical activity were undefined. The FAO/WHO/UNU 1985 recommendations were 9 – 39% higher than those reported by Butte (1996). These discrepancies are not trivial and could lead to overfeeding of infants. The current recommendations therefore adopted the FAO/WHO/UNU (2004) principles as discussed below.

The principle of calculating energy requirements from total energy expenditure (TEE) plus the energy needs for growth applies to infants and children of all ages. TEE had been shown to have good linear relationship with body weight (Butte *et al.*, 2000), and the predictive equation for infants is as follows:

TEE (MJ/d) = - 0.416 + 0.371W (kg)

Energy needs for growth have two components; namely (i) the energy used to synthesize growing tissues, and (ii) the energy deposited in those tissues. Hence, energy requirements in infancy can be calculated by adding the energy deposited in growing tissues to TEE.

Energy requirement for infants

Boys	**0 – 5 months**	**560 kcal/day or 2.34 MJ/day**
	6 – 11 months	**640 kcal/day or 2.68 MJ/day**
Girls	**0 – 5 months**	**550 kcal/day or 2.30 MJ/day**
	6 – 11 months	**630 kcal/day or 2.64 MJ/day**

Children and adolescents

There was very little information available in 1981 on total energy expenditure (TEE) of children. The paucity of information on time allocated to different activities and energy cost of such activities, did not allow reliable estimates of TEE in children below 10 years of age. Consequently, estimates of energy requirements for 1-10 years old were derived from a review of published dietary intake data involving some 6,500 children, mostly from developed countries (Ferro-Luzzi & Durnin, 1981). The FAO/WHO/UNU 1985 Consultation felt the need to increase the reported energy intake by 5% to accommodate a desirable level of physical activity.

The estimation of energy requirements, after 10 years of age, is based on energy expenditure expressed as multiples of BMR rather than energy intake data. BMR for boys and girls of a given age and weight were predicted with the mathematical equations derived by Schofield, Schofield & James (1985). The additional energy expended during the day was calculated based on the assumed energy cost of activities performed by the children and adolescents in developing countries. Extra allowance for growth was assumed to be 5.6 kcal (23.4 kJ) per gram of expected weight gain. This corresponds to about 3%, of the daily energy requirement at 1 year of age, with a gradual decrease to about 1% at 15 years (Torun *et al.*, 1996).

The current recommendations adopted the FAO/WHO/UNU (2004) method of estimating energy requirements for children and adolescents. Energy needs of children and adolescents were also calculated from measurements of energy expenditure and the energy needs of growth. Torun (2001) analysed a large number of studies on TEE, growth and habitual activity pattern of children and adolescents in different parts of the world for the FAO/WHO/UNU expert consultation. Studies using either doubly-labelled water (DLW) or heart-rate monitoring (HRM) were included in the evaluation.

Energy needs for growth comprises (i) energy used to synthesize growing tissues, and (ii) energy deposited in those tissues. The energy spent in tissue synthesis is part of TEE measured with either DLW or HRM. Hence, only the energy deposited in growing tissues was added to TEE in order to calculate energy requirements (FAO/WHO/UNU, 2004).

For children aged 1 – 9 years, TEE was calculated based on Torun's quadratic polynomial regression equations and the mean body weights of Malaysian children collected from three studies (MOH, 2000; UKM, 2001; UKM, 2004). For adolescents aged 10 – 18 years, the calculations was based on the PAL values of FAO/WHO/UNU (2004) and BMR values as calculated from Poh *et al.*, (1999) for those aged 10 – 14 years and Poh *et al.*, (2004) for those aged 15 – 18 years.

