UNIT 2 HUMAN ENERGY REQUIREMENTS

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2.1 INTRODUCTION

This unit focuses on the human energy requirements. The nutrient requirement for Indian population, you may recall studying in the last unit, are computed by the Indian Council of Medical Research (ICMR) and published in its recent "Nutrient Requirements and Recommended Dietary Allowance for Indians"(1989 reprinted in 1998). The energy requirements have been computed on the basis of recommendations made by a Joint Expert Consultation of the World Health Organization(WHO)/Food and Agricultural Organization (FAO)/United Nations University (UNU) in 1985 and by an Expert Committee constituted in 1988 by ICMR, These data, of course, have to be continuously updated particularly now in the light of the new Food and Agriculture Organization/ World Health Organization/United Nations University (FAO/WHO/UNU) recommendations.

A Joint FAO/WHO/UNU Expert Consultation on Human Energy Requirements, convened in October 2001 at FAO headquarters in Rome, Italy has formulated recommendations for human energy requirements published in 2004. The levels of energy intake recommended by this expert consultation are based on estimates of the requirements of *healthy, well-nourished individuals.* The recommendations that have resulted from this consultation are important guidelines on energy in human nutrition for the academia, scientists, nutritionists, physicians and other health workers, as well as, for planners and policy-makers in both the agriculture and health sectors throughout the world.

The ICMR is in the process of now updating the earlier recommendations. Till such time the new recommendations are published the old recommendations are being followed in our countsy and have been included in this unit. The new FAO/WHO/ UNU 2004 recommendations for human energy requirements throughout the life cycle are also presented in this unit on the basis of which our new recommendations for energy may be formulated in course of time.

What are the components of energy requirement? Which are the factors which influence the energy expenditure and requirements of individuals? What are the old and new methods we can use for measuring the energy expenditure and requirement? What are the problems associated with high and low energy intakes? These me some of the issues covered in this unit.

Objectives

After studying this unit, you will be able to:

- define the units of energy and physiological fuel value of foods,
- discuss the components of energy requirements,
- describe the methods of estimation of energy requirements,
- define and explain the basis for formulating the energy requirements of different physiological groups, and
- critically 'analyze the regulation of energy metabolism– problems associatecl with high and low energy intake.

2.2 ENERGY: SOME BASIC CONCEPTS

Energy in simple terms may be defined as the ability, or power, to do work. As a student of dietetics and nutrition, you already know that the physiological sources of energy are carbohydrates, protein, fats – the macronutrients present in food. Energy is released by the metabolism of food and the potential energy value of foods is expressed in terms of the kilocalorie (Kcal). A *kilocalorie is defined as the amount of heat required to raise the temperature of 1 kg of water through I' Celsius (centigrade).* Internationally, you may notice that the unit of energy measurement commonly used is the Joule (J). It expresses the amount of energy expended when 1 kg of a substance is moved 1 meter by a force of 1 newton. The conversion factor for changing kilocalories to kilojoules is 1 kilocalorie = 4.184 kilojoules.

The amount of heat energy (kilocalorie) per gram that can be made available to the body by each of the energy-yielding macronutsients – carbohydrate, protein, fat – must be known to you. Yes, 1 g of carbohydrates yields 4 Kcal, 1 g of fat yields 9 Kcal, and 1 g protein yields 4 Kcal. These values are known as the physiological *fuel factors,*

Do you know how the energy in various foods is generally measured? The amount of energy available in a food is precisely determined by a laboratory technique known as *calorimetry.* In this process, a weighed amount of food is placed inside a metal container called a *bonzb calorimeter*, which is immersed in water. The food is then ignited in the presence of oxygen and burned. The increase in temperature of the surrounding water is measured and used in calculating the number of kilocalories given off by the oxidation of the food,

An alternate method of measuring food energy is to use the macronutrient composition of foods in the food composition tables and by using the physiological fuel factors referred to earlier. The Indian Council of Medical Research (ICMR), India has published food value tables in a book titled 'Nutritive Value of Indian Foods'. Certainly, as a student of nutrition or dietetics, you may have referred to this book some time or other.

With this basic understanding of the measurement of energy, let us move on to studying the energy requirements. But before we move on to the requirements we must give a definition of what we understand by energy requirements and also know about the components of energy requirements. These are described next.

2.3 DEFINITION AND COMPONENTS OF ENERGY REQUIREMENT

We shall begin our study in this section by first understanding what we mean by energy requirement. *Energy requirement (ER)* is defined 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, and also to allow optimal growth and development of children, deposition of tissues during pregnancy, and secretion of milk during lactation, consistent with long-term good health. For healthy, well-nourished adults, it is equivalent to *total energy expenditure* (TEE). There are additional energy needs to support growth in children and in women during pregnancy, and for milk production during lactation.

Total energy expenditure (TEE), may be defined *as the energy spent, on average, in a 24-hour period by an individual or a group of individuals.* By delinition, it reflects the average amount of energy spent in a typical day, but it is not the exact amount of energy spent each and every day.

The energy needs vary widely among individuals in a group. You will find it impossible to compute an individuals energy need without knowing something about the personal lifestyle and metabolism. Consider the following situations:

Situation 1: A *30* year old women who bikes, and swims each day, would require more energy than a 30 year old who does a desk job.

Situation 2: In a group of 20 odd people, with similar body weight and activity levels, some individuals may require more energy per day than others.

Why do you think the energy requirements are different in these situations?

Well the requirement is dependent on the ways in which the body spends energy. For example in the first case the intensity of work or voluntary activity i.e. intentional activities (such as cycling, swimming) conducted by voluntary muscles affects the amount of energy used, hence the variation in the requirement. On the other hand, think of all the involuntary activities of our body that are necessary to sustain life, including circulation, respiration, temperature maintenance, hormone secretion, nerve activity, new tissue synthesis etc. All these involuntary activities of the body, which continue day in and day out without our conscious awareness, require energy. Further, as the food is chewed, digested, absorbed, these metabolic response to food increases total energy expenditure. Therefore, the human beings need energy for the following:

- *Basal metabolism.* This comprises *a* series of functions that are essential for life, such as cell function and replacement; the synthesis, secretion and metabolism of enzymes and hormones to transport proteins and other substances and molecules; the maintenance of body temperature; uninterrupted work of cardiac and respiratory muscles; and brain function. The amount of energy used for basal metabolism in a period of time is called the *basal metabolic rate (BMR). BMR* is measured under standard conditions that include being awake in the supine position after 10 to 12 hours of fasting and eight hours of physical rest, and being in a state of mental relaxation in an ambient environmental temperature that does not elicit heat-generating or heat-dissipating processes, Depending on age and lifestyle, BMR represents 45 to 70 *percent* of the total daily energy expenditure, and it is determined mainly by the individual's age, gender, as well as, body size and body composition. We will learn more about these factors which influence the BMR in the next section.

BMR is commonly extrapolated to 24 h to be more meaningful, it is then referred to as *Basal Energy Expenditure* (BEE) and is expressed as Kilocalories per 24 hours. The basal metabolic rate, as defined originally by *Boothby* and *Sandiford* was measured in the morning upon awakening, before any physical activity and 12-18 h after a meal. A closely related term used now is *Resting Metabolic Rate* (RMR). RMR is measured with the subject in a supine or sitting position in a comfortable environment several hours after a meal and without any significant activity. RMR is slightly higher than BMR but the difference is small. RMR when extrapolated to 24 hours is the *resting energy expenditure* (*REE*).

- *Metabolic response to food.* Eating requires energy for the ingestion and digestion of food, and for the absorption, transport, interconversion, oxidation and deposition of nutrients. These metabolic processes increase heal production and oxygen consumption, and are known by terms such as *'dietary-induced thermpgenesis', 'specific dynanzio action of food'* and *'thermic effect of feeding' (TEF).* The metabolic response to food increases total energy expenditure by about 10 *percent of the* BMR over a 24-hour period in individuals eating a mixed diet.

- *Physical activity.* This is the most variable and, after BMR, the second largest component of daily energy expenditure. Humans perform *obligatory* and *discretionary* physical activities. Obligatory activities can seldom be avoided within a given setting, and they are imposed on the individual by economic, cultural or societal demands. The term "occupational" was used earlier in the WHO/FAO/UNU 1985 report but the preferred term now is *obligatory* as it is more comprehensive. In addition to occupational work, obligatory activities include daily activities such as going to school, attending to the home and family and other demands made on children and adults by their economic, social and cultural environment. *Discretionary activities,* although not socially or economically essential, are important for health, well-being and a good quality of life in general. They include the regular practice of physical activity for fitness and health, the performance of optional household tasks that may contribute lo family comfort and well-being; and the engagement in individually and socially desirable activities for personal enjoyment, social interaction and community development. We will dwell further on this aspect later in this unit; however, we need to look at two concepts in the context of physical activity namely physical activity level (PAL) and physical activity ratio (PAR), which find extensive use in calculating the total energy requirement of healthy, well-nourished adults.

  Physical activity level (PAL) is defined as the total energy required over 24 hours divided by the energy needed for basal metabolism over 24 hours. In simple terms, TEE for 24 hours expressed as a multiple of BMR, and calculated as TEE/BMR for 24 hours. In adult men and non-pregnant, non-lactating women, **BMR** multplied by PAL is equal to TEE or the daily energy requirement.

  Physical activity ratio (PAR): The energy cost of an activity per unit of time (usually a minute or an hour) expressed as a multiple of **BMR.** It is calculated as energy spent in an activity/BMR, for the selected time unit.

- *Growth.* The energy cost of growth has two components: 1) the energy needed to synthesize growing tissues; and 2) the energy deposited in these tissues. The energy cost of growth is about 35 percent of total energy requirement during the first three months of age, falls rapidly to about 5 percent at 12 months and about 3 percent in the second year, remains at 1 to 2 percent until mid-adolescence, and is negligible in the late teens.

- *Pregnancy.* During pregnancy, extra energy is needed for the growth of the foetus, placenta and various maternal tissues, such as in the uterus, breasts and fat stores, as well as, for changes in maternal metabolism and the increase in maternal effort at rest and during physical activity.
- *Lactation.* The energy cost of lactation has two components: 1) the energy content of the milk secreted, and 2) the energy required to produce that milk. Well-nourished lactating women can derive part of this additional requirement from body fat stores accumulated during pregnancy.

From our discussion above, it is evident that the total energy expenditure over a 24-hour period is the sum of BMR, TEF, and energy for physical activities as also highlighted in Figure 2.1. For adults, this is equivalent to daily energy requirements. Additional energy for deposition in growing tissues is needed to determine energy requirements in infancy, childhood, adolescence and during pregnancy, and for the production and secretion of milk during lactation. Energy balance is achieved when input (i.e. dietary energy intake) is equal to the output (i.e. total energy expenditure), plus the energy cost of growth in childhood and pregnancy, or the energy cost to produce milk during lactation. When energy balance is maintained over a prolonged period, an individual is considered to be in a steady state.

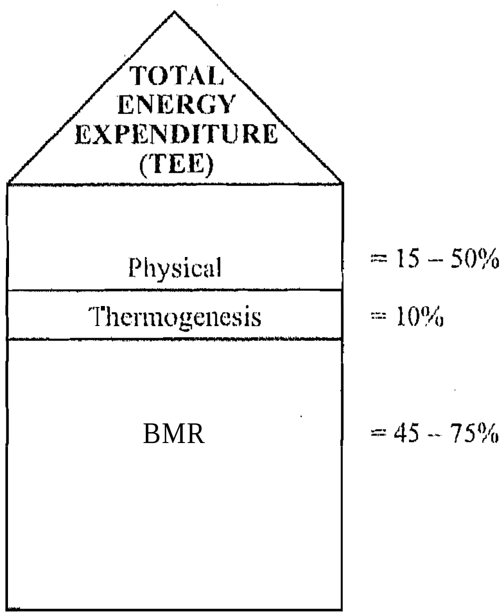

Figure 2.1: Components of total energy expenditure

In the next section, we shall review the factors which influence the energy expenditure and requirements.

