2. Energy

Definition

Energy requirement has recently been defined [1,2] in terms of the energy expenditure rather than the intake of an individual or group. Previous definitions described requirements on the basis of an assessment of energy intakes but this is now considered unacceptable because intakes may not match the energy demands of the body and the intake may also be incompatible with the long term maintenance of desirable levels of body weight and physical activity. Several EC member countries have now adopted the use of energy expenditure values. In this report energy requirements of adults are therefore defined as the levels of energy intake from food which will balance energy expenditure when individuals have a body size and composition and a level of physical activity which are consistent with long-term good health. The requirement also allows for the maintenance of economically necessary and socially desirable physical activities.

Glossary

BMR: Basal metabolic rate, is the rate of energy used in the postabsorptive state under highly standardised conditions of thermal neutrality, with the individual awake but at complete psychological and physical rest [3].

PAR: Physical activity ratio, is the energy cost of specific tasks, expressed as a ratio of the BMR. The task may include a variety of movements and activities. For example, shopping includes the walking and standing required to choose from shelves, to pay, and carry the purchased goods. PARs are considered on a daily basis, which means that they are not weighted on a weekly or yearly basis.

IEI: Integrated energy index, describes the energy cost of specific occupations as a ratio of the BMR. This value is weighted for the pauses in activity and integrates the cost of various tasks. Thus a domestic helper's IEI specifies the energy spent over the whole work shift, while carrying out the appropriate variety of specific tasks (cooking, ironing, washing etc.) and having a number of interspersed periods of rest.

PAL: Physical activity level integrates on a 24 hours basis the energy spent on all types of activities, i.e. the IEIs specific to various occupations, and the cost of inactive periods such as sleep. Strictly speaking, both IEI and PAL are calculated so that they refer to typical days.

It is possible to calculate average yearly IEIs and PALs, accounting for the average number of hours worked per day, the number of days worked per week, and weeks per year. It is important to distinguish between the two series of values. The yearly weighted averages are expressed as $\overline{IEI}$ and $\overline{PAL}$, and assume that the number of occupational hours correspond to 40 hrs/week for 48 weeks/year.

BMI: Body Mass Index (Quetelet's Index). Body weight (kg) divided by square of body height (m).

Physiology and metabolism

Three major components contribute to the energy expenditure of adults. The first and largest component is the basal metabolic rate, BMR, which is the energy used in maintaining the body in a fasting, relaxed and physically inactive state in a thermoneutral environment. This component usually accounts for 50 - 60 % of the total energy expended. The second component is the energy used in processing and storing the nutrients eaten. This cost usually amounts to about 10 % of the energy ingested but the value depends on the balance of the diet, on individual differences in response and on the extent to which individuals are being underfed or overfed. The third major component is the energy expended in undertaking the variety of physical activities involved in living, working and in social activities.

The BMR of an adult is determined principally by body size, body composition and age. Men have on average more lean tissue than women and it is the lean tissue and the relative sizes of different organs which determine the BMR. The taller and heavier the individual the greater the amount of lean tissue and therefore the higher the BMR. With age there is usually a progressive loss of lean tissue and an increase in body fat. These differences and changes in body composition account for the lower BMR per kg body weight of women than men and for the declining BMR with age even when body weight is taken into account.

The level of physical activity must obviously be considered in detail when assessing the energy needs of an individual or group. Some activities involve the minimum of movement compatible with the individuals' needs at home whereas other activities involve the energy expended at work in a variety of different tasks. Further energy is expended in discretionary activities which include many useful contributions to the well-being of the individual and society; these can therefore be considered as socially desirable energy costs. There is also increasing recognition that maintaining physical fitness, promoting a sense of well-being by exercise and helping to prevent chronic diseases such as coronary heart disease, osteoporosis and muscle wasting in old age, may involve additional desirable physical activity if the physical cost of occupational work is modest. These additional needs are difficult to quantitate but it is recognised that physical activity is important for health and an allowance may need to be made for these additional exercise costs.

The basis for variation in energy requirements

The energy requirement of an individual is difficult to predict even when account is taken of the sex, age, body size and degree of physical activity. This is because of the substantial differences between individuals in their basal metabolism, in the efficiency with which they store food and in the muscle tone and physical cost of movement. Thus there remains a variation between individuals under standardised conditions with a range of values which extend to ± 15 % of the mean. A group of men or women of the same age and weight who engage in a variety of physical activities may show a range of individual needs which amounts to ± 20 % of the average for the group. It is therefore not possible to predict individual energy needs with any accuracy without special measurements of, for example, the BMR and physical activity patterns.