Energy requirement for children

Boys	**1 – 3 years**	**980 kcal/day or**	**4.10 MJ/day**
	4 – 6 years	**1340 kcal/day or**	**5.61 MJ/day**
	7 – 9 years	**1780 kcal/day or**	**7.45 MJ/day**
Girls	**1 – 3 years**	**910 kcal/day or**	**3.81 MJ/day**
	4 – 6 years	**1290 kcal/day or**	**5.40 MJ/day**
	7 – 9 years	**1590 kcal/day or**	**6.65 MJ/day**

Energy requirement for adolescents

Boys	**10 – 12 years**	**2180 kcal/day or**	**9.12 MJ/day**
	13 – 15 years	**2690 kcal/day or**	**11.25 MJ/day**
	16 – 18 years	**2840 kcal/day or**	**11.88 MJ/day**
Girls	**10 – 12 years**	**1990 kcal/day or**	**8.33 MJ/day**
	13 – 15 years	**2180 kcal/day or**	**9.12 MJ/day**
	16 – 18 years	**2050 kcal/day or**	**8.58 MJ/day**

Adults and elderly

The FAO/WHO/UNU Expert Consultation (1985) adopted the principle of relying on estimates of energy expenditure rather than energy intake from dietary surveys to estimate the energy requirements of adults. Since the largest component of total energy expenditure (TEE) is the BMR, which can be measured with accuracy under standardised conditions, the 1985 Report adopted in principle for the sake of simplicity, all components of TEE as multiples of BMR also known as PAL approach. Besides BMR, other components of energy expenditure such as occupational activities, discretionary activities and residual time have been identified and evaluated to derive total energy requirements.

The FAO/WHO/UNU (2004) preserved the 1985 Expert Consultation's principle of using estimates of energy expenditure to estimate the energy requirements of adults. The use of techniques such as DLW and HRM confirmed the large diversity of TEE among adults, and hence of energy requirements, previously reported by time-motion studies. Growth is no longer an energy-demanding factor in adulthood, and BMR is relatively constant among population groups of a given age and gender. Consequently, habitual physical activity and body weight are the main determinants for the diversity in energy requirements of adult populations with different lifestyles.

TEE was estimated though factorial estimation that combined the time allocated to habitual activities, and the energy cost of those activities. To account for differences in body size and composition, the energy cost of activities was calculated as a multiple of BMR per minute, or physical activity ratio (PAR), and the 24-hour requirement was expressed as a multiple of BMR per 24 hours, by using the physical activity level (PAL) value. Energy requirements are calculated by multiplying the PAL value by the energy equivalent of the corresponding BMR.

The energy requirements recommended for adults and elderly are based on moderately active lifestyles (PAL 1.75 for adults and PAL 1.60 for elderly) and the average body weight of Malaysians as reported by Lim *et al.* (2000). The BMR for adult Malaysians is derived from local studies (Ismail *et al.*, 1998); while for the elderly, FAO/WHO/UNU (1985) equations were used.

The requirements for groups with different body weights and level of physical activity are shown in Appendix 2.1 – 2.4. It must however be emphasized that these values are intended to be general guidelines. It may be useful to make adjustments according to the characteristics of the population concerned.

Energy requirements for adults and elderly

Men	**19 – 29 years**	**2440 kcal/day or**	**10.21 MJ/day**
	30 – 59 years	**2460 kcal/day or**	**10.29 MJ/day**
	≥ 60 years	**2010 kcal/day or**	**8.41 MJ/day**
Women	**19 – 29 years**	**2000 kcal/day or**	**8.37 MJ/day**
	30 – 59 years	**2180 kcal/day or**	**9.12 MJ/day**
	≥ 60 years	**1780 kcal/day or**	**7.45 MJ/day**

Pregnancy

The FAO/WHO/UNU 1985 recommendations for pregnancy were based on a general acceptance that total energy needs of pregnancy were estimated at 335MJ (80, 000 kcal) or about 1.2 MJ or 285 kcal/day. Most reports published after 1985 have recommended lower increments at 0.84 MJ/day or 200 kcal/day for healthy women with reduced activity (Prentice *et al.,* 1996).