2.4 FACTORS AFFECTING ENERGY EXPENDITURE AND REQUIREMENT

As mentioned earlier, the energy needs vary widely among individuals in a group. Why? A number of factors cause the RMR or more appropriately the REE to vary among individuals. Major determinants are the body size, composition, age, sex, growth etc. Similarly, there are factors affecting the thermic effect of food and energy expended in physical activity. A brief review on these factors follows.

2.4.1 Factors Affecting the BMR

Basal metabolic rate, we know, is the largest component of the daily energy demand representing *45 to 70 percent* of daily total energy expenditure. It is highly variable and the causes of this variation include factors such as fat free mass (FFM), fat mass

(FM), age, sex, hormonal status, growth, disease/infections etc. Let us learn about these factors starting with body size and composition.

Body size and composition: Basal and resting energy expenditures are related to body size, being most closely correlated with the size of the *fat-free mass* (FFM), *which is the weight of the body less the weight of its fat muss.* The size of the FFM generally explains about 70 to 80 percent of the variance in RMR. FFM is the metabolicaly active tissue in the body; what we also call as the lean body mass (LBM) and so most of the variation in BMR between people can be accounted for by the variation in their FFM. For example, athletes with greater muscular development have approximately a 5% higher basal metabolism than non-athletic individuals. Thus, exercise can help maintain a higher lean body mass and hence a higher metabolic rate. Similarly, the lower basal metabolic energy requirement of women is primarily related to their generally lower amount of lean muscle tnass (more of fat mass) as compared to men. The decline in BMR with increasing age is also to some extent the consequence of changes in the relative size of organs and tissues. Further larger people (big size) have higher metabolic rates than people of smaller size. In fact, individuals with greater surface area have higher metabolic rate. To illustrate, if two people of different heights weigh the same, the taller individual with the larger body surface area will have a higher metabolic rate. In adults with higher percentages of body fat composition, mechanical hindrances can also increase the energy expenditure associated with certain types of activity.

Age: The *BMR* per unit weight also varies with age, being higher in children and lower in the elderly. The loss of FFM with ageing is associated with a decline in the metabolic rate, amounting to about 1-2% decline per decade after early adulthood The REE is highest during the periods of rapid growth, chiefly during the first and second year of life, and reaches a lesser peak through the periods of puberty and adolescence in both sexes.

Gender: We have already emphasized earlier that sex difference in metabolic rates are primarily attributable to difference in body size and composition. Women who have generally more fat in propo tion to muscle than men, have metabolic rates which are 5-10% lower than men of the same weight and height. Thus, differences in BMR between genders are due to the greater level of body fatness in women.

Hormonal ***Status:*** Thyroid status may be most important factor and can make differences of up to plus or minus 50% for hyperthyroidism or hypothyroidism, respectively. Hyperthyroidism increases the resting metabolic rate, whereas hypothyroidism decreases the RMR. Stimulation of the sympathetic nervous system (e.g. during the period of stress or emotional excitement or fear, anxiety) causes the release of epinephrine, which directly promotes glycogenolysis and increases cellular activity. This too is associated with increased metabolic rate. In adult premenopausal women, the metabolic rate fluctuates with the menstrual cycle. An average of 359 Kcal/ day difference in the BMR has been measured between the low point, about 1 week before ovulation on day 14, and the high point, just before the onset of menstruation.

Environmental Conditions: Extremes in environmental temperatures also affect the metabolic rate. Energy expenditure will be increased if extra heat production is needed to maintain body temperature in a cold climate. The extent to which the energy metabolism increases in extremely cold environment depends on the insulation available from .body fat and protective clothing. Conversely, there is some evidence that the basal metabolic rate is reduced in hot climates. For example, BMK is on an average 10% lower in Indians than in North Europeans. Further exercise undertaken in temperatures greater than 86°F also imposes an additional metabolic load of about 5% from increased sweat gland activity.

Besides climatic conditions, altitude too has been shown to affect metabolic rates. Hypoxia (lack of oxygen in tissues) of high altitude increases BMR. Hypoxia increases glucose utilization, which might affect the lnetabolic rate. However, these are temporary effects, which disappear with acclimatization. We learn more about this aspect later in Unit 18 at the end of this course.

Pregnancy and Lactation: These periods of physiological stress also have an impact on the metabolic rate. Earlier, we studied that REE is highest during the periods of rapid growth, i.e. chiefly during the first and second year of life, In pregnancy too, which is the foetal growth period, the metabolic rate increases, particularly later in pregnancy because of uterine, placental and foetal growth and the mother's increased cardiac work load.

Fever/Illness/Infections/Injury: Any illness or fever caused by an illness influences the metabolic rate. Fevers increase the lnetabolic rate by about 7% for each degree increase in body temperature above 98.6°F or in other words 13% for each degree above 37°C.

During injury or infections there is an increased BMR, and this increase is dependent on the severity of the injury. For example, the BMR may even double with bums of more than 40% of the body sui-face, in severe sepsis, multiple traumas, whereas it may only increase by about 25% in patients with long bone fractures and even less after surgery. But we need to understand that in sick patients who are likely to be in bed, the increase in the BMR due to the stress imposed by the disease may be offset by the decrease in physical activity, such that the total daily energy expenditure may not change drastically.

Nutritional status: Undernutrition and starvation are the factors which require consideration. Prolonged undernutrition or starvation causes a reduction of about 10-20% in BMR. In semi-starvation studies, data suggest that the subjects BMR decrease by about 25% when expressed per kilogram of their free fat mass (FFM) (or metabolic active tissue). Reduction in BMR are partly mediated through weight loss itself, in which metabolically demanding tissue of the body (the FFM i.e. the lean body tissue) are reduced in size, and partly through reduction in the metabolic activity of these tissues. We will learn more about this aspect later in section 2.6 in this unit.

Other Factors: Smoking is one variable thought to influence the lnetabolic rate. Smoking increases BMR, cessation of smoking lowers BMR. The BMR in sleep is about 5% less than in the basal condition.

Thus, there is an exhaustive list of factors which influence BMR and hence the total energy requirements, under different conditions. Next, we shall move on to the study of the factors affecting the thermic effect of food.

2.4.2 Factors Affecting the Thermic Effect of Food

The thermic effect of food, as we learnt earlier, is the increase in energy expenditure associated with the consumption of food and it accounts for approximately 10% of TEE (Total Energy Expenditure). The intensity and duration of meal induced TEF (Thermic effect of food) is, however, determinecl primarily by the amount and composition of the foods consumed. TEF, for example, *is greater after consumption of carbohydrate and protein than after fat.* The increments in energy expenditure during digestion above baseline rates, divided by the energy content of the food consumed, vary from 5 to 10 percent for carbohydrate, 0 to 5 percent for fat, and 20 to 30 percent for protein. The high TEF for protein reflects the relatively high metabolic cost involved in processing the amino acids yielded by absorption of dietary protein, for protein synthesis, or for the synthesis of urea and glucose. Activation of the sympathetic nervous system elicited by dietary carbohydrate and by sensory stimulation causes an increase in energy expenditure.

Consumption of the usual mixture of nutrients (i.e. a mixed diet) is generally considered to elicit increases in energy expenditure equivalent to 10 percent of the food's energy content. Spicy foods enhance and prolong the effect of TEF. Meals with chili and mustard may increase the metabolic rate as much as **33%** more than unspiced meal, and this affect may last for more than **3** hours. Caffeine and nicotine also stimulate TEF.

Next, we shall review the factors influencing the energy expended on physical activity.

2.4.3 Factors Affecting the Energy Expended in Physical Activity

Physical activity as we learnt earlier, is the second largest component of daily energy expenditure, after BMR. However, the energy expended in physical activity is most variable as it may range from 10% in a person who is bedridden to as much as 50% of TEE in an athelete. In fact, *different lfestyles* have different levels of energy demands. The examples of lifestyles with different levels of energy demands as given by FAO/WHO/UNU 2004 are enumerated herewith.

- *Sedentary or light activity lifestyles:* These people have occupations that do not demand much physical effort, are not required to walk long distances, generally use motor vehicles for transportation, do not exercise or participate in sports regularly, and spend most of their leisure time sitting or standing, with little body displacement (e.g. talking, reading, watching television, listening to the radio, using computers). One example is male/female teachers, office workers (executives, clerks, typists etc.) in urban areas, who only occasionally engage in physically demanding activities during or outside working hours. Another example are housewives living in urban areas with access to energy saving devices and domestic help to carry out most of the manual chores and other moderate energy activities.
- *Active or moderately active lifestyles*: These people have occupations that are not strenuous in terms of energy demands, but involve more energy expenditure than that described for sedentary lifestyles. Alternatively, they can be people with sedentary occupations who regularly spend a certain amount of time in moderate to vigorous physical activities, during either the obligatory or the discretionary part of their daily routine. For example, the daily performance of one hour (either continuous or in several bouts during the day) of moderate to vigorous exercise, such as jogging/running, cycling, aerobic dancing or various sports activities. Other examples of moderately active lifestyles are associated with occupations such as servants, house cleaners, masons and construction workers, or rural women in less developed traditional villages who participate in agricultural chores or walk long distances to fetch water and fuel wood.
- *Vigorous or vigorously active lifestyles*: These people engage regularly in strenuous work or in strenuous leisure activities for several hours. Examples are women with non-sedentary occupations who swim or dance an average of two hours each day, or non-mechanized agricultural labourers who work with a machete, hoe or axe for several hours daily and walk long distances over rugged terrains, often carrying heavy loads. Other examples of vigorously active occupations include rickshaw pullers, mine workers, coolies etc.

Now that we have classified the different lifestyles, it is important to note that the energy expended will vary not only with the different types of activity undertaken by an individual (both occupational and discretionary physical activity), *but also by time spent in each activity/task and the energy cost of each activity throughout a theoretical* ***24-hour*** *period.* The classification of lifestyles in relation to the energy cost of each activity or the intensity of habitual physical activity, or physical activity level (PAL) is given in Table 2.1. *Physical activity level (PAL)*, we learnt earlier, is defined as the total energy required over 24 hours divided by the basal metabolic rate over 24 hours. In adult men and non-pregnant, non-lactating women, BMR times PAL is equal to TEE or the daily energy requirement.

Table 2.1: Classification of lifestyles in relation to the intensity of habitual physical activity, or PAL

Category	PAL value
Sedentary or light activity lifestyle	**1.40 - 1.69**
Active or moderately active lifestyle	1.70 - 1.99
Vigorous or vigorously active lifestyle	2.00 - 2.40*

* PAL values > 2.40 are difficult to maintain over a long period of time.

You would realize that the energy expended in physical activity tends to decrease with *age*, a trend that as you may already be aware is associated with a decline in FFM and an increase in fat mass which influences the energy requirement.

In addition to the immediate energy cost of individual activities, physical activity also affects energy expenditure in the *post-exercise* **period.** Excess post-exercise oxygen consumption (EPOC) depends on exercise intensity and duration, as well as, other factors, such as environmental temperatures, state of hydration, and degree of trauma, demonstrable sometimes up to 24 hours after exercise. The increase in daily energy expenditure is somewhat greater, however, because exercise induces an additional small increase in expenditure for some time after the exertion itself has been completed. This excess post-exercise oxygen consumption (EPOC), as mentioned above, depends on exercise intensity and duration and has been estimated at some 15 percent of the increment in expenditure that occurs during exertions like walking/jogging.

There may also be chronic changes in energy expenditure associated with regular physical activity as a result of changes in body composition and alterations in the metabolic rate of muscle tissue, neuroendocrine status, and changes in spontaneous physical activity associated with altered levels of fitness. Habitual exercise does not cause a significant prolonged increase in metabolic sate per unit of active tissue, but it does cause an 8-14% higher metabolic rate in men who are moderately and highly active because of their increased fat free mass i.e. lean body tissue. Since FFM is the major predictor of BMR and RMR, increases in FFM due to increased physical activity would be expected to increase BMR or RMR. The level of fitness also affects the energy expenditure of voluntary activity, probably because of variation in muscle mass.

To conclude, *intensity, duration* and *frequency of the activity*, the *body mass* of the person, *efficiency* at *performing the* **activity** and *age* influences the energy expended in physical activity.