The traditional approach to deriving nutrient recommended dietary allowances has never been appropriate to estimating energy requirements because a sustained intake of energy either below or above the individual's specific needs has deleterious effects. This is in contrast to the effects of other nutrients where the provision of an ample amount of the nutrient ensures the whole population's needs are covered; individuals who receive more than they need are unlikely to suffer deleterious effects unless the nutrient is taken in very large amounts. It is therefore usual to calculate the average energy needs of a group.

Effects of energy excess

Adults have only a modest ability to dissipate excess dietary energy by altering their metabolic efficiency and thereby increasing their energy expenditure [4]. Weight is readily gained with fat and protein being deposited in adipose and lean tissue respectively. About 30 % of the excess weight gain is lean tissue so the BMR slowly increases [5,6]. This increase and the energy cost of moving a heavier body during physical activity means that an individual or group eventually comes back into equilibrium at a higher energy intake and expenditure but at the cost of being overweight. The increases in morbidity and mortality associated with excess weight are well documented and include greater risk of arthritis, gallbladder disease, diabetes, coronary heart disease, hypertension, stroke and an increased risk of some cancers [7]. These risks can be avoided if energy intakes and expenditure are matched within a desirable weight range. This has been defined as equivalent to a BMI of about 20-25 [8,9,10]. On a population basis, however, the risk of having individuals who have either chronic energy deficiency with a BMI below 18.5 or overweight with a BMI above 25 is minimised when the median BMI of the population is between 20 and 22. This may therefore be taken as the optimal population BMI range.

Estimation of energy requirement

To estimate energy requirement at the individual or group level it is necessary to establish the habitual level of energy expenditure. This is done in two steps. First the basic expenditure, BMR, is estimated. This can be predicted accurately on a group basis with a standard error of about 2 %, by the set of regressive equations developed for WHO/FAO/UNU [1]. These equations are based on age and weight for males and females separately. Recently new data on BMR of European elderly men and women have been collected so that a more extensive and relevant set of values is now available [11,12] . (See Appendix, Table A.1).

The next step consists in defining the level of activity which the individual or group engages in habitually. This is defined as the physical activity level (PAL) and expressed as a multiple of BMR. This PAL figure integrates in one single value the total energy expended over the whole day. While it is possible to derive the PAL from actual measurement of the energy spent in all the activities during a day, in most cases it is estimated from a knowledge of the type of occupation and recreational activity; these types are then linked to the energy cost of the activity defined as the physical activity ratio (PAR). Thus the total energy cost per minute of each task can be calculated. There are published tables of PARs for various activities and also estimates of the daily PALs of various life styles [13].

The energy cost of different occupations integrated over the working day is also given in specially designed tables which classify the occupations into various activity levels [1,13]. This cost is explained as the integrated energy index (IEI), and integrates the energy costs of a variety of activities carried out in performing a specific task. It is, however, appropriate to reclassify a group's lifestyle if it is apparent that modern living conditions have changed the energy demands. Thus a domestic helper may be classified as holding a "moderately" active job in some European countries where there are short working weeks and appliances designed to save human energy are available. The same occupation may involve heavy work when performed with little mechanisation and for many hours per day or with more days worked per year in other European countries.

It is now advisable to group daily activities not only in terms of occupation but also to take account of discretionary activities, the latter being further subdivided into socially desirable activities and activity intended for the maintenance of a healthy cardiovascular and muscular system [1]. This health maintenance activity may be totally absent from the life style of modern sedentary populations in Europe. If it is considered desirable, the cost associated with these activities for a given minimum time each day may be provided as an extra energy allowance. This approach implies a prescriptive or normative scheme rather than simply taking the observed patterns of activity and then specifying the energy needs accordingly.

Therefore when attempting to estimate the energy requirement of an individual or group, the following information is needed:

1) age, sex and body weight;

2) type of occupation, the time involved and its energy costs;

3) type of discretionary activity, the time involved and its energy costs;

4) hours of sleep.

The BMR is then calculated from the observed body weight provided the body mass index is between 20 and 25 for an individual. If the body mass index exceeds 25 then a desirable weight should be defined as that corresponding to a BMI of 25. For estimating the BMI of groups, however, a BMI of 22 should be chosen as desirable if the observed average BMI exceeds this value.

The energy cost of the various activities is usually established on the basis of tables of PARs (physical activity ratios), i.e. as a ratio of the cost to BMR. By knowing the time involved in each activity and with the use of tables it is possible to build up a picture of the total 24 hour energy expenditure, which may also be expressed as a ratio of the estimated 24 hr BMR of the individual. This is then the individual's PAL for that day. Experts conversant with the problems of establishing these PAL values are needed in developing this approach to energy requirements since serious errors and misinterpretations are readily made by the untrained analyst.

Simplifying the estimates of energy requirements

The various occupational activities can be grouped, on the basis of their mean IEI, into four major intensity levels. These are set out in Table 2.1 separately for men and women.