Dietary intake during pregnancy must provide the energy that will result in the full-term delivery of a healthy newborn baby of adequate size and body composition. The ideal situation is that women enter pregnancy with normal weight and good nutritional conditions. Therefore, the energy requirements of pregnancy are those needed for the growth of the fetus, placenta and associated maternal tissues, and for the increased metabolic demands of pregnancy, in addition to the energy needed to maintain adequate maternal weight, body composition and physical activity throughout the gestational period. Special considerations must be made for women who are under- or overweight when they enter pregnancy.

The extra amount of energy required during pregnancy was calculated in association with a mean gestational weight gain of 12 kg by using factorial approaches (FAO/WHO/UNU 2004). The increment in energy requirement is relatively small in the first trimester (350 kJ/d or 85 kcal/d), and most women in many societies do not seek nutritional advice before the second or third month of pregnancy. Thus, a practical option is to add the extra requirement of the first trimester to the 1175 kJ/d (281 kcal/d) required in the second trimester.

Additional energy requirements during pregnancy

2nd trimester	**+ 360 kcal/day or + 1.51 MJ/day**
3rd trimester	**+ 470 kcal/day or + 1.97 MJ/day**

Lactation

The FAO/WHO/UNU 1985 recommendation for lactation were based on the median milk consumption of breast-fed Swedish infants for the first 6 months. It was assumed that milk energy was 2.9 kJ/g or 0.7 kcal/g and the efficiency of conversion of dietary to milk energy was 80%. Further more, it was assumed that the average women would start lactation with 150MJ (36,000 kcal) of additional fat reserves laid down during pregnancy and that these would be used to subsidize the cost of lactation over the first 6 months thus yielding about 0.84MJ/day or 200 kcal/day (Prentice *et al*., 1996).

The energy requirement of a lactating woman is defined as the level of energy intake from food that will balance the energy expenditure needed to maintain a body size and composition, a level of physical activity, and a breast milk production, which are consistent with good health for the woman and her child, and that will allow performing economically necessary and socially desirable activities. To operationalise this definition, the energy needed to produce an appropriate volume of milk must be added to the woman's habitual energy requirement, assuming that she resumes her usual level of physical activity soon after giving birth. The energy cost of lactation is determined by the amount of milk that is produced and secreted, its energy content, and the efficiency with which dietary energy is converted to milk energy.

Postpartum loss of body weight is usually highest in the first three months, and generally greater among women who practice exclusive breastfeeding, but the extent to which energy immobilized to support lactation depends on the gestational weight gain and the nutritional status of the mother. Thus, the recommendations for lactating women to a large part depend on the women's nutritional status.

For women who feed their infants exclusively with breast milk during the first six months of life, the mean energy cost over the six month period is: 807g milk/day x 2.8 kJ/d / 0.80 efficiency = 2.8 MJ/day (675 kcal/day). From the age of six month onwards, when infants are partially breast-fed and milk production is on average 550 g/day, the energy cost imposed by lactation is 1.925MJ/day (460 kcal/day).

Fat stores accumulated during pregnancy may cover part of the additional energy need in the first few months of lactation. Assuming an energy factor of 27.2 MJ/kg, the rate of weight loss in well-nourished women (0.8 kg/month) would correspond to the mobilization of 27.2 x 0.8 kg/month = 21.8MJ/month, or 0.72 MJ/day (170 kcal/day) from body energy stores. This amount of energy can be deducted from the 2.8 MJ (675 kcal) per day needed during the first six months of lactations. Energy requirements for milk production in the second six months are dependent of rates of milk production, which are highly variable between women and populations.