Next, we shall move to a review the methods/means to calculate the energy expenditure and/or requirements. But before that let us recapitulate what we have learnt so far by answering the questions in the check your progress exercise 1.

Check Your Progress Exercise 1

1) Define the following

Energy:..

Kilocalorie:..

Physiological fuel factor: ....

TEF:...

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2) List the different components of energy requirements.

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3) Define BMR? Give the factors which influence BMR.

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4) Give the different lifestyle classifications with their PAL value.

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Now let us learn about the methods we can use to measure energy expenditure and requirements,

2.5 METHODS OF ESTIMATION OF ENERGY EXPENDITURE AND REQUIREMENTS

There are a variety of methods available to measure human energy expenditure. Knowledge of these methods will help us in calculating the expenditure either in the practical sessions or in the research setting. Some of these methods covered in this section include:

- Direct calorimetry
- Indirect calorimetry
- Factorial estimation
- The doubly labelled water (DLW) technique
- Heart rate monitoring (HRM)

Let us get to know about these techniques.

2.5.1 Direct Calorimetry

Calorimetry refers to the measurement of the amount of heat evolved or absorbed in a chemical reaction, change of state, or formation of a solution. ***Direct calorimetry*** is the method, which monitors the amount of heat produced by a subject placed inside a structure large enough to permit inoderate ainount of activity, These structures are referred to as whole room calorimeters. This method provides a measure of energy expended in form of heat, but provides no information on the kind of fuel being oxidized. Further, this method is limited by the high cost and by the confined nature of the testing conditions i.e. the physical activity within the chamber is limited and therefore not representative of free-living environment.

Another method to be considered is the use of a respiration chamber or of a direct calorimeter. To obtain reliable data with either of these techniques involves an experimental set-up which is both expensive and technically complex. Relatively few of these chambers exist and their usefulness in the present context is restricted to specific basic problems which do not require a natural free-living environment

2.5.2 Indirect Calorimetry

This method estimates energy expenditure by determining the oxygen consumption and carbon dioxide production of the body or a cell over a given period of time. Data so obtained from this method permits calculation of the respiratory quotient (RQ) which is expressed as:

$$RQ = \frac{\text{moles } CO_2 \text{ expired}}{\text{moles } O_2 \text{ consumed}}$$

The RQ indicates the source of metabolic energy. It ranges from 1.0 (carbohydrate oxidation) to 0.7 (fat oxidation). On a mixed diet the RQ is about 0.85.

This determination is converted into kilocalories of heat produced per square meter of body surface area per hour and is extrapolated to energy expenditure in 24 hours.

2.5.3 Double Labeled Water (DLW) Technique

DLW is currently considered the most accurate technique for measuring TEE in free-living individuals. It is the method used to measure the average total energy expenditure of free-living individuals over several days (usually 10 to 14), based on the disappearance of a dose of water enriched with the stable isotopes ^2H and ^{18}O. The use of the doubly labeled water (DLW) (^2H,^{18}O) technique to calculate total production of carbon dioxide (CO_2) over several day's and, from this, total energy expenditure was originally developed for use in small mammals and its application was later validated in humans. TEE measured by this method includes basal metabolism, the metabolic response to food, thermoregulatory needs, physical activity costs, and the energy cost to synthesize growing tissues. Consequently, energy requirements are calculated as the sum of TEE plus the energy deposited as protein and fat in growing tissues and organs.

2.5.4 Heart Rate Monitoring (HRM) Method

HRM is a method to measure the daily energy expenditure of free-living individuals, based on the relationship of heart rate and oxygen consumption and on minute-by-minute monitoring of heart rate.

Extrapolating from heart rate to energy expenditure is a method which has been widely believed to be valuable and reasonably valid. The technique is fairly practicable, there are several instruments on the market which are not very expensive, and it is probably the method of choice in some population groups, such as young children, old people, and ill people. This is not the place to give a detailed critique of the methodology, other than to say that it must be used with circumspection and an awareness of the variable relationships of heart rate and energy expenditure.

Finally, let us learn about the factorial estimation of total energy expenditure which is most practical and provides a good indication of total requirements.

2.5.5 Factorial Estimation of Total Energy Expenditure

The wide variations observed in the physical activity patterns of adults from different geographic, social and economic groups combined with the variations observed in body size and composition of adults, do not allow the universal application of TEE measured by DLW technique, described above, to be used directly for estimating the energy requirements for adults. Therefore, the factorial estimate is used which combines the time allocated to different habitual activities and the energy cost of these activities expressed in multiples of BMR per unit of time, i.e. either per minute or per hour. Total energy expenditure can, therefore, be estimated by a factorial approach involving summation of all the expected components of energy expenditure, including BMR and taking into account the energy costs of different activities and their durations. Table 2.2 shows examples of these calculations. To account for differences in body size and composition, the energy cost of activities is calculated as a multiple of BMR per minute also referred to as the physical activity ratio (PAR) (refer to Table 2.2), and the 24-hour energy requirements are expressed as a multiple of BMR per 24 hours by using the PAL value. Together with BMR of the population, PAL when known or when derived using BMR estimated from age and gender-specific predictive equations based on the average body weight of the population provides an estimate of TEE and hence the mean energy requirement For that population.

It must be noted here that the factorial approach should be used only for adults. It should not be used in the case of infants and children.

Table 2.2: Factorial calculations of total energy expenditure for a population group

Main **Daily** Activities	Time Allocation **Hours**	Energy **Cost**[a] PAR	Time x Energy Cost	Mean PAL" Multiple of 24-hour BMR
Sedentary or light activity lifestyle				
Sleeping	8	1	8.0	
Personal care (dressing, showering)	I	2.3	2.3	
Eating	1	1.5	1.5	
Cooking	1	2.1	2.1	
Silting (office work, selling produce, tending shop)	8	1.5	12.0	
General household work	1	2.8	2.8	
Driving car to/from work	1	2.0	2.0	
Walking at varying paces without a load	1	3.2	3.2	
Light leisure activities (watching TV, chatting)	2	1.4	2.8	
Total	**24**		36.7	36.7124 = 1.53
Active or **moderately** active lifestyle				
Sleeping	8	1	8.0	
Personal care (dressing, showering)	1	2.3	2.3	
Eating	1	1.5	1.5	
Standing, carrying light loads (waiting on tables, arranging merchandise)'	8	2.2	17.6	
Commuting to/from work on the bus	1	1.2	1.2	
Walking at varying paces without a load	1	3.2	3.2	
Low intensity aerobic exercise	1	4.2	4.2	
Light leisure activities (watching TV, chatting)	3	1.4	4.2	
Total	24		42.2	42.2124 = 1.76

Vigorous **or** vigorously active lifestyle				
Sleeping	8	1	8.0	
Personal care (dressing, bathing)	1	2.3	2.3	
Eating	1	1.4	1.4	
Cooking	1	2.1	2.1	
Non-mechanized agricultural work (planting, weeding, gathering)	6	4.1	24.6	
Collecting water/wood	1	4.4	4.4	
Non-mechanized domestic chores (sweeping, washing clothes and dishes by hand)	1	2.3	2.3	
Walking at varying paces without a load	1	3.2	**3.2**	
Miscellaneous light leisure activities	4	1.4	**5.6**	
Total	24		**53.9**	53.9124 = **2.25**

[a] Energy costs of activities, expressed as multiples of basal metabolic rate, or PAR, are based on data presented in Annexure I given at the end of the course.

[b] PAL= physical activity level, or energy requirement expressed as a multiple of 24-hour BMR,

[c] Composite of the energy cost of standing, walking slowly and serving meals or carrying a light load.

Let us understand this calculation with the help of an example. However, we shall first learn about the use of predictive equations to measure BMR.

We already know that BMR constitutes about 45 to 70 percent of TEE in adults, and is determined principally by gender, body size, body composition and age. It can be measured accurately with small intra-individual variation by direct or indirect calorimetry under standard conditions as described above. But, BMR can be measured only under laboratory conditions and in small groups of representative individuals by these methods. There is a need to estimate BMR at the population level when using the factorial approach to estimate TEE from the average BMR and PAL value attributable to that population. Hence, the alternative has been to estimate a group's mean BMR using predictive equations based on measurements that are easier to obtain, such as body weight and/or height. The report from the 1985 FAO/WHO/UNU expert consultation used a set of equations proposed in 1985 by *Schofield* derived mostly from studies in Western Europe and North America. Table **2.3** present these equations.

Table 2.3: Equations for estimating BMR from body weight*

Age ***Years***	**No.**	**BMR: MJ/day**	**see**	**BMR: Kcal/day**	**see**
Males					
< 3	162	0.249 kg - 0.127	0.292	59.512 kg - 30.4	70
3 - 10	338	0.095 kg + 2.110	0.280	22.706 kg + 504.3	67
10 - 18	734	0.074 kg + 2.754	0.441	17.686 kg + 658.2	105
18 - 30	2879	0.063 kg + 2.896	0.641	15.057 kg + 692.2	153
30 - 60	646	0.048 kg + 3,653	0.700	11.472 kg + 873.1	167
> 60	50	0,049 kg + 2.459	0.686	11.711 kg + 587.7	164
Females					
< 3	137	0.244 kg - 0,130	0.246	58.317 kg - 31.1	**59**
3 - 10	413	0.085 kg + 2.033	0.292	20.315 kg + 485.9	**70**
10 - 18	575	0.056 kg + 2.898	0.466	13.384 kg + 692.6	111
18 - 30	829	0.062 kg + 2.036	0.497	14.818 kg + 486.6	119
30 - 60	372	0.034 kg + 3.538	0.465	8.126 kg + 845.6	111
> 60	38	0.038 kg + 2.755	0.451	9,082 kg + 658.5	108

* Weight is expressed in kg. Predictive equations for children and adolescents are presented for the sake of completeness.

see = standard error of estimate.

Source: Schofield, 1985.

We can use these equations to estimate **BMR** from body weight. Multiplying the PAL by the BMR then gives the actual energy requirements. The PAL values as given in Table 2.1 for different lifestyles may be considered.

Now, let us understand the factorial calculation of total energy expenditure using the predictive equations to estimate **BMR** and using the PAL values with the help of an example.

Example: Manju is a female, 25 years of age, with a moderately active lifestyle and a mean body weight of 55 kg. Now let us calculate her energy requirements.

Calculations:

- From the Table 2.3, BMR *calculated from the predictive* equation is: 5.45 MJ/day (1302 *Kcal/day*) (i.e. 0.062 x 55 + 2.036 = 5.446 MJ/ 14.818 x 55 + 486.6 = 1301.59).

  PAL from mid-point of the moderately active lifestyle in Table 2.1 is 1.85.

  TEE or Energy *requirement*: 5.45 x 1.85 = 10.08 MJ/day (2409 *Kcal/day*), or 10.08/55 = 183 kJ/kg/day (44 *Kcal/kg/day*).

We hope that with this example you have understood the factorial estimation of total energy requirement. In this manner, with the help of the **BMR** predicitve equation and the PAL value you can calculate the total energy expenditure (TEE) which will be the energy requirement for the individual.

Few other examples specific to different lifestyles are presented next, to help you understand the concept better.

Examples:

Sedentary or light activity: If this PAL was from a female population, 30 to 50 years old, with mean weight of 55 kg and mean BMR of 5.40 MJ/day (1290 *Kcal/* day), TEE = 1.53 x 5.40 = 8.26 MJ (1975 Kcal), or 150 kJ (36 Kcal)/kg/d.

Active or moderately *active*: If this PAL was from a female population, 20 to 25 years old, with mean weight of 57 kg and mean **BMR** of 5.60 MJ/day (1338 *Kcal/* day), TEE = 1.76 x 5.60 = 9.86 MJ (2355 Kcal), or 173 kJ (41 *Kcal*)/kg/d.

Vigorous or *vigorously* active: If this PAL was from a male population, 20 to 25 years old, with mean weight of 70 kg and mean BMR of 7.30 MJ/day (*1745 Kcal/* day), TEE = 2.25 x 7.30 = 16.42 MJ (3925 *Kcal*), or 235 kJ (*56 Kcal*)/kg/d.

Next, let us study about the energy requirements for different age groups.