These values result from an integration of the energy spent on the actual work and of the interspersed pauses; the heavier the work the longer the pauses. The job specifications of the IEI categories are shown in Table 2.1, but this is meant to provide only general guidance; better definitions may eventually become available.

Table A.2 (Appendix) shows how the differences in body weight and in physical activity levels affect the average daily energy requirements of groups of men and women. There is over a threefold variation in needs. This emphasises the importance of establishing the characteristics of the group whose energy needs are to be met. Therefore, in developing the European average energy requirement, weights and heights and physical activity patterns (as $\overline{\text{IEI}}$ and/or as $\overline{\text{PAL}}$) within the community are needed. Very little suitable information is available currently, but extensive and representative data are likely to become available as part of current or planned nutritional surveillance surveys.

Developing individual or group requirement values

Table 2.2 provides an example of how the energy requirement of a domestic helper is estimated. She is considered to work in a Southern European country with a relatively low level of mechanisation. She is aged 25 and weighs 60 kg, so that from Table A.1 (Appendix) her BMR can be estimated as 5.8 MJ per day. To illustrate the need to integrate all her activities it is assumed that for two months of the year she also engages in harvesting a crop as part of the regular summer work in the area. In addition she has commitments to maintaining her own household. Three types of activity patterns therefore need to be considered: (a) her regular domestic work combined with her own household duties for three days per week, (b) an average pattern of activity for four week and weekend days when she copes predominantly with her household duties and (c) the two months weekday work picking crops. In this latter period it is assumed that she also works as a domestic for one weekend day to maintain her regular employment. Thus it is possible to obtain three different PAL values to cover the three types of day in the year. By integrating these for the whole year one arrives at an average energy requirement equivalent to 1.69 $\overline{\text{PAL}}$ or a total energy need, given her age and weight, of 9.78 MJ (2340 kcal) per day.

Generating an average value for European adult energy requirements

It is useful to determine if possible the average energy requirement of European adults taking into account the known or estimated variations in population structure, in adult weights and heights and the physical activity patterns within the Community.

First estimates of light, moderate and heavy life styles activity levels were specified with or without desirable increments in activity for promoting health and general well-being. These life style $\overline{\text{PAL}}$ values, expressed as ratios of the basal metabolic rate, are set out in Table 2.3.

It is more difficult to obtain a suitable estimate of European adult weights. Desirable weights for observed heights were calculated taking a BMI of 22. Actual adult weights and heights were taken from representative national samples or from specific surveys (see data sources in footnote to Table 2.4). These adult body weights and heights were weighted for the total number of adults in each age group in each country, as obtained from Eurostat [14], to obtain estimates of the average weight and height of European men and women of the various age groups. The calculated weights are given in Table 2.4.

Subsequently in this report when standard weights are required for calculating nutrient needs, the value for an adult male is taken as 75 kg, with 62 kg for an adult female, as being the mean actual body weights in the age range 30-59 years.

Energy requirements for each age and sex group were then derived (Table 2.4) by making assumptions about the proportion of men and women of different ages who are involved in different activity levels. These arbitrary assumptions are set out in the footnote to Table 2.4. Table 2.4 also indicates the extent to which the requirements are altered if an allowance is made for physically desirable activities.

Elsewhere in this report, when an average energy intake is required for calculating nutrient needs, the daily value for adult men is taken as 11.3 MJ, and for adult women, 8.5 MJ, from the mean energy requirement of men and women, without any addition being made for desirable physical activity.

In developing these estimates of energy requirements it should be recognised that they are based on extensive data relating to the basal metabolic rate of individuals of different ages but on very limited information on the average and range of physical activity patterns in European adults of different ages. These estimates of requirements may then need to be changed. Social and economic changes will also alter our estimates. Health promotion is already leading some adults to undertake more physical exercise in their spare time. But automation at work and in the home is tending to reduce the demand for physical activity to an unknown degree. The more generalised introduction of central heating and cooling of offices, factories and homes may also alter behavioural patterns to an unknown extent. These social changes mean that the energy needs of European adults are likely to alter with time. The values presented here are estimates of current European patterns of activity at work and in leisure time. They should therefore be treated with great caution.

Children

Estimating energy requirements from measurements of expenditure is ideal but this is particularly difficult in children because so few measurements have been made. There are coherent, long standing data on the BMR of infants, young children and adolescents but measures of physical activity are few and rarely apply to modern European circumstances, where there seems to have been an appreciable decline in activity patterns over the last 40 years. There are now a few measurements of total energy expenditure by the $^{2}H_{2}{}^{18}O$ method in a selected group of British children but they may well not be representative of the usual pattern in Europe. Reliance must therefore be placed on measures of food intake as well as expenditure data and these need to be related to the European children's growth patterns.