Additional energy requirements during lactation

First 6 months + 500 kcal/day or + 2.09 MJ/day

Discussions on revised energy requirements for Malaysia

The recommendations of the TSC on Energy and Macronutrients for energy requirements for Malaysians according to life stages are shown in Table 2.5. The requirements were derived based on the principles suggested in the FAO/WHO/UNU (2004) report using reliable measurements of total energy expenditure obtained from various age-groups as well as in special physiological status such as pregnancy and lactation. To derive requirements, the body weights were obtained from local studies and the physical activity level (PAL) values adopted from the FAO/WHO/UNU 2004 report. With the exception of adolescents and adults for which locally data are available, all BMR values were adopted from the FAO/WHO/UNU (2004) report.

The recommended energy requirements for Malaysia (2005) were then compared to the previous recommendations for Malaysian (Teoh, 1975), as well as the reports of IOM (2002) and FAO/WHO/UNU (2004) (Appendix 2.5). For infants, the revised energy requirement is on the average 20% lower than the 1975 recommendations. The differences of these revised recommendations with the recommendations of the FAO/WHO/UNU (2004) report are somewhat less; on average 15% for this age-group.

Table 2.5 Recommendations for energy requirements by life stages

	Males		**Females**	
Age	**Reference body weight[1] (kg)**	**Estimated Energy Requirements[2] kcal/day (MJ/d)**	**Reference body weight[1] (kg)**	**Estimated Energy Requirements[2] kcal/day (MJ/d)**
Infant				
0 - 5 months	6	560 (2.34)	6	550 (2.30)
6 - 11 months	8	640 (2.68)	8	630 (2.64)
Children				
1 - 3 years	12	980 (4.10)	11	910 (3.81)
4 - 6 years	18	1340 (5.61)	18	1290 (5.40)
7 - 9 years	26	1780 (7.45)	25	1590 (6.65)
Adolescents				
10 - 12 years	36	2180 (9.12)	37	1990 (8.33)
13 - 15 years	53	2690 (11.25)	49	2180 (9.12)
16 - 18 years	59	2840 (11.88)	52	2050 (8.58)
Adults				
19 – 29 years	61	2440 (10.21)	52	2000 (8.37)
30 – 59 years	64	2460 (10.29)	57	2180 (9.12)
≥60 years	57	2010 (8.41)	49	1780 (7.45)
Pregnancy				
2nd trimester				+ 360 (+1.51)
3rd trimester				+ 470 (+1.97)
Lactation				
1st six months				+ 500 (+2.09)

[1] Mean body weights for children and adolescents were obtained from MOH (2000), UKM (2001), UKM (2004); and for adults were obtained from Lim *et al*. (2000).

[2] Calculation of estimated energy requirements for infants and children up to 9 years old were based on recommended energy requirement per kg body weight per day (FAO/WHO/UNU 2004); for adolescents (PAL 1.71 – 1.84), adults (PAL 1.75) and elderly (PAL 1.60) were based on PAL values for moderate activity as recommended by (FAO/WHO/UNU 2004).

For children and adolescents, the revised energy requirements are on an average 22% lower for boys and 26% lower for girls under 12 years old compared to Teoh (1975). From age 12 years onwards, the requirement for boys was on average 10% higher while the girls 2% lower. Among children, current recommendations was on average less than 10% lower than the FAO/WHO/UNU (2004) report for both boys and girls. While for adolescents, the FAO/WHO/UNU (2004) report recommendations were 12% higher for boys and 14% higher for girls as compared to the current Malaysian recommendations. The differences observed may be expected since our requirements were based on body weights and BMRs of Malaysian children and adolescents.

For adults and the elderly, it is somewhat difficult to compare the values of the 1975 and 2005 recommendations because age groups and body weights were different. Nevertheless, the current RNI generally recommends marginally lower requirements for men and the elderly.

As for pregnancy, in line with the FAO/WHO/UNU (2004) report, the revised RNI proposed no additional calories for the 1st trimester whereas the 1975 recommendations had an additional energy requirement of 150 kcal. The additional energy requirement in the revised RNI for the 2nd is only marginally higher than the Teoh (1975) recommendations. However for the 3rd trimester, the additional energy requirement in the revised RNI is 34% higher than the Teoh (1975) recommendations. For lactation up to 6 months, the revised RNI proposed 9% less calories as compared to the 1975 report.