2.6 ENERGY REQUIREMENTS AND DIETARY ENERGY RECOMMENDATIONS

Energy requirement, as you may recall studying earlier, is 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 the good health of mother and child. *The* recommended level of dietary energy *intake* for a population group is the mean energy requirement of the healthy, well-nourished individuals who constitute that group.

Energy requirements and recommended levels of intake are often referred to as *daily requirements* or *recommended daily intakes*. These terms are used as. a matter of convention and convenience, indicating that the *requirement* represents an average of energy needs over a certain number of days, and that the *recommended energy intake* is the amount of energy that should be ingested as a daily average over a certain period of time.There is no implication that this amount of energy must be consumed every day or that the requirement and the recommended intake remain constant day after day. A convenient time frame of one week has been often used in practice for defining the number of days over which the requirement and the recommended energy intake may be averaged, although there is no biological basis for this or any other time frame. Considering that habitual physical activities may vary on some days of the week a seven day period appears reasonable for averaging the requirement and the recommended intakes.

Remember, estimates of energy requirements are derived from measurements of individuals. Measurements of a collection of individuals of the same gender and similar age, body size and physical activity are grouped together to give the average energy requirement – or recommended level of dietary intake – for a *class* of people or a *population group*.

The energy needs for Indian population has been computed on the basis of recommendations made by a Joint Expert Consultation of the World Health Organization (WHO)/Food and Agricultural Organization (FAO)/United Nations University (UNU) in 1985 and by an Expert Committee constituted in 1988 by the Indian Council of Medical Research (ICMR) as already informed earlier in the introduction section. However, recently the Joint FAO/WHO/UNU Expert Consultation on Human Energy Requirements, convened in October 2001 at FAO headquarters in Rome, Italy has formulated recommendations for human energy requirements published in 2004. The ICMR is in the process of now updating the earlier recommendations. Till such time the new recommendations are published the old recommendations are being followed in our country. A brief review on these recommendations along with the new FAO/WHO/UNU 2004 recommendations for human energy requirements through out the life cycle is presented herewith.

2.6.1 Energy Requirements of Infants (from Birth to 12 Months)

Energy requirements during infancy are very high because this is one of the periods of very rapid growth. Energy requirement for infants and children of all age group are based on the principle of calculating energy requirements from total energy expenditure (TEE) plus the energy needs for growth. Energy needs for growth have two components: 1) the energy used to synthesize growing tissues, which is part of the total energy expenditure, and 2) the energy deposited in those tissues, basically as fat and protein, because carbohydrate content is insignificant. This has to be taken into account along with the basal energy needs and energy needs for activity in infants and children.

Available data suggest that energy needs are highest during the first three months and then fall over the next six months when the growth rates are lower. It rises again after nine months as the child becomes physically more active. The RDA for infants drawn by ICMR, as given in Table 2.4 takes this phenomenon inta account. The requirements are categorized into two groups: 0-6 months and 6-12 months, and are calculated as energy units per kilogram of body weight.

Table 2.4: RDA for infants and children

	Energy per kg Body Weight	Net Energy (Kcal/d)	Body Weight (kg)
< 6 months	108/kg	583	5.4
6 - 12 months	98/kg	844	8.6

Source: ICMR, 1988.

Breastmilk is the best food for infants, and exclusive breastfeeding is strongly recommended during the first six months of life which is sufficient to meet the energy requirements. Thereafter, a combination of breastmilk and complementary foods throughout infancy is recommended to meet the requirements. We will learn more about the requirements and how to meet these requirements later in Unit 14.

Table 2.5 presents the FAO/WHO/UNU 2004 recommended average energy requirements of infants from one to 12 months of age, combining the needs of breastfed and formula-fed infants. TEE is calculated with the predictive linear equations described later in this section. The sum of TEE and energy deposition is the mean daily energy requirement (in MJ or Kcal). It is calculated as energy units per kilogram of body weight, dividing the daily requirement by the median weight at each month of age.

The TEE is lower among breastfed than formula-fed infants during the first year of life; hence the energy requirements of breastfed infants are also lower, as you may have noticed in Table 2.5.

Table 2.5: Energy requirement of breastfed,formula-fed and all infants

Age	Breast-fed			Formula-fed			All breast&formula-fed		
Months	Boys	Girls	Mean	Boys	Girls	Mean	Boys	Girls	Mean
MJ/kg/d									
1	445	415	430	510	490	500	475	445	400
2	410	395	405	400	455	460	435	420	430
3	380	375	380	420	420	420	395	395	395
4	330	335	330	360	370	365	345	350	345
5	330	330	330	355	365	360	340	345	345
6	325	330	330	350	355	355	335	340	340
7	320	315	320	340	340	340	330	330	330
8	320	320	320	340	340	340	330	330	330
9	325	320	320	340	340	340	330	330	330
10	330	325	325	340	340	340	335	330	335
11	330	325	325	340	340	340	335	330	335
12	330	325	330	345	340	340	335	330	335
Kcal/kg/d									
1	106	99	102	122	117	120	113	107	110
2	98	95	97	110	108	109	104	101	102
3	91	90	90	100	101	100	95	94	95
4	79	80	79	86	89	87	82	84	83
5	79	79	79	85	87	86	81	82	82
6	78	79	78	83	85	84	81	81	81
7	76	76	76	81	81	81	79	78	79
8	77	76	76	81	81	81	81	79	78
9	77	76	77	81	81	81	79	78	79
10	79	77	78	82	81	81	80	79	80
11	79	77	78	82	81	81	80	79	80
12	79	77	78	82	81	81	81	79	80

Compared with the values in the FAO/WHO/UNU 1985 report, energy requirements proposed by FAO/WHO/UNU 2004 consultation are about 12 percent lower in the first three months of life, 17 percent lower from three to nine months, and 20 percent lower from nine to 12 months. The requirements for breastfed infants are 17, 20 and 22 percent lower than the 1985 estimates at ages 0 to three, three to nine and nine to 12 months, respectively.

The equations to predict TEE from body weight of infants are as follows:

Breast-fed:

TEE (MJ/day) = – 0.635 + 0.388 kg

TEE (Kcallday) = – 152.0 + 92.8 kg

Formula-fed:

TEE (MJ/day) = – 0.122 + 0.346 kg

TEE (Kcallday) = – 29.0 + 82.6 kg

Breast and formula-fed:

TEE (MJ/kg/day) = – 0.416 + 0.371 kg

In populations around the world, and particularly in India, we have large numbers of newborns with intrauterine growth retardation, and malnourished children less than one year of age. In addition to proper health, social and emotional support, these infants require special nutritional care for a rapid, catch-up growth that will allow them to attain the expected weight and height of normal children born with adequate size at term, and who have never been malnourished. Therefore, diets for catch-up growth must provide all nutrients and energy sourcesin amounts that are proportionally higher than those required by well-nourished infants of adequate size. However it is difficult to generalize the quantitative energy requirements for catch up growth and it is best done on individual basis. Some tentative estimates as proposed by the FAO/WHO/UNU expert Consultation of 2001 are given in Table 2.6.

Table 2.6: Increase in energy requirements needed to allow for twice the normal growth rate of children six to 24 months old*

Age (Months)	Average Weight Gain	% Increase Over Energy Requirement
6 - 9	1.83	14.5
9 - 12	1.15	8.5
12 - 18	0.67	5
18 - 24	0.51	3.5

* It was assumed that the requirements for normal growth were 1,5 times the theoretical estimates based on weight gain.

Source: Adapted from WHO, 1985.

Next, let us learn about the requirements of older children and adolescents.

2.6.2 Energy Requirement for Children and Adolescent

The preschool years represent the age from approximately 1 to 6 years. Marked variability exists between requirements during the preschool years because of variation in growth and physical activity. Energy needs for growth have two components: 1) the energy used to synthesize growing tissues; and 2) the energy deposited in those tissues, basically as fat and protein, because carbohydrate content is negligible. Dietary energy recommendations also include recommendations for physical activity compatible with maintenance of health and optimal growth and maturation. The WHO/FAO/UNU and the ICMR Expert Committee took note of the fact that Indian children are smaller at birth, infancy, childhood and adolescence but suggested that it is desirable that the growth potential of children should be fully expressed and that the estimates of energy and protein requirement should allow for this. However, as the normal Indian children are smaller and they weigh less, the actual energy requirements may be substantially lower. The dietary intakes thus recommended by ICMR for Indian children are presented in Table 2.7. You would have noticed that the energy needs for preschoolers is given in two categories: 1-3 years and 4-6 years.

Table 2.7: Energy requirement for Indian children and adolescent

Group	Particulars	Body Weight (kg)	Net Energy (Kcal/d)
Children	1-3 years	12.2	1240
	4-6 years	19.0	1690
	7-9 Years	26.9	1650
Adolescent			
Boys	10-12 years	35.4	2190
Girls	10-12 years	31.5	1970
Boys	13-15 years	47.8	2450
Girls	13-15 years	46.7	2060
Boys	16-18 years	57.1	2640
Girls	16-18 years	49.9	2060

Source: ICMR, 1988.

Marked variability exists 'for boys and girls in the energy requirements after 9 years of age because of variations in growth rate and physical activity levels. Marked gender differences in intensity and duration of the adolescent growth spurt in fat free mass (FFM) dictates higher energy needs in boys than girls. Hence energy requirements are specified separately for boys and girls after the age of 9 years as you can see in Table 2.7.

The energy requirements for adolescents are based on estimates of energy expenditure and requirements for growth based on tissue deposition. Dietary energy recommendations also include recommendations for physical activity compatible with health, prevention of obesity, and appropriate social and psychological development. In adolescents, growth is relatively slow except around the adolescent growth spurt, which varies considerably in timing and magnitude among individuals between 10 and 19 years. Adolescents gain 30 percent of their adult weight and more than 20 percent of their adult height between 10 and 19 years. Taking into account, the desirability of achieving full potential for growth, ICMR has used NCHS/well-to-do Indian children's body weight for computing RDA for adolescents as given in Table 2.7.

However, children from the poorer segments of the population in India are shorter and weigh less. It is unlikely that any extra food at this stage can accelerate or extend the duration of physical growth. Additional dietary intake at this period can only lead to adolescent obesity. The new ICMR Expert Committee for RDA, which is already working on revising the requirements for Indians, may have to take all these into account and evolve appropriate recommendations for dietary intake in Indian adolescents.

Occupational and recreational activities variably affect energy requirements. The WHO/FAO/UNU 2004 recommendations, have taken this into consideration and energy requirements are calculated for children over five years of age and for adolescents with lifestyles involving three levels of habitual physical activity as enumerated herewith:

Examples of populations with light physical lifestyles, or that are less active *than* average, are children and adolescents who every day spend several hours at school or in sedentary occupations; do not practice physical sports regularly; generally use motor vehicles for transportation; and spend most leisure time in activities that require little physical effort, such as watching television, reading, using computers or playing without much body displacement.

Examples of populations with vigorous lifestyles, or that are more active than average, are children and adolescents who walk long distances every day or use bicycles for transportation; engage in high energy-demanding occupations, or perform high energy-demanding chores for several hours each day; and/or practise sports or exercise that demand a high level of physical effort for several hours, several days of the week.

Children and adolescents with habitual physical activity that is more strenuous than the examples given for a light lifestyle, but not as demanding as the examples for vigorous lifestyle, would qualify in the category of *average* or *moderate* physically active lifestyles.

Table 2.8 and 2.9 presents the energy requirements for boys and girls (WHO/FAO/ UNU 2004) in populations with these three levels of habitual physical activity.