Growth patterns of children in Europe

There has been a substantial number of studies of children's weight and height at different ages but these are rarely conducted on representative populations and no attempt has been made as yet to derive a collated set of data taking into account the size of different European groups and the nature of the sampling and measurement techniques. The Tanner standards [15], based on about 2000 London schoolchildren and on a smaller sample of pre-school children studied repeatedly over many years, were set out in the 1960s. These have been widely used and a British nation-wide survey [16] showed that Tanner's graphs were still a reasonable reflection of British growth patterns in the 1970s. Primary data sources have been obtained from nine European countries, where cross-sectional, mixed longitudinal and longitudinal studies have been published in the 1970s and 1980s. Values from each country have been weighted by the size of the population in each age and sex group and averaged. Plots of the European growth curves are very close to the United States National Center for Health Statistics (NCHS) growth curves. Tables A.3 and A.4 (Appendix) show the mean values for height and weight from 1 month to 17 years of age; they correspond closely with the NCHS values.

Basal metabolic rates of children

These were collected and calculated by Schofield *et al.* [17] for use by the FAO/WHO/UNU Committee. Equations were derived based on age, sex, weight and height to derive the average BMR of boys and girls. These are given in Table A.1 (Appendix). In practice it is simple to use weight alone, although height does reduce the variability of the predicted BMR in children [17].

Physical activity and other thermogenic processes

Unfortunately there are few data on physical activity patterns, energy costs of growth or the thermogenic response to meals in European children of different ages. If these were available it could be possible to build up estimates of the energy used for BMR and these other processes and thereby derive requirement values in the same way as in adults. The pre-adolescent data are sparse and information on adolescents is confined to an unpublished Italian study. Two alternative approaches involve the use of the $^{2}H_{2}{}^{18}O$ method for measuring the total energy expenditure of children or the estimation of requirements from intake data. The $^{2}H_{2}{}^{18}O$ method has recently been introduced into human studies and only lately have some of the theoretical and technical problems associated with its use been evaluated [18]. Nevertheless the recent British report [19] used the data collected by the Cambridge group on 355 healthy infants to illustrate that the energy allowances set out for children by FAO/WHO/UNU [1] were higher than those estimated by adding the estimated energy deposited during growth to the $^{2}H_{2}{}^{18}O$ estimation of total energy expenditure. This new approach used a variety of assumptions which differed from those chosen in the initial validation studies on the $^{2}H_{2}{}^{18}O$ method and it is possible that there might be a small systematic bias in these data.

The FAO/WHO/UNU's [1] allowances for children under 3 years were based on measurements of energy intakes which themselves are subject to error and include assumptions for the digestibility factors for different diets which were derived from adult studies and may not be transferable to children. The FAO/WHO/UNU allowances also included a 5 % increase for a possible underestimate of intakes of energy from breast milk in the first year of life. The same increment was assigned on a prescriptive basis for children in the second and third year. In the values given here for European children this adjustment is not included. The daily energy needs of children decline from 480 kJ/kg at birth to about 360 kJ/kg at 9 months of age because of the very marked fall in the energy need for deposition of new tissue. The total energy cost of synthesizing and storing new tissue amounts to a little over 20 kJ/g weight gain and after the first year of life is always less than 4% of energy needs.

Infants

Breast feeding provides the best nourishment for new born babies and young infants. In these children there is no need to develop energy requirement figures; however it is sometimes useful to have these values for those who are bottle fed. The older data were based on energy-dense milk formulas and energy intakes tended to be 40-50 kJ/kg higher than those now found with infants feeding on new formulas which have a lower solute and energy load. These modern formulas still seem to be consumed in excess of the estimated energy intake of wholly or partially breast-fed babies. This may reflect the greater induction of thermogenic responses by formula feeding or differences in digestibility as well as perhaps the induction of faster growth rates in formula than breast-fed children.

Since estimates of energy requirements are derived in part to help with the artificial feeding of children and in the absence of clear information on the optimal growth rate for long term health, it is sensible for the present to base infant energy requirements on modern formula feeding data. These are set out in Table 2.5. The intake of 400 kJ/kg/d should be ample for growth since new estimates of intake are now tending to be somewhat lower [20]. It is better, however, to err on the side of a slight over-estimate than an underestimate.

In children aged 1-3 years there seems to be increasing evidence that their expenditure is lower than 40 years ago. This may reflect the lower activity or a lower thermoregulatory demand in modern children living indoors at higher environmental temperatures controlled by central heating, or a reduction in physical exertion consequent upon the increasing use of cars.