Several studies have revealed that most Malaysians maintained energy balance on a low intake while leading a sedentary lifestyle (Ismail *et al*., 2002). The increasing trend in over weight and obesity in urban and rural areas is a useful signal to revisit previous energy recommendations. Adopting the revised RNI would mean that we need to double our efforts in encouraging all age groups to be physically active habitually, necessary to match the proposed requirements.

2.8 Research recommendations

The following priority areas of research are recommended:

- Critical re-assessment of all data available, particularly on the extent of intra and inter- individual variability.
- Studies to determine energy cost of different activities
- Data on physical activity levels of different activities in all age groups.
- More basal metabolic rate measurements using strict criteria in order to generate predictive equations in all age groups, particularly in children under 10 years and in the above 60 years age groups.
- Use doubly-labelled water method to validate other conventional techniques in estimating energy expenditure particularly in children and adolescents.

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Appendix 2.1 Energy requirements of adolescents in populations with three levels of habitual physical activity

Age group	**Light Physical Activity**		**Moderate Physical Activity**		**Heavy Physical Activity**	
(years)	**kcal/day**	**MJ/day**	**kcal/day**	**MJ/day**	**kcal/day**	**MJ/day**
Boys						
10 – 12	1870	7.82	2180	9.12	2490	10.42
13 – 15	2330	9.75	2690	11.25	3110	13.01
16 – 18	2400	10.04	2860	11.97	3330	13.93
Girls						
10 – 12	1700	7.11	1990	8.33	2270	9.50
13 – 15	1880	7.87	2190	9.16	2500	10.46
16 – 18	1740	7.28	2040	8.54	2340	9.79

Appendix 2.2 Energy requirements of adults aged 19 – 29 years in populations with three levels of habitual physical activity

Body weight (kg)	Light Physical Activity (PAL 1.45)		Moderate Physical Activity (PAL 1.75)		Heavy Physical Activity (PAL 2.05)		Height (m) for BMI values of [1]		
	kcal/day	MJ/day	kcal/day	MJ/day	kcal/day	MJ/day	24.9	21.0	18.5
Men (19 – 29 years)									
40 kg	1620	6.79	1960	8.19	2290	9.59	1.27	1.38	1.47
45 kg	1720	7.19	2070	8.67	2430	10.16	1.34	1.46	1.56
50 kg	1810	7.58	2190	9.15	2560	10.72	1.42	1.54	1.64
55 kg	1910	7.98	2300	9.63	2700	11.89	1.49	1.62	1.72
60 kg	2000	8.38	2420	10.12	2830	11.85	1.55	1.69	1.80
65 kg	2100	8.78	2530	10.60	2970	12.41	1.62	1.76	1.87
70 kg	2190	9.18	2650	11.08	3100	12.98	1.68	1.83	1.95
75 kg	2290	9.58	2760	11.56	3240	13.54	1.74	1.89	2.01
80 kg	2380	9.98	2880	12.04	3370	14.10	1.79	1.95	2.08
85 kg	2480	10.38	2990	12.52	3510	14.67	1.85	2.01	2.14
90 kg	2575	10.77	3110	13.00	3640	15.23	1.90	2.07	2.21
Women (19 – 29 years)									
40 kg	1430	5.99	1730	7.24	2030	8.48	1.27	1.38	1.47
45 kg	1525	6.38	1840	7.70	2160	9.02	1.34	1.46	1.56
50 kg	1620	6.77	1950	8.17	2290	9.57	1.42	1.54	1.64
55 kg	1710	7.16	2065	8.64	2420	10.12	1.49	1.62	1.72
60 kg	1800	7.55	2180	9.11	2550	10.67	1.55	1.69	1.80
65 kg	1895	7.93	2290	9.58	2680	11.22	1.62	1.76	1.87
70 kg	1990	8.32	2400	10.04	2810	11.77	1.68	1.83	1.95
75 kg	2080	8.71	2510	10.51	2940	12.31	1.74	1.89	2.01
80 kg	2175	9.10	2625	10.98	3075	12.86	1.79	1.95	2.08
85 kg	2270	9.49	1740	11.45	3205	13.41	1.85	2.01	2.14
90 kg	2360	9.87	2850	11.92	3340	13.96	1.90	2.07	2.21