Table 2.8: Boys' energy requirements in populations with three levds of habitual physical activity

Age	Weight	Light Phycial Acfivity Daily Energy Requirement				PAL	Moderate Physical Activity Daily Energy Requirement				PAL	Heavy Physical Activity Daily Energy Requirement				PAL
Years	Kg	MJ/d	Kcal/d	KJ/kg/d	Kcal/kg/d		MJW	Kcal/d	KJ/kg/d	Kcal/kg/d		MJ/d	Kcal/d	KJ/kg/d	Kcal/kg/d	
1-2	11.5						4.0	950	345	82	1.45					
2-3	13.5						4.7	1125	350	84	1.45					
3-4	15.7						5.2	1250	335	80	1.45					
4-5	17.7						5.7	1350	320	77	1.50					
5-6	19.7						6.1	1475	310	74	1.55					
6-7	21.7	5.6	1350	260	62	1.30	6.6	1575	305	73	1.55	7.6	1800	350	84	1.80
7-8	24.0	6.0	1450	250	60	1.35	7.1	1700	295	71	1.60	8.2	1950	340	81	1.85
8-9	26.7	6.5	1550	245	59	1.40	7.7	1825	285	69	1.65	8.8	2100	330	79	1.90
9-10	29.7	7.0	1675	235	56	3.40	8.3	1975	280	67	1.65	9.5	2275	320	76	1.90
10-11	33.3	7.7	1825	230	55	1.45	9.0	2150	270	65	1.70	10.4	2475	310	74	1.95
11-12	37.5	8.3	2000	220	53	1.50	9.8	2350	260	62	1.75	11.3	2700	300	72	2.00
12-13	42.3	9.1	2175	215	51	1.55	10.7	2550	250	60	1.80	12.3	2925	290	69	2.05
13-14	47.8	9.8	2350	205	49	1.55	11.6	2775	240	58	1.80	13.3	3175	275	66	2.05
14-15	53.8	10.6	2550	200	48	1.60	12.5	3000	235	56	1.85	14.4	3450	270	65	2.15
15-16	59.5	11.3	2700	190	45	1.60	13.3	3175	225	53	1.85	15.3	3650	260	62	2.15
16-17	64.4	11.8	2825	185	44	1.55	13.9	3325	215	52	1.85	16.0	3825	245	59	2.15
17-18	67.8	12.1	2900	180	43	1.55	14.3	3400	210	50	1.85	16.4	3925	240	57	2.15

Note:

Body weight at mid-point of age interval (WHO, 1983).

Moderate physical activity, MJ/d = (1.298 + 0.265 kg − 0.0011 kg^2) + 8.6 KJ/g daily weight gain.

Vigorous physical activity: 15% > moderate physical activity.

Source: Torun, 2001.

Numbers rounded to the closest 0.1 MJ/d, 25 Kcal/d, 5KJ/kg/d, 1 Kcal/kg/d, 0.05 PAL unit.

Light physical activity: 15% < moderate physical activity.

PAL = TEE/(Predicted BMR/d).

Table 2.9 : Girls' energy requirement in populations with three levels of habitual physical activity

Age	Weight	Light Physical Activity					Moderate Physical Activity					Heavy Physical Activity				
		Daily Energy Requirement				PAL	Daily Energy Requirement				PAL	Daily Energy Requirement				PAL
Yenrs	Kg	MJ/d	Kcal/d	KJ/kg/d	Kcal/kg/d		MJ/d	Kcal/d	KJ/kg/d	Kcal/kg/d		MJ/d	Kcal/d	KJ/kg/d	Kcal/kg/d	
1-2	10.8						3.6	850	335	80	1.40					
2-3	13.0						4.4	1050	335	81	1.40					
3-4	15.1						4.8	1150	320	77	1.45					
4-5	16.8						5.2	1250	310	74	1.50					
5-6	18.6						5.6	1325	300	72	1.55					
6-7	20.6	5.1	1225	245	59	1.30	6.0	1425	290	69	1.55	6.9	1650	335	80	1.80
7-8	23.3	5.5	1325	235	57	1.35	6.5	1550	280	67	1.60	7.5	1775	320	77	1.85
8-9	26.6	6.0	1450	225	54	1.40	7.1	1700	265	64	1.65	8.2	1950	305	73	1.90
9-10	30.5	6.6	1575	215	52	1.40	7.7	1850	255	61	1.65	8.9	2125	295	70	1.90
10-11	34.7	7.1	1700	205	49	1.45	8.4	2000	240	58	1.70	9.6	2300	275	66	1.95
11-12	39.2	7.6	1825	195	47	1.50	9.0	2150	230	55	1.75	10.3	2475	265	63	2.00
12-13	43.8	8.1	1925	185	44	1.50	9.5	2275	215	52	1.75	11.0	2625	245	60	2.00
13-14	46.3	8.5	2025	175	42	1.50	10.0	2375	205	49	1.75	11.4	2725	235	57	2.00
14-15	52.1	8.7	2075	165	40	1.50	10.2	2450	195	47	1.75	11.8	2825	225	54	2.00
15-16	55.0	8.9	2125	160	39	1.50	10.4	2500	190	45	1.75	12.0	2875	220	52	2.00
16-17	56.4	8.9	2125	160	38	1.50	10.5	2500	185	44	1.75	12.0	2875	215	51	2.00
17-18	56.7	8.9	2125	155	37	1.45	10.5	2500	185	44	1.70	12.0	2875	215	51	1.95

Note:

Body weight at mid-point of age interval (WHO, 1983).
Moderate physical activity, MJ/d = (1.102 + 0,273 kg – 0.0019 **kg²)** + 8.6 **KJ/g** daily weight gain.
Vigorous physical activity: 15% > moderate physical activity.
Source: Torun, 2001.

Number rounded to the doses 0.1 MJ/d, 25 Kcal/d, 5KJ/kg/d, 1 Kcal/MJ/d, 0.05 PAL unit
Light physical activity: 15% < moderate physical activity.
PAL = TEE/(Predicted BMR/d).

Compared with previous estimates (WHO/FAO/UNU 1985), energy requirements thus proposed by this consultation are on average 18 percent lower for boys and 20 percent lower for girls under seven years of age, and 12 and 5 percent lower, respectively, for boys and girls seven to ten years of age. From 12 years onwards, the proposed requirements are an average of 12 percent higher for both boys and girls.

Next, we move on to the energy requirement for the adults.

2.6.3 Energy Requirement of Adults

The energy needs of Indian men and women for different activity levels computed on the basis of recommendations made by ICMR are shown in Table 2.10.

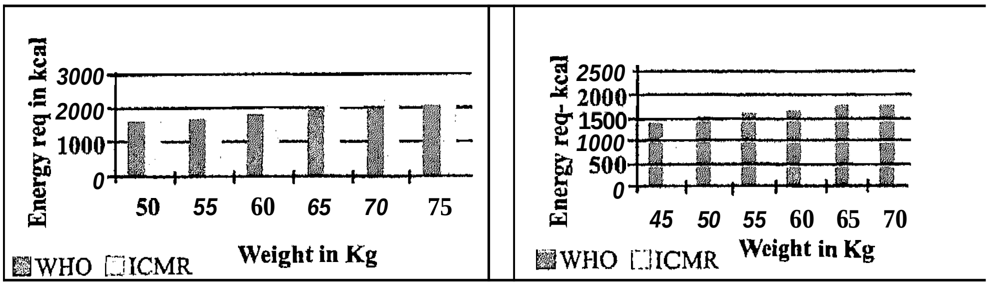
For computing RDA, the ICMR has taken body weight of 'reference man' as 60 kg and that of woman' as 50 kg. Average weight of Indian men, however, is 52 kg and women 44 kg. In view of these, it is likely that the energy requirement of Indians is likely to be substantially lower (about 10-12% lower) than the current ICMR recommendations as highlighted in Table 2.10. The present ICMR recommendations are therefore likely to be revised.

Table 2.10: ICMR's RDA for energy (reference body weight and actual body weight)

Sex	Ref.Body Weight	Actual Body Weight	Energy RDA			
			Acitivity Category	For Ref. Body Weight	For Actual Body Weight	Percent Difference
Man	60.0	52.0	Sedentary	2425	2115	13
			Moderate	2875	2492	13
			Heavy	3800	3293	13
Woman	50.0	44.0	Sedentary	1875	1740	12
			Moderate	2225	1958	12
			Heavy	2925	2594	11

Source: Dr. *B.S.* Narasinga Rao-Gopalan Oration **2001.**

With increasing age, there are metabolic changes and also reduction in physical activity and, as a result, the energy requirement of older adults and elderly is substantially lower than younger adults as highlighted in Figure 2.2(a) and 2.2(b).



(a): Daily average energy requirement of sedentary males > 60 years.

(b): Daily average energy requirement of sedentary females >60 Years

Figure 2.2: Daily average energy requirement of sedentary adults

Source: **10th** Five Year Plan (2002-2007), Planning Commission, Government of India.

The previous expert consultation (WHO/FAO/UNU, 1985) classified the PAL of adult population groups as light, moderate or heavy, depending on their occupational or other work, and multiplied it by the corresponding BMR to arrive at requirements. The recent FAO/WHO/UNU 2004 report considered that the 24-hour PAL should not be based only on the physical effort demanded by occupational work, as there are people with light occupations who perform vigorous physical activity in their spare time, and people with heavy work who are quite sedentary the rest of the day. Therefore, as discussed earlier in section 2.3, (wherein the examples of lifestyles with different levels of energy demands are enumerated) the new recommendations base the factorial estimates of energy requirements on the energy expenditure associated with lifestyles that combine occupational and discretionary physical activities. Multiplying the PAL value (as given in Table 2.1 earlier for different lifestyles) by the BMR gives the actual energy requirements. Table 2.11, 2.12, 2.13 and 2.14 gives the energy requirement as recommended by FAO/WHO/UNU 2004 report for men and women aged 18 to 29.9 years and 30 to 59.5 years, respectively. The consultation also suggested that the average energy cost of activities expressed as a multiple of BMR, or PAR, should be similar for men and women, Further, the report suggests that the energy requirements for older adults and the elderly should be calculated on the basis of PALs, just as they are calculated for younger adults. Allowances must be made for population groups who are more or less active at an advanced age, rather than using age as the single cut-off point to define energy requirements for the elderly. Table 2.15 and 2.16 presents the recommendations for elderly male and female, respectively over 60 years,

The practice of regular physical activity is associated with the maintenance of adequate body weight, cardiovascular and respiratory health, and fitness and a lower risk of developing chronic non communicable diseases associated with diet and lifestyle. Consequently, dietary energy recommendations to satisfy requirements should be accompanied by recommendations to perform adequate amounts of physical activity regularly has been strongly advocated by the WHO/FAO/UNU 2004 recommendation.

Table 2.11: Daily average energy requirement for men aged 18 to 29.9 years*

Mean Weight	BMR per kg[a]		Daily energy requirement according to BMR factor (or PAL) and body weight indicated																								Height (m) for BMI values[b]		
			1.45xBMR				1.60xBMR				1.75xBMR				1.90 xBMR				2.05xBMR				2.20xBMR						
kg	KJ	Kcal	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	24.9	21.0	18.5
50	121	29	8.8	175	2100	42	9.7	195	2300	46	10.6	210	2 550	51	11.5	230	2750	55	12.4	250	2950	59	13.3	265	3200	64	1.42	1.54	1.64
55	116	28	9.2	170	2200	40	10.2	185	2450	44	11.1	200	2650	48	12.1	220	2900	53	13.0	235	3100	57	14.0	255	3350	61	1.49	1.62	1.72
60	111	27	9.7	160	2300	39	10.7	180	2550	43	11.7	195	2800	47	12.7	210	3050	51	13.7	230	3250	55	14.7	245	3500	59	1.55	1.69	1:80
65	108	26	10.1	155	2400	37	11.2	170	2650	41	12.2	190	2900	45	13.3	205	3150	49	14.3	220	3450	53	15.4	235	3700	57	1.62	1.76	1.87
70	104	25	10.6	150	2550	36	11.7	165	2800	40	12.8	185	3050	44	13.9	200	3300	47	15.0	215	3600	51	16.1	230	3850	55	1.68	1.83	1.95
75	102	24	11.1	145	2650	35	12.2	165	2900	39	13.3	180	3200	42	14.5	195	3450	46	15.6	210	3750	50	16.8	225	4000	53	1.74	1.89	2.01
80	99	24	11.5	145	2750	34	12.7	160	3050	38	13.9	175	3300	41	15.1	190	3600	45	16.3	205	3900	49	17.5	220	4150	52	1.79	1.95	2.08
85	97	23	12.0	140	2850	34	13.2	155	3150	37	14.4	170	3450	41	15.7	185	3750	44	16.9	200	4050	48	18.2	215	4350	51	1.85	2.01	2.14
90	95	23	12.4	140	2950	33	13.7	150	3300	36	15.0	165	3600	40	16.3	180	3900	43	17.6	195	4200	47	18.8	210	4500	50	1.90	2.07	2.21

* Values rounded to closest 0.1 MJ/d, 50 Kcal/d, 5 KJ/kg/d, 1 Kcal/kg/d.