Children aged 3-9 years

The FAO/WHO/UNU report [1] had to rely on intake data for this age group because physical activity and total energy expenditure data are very limited. Few new studies have been reported since then so it remains appropriate to rely on intake data. In a European context the principal concern in relation to energy is one of overweight and obesity in children rather than of underweight and malnutrition. So the additional 5 % allowance prescribed by FAO/WHO/UNU [1] was not used in deriving the estimates shown in Table 2.6.

Children and adolescents aged 10-18 years

These can more readily be assessed in terms of energy expenditure using a system similar to that applied to adults. Typical time use and energy costs of activities in boys and girls were provided by the FAO/WHO/UNU approach (Table A.5, Appendix). In different parts of Europe the demand on adolescents will vary substantially with many, perhaps especially in rural areas, contributing to the physical work of the household.

Adjustments for these differing activity patterns can readily be made by reference to Table A.5 (Appendix) and the approach adopted for adults. Table 2.7 summarises the components of energy expenditure and the average energy requirement of adolescents who are moderately active with a physical activity level of about 1.65 for boys and 1.55 for girls, aged 10-13 years. For older adolescents, spending more time in school and related light type activities, calculations are made on the basis of physical activity levels of 1.58 for boys and 1.50 for the girls.

Pregnancy

There have been several detailed European studies of energy metabolism in pregnancy since the FAO/WHO/UNU collation of data in 1981. This has allowed a re-evaluation of the estimates of need. Studies on total energy expenditure in whole body calorimeters [21] have shown considerable variability in the metabolic changes in pregnancy in different women. Analyses of post-prandial thermogenesis have found a more efficient processing of nutrients with a lower metabolic response to meals in pregnant and lactating women [22]. There have also been two major studies in Glasgow and Wageningen as part of an international prospective study of the changes in food intake, energy expenditure and body composition during pregnancy [24]. These European studies are still in progress but sufficient data are available to justify the derivation of values which differ from those given by FAO/WHO/UNU [1].

The original estimates of energy need were based on data collected on the weight gain and body compositional changes in careful studies conducted before and after the war in Scotland. These data and the approach adopted have been used throughout the world for the last 30 years [25]. If a mother gained 12.5 kg and gave birth to a 3.3 kg baby then the total cost of the energy deposited in both maternal and fetal tissues together with the additional cost of maintaining the extra tissue amounted to an extra demand for 80,000 kcal (335 MJ) over the whole of pregnancy [25]. The FAO/WHO/UNU Consultation therefore divided this value by the 250 days after the first month of pregnancy to derive an additional need of about 1.3 MJ per day [1].

The supposed extra energy requirement is not matched by a corresponding increase in measured food intake in the new Glasgow and Wageningen studies. In fact an analysis of 10 studies in Australia, Holland and Britain showed increased intakes of only about 0.42 MJ/d in the third trimester of pregnancy and there was little if any change before that [19]. The UK proposed an increment of 0.8 MJ/day during the last trimester in view of the conflicting evidence from intake data and estimates based on BMR and tissue compositional changes [19].

The discrepancies in the European data between the estimated need for energy retention in pregnancy and the actual intake amount to 193 MJ in the Glasgow studies and to 264 MJ in Wageningen. This implies an average energy storage of 0.77-1.06 MJ/day [24]. Some of this saving may reflect differences between the pre-pregnancy values for intake and BMR and those used for calculating data which were collected at 10 weeks of pregnancy.

The decline in physical activity in late pregnancy is also difficult to document and may be a mechanism for saving energy.

Variable needs in pregnancy

The estimate of need presupposes that all women are of normal weight and sustain the appropriate weight gain which, in the five country study, amounted to 11.7 kg in Scotland, 10.5 kg in the Netherlands and 7.3-8.9 kg in the other three countries [24]. However new detailed analyses from the US show that both pre-pregnancy weight and weight gain are important indices of birth weight, and perinatal morbidity and mortality.

Provisional weight gain charts related to pre-pregnancy body mass index are now available showing that thin women, e.g. with a BMI below 20, need to gain between 12.5 and 18 kg by 40 weeks of pregnancy and at a rate of 0.5 kg/week during the second and third trimester [5] to reduce the risk to the baby. This compares with a 11.4 to 16 kg gain for most European women with a BMI of 20 to 26 before pregnancy and 7-11.5 kg weight gain for overweight women with BMI > 26. The latest US National Academy report [26] estimates the lowest neonatal and post neonatal mortality rate is achieved when babies are born weighing more than 3.5 kg. Underweight women respond to food supplementation during pregnancy by increasing their own body weight and the birth weight of their children. This implies that the energy requirements of pregnant women should be individually determined and that underweight women should be encouraged to eat more to improve the chance of having a normal weight child. Table 2.8 provides estimates for the additional energy requirements of underweight, normal and overweight European women who may either reduce their physical activity or be forced to maintain their activity patterns, for example because of the demands made by the family and the continuing need to work. Thus thin women require an increase in daily intake of about 1.7 MJ/day from the 10th week of pregnancy unless they become remarkably inactive with a $\overline{\text{PAL}}$ of 1.31 (Table 2.8). Clearly overweight and normal weight women who are usually moderately active can adjust for the extra energy needs by becoming sedentary. There is no direct evidence that such a change occurs, but food intake data suggest that some adjustment has been made in either physical activity or metabolism by the second trimester of pregnancy. On practical grounds therefore, it seems reasonable to halve the supposed extra energy demand, which therefore would be 0.75 MJ/d from the 10th week of pregnancy for normal weight women.