[1] Height ranges are presented for each mean weight for ease of making dietary energy recommendations to maintain an adequate BMI based on a population's mean height and PAL. For example, the recommended mean energy intake for a male population of this age group with a mean height of 1.70m and a lifestyle with a mean PAL of 1.75, is around 10.12 MJ (2,420 kcal) per day, to maintain an optimum population median BMI of 21.0, with an individual range of about 9.63 – 11.08 MJ (2,300 – 2,650 kcal) per day, to maintain the individual BMI limits of 18.5 – 24.9.

Appendix 2.3 Energy requirements of adults aged 30 – 59 years in populations with three levels of habitual physical activity

Body weight (kg)	Light Physical Activity (PAL 1.45)		Moderate Physical Activity (PAL 1.75)		Heavy Physical Activity (PAL 2.05)		Height (m) for BMI values of [1]		
	kcal/day	MJ/day	kcal/day	MJ/day	kcal/day	MJ/day	24.9	21.0	18.5
Men (30 - 59 years)									
40 kg	1680	7.02	2025	8.47	2370	9.92	1.27	1.38	1.47
45 kg	1750	7.33	2115	8.85	2480	10.37	1.34	1.46	1.56
50 kg	1830	7.64	2205	9.23	2580	10.81	1.42	1.54	1.64
55 kg	1900	7.96	2295	9.60	2690	11.25	1.49	1.62	1.72
60 kg	1980	8.27	2385	9.98	2795	11.69	1.55	1.69	1.80
65 kg	2050	8.58	2475	10.36	2900	12.14	1.62	1.76	1.87
70 kg	2125	8.90	2565	10.74	3010	12.58	1.68	1.83	1.95
75 kg	2200	9.21	2660	11.12	3110	13.02	1.74	1.89	2.01
80 kg	2275	9.52	2750	11.49	3220	13.46	1.79	1.95	2.08
85 kg	2350	9.84	2840	11.87	3325	13.91	1.85	2.01	2.14
90 kg	2425	10.15	2930	12.25	3430	14.35	1.90	2.07	2.21
Women (30 - 59 years)									
40 kg	1490	6.24	1800	7.53	2110	8.82	1.27	1.38	1.47
45 kg	1585	6.63	1910	8.00	2240	9.37	1.34	1.46	1.56
50 kg	1680	7.02	2025	8.47	2370	9.93	1.42	1.54	1.64
55 kg	1770	7.41	2140	8.95	2505	10.48	1.49	1.62	1.72
60 kg	1865	7.80	2250	9.42	2640	11.03	1.55	1.69	1.80
65 kg	1960	8.19	2360	9.89	2770	11.58	1.62	1.76	1.87
70 kg	2050	8.58	2475	10.36	2900	12.14	1.68	1.83	1.95
75 kg	2145	8.98	2590	10.83	3030	12.69	1.74	1.89	2.01
80 kg	2340	9.37	2700	11.30	3165	13.24	1.79	1.95	2.08
85 kg	2330	9.76	2815	11.78	3300	13.79	1.85	2.01	2.14
90 kg	2425	10.15	2930	12.25	3430	14.35	1.90	2.07	2.21

[1] Height ranges are presented for each mean weight for ease of making dietary energy recommendations to maintain an adequate BMI based on a population's mean height and PAL. For example, the recommended mean energy intake for a male population of this age group with a mean height of 1.70m and a lifestyle with a mean PAL of 1.75, is around 9.98 MJ (2,385 kcal) per day, to maintain an optimum population median BMI of 21.0, with an individual range of about 9.60 – 10.74 MJ (2,295 – 2,565 kcal) per day, to maintain the individual BMI limits of 18.5 – 24.9.