[a] BMR calculated for each weight from the equations in Table 2.3. Values of BMR/kg are presented for ease of calculations for those who wish to use different PAL values or different weights.

[b] 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 1.70 m and a lifestyle with a mean PAL of 1.75, is about 11.7 MJ(2800 Kcal)/day or 195 KJ(47Kcal)/kg/day to maintain an optimun population median of 21.0 (WHO/FAO, 2002), with an indivual range of about 11.1 to 12.8 MJ(2650 to 3050 Kcal)/day or 185 to 200 KJ(44 to 48 Kcal)/kg /day to maintain the individual BMI limits of 18.5 to 24.9 (WHO, 2000).

Table 2.12: Daily average energy requirement for men aged 30 to 59.9 years*

Mean Weight	BMR per kg[a]		Daily energy requirement according to BMR factor (or PAL) and body weight indicated																								Height (m) for BMI values[b]		
			1.45×BMR				1.60×BMR				1.75×BMR				1.90 ×BMR				2.05×BMR				2.20×BMR						
kg	KJ	Kcal	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	24.9	21.0	18.5
50	121	29	8.8	175	2100	42	9.7	195	2300	46	10.6	210	2550	51	11.5	230	2750	55	12.4	250	2950	59	13.3	265	3200	64	1.42	1.54	1.64
55	114	27	9.1	165	2200	40	10.1	185	2400	44	11.0	200	2650	48	12.0	215	2850	52	12.9	235	3100	56	13.8	250	3300	60	1.49	1.62	1.72
60	109	26	9.5	160	2250	38	10.5	175	2500	42	11.4	190	2750	46	12.4	205	2950	49	13.4	225	3200	53	14.4	240	3450	57	1.55	1.69	1.80
65	104	25	9.8	150	2350	36	10.8	165	2600	40	11.9	180	2850	44	12.9	200	3100	47	13.9	215	3300	51	14.9	230	3550	55	1.62	1.76	1.87
70	100	24	10.2	145	2450	35	11.2	160	2700	38	12.3	175	2950	42	13.3	190	3200	45	14.4	205	3450	49	15.4	220	3700	53	1.68	1.83	1.95
75	97	23	10.5	140	2500	34	11.6	155	2750	37	12.7	170	3050	40	13.8	185	3300	44	14.9	200	3550	47	16.0	215	3800	51	1.74	1.89	2.01
80	94	22	10.9	135	2600	32	12.0	150	2850	36	13.1	165	3150	39	14.2	180	3400	43	15.4	190	3650	46	16.5	205	3950	49	1.79	1.95	2.08
85	91	22	11.2	130	2700	32	12.4	145	2950	35	13.5	160	3250	38	14.7	175	3500	41	15.9	185	3800	45	17.0	200	4050	48	1.85	2.01	2.14
90	89	21	11.6	130	2750	31	12.8	140	3050	34	14.0	155	3350	37	15.1	170	3600	40	16.3	180	3900	43	17.5	195	4200	47	1.90	2.07	2.21

* Values rounded to closest 0.1 MJ/d, 50 Kcal/d, 5 KJ/kg/d, 1 Kcal/kg/d.

[a] BMR calculated for each weight from the equations in Table 2.3. Values of BMR/kg are presented for ease of calculations for those who wish to use different PAL values or different weights.

[b] 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 1.70 m and a lifestyle with a mean PAL of 1.75, is about 11.4 MJ(2750 Kcal)/day or 190 KJ(46Kcal)/kg/day *to maintain an optimun population median of* 21.0 (WHO/FAO, 2002), *with an indivual range of about* 11.0 to 12.3 MJ(2650 to 2950 Kcal)/day or 175 to 200 KJ(42 to 48 Kcal)/kg /day *to maintain the individual* BMI limits of 18.5 to 24.9 (WHO, 2000).

Table 2.13: Daily average energy requirement for women aged 18 to 29.9 years*

Mean Weight	BMR per kg[a]		Daily energy requirement according to BMR factor (or PAL) and body weight indicated																								Height (m) for BMI values[b]		
			1.45×BMR				1.60×BMR				1.75×BMR				1.90 ×BMR				2.05×BMR				2.20×BMR						
kg	KJ	Kcal	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	24.9	21.0	18.5
45	107	26	7.0	155	1650	37	7.7	170	1850	41	8.4	190	2000	44	9.2	205	2200	49	9.9	220	2350	52	10.6	235	2550	57	1.34	1.46	1.56
50	103	25	7.4	150	1800	36	8.2	165	1950	39	9.0	180	2150	43	9.8	195	2350	47	10.5	210	2500	50	11.3	225	2700	54	1.42	1.54	1.64
55	99	24	7.9	145	1900	35	8.7	160	2100	38	9.5	175	2300	42	10.3	190	2450	45	11.2	205	2650	48	12.0	220	2850	52	1.49	1.62	1.72
60	96	23	8.3	140	2000	33	9.2	155	2200	37	10.1	170	2400	40	10.9	180	2600	43	11.8	195	2800	47	12.7	210	3050	51	1.55	1.69	1.80
65	93	22	8.8	135	2100	32	9.7	150	2300	35	10.6	165	2550	39	11.5	175	2750	42	12.4	190	2950	45	13.3	205	3200	49	1.62	1.76	1.87
70	91	22	9.2	130	2200	31	10.2	145	2450	35	11.2	160	2650	38	12.1	175	2900	41	13.1	185	3100	44	14.0	200	3350	48	1.68	1.83	1.95
75	89	21	9.7	130	2300	31	10.7	145	2550	34	11.7	155	2800	37	12.7	170	3050	41	13.7	185	3300	44	14.7	195	3500	47	1.74	1.89	2.01
80	87	21	10.1	125	2400	30	11.2	140	2700	34	12.2	155	2950	37	13.3	165	3200	40	14.3	180	3450	43	15.4	190	3700	46	1.79	1.95	2.08
85	86	21	10.6	125	2550	30	11.7	140	2800	33	12.8	150	3050	36	13.9	165	3300	39	15.0	175	3600	42	16.1	190	3850	45	1.85	2.01	2.14

* Values **rounded** to closest 0.1 MJ/d, 50 Kcal/d, 5 KJ/kg/d, 1 Kcal/kg/d.

[a] BMR calculated for each weight from the equations in Table 2.3. Values of BMR/kg are presented for ease of calculations for those who wish to use different PAL values or different weights.

[b] 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 1.70 m and a lifestyle with a mean PAL of 1.75, is about 10.1 MJ(2400 Kcal)/day or 170 KJ(40Kcal)/kg/day to **maintain an** optimun population median of 21.0 (WHO/FAO, 2002), with an indivual range of about 9.5 to 11.2 MJ(2300 to 2650 Kcal)/day or 160 to 175 KJ(38 to 42 Kcal)/kg /day to maintain the individual BMI limits of **18.5** to 24.9 (WHO, 2000).

Table 2.14: Daily average energy requirement for women aged 30 to 59.9 years*

Mean Weight	BMR per kg[a]		Daily energy requirement according to BMR factor (or PAL) and body weight indicated																								Height (m) for BMI values[b]		
			1.45×BMR				1.60×BMR				1.75×BMR				1.90 ×BMR				2.05×BMR				2.20×BMR						
kg	KJ	Kcal	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	24.9	21.0	18.5
45	113	27	7.3	165	1750	39	8.1	180	1950	43	8.9	195	2100	47	9.6	215	2300	51	10.4	230	2500	56	11.1	250	2650	59	1.34	1.46	1.56
50	105	25	7.6	150	1800	36	8.4	170	2000	40	9.2	185	2200	44	10.0	200	2400	48	10.7	215	2550	51	11.5	230	2750	55	1.42	1.54	1.64
55	98	24	7.8	145	1850	34	8.7	155	2050	37	9.5	170	2250	41	10.3	185	2450	45	11.1	200	2650	48	11.9	215	2850	52	1.49	1.62	1.72
60	93	22	8.1	135	1950	33	8.9	150	2150	36	9.8	165	2350	39	10.6	175	2550	43	11.4	190	2750	46	12.3	205	2950	49	1.55	1.69	1.80
65	88	21	8.3	130	2000	31	9.2	140	2200	34	10.1	155	2400	37	10.9	170	2600	40	11.8	180	2800	43	12.6	295	3000	46	1.62	1.76	1.87
70	85	20	8.6	125	2050	29	9.5	135	2250	32	10.4	150	2500	36	11.2	160	2700	39	12.1	175	2900	41	13.0	185	3100	44	1.68	1.83	1.95
75	81	19	8.8	120	2100	28	9.7	130	2350	31	10.7	140	2550	34	11.6	155	2750	37	12.5	165	3000	40	13.4	180	3200	43	1.74	1.89	2.01
80	78	19	9.1	115	2150	27	10.0	125	2400	30	11.0	135	2600	33	11.9	150	2850	36	12.8	160	3050	38	13.8	170	3300	41	1.79	1.95	2.08
85	76	18	9.3	110	2250	26	10.3	120	2450	29	11.2	130	2700	32	12.2	145	2900	34	13.2	155	3150	37	14.1	165	3400	40	1.85	2.01	2.14

* Values rounded to closest 0.1 MJ/d, 50 Kcal/d, 5 KJ/kg/d, 1 Kcal/kg/d.

[a] BMR calculated for each weight from the equations in Table 2.3. Values of BMR/kg are presented for ease of calculations for those who wish to use different PAL values or different weights.

[b] 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 1.70 m and a lifestyle with a mean PAL of 1.75, is about 9.8 MJ(2350 Kcal)/day or 165 KJ(39 Kcal)/kg/day to maintain an optimun population median of 21.0 (WHO/FAO, 2002), with an indivual range of about 9.5 to 10.4 MJ(2250 to 2500 Kcal)/day or 150 to 170 KJ(36 to 41 Kcal)/kg /day to maintain the individual BMI limits of 18.5 to 24.9 (WHO, 2000).

Table 2.15: Daily average energy requirement for men aged > 60 years*

Mean Weight	BMR per kg[a]		Daily energy requirement according to BMR factor (or PAL) and body weight indicated																								Height (m) for BMI values[b]		
			1.45×BMR				1.60×BMR				1.75×BMR				1.90 ×BMR				2.05×BMR				2.20×BMR						
kg	KJ	Kcal	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	24.9	21.0	18.5
50	98	23	7.1	140	1700	34	7.9	155	1900	38	8.6	170	2050	41	9.3	185	2250	45	10.1	200	2400	48	10.8	215	2600	52	1.42	1.54	1.64
55	94	22	7.5	135	1800	33	8.2	150	1950	35	9.0	165	2150	39	9.8	180	2350	43	10.6	190	2550	46	11.3	205	2700	49	1.49	1.62	1.72
60	90	22	7.8	130	1850	31	8.6	145	2050	34	9.4	155	2250	38	10.3	170	2450	41	11.1	185	2650	44	11.9	200	2850	48	1.55	1.69	1.80
65	87	21	8.2	125	1950	30	9.0	140	2150	36	9.9	150	2350	36	10.7	165	2550	39	11.6	180	2750	42	12.4	190	2950	45	1.62	1.76	1.87
70	84	20	8.5	120	2050	29	9.4	135	2250	32	10.3	145	2450	35	11.2	160	2650	38	12.1	170	2900	41	13.0	185	3100	44	1.68	1.83	1.95
75	82	20	8.9	120	2150	29	9.8	130	2350	31	10.7	145	2550	34	11.7	155	2800	37	12.6	170	3000	40	13.5	180	3250	43	1.74	1.89	2.01
80	80	19	9.2	115	2200	28	10.2	130	2450	31	11.2	140	2650	33	12.1	150	2900	36	13.1	165	3150	39	14.0	175	3350	42	1.79	1.95	2.08
85	78	19	9.6	115	2300	27	10.6	125	2550	30	11.6	135	2750	32	12.6	150	3000	35	13.6	160	3250	38	14.6	170	3500	41	1.85	2.01	2.14
90	76	18	10.0	110	2400	27	11.0	120	2650	29	12.0	135	2850	32	13.1	145	3100	34	14.1	155	3350	37	15.1	170	3600	40	1.90	2.07	2.21

* Values rounded to closest 0.1 MJ/d, 50 Kcal/d, 5 KJ/kg/d, 1 Kcal/kg/d.