Lactation

The energy requirements for lactation are proportional to the quantity of milk produced. The average energy content of human milk is about 280 kJ/100 ml [1]. Milk output data for Swedish and British women corrected for insensible water losses from the infant being test-weighed reveal that the amount of milk produced increases steadily in the first 3 months of breast feeding. Thereafter output depends on the extent to which weaning foods are introduced. The greater their use the less breast milk the baby drinks. Thus mothers who continue almost exclusively breast feeding to 6 months of age produce 750 ml/d but this can decline rapidly to 300 ml/d with the use of appreciable weaning food.

In calculating energy costs of milk production an assessment of the conversion efficiency of dietary energy to milk energy is needed. This has been traditionally taken as 80 % although in the original calculation [27] this figure was taken as the extreme; the actual value was estimated as 97 %. Recently the issue has been reassessed in Gambian women in a whole body indirect calorimeter [28]. The efficiency was calculated from the energy content of the milk produced and the increment in BMR due to the lactational process. The mean efficiency of milk production was 94.2 % with a milk density of 2.9 kJ/g. Therefore it is now proposed to use an efficiency value of 95 % rather then 80 %. Recent separate studies in Scotland, Sweden and England also found efficiency values of between 97 and 100 %.

Table 2.9 provides new estimates which make use of these allowances and include 2 groups of women who wean their children to varying degrees after 6 months of breast feeding. An allowance is included for the average weight loss of 0.5 kg/month following delivery. From these data it is clear that the energy demands of lactation are substantial compared with those of pregnancy.

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Table 2.1 Classification of occupations into IEI categories*

Light		Moderate		Moderate/Heavy		Heavy	
M	F	M	F	M	F	M	F
1.60	1.60	2.25	1.90	3.0	2.3	3.8	2.8
Housewives Clerical and related workers Administrative and managerial Professional, technical and related workers		Domestic helpers Sales workers Service workers		Agricultural, animal husbandry, forestry and fishery workers Labourers Production and related transport equipment operators		Occupations are as in the moderate/ heavy category but conducted under poorly mechanised conditions	

* These IEIs apply under moderately mechanised work conditions. They may need to be shifted towards higher values when dealing with relatively low automation levels. The values for IEI reported in this Table only apply to the part of the day involved in work. The values take account of pauses and intervals in working but they are not weighted to generate an average daily value which includes week-end, summer vacations etc.

Table 2.2 ***Energy requirements of a female domestic helper in a Southern European country***

(age 25 years; weight 60 kg; BMR 5.8 MJ/day)

		Day type 1		Day type 2		Day type 3	
		housewife		domestic labour		agric. labour	
	IEI*	hr	MJ	hr	MJ	hr	MJ
1) In bed	1.0	8	1.93	8	1.93	8	1.93
2) Occupational activities							
a) Household work	2.7	2	1.31	1	0.65	1	0.65
b) Domestic labour	2.8	–	–	8	5.41	–	–
c) Tomato harvesting	3.0	–	–	–	–	8	5.8
3) Discretionary activities							
a) Household maintenance	2.0	2	1.00	-	–	–	–
b) Socially desirable	1.7	4	1.64	2	0.82	2	0.82
c) Cardiovascular and muscular maintenance	6.0	0.25	0.36	–	–	–	–
4) Rest of day	1.4	7.75	2.62	5	1.69	5	1.69
Daily Total PAL (MJ)	–	**1.53**	**(8.86)**	**1.81**	**(10.50)**	**1.88**	**(10.89)**

Integrated $\overline{PAL}$ (MJ) 1.69 (9.78)

Day type 1 = 4 days per week for 10 months (48% of the year)

Day type 2 = 3 days per week for 10 months + 1 day per week for 2 months (38% of the year)

Day type 3 = 5 days per week for 2 months (14% of the year)

* The IEI values used in this Table are higher than the corresponding values in Table 2.1, because the example describes a poorly mechanised situation. The value for cardiovascular and muscular maintenance is a PAR.