Appendix 2.4 Energy requirements of elderly aged 60 years and above in populations with three levels of habitual physical activity

Body weight (kg)	**Light Physical Activity (PAL 1.45)**		**Moderate Physical Activity (PAL 1.75)**		**Heavy Physical Activity (PAL 2.05)**		**Height (m) for BMI values of [1]**		
	kcal/day	**MJ/day**	**kcal/day**	**MJ/day**	**kcal/day**	**MJ/day**	**24.9**	**21.0**	**18.5**
Men (≥ 60 years)									
40 kg	1390	5.83	1535	6.43	1825	7.63	1.27	1.38	1.47
45 kg	1490	6.24	2645	6.88	2950	8.17	1.34	1.46	1.56
50 kg	1590	6.65	1750	7.33	2080	8.71	1.42	1.54	1.64
55 kg	1685	7.05	1860	7.78	2210	9.24	1.49	1.62	1.72
60 kg	1785	7.46	1970	8.24	2340	9.78	1.55	1.69	1.80
65 kg	1880	7.87	2075	8.69	2465	10.32	1.62	1.76	1.87
70 kg	1980	8.28	2185	9.14	2595	10.85	1.68	1.83	1.95
75 kg	2080	8.69	2290	9.59	2720	11.39	1.74	1.89	2.01
80 kg	2175	9.10	2400	10.04	2850	11.93	1.79	1.95	2.08
85 kg	2270	9.51	2510	10.50	2980	12.46	1.85	2.01	2.14
90 kg	2370	9.92	2620	10.95	3110	13.00	1.90	2.07	2.21
Women (≥ 60 years)									
40 kg	1470	6.16	1625	6.79	1930	8.07	1.27	1.38	1.47
45 kg	1550	6.48	1710	7.15	2030	8.48	1.34	1.46	1.56
50 kg	1625	6.79	1790	7.50	2130	8.90	1.42	1.54	1.64
55 kg	1700	7.11	1875	7.85	2230	9.32	1.49	1.62	1.72
60 kg	1775	7.43	1960	8.20	2330	9.74	1.55	1.69	1.80
65 kg	1850	7.75	2040	8.55	2430	10.15	1.62	1.76	1.87
70 kg	1930	8.07	2130	8.90	2525	10.57	1.68	1.83	1.95
75 kg	2005	8.39	2210	9.25	2625	10.99	1.74	1.89	2.01
80 kg	2080	8.70	2295	9.60	2725	11.40	1.79	1.95	2.08
85 kg	2155	9.02	2380	9.95	2825	11.82	1.85	2.01	2.14
90 kg	2230	9.34	2460	10.31	2925	12.24	1.90	2.07	2.21

[1] Height ranges are presented for each mean weight for ease of making dietary energy recommendations to maintain an adequate BMI based on a population's mean height and PAL. For example, the recommended mean energy intake for a male population of this age group with a mean height of 1.70m and a lifestyle with a mean PAL of 1.75, is around 8.24 MJ (1,970 kcal) per day, to maintain an optimum population median BMI of 21.0, with an individual range of about 7.78 – 9.14 MJ (1,860 – 2,185 kcal) per day, to maintain the individual BMI limits of 18.5 – 24.9.

Appendix 2.5 Comparison of recommended energy requirement: Malaysia (1975), Malaysia (2004), FAO/WHO/UNU (2004) and IOM (2002)

Malaysia (1975)		Malaysia (2005)		FAO/WHO/UNU (2004)		IOM (2002)	
Age groups	**kcal/day**	**Age groups**	**kcal/day**	**Age groups**	**kcal/day**	**Age groups**	**kcal/day**
Infants		Infants (boys)		Infants (boys)		Infants (boys)	
< 1 year	112/kg	0 – 5 months	560	0 – 5 months	580	0 – 5 months	550
		6 – 11 months	640	6 – 11 months	720	6 – 11 months	730
		Infants (girls)		Infants (girls)		Infants (girls)	
		0 – 5 months	550	0 – 5 months	540	0 – 5 months	500
		6 – 11 months	630	6 – 11 months	660	6 – 11 months	660
Children		Children (boys)		Children (boys)		Children (boys)	
1 – 3 years	1360	1 – 3 years	980	1 – 3 years	1110	1 – 2 years	1060
4 – 6 years	1830	4 – 6 years	1340	4 – 6 years	1470	3 – 8 years	1700
7 – 9 years	2190	7 – 9 years	1780	7 – 9 years	1830		
		Children (girls)		Children (girls)		Children (girls)	
		1 – 3 years	910	1 – 3 years	1020	1 – 2 years	1000
		4 – 6 years	1290	4 – 6 years	1330	3 – 8 years	1600
		7 – 9 years	1590	7 – 9 years	1700		
Boys		Boys		Boys		Boys	
10 – 12 years	2600	10 – 12 years	2180	10 – 12 years	2350	9 – 13 years	2300
13 – 15 years	2450	13 – 15 years	2690	13 – 15 years	2980	14 – 18 years	3100
16 – 19 years	2580	16 – 18 years	2840	16 – 17 years	3370		
Girls		Girls		Girls		Girls	
10 – 12 years	2350	10 – 12 years	1990	10 – 12 years	2140	9 – 13 years	2080
13 – 15 years	2200	13 – 15 years	2180	13 – 15 years	2440	14 – 18 years	2350
16 – 19 years	2100	16 – 18 years	2050	16 – 17 years	2500		
Men		Men		Men		Men [1]	
20 – 39 years	2530	19 – 29 years	2440	18 – 29 years	2800	19 – 30 years	2770
40 – 49 years	2400	30 – 59 years	2460	30 – 59 years	2850	31 – 50 years	2840
50 – 59 years	2280	≥ 60 years	2010	≥ 60 years	1950	51 – 70 years	2630
≥ 60 years	2020					> 70 years	1940
Women		Women		Women		Women [2]	
20 – 39 years	2000	19 – 29 years	2000	18 – 29 years	2150	19 – 30 years	2265
40 – 49 years	1900	30 – 59 years	2180	30 – 59 years	2250	31 – 50 years	2160
50 – 59 years	1800	≥ 60 years	1780	≥ 60 years	1800	51 – 70 years	2020
≥ 60 years	1600					> 70 years	1610
Pregnancy		Pregnancy		Pregnancy		Pregnancy	
1st trimester	+ 150	1st trimester	+ 0	1st trimester	+ 0	1st trimester	
2nd trimester	+ 350	2nd trimester	+ 360	2nd trimester	+ 360	2nd trimester	+ 180
3rd trimester	+ 350	3rd trimester	+ 470	3rd trimester	+ 475	3rd trimester	+ 180
Lactation		Lactation		Lactation		Lactation	
1st 6 months	+ 550	1st 6 months	+ 500	Well-nourished	+ 505	First 6 months	+ 500
				Undernourished	+ 675	2nd 6 months	+ 400
				(up to 6 months)			

[1] Values are calculated based on height of 1.65m; reference weight of Malaysian men of 62 kg for adults and 57 kg for elderly; and PAL of 1.6 – 1.9 (active) for adults and 1.4 – 1.6 (low active) for elderly.

[2] Values are calculated based on height of 1.55m; reference weight of Malaysian women of 55 kg for adults and 49 kg for elderly; and PAL of 1.6 – 1.9 (active) for adults and 1.4 – 1.6 (low active) for elderly.