[a] BMR calculated for each weight from the equations in Table 2.3. Values of BMR/kg are presented for ease of calculations for those who wish to use different PAL values or different weights.

[b] 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 1.70 m and a lifestyle with a mean PAL of 1.75, is about 9.4 MJ(2250 Kcal)/day or 155 KJ(38 Kcal)/kg/day to maintain an optimun population median of 21.0 (WHO/FAO, 2002), with an indivual range of about 9.0 to 10.3 MJ(2150 to 2450 Kcal)/day or 145 to 160 KJ(35 to 39 Kcal)/kg /day to maintain the individual BMI limits of 18.5 to 24.9 (WHO, 2000).

Table 2.16: Daily average energy requirement for women aged > 60 years*

Mean Weight	BMR per kg[a]		Daily energy requirement according to BMR factor (or PAL) and body weight indicated																								Height (m) for BMI values[b]		
			1.45×BMR				1.60×BMR				1.75×BMR				1.90 ×BMR				2.05×BMR				2.20×BMR						
kg	KJ	Kcal	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	MJ	KJ/kg	Kcal	Kcal/kg	24.9	21.0	18.5
45	99	24	6.5	145	1550	34	7.1	160	1700	38	7.8	175	1850	41	8.5	190	2050	45	9.2	205	2200	49	9.8	220	2350	52	1.34	1.46	1.56
50	93	22	6.7	135	1600	32	7.4	150	1800	36	8.1	165	1950	39	8.8	175	2100	42	9.5	190	2300	46	10.2	205	2450	49	1.42	1.54	1.64
55	88	21	7.0	130	1700	31	7.8	140	1850	34	8.5	155	2050	37	9.2	165	2200	40	9.9	180	2350	43	10.7	195	2550	46	1.49	1.62	1.72
60	84	20	7.3	120	1750	29	8.1	135	1950	32	8.8	145	2100	35	9.6	160	2300	38	10.3	170	2450	41	11.1	185	2650	44	1.55	1.69	1.80
65	80	19	7.6	115	1800	28	8.4	130	2000	31	9.1	140	2200	34	9.9	155	2350	37	10.7	165	2550	39	11.5	175	2750	42	1.62	1.76	1.87
70	77	18	7.9	110	1900	27	8.7	125	2050	30	9.5	135	2250	32	10.3	145	2450	35	11.1	160	2650	38	11.9	170	2850	41	1.68	1.83	1.95
75	75	18	8.1	110	1950	26	9.0	120	2150	29	9.8	130	2350	31	10.6	140	2550	34	11.5	155	2750	37	12.3	165	2950	39	1.74	1.89	2.01
80	72	17	8.4	105	2000	25	9.3	115	2200	28	10.1	125	2400	30	11.0	140	2650	33	11.9	150	2850	35	12.7	160	3050	38	1.79	1.95	2.08
85	70	17	8.7	100	2050	24	9.6	115	2300	27	10.5	125	2500	29	11.4	135	2700	32	12.3	145	2950	34	13.2	155	3150	37	1.85	2.01	2.14

* Values rounded to closest 0.1 MJ/d, 50 Kcal/d, 5 KJ/kg/d, 1 Kcal/kg/d.

[a] BMR calculated for each weight from the equations in Table 2.3. Values of BMR/kg are presented for ease of calculations for those who wish to use different PAL values or different weights.

[b] 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 1.70 m and a lifestyle with a mean PAL of 1.75, is about 8.8 MJ(2100 Kcal)/day or 145 KJ(35 Kcal)/kg/ day to maintain an optimun population median of 21.0 (WHO/FAO, 2002), with an indivual range of about 8.5 to 9.5 MJ(2050 to 2250 Kcal)/day or 135 to 155 KJ(32 to 37 Kcal)/kg /day to maintain the individual BMI limits of 18.5 to 24.9 (WHO, 2000).

2.6.4 Energy Requirement During Pregnancy

The energy requirements of pregnancy are those needed for adequate maternal gain to ensure the growth of the foetus, placenta and associated maternal tissues, and to provide 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, as well as, for sufficient energy stores to assist in proper lactation after delivery. Basal metabolism, we learnt, increases during pregnancy as a result of accelerated tissue synthesis, increased active tissue mass, and increased cardiovascular and respiratory work. Based on these considerations the ICMR recommendation during pregnancy is given in Table 2.17. As you may have noticed the extra energy cost of pregnancy is 300 Kcal during the second and third trimester of pregnancy. This is over and above the women's habitual energy requirement before pregnancy. The additional energy allowance could be lowered in cases where women reduce their activity level during pregnancy.

Table 2.17: Additional energy cost of pregnancy

	Energy(Kcal)	
	ICMR	FAO/WHO/UNU 2004
1st Trimester	-	+85
2nd Trimester	+300	+285
3rd Trimester	+300	+475

Now let us look at the FAO/WHO/UNU 2004 recommendations. The FAO/WHO/UNU 2004 recommendation for the extra energy cost of pregnancy is 85 Kcal/day, 285 Kcal/day and 475 Kcal/day during the first, second and third trimesters, respectively as highlighted in Table 2.17. There are many societies with a high proportion of non-obese women who do not seek prenatal advice before the second or third month of pregnancy. Under these circumstances, this consultation recommends that in such societies pregnant women increase their food intake by 360 Kcal/day in the second trimester and by 475 Kcal/day in the third. Further, not all women have the option to reduce physical activity during pregnancy. In particular, women belonging to low-income group from developing countries must often continue a strenuous work pattern until shortly before delivery. Furthermore, women who are sedentary prior to pregnancy have little flexibility to reduce their level of physical activity. Consequently, this consultation does not recommend a reduction in the additional energy allowance for pregnancy.

Finally let us get to know about the requirement during lactation.

2.6.5 Energy Requirement During Lactation

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 weight and body composition, a level of physical activity and breastmilk production that are consistent with good health for the woman and her child, and that will allow economically necessary and socially desirable activities to be performed (assuming that she resumes her usual level of physical activity soon after giving birth). Table 2.18 presents the energy requirement for lactation. The ICMR has recommended an additional intake of 550 Kcal during the first six months of lactation and 400 Kcal during 7-12 months of lactation.

Table 2.18: RDA's for lactation

	Energy (Kcal)/day	
	ICMR	FAO/WHO/UNU (2004)
0-6 months	+550	+ 600
6-12 months	+440	+ 450

Exclusive breastfeeding is recommended during the six months after delivery, with introduction of complementary foods and continued breastfeeding thereafter. For women who feed their infants exclusively with breastmilk during the first six months of life, the mean energy cost as recommended by FAO/WHO/UNU 2004 over the six-month period is 600 Kcal/day (refer to Table 2.18). From the age of six months onwards, when infants are partially breastfed and milk production is on average 550 g/day, the energy cost imposed by lactation is 450 Kcal/day.

It further suggests that *well-nourished women* with adequate gestational weight gain should increase their food intake *by* 505 *Kcal/day* for the first six months of lactation, while *undernourished women* and those with insufficient gestational weight gain should add to their personal energy demands 675 *Kcal/day* during the first six months of lactation. Energy requirements for milk production in the second six months are dependent on rates of milk production, which are highly variable among women and populations.

With a review of the energy requirement during the different ages and physiological stages, we end our discussion on the requirements here. Finally, we shall look at the energy imbalance problems.

2.7 ENERGY IMBALANCE: AN OVERVIEW

Energy balance, we have learnt from our discussion so far, is achieved when input (i.e. dietary energy intake) is equal to output (i.e. total energy expenditure). When energy balance is maintained over a prolonged period, an individual is considered to be in a steady state.

The recommended intake of energy of a group is equal to the average energy requirement of individuals of the group because both lower and higher energy intakes are associated with health hazards. Too much deviation on either side from the appropriate range of body weight increases our risk of health problems. Just as overweight is the result of positive energy balance, underweight results when the energy balance is negative.

A growing literature supports the use of the body mass index (BMI) as a predictor of the impact of body weight on morbidity and mortality risks. BMI, *defined* as *weight in kilograms divided by the square of height in meters,* is also termed the Quetelet's index. It is used in preference to other weight/height indices, including the weight/height ratio, the Ponderal Index and the Benn's Index as highlighted in Table 2.19.

Table 2.19: Indices for weight relative to height

Index	Formula
Weight/Height ratio	wt/ht
Body Mass Index (BMI)	$wt/(ht)^2$
Ponderal Index	$ht/\sqrt[3]{wt}$
Benn's Index	$wt/(ht)^P$

The power P in Benn's index is calculated to minimize the direct relationship with height. Weight in all indices is in kg and height in meters.

BMI, although only an indirect indicator of body composition, is now used to classify underweight and overweight individuals. Table 2.20 presents the WHO classification of underweight, overweight and obesity in adults according to BMI.

Table 2.20: WHO classification of underweight, overweight and obesity in adults according to body mass index (BMI)

Classification	BMI (Kg/m²)	Risk of Comorbidity
Underweight	< 18.5	Low*
Normal range	18.5 - 24.9	Average
Overweight	25 - 29.9	Increased
Obesity	> 30.0	
Classs 1	30.0 - 34.9	Moderate
Class 11	35.0 - 39.9	Severe
Class 111 (morbid)	≥ 40.0	Very Severe

* Low for the non-communicable diseases associated with obesity, but increased mortality due to cancer and infectious diseases

Source: WHO (1998).

As both underweight and obesity are associated with adverse health consequences, it has been suggested that each country should develop its own BMI and cut-off points indicative of various degrees of undernutrition and overnutrition based on their own data on health problems in persons with varying BMI levels. It has been found that for **a** given BMI, Indians have more body fat than other ethnic groups, both within and outside Asia. This relative increase in adiposity in Indians has led to the suggestion that the BMI cut-off for non-communicable diseases such as obesity should be reduced for Indians to *about* 23 *kg/m²* or lower. In other words, we can refer to it as a public health action point at a BMI of 23 kg/m². The point at which low BMI poses a health risk is poorly defined. The ability to identify persons with low BMIs who are at increased risk for morbidity and mortality is highly nonspecific.

Weight status in children can be classified based on percentile curves for BMI for age. Table 2.21 presents the weight status based on percentile BMI for age. The latest BMI for age percentile for boys and girls, aged 2-20 years have been published by the United States Centre for Health Statistics (NCHS) in collaboration with the National Centre for Chronic Diseases Prevention and Health Promotion in the Year 2000 which may be applied to health of well-nourished Indian children also.

Table 2.21: WHO classification of weight status in children based on percentile curves for BMI for age

Weight Status	BMI for Age
Underweight	< 5th percentile
At risk of overweight	≥ 85th to < 95th percentile

Source: WHO Technical Report (1995).

From our discussion above, it is clear that the common way to assess undernutrition or overnutrition (obesity) is in terms of body weight. Undernutrition is caused by a less than adequate intake of nutrient, most of which are related to the energy intake. In adults, this has led to the tenn 'energy deficiency'. ***Obesity,*** on the other hand, is energy imbalance where energy intake exceeds energy expenditure. Let us review these two conditions, linked to energy imbalance, briefly here.

Chronic Energy Deficiency ***(CED)***

Energy deficiency we have seen refers to less than adequate intake of energy. It is further sub classified into acute and chronic energy deficiency. Acute energy *deficiency* is suspected when an involuntary weight loss of greater than 10% of body weight occurs over the preceding 3-6 months. We can say it is sudden and associated with a declining body weight. *Chronic energy deficiency (CED)*, on the other hand, occurs over a long period of time, such that body weight over the preceding few months may be low, but stable. It is characterized by low body mass index in weight-stable individuals.

In 1994, FAO adopted the term 'chronic energy deficiency' for underweight. They categorized three degrees of underweight on the basis of BMI as presented in Table 2.22. WHO has adopted the same cut-off as presented in Table 2.22 to define three grades of low BMI, referred to as 'underweight' (refer to Table 2.22) rather than 'chronic energy deficiency'.

Table 2.22: FAO/WHO classification for chronic energy deficiency and/or underweight

Chronic Energy Deficiency Grade (FAO)	Underweight Grade (WHO)	BMI (kg/m^2)
Normal	Normal	> 18.5
Grade I	Mild Underweight	17.0 - 18.4
Grade II	Moderate Underweight	16.0 - 16.9
Grade III	Severe Underweight	< 16.0

Energy deficiency is associated with body weight loss along with changes in body composition (both body fat and the fat free mass are decreased), as well as, a reduced BMR and physical activity. Figure 2.3 illustrates how these factors interact with each other to attain lower energy expenditure when an acute negative energy balance exists.

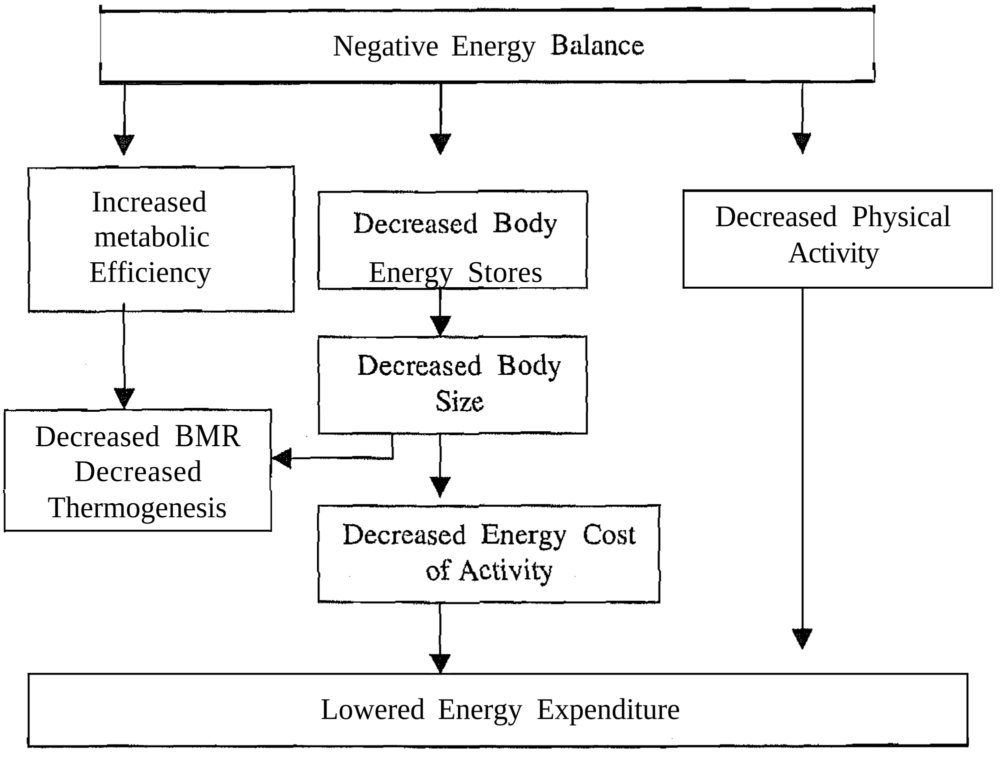


Figure 2.3: Factors leading to lowered energy expenditure

Now if the lowered energy expenditure (as illustrated in Figure 2.3) is adequate to compensate the lowered or decreased energy intake (which was the cause of negative energy balance in the first place) a new energy balance is achieved which allows a person to survive, albeit at a lower plane of nutrition and this is what is referred to as *chronic energy deficiency*. Thus, you would notice, it is a weight-stable condition, in the presence of lower than normal energy intake. It is characterized by low body weight and fat stores, but the individual's health is normal and the body's physiological function is also not compromised and therefore the individuals ability to lead an economically productive life is maintained.

However, the consequences of inadequate energy intake during the childhood and adolescence of an individual is a reduced body size and a low BMI. In the presence of concomitant repeated infections in childhood and adolescence, an individual with CED, will also show stunting. Both the body fat and the fat free mass are decreased as compared to a normally nourished individual. Reduction in muscle mass leads to reduced skeletal muscle performance, which may also be partly due to functional changes in skeletal muscles. Further adults with CED have lowered handgrip strength and they also fatigue faster when subjected to standard exercise protocols. Statistics suggest that nearly 25-50% of adults from developing countries, including India may be described as having CED. *Low values of BMI in adults have been consistently associated with a decline in work output, productivity, and income-generating ability, as well as, a compronzised ability to respond to stressful conditions.*

Eight percent (8%) of Indians do not get two square meals a day and there are pockets where severe undernutrition takes its toll even today. Every third child born is underweight. Around half of the preschool children suffer from undernutrition problem low birth weight is associated not only with higher infant mortality but also long-term health consequences including increased risk of non-communicable diseases such as' obesity, diabetes mellitus, coronary heart diseases etc.

Chronic energy deficiency and undernutrition is a public health problem in India. The contributory factors include:

- low dietary intake because of poverty and low purchasing power;
- high prevalence of infection because of poor access to safe-drinking water, sanitation and health care;
- poor utilization of available health and other facilities due to low literacy and lack of awareness.

Next, let us review another energy imbalance condition viz. obesity which is a state of excess energy intake over expenditure.

Obesity

The World Health Organization has declared obesity as the largest global chronic health problem in adults, which by 2025 will emerge as a more serious world problem than undernutrition.

Recent data from National Nutrition Monitoring Bureau (NNMB) repeat surveys indicate that there has been some reduction in undernutrition and alarmingly some increase in obesity over the last two decades in India. Data from National Family Health Survey-2 (NFHS) confirms that currently both undernutrition and overnutrition are problems in women (Table 2.23)

Table 2.23: Nutritional status of ever married women aged 15-49 years

	BMI < 18.5 (kg/m^2)	BMI > 25 (kg/m^2)
All India	35.8%	10.6%

Source: NFHS *-2 1998-99.*

Alterations in lifestyles and dietary intake have led to the increasing incidence of obesity and associated non-communicable diseases. Obesity results from an imbalance between energy intake and energy expenditure. The health risks associated with obesity include increased mortality, hyperlension, cardiovascular disease, diabetes mellitus, gallbladder disease, some cancers, and changes in endocrine function and metabolism. The risk factors for becoming obese are not entirely understood but are thought to include genetics, food intake, physical inactivity, and some rare metabolic disorders. Obesity rates in all age groups are increasing also mainly because of the reduction in physical activity without concomitant reduction in energy intake.'

Energy expenditure by physical activity varies considerably between individuals, affecting the energy balance and the body composition by which energy balance and weight maintenance are achieved. Indeed, physical inactivity is a major risk factor for development of obesity in children and adults. Therefore, a certain amount of habitual physical activity is desirable for biological and social well-being. The regular performance of physical activity by children, in conjunction with good nutrition, is associated with health, adequate growth and well-being, and probably with lower risk of disease in adult life. There is consensus (FAO/WHO/UNU 2004) that, in order to promote general health, at least 30 minutes of moderate to vigorous activity should be performed, three or more days per week.

In view of the known adverse health consequences of both excess and deficient energy intake, it is essential that appropriate recommendation for the RDA for Indians is evolved. This is important as the country is entering an era of dual disease burden of CED and infections on the one hand and that of obesity and non-communicable diseases on the other.

Check Your Progress Exercise 2

1) What does the factorial estimation of energy expenditure involve'? Rani is a female, 25 years of age, with a moderately active lifestyle and a mean body weight of 50 kg. Calculate her energy requirements using the factorial approach.

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2) Give the energy requirement as recommended by ICMR' and FAO/WHO/UNU 2004 for the following:

Lactating Mothers:...

....

Adults: ....

....

3) Compared with the values in the FAO/WHO/UNU 1985 report, how are the energy requirements for infants proposed by FAO/WHO/UNU 2004 consultation different.

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....

....

4) List two conditions arising due to energy imbalance. What are the consequences of these conditions?

....

....

....

2.7 LET US SUM UP

In this unit we learnt about the human energy requirements. Energy requirement we learnt is 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, and to allow optimal growth and development of children, deposition of tissues during pregnancy, and secretion of milk during lactation, consistent with long-term good health. For healthy, well-nourished adults, it is equivalent to total energy expenditure (TEE). The total energy expenditure over a 24-hour period is the sum of basal metabolic rate (BMR), thermic effect of feeding (TEF), physical activity and the energy cost of tissue synthesis.

Further, we studied that the energy needs vary widely among individuals in a group. A number of factors cause the BMR to vary among individuals. Major determinants are the body size, composition, age, sex, growth etc. Similarly, there are factors affecting the thermic effect of food and energy expended in physical activity which influence energy requirements.

When energy balance is maintained over a prolonged period, an individual is considered to be in a steady state. However, too much deviation on either side from the appropriate range of body weight, either due to intakes in excess of requirements or intakes lower than requirements, increases our risk of health problems. Just as overweight (obesity) is the result of positive energy balance, undernutrition (chronic energy deficiency) results when the energy balance is negative.

2.8 GLOSSARY

Glycogenolysis : catabolism of glycogen leading to glucose availability.

Sepsis : serious medical condition, resulting from the immune response to a severe infection.

2.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1) Energy in simple terms may be defined as the ability, or power, to do work.

   A kilocalorie is defined as the amount of heat required to raise the temperature of 1 kg of water through 1° Celsius (centigrade).

   The amount of heat energy (kilocalorie) per gram that can be made available to the body by each of the energy-yielding macronutrients – carbohydrate (1 g yields 4 Kcal), protein (1 g yields 4 Kcal), fat (1 g yields 9 Kcal) is known as the physiological *fuel* factor.

   The metabolic processes (such as ingestion and digestion of food, the absorption, transport, interconversion, oxidation and deposition of nutrients) increase heat production and oxygen consumption, and are known as by term 'thermic effect of feeding' (TEF).

2) The total energy expenditure over a 24-hour period is the sum of BMR, TEF, and energy for physical activities. For adults, this is equivalent to daily energy requirements. Additional energy for deposition in growing tissues is needed to determine energy requirements in infancy, childhood, adolescence and during pregnancy, and for the production and secretion of milk during lactation.

3) The amount of energy used for basal metabolism, which includes a series of functions that are essential for life, such as cell function and replacement; the synthesis, secretion and metabolism of enzymes and hormones to transport proteins and other substances and molecules; the maintenance of body temperature; uninterrupted work of cardiac and respiratory muscles; and brain function, in a period of time is called the basal metabolic rate (BMR).The factors which influence BMR include fat free mass (FFM), fat mass (FM), age, sex, hormonal status, nutritional status, growth, disease/infections etc.

4) The different lifestyle classifications with their PAL values are as follows;.

Category	PAL Value
Sedentary or light activity lifestyle	1.40 - 1.69
Active or moderate1 activity lifestyle	1.70 - 1.99
Vigorous or heavy activity lifestyle	2.00 - 2.40"

Check Your Progress Exercise 2

1) The factorial estimation of energy expenditure involve summation of all the expected components of energy expenditure, including BMR and taking into account the energy costs of different activities and their durations.

- Energy requirement for Rani can be calculated as:
- From the Table 2.3, BMR calculated "from the predictive equation is: 1227.5 Kcal/day) (i.e. 14.818 x 50 + 486.6 = 1227.5).
- PAL from mid-point of the moderately active lifestyle in Table 2.1 is: 1.85.
- TEE or Energy requirement: 1227.5 x 1.85 = 2271 Kcal/day), or 2271150 = 45 Kcal/kg/day).

2) The energy requirements for lactation as given by ICMR and FAOIWHO are presented in Table 2.18. Look up the values and write on your own,

The energy requirements for adults as given by ICMR and FAOIWHO are presented in Table 2.10, 2.11, 2.12, 2.13 and 2.14. Look up the values and write on your own.

3) Compared