Table 2.3 ***The variety of physical activity levels (in $\overline{PAL}$ and in MJ/d) used in estimating energy requirements in European men and women (actual body weight, see table 2.4).***

	Lifestyle Activity Level	Including desirable physical activities		Without desirable physical activities	
		$\overline{PAL}$	MJ/d	$\overline{PAL}$	MJ/d
Men	aged 18-59 years (wt. 74.6 kg)				
	Light	1.55	11.5	1.41	10.5
	Moderate	1.78	13.3	1.70	12.7
	Heavy	2.10	15.6	2.01	15.0
	aged 60-74 years (wt. 73.5 kg)	1.51	10.0	1.40	9.2
	aged≥ 75 years (wt. 73.5 kg)	1.51	9.1	1.33	8.0
Women	aged 18-59 years (wt. 62.1 kg)				
	Light	1.56	9.1	1.42	8.3
	Moderate	1.64	9.5	1.56	9.1
	Heavy	1.82	10.6	1.73	10.1
	aged 60-74 years (wt. 66.1 kg)	1.56	8.5	1.44	7.8
	aged≥ 75 years (wt. 66.1 kg)	1.56	8.3	1.37	7.3

The physical activity levels are based on the 1985 WHO/FAO/UNU report [1] on energy requirements for the men and women under 60 years. An adjustment for estimating $\overline{PAL}$ values without desirable physical activity has been specified by James and Schofield [13] and data on the elderly depend on new assessments of physical activity in these groups as monitored by Ferro-Luzzi [12].

Table 2.4 ***Desirable and actual average body weights (kg) and normative and actual energy requirements (in MJ/d and as $\overline{PAL}$) for European men and women of various ages.***

Age in years		With desirable physical activity		Without desirable physical activity	
	Desirable* body weight (kg)	MJ/d	$\overline{PAL}$	MJ/d	$\overline{PAL}$
Men					
18-29	66.3	12.5	1.77	11.9	1.67
30-59	66.3	11.5	1.66	10.7	1.55
60-74	63.5	9.2	1.51	8.5	1.40
≥ 75	63.5	8.5	1.51	7.5	1.33
Average		**11.4**	**1.67**	**10.7**	**1.56**
Women					
18-29	57.3	9.1	1.63	8.5	1.52
30-59	57.3	8.9	1.60	8.3	1.49
60-74	55.5	7.8	1.56	7.2	1.44
≥ 75	55.5	7.6	1.56	6.7	1.37
Average		**8.7**	**1.60**	**8.1**	**1.48**
	Actual**body weight	MJ/d	$\overline{PAL}$	MJ/d	$\overline{PAL}$
Men					
18-29	74.6	13.4	1.77	12.7	1.67
30-59	74.6	12.1	1.67	11.3	1.56
60-74	73.5	10.0	1.51	9.2	1.40
≥ 75	73.5	9.1	1.51	8.0	1.33
Average		**12.1**	**1.68**	**11.3**	**1.57**
Women					
18-29	62.1	9.6	1.63	9.0	1.52
30-59	62.1	9.2	1.60	8.5	1.49
60-74	66.1	8.5	1.56	7.8	1.44
≥ 75	66.1	8.3	1.56	7.3	1.37
Average		**9.2**	**1.60**	**8.5**	**1.48**

(continues Table 2.4)

* Desirable weight for observed height taking the BMI as 22.

** Weighted median weights of European men and women derived from the studies listed below. Data had to be combined for the whole age ranges 18-59 years and 60 to 75 years because appropriate age groupings were not available. In calculating energy requirements, BMR and activity data appropriate to the specified age groups were applied. The basal metabolic rate values were obtained from Table A.1 (Appendix) and a series of assumptions were made for the proportion of each age group involved at light, moderate and heavy physical activity levels, the cost of these levels being taken as in Table 2.3. It was assumed that for 18-29 year old European men 10 % were engaged in heavy activity, 70 % in moderate and 20 % in light activity levels. For women of the same age 10 % were also considered to engage in heavy activity, 50 % in moderate and 40 % in light activity. For 30-59 years old men and women half were considered to be at moderate activity and the remaining half at light activity levels. All men and women over 60 years were specified as engaged in light activity patterns.

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for Tables 2.1 to 2.4

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Table 2.5 ***Estimated average requirements of energy for children aged 0-36 months.***

	Average weight (kg)		Intake (kJ/kg body weight)	Estimated energy requirements (kJ/d)	
Age (months)	*Boys*	*Girls*		*Boys*	*Girls*
1	4.0	4.0	480	1900	1900
3	6.0	5.5	420	2500	2300
6	8.0	7.5	400	3200	3000
9	9.0	8.5	400	3600	3400
12	10.0	9.5	400	4000	3800
18	11.5	11.0	400	4600	4400
24	12.5	12.0	400	5000	4800
30	14.0	13.0	400	5600	5200
36	15.0	14.0	400	6000	5600

Taken in part from reference 19. The body weights have been rounded to the nearest 0.5 kg and the estimated energy requirements to the nearest 50 KJ/d

Table 2.6 Estimated average requirements of energy for children aged 3-9 years

	Average weight (kg)		**Intake* (kJ/kg)**		**Estimated energy requirements (kJ/d)**	
Age (years)	*Boys*	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*
3.5	15.5	15.0	395	375	6100	5650
4.5	17.5	17.0	375	365	6550	6200
5.5	19.5	19.5	365	350	7100	6800
6.5	22.0	21.5	350	330	7700	7100
7.5	24.5	24.0	330	305	8100	7300
8.5	27.0	27.0	305	275	8250	7400
9.5	30.0	30.5	285	245	8550	7500

* Intake derived from table 23 of reference 1. The body weights have been rounded to the nearest 0.5 kg, and the estimated energy requirements to the nearest 50 KJ/d, with some smoothing of the final values.

Table 2.7 ***Calculation of basal metabolic rate (BMR), total energy expenditure (TEE) and average requirements of energy of older children and adolescents aged 10-17 years***

Age (years)	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5
Boys								
Weight (kg)	33.0	36.5	41.0	47.0	53.0	58.0	62.5	64.5
BMR (MJ/day)	5.19	5.45	5.78	6.23	6.67	7.04	7.38	7.52
TEE (MJ/day) *	8.56	8.99	9.54	10.28	10.54	11.12	11.66	11.88
Growth (MJ/day) **	0.17	0.20	0.26	0.35	0.35	0.29	0.26	0.12
Estimated energy requirements (MJ/day)	8.73	9.19	9.80	10.63	10.89	11.41	11.92	12.00
Girls								
Weight (kg)	34.0	37.5	43.0	48.0	50.5	52.5	54.0	54.5
BMR (MJ/day)	4.80	5.00	5.31	5.59	5.73	5.84	5.92	5.95
TEE (MJ/day) *	7.44	7.75	8.23	8.66	8.60	8.76	8.88	8.93
Growth (MJ/day) **	0.20	0.20	0.32	0.29	0.14	0.12	0.09	0.03
Estimated Energy Requirements (MJ/day)	7.64	7.95	8.55	8.95	8.74 ***	8.88	8.97	8.96

* at a $\overline{PAL}$ of 1.65 for boys and 1.58 for girls aged 10-13 years, and 1.55 for boys and 1.50 for girls aged 14-17 years.

** at a cost of 21 kJ per daily weight gain.

*** The small decrease in energy requirement at this stage relates mainly to the fall in the growth rate.

Table 2.8 Assessing pregnancy energy needs in relation to pre-pregnancy weight and desirable weight gain.

Pre-pregnancy BMI	18.5-19.9	20.0-25.9	>25.9
Ideal weight gain (kg)	12.5-18.0	11.4-16.0	7.0-11.5
Estimated extra needs (MJ)			
BMR	175	150	100
Maternal fat store	150	110	60
Other maternal tissue	20	15	10
Fetus	35	35	35
Theoretical total extra need from 10th week of pregnancy	360	310	205
Calculated daily extra demand (MJ) from 10th week	1.7	1.5	1.0
Practical recommendation for extra intake from 10th week (MJ/d)	1.7	0.75	0.5
Pre-pregnancy intake (MJ/d) at moderate activity ($\overline{PAL}$ 1.64)	6.78	10.30	12.50
Activity $\overline{PAL}$ to adjust for tissue storage and metabolism while maintaining pre-pregnancy intake	1.31	1.40	1.51

Calculations based on National Academy of Science assessment [26] of ranges of pre-pregnancy weight and desirable weight gains which on average were assumed to be BMIs of 19, 23 and 28 with weight gains of 15.5, 13.5 and 9 kg. All women were assumed to be 1.65 m and moderately active ($\overline{PAL}$ 1.64 before pregnancy). Values for storage adapted from Durnin [24].

Table 2.9 Additional energy requirements for lactation

Full breast feeding	**Milk Volume**	**Energy Cost**	**Allowance weight loss**	**Total extra requirements**
Months	*ml/d*	*MJ/d*	*MJ/d*	*MJ/d*
0-1	680	2.00	-0.5	1.5
1-2	780	2.30	-0.5	1.8
2-3	820	2.42	-0.5	1.92
3-6	750	2.21	-0.5	1.71

Weaning Practice from 6 months

Minor	650	1.92	0	1.92
Substantial	300	0.88	0	0.88

Derived from the UK report [19] but using new value for the efficiency of milk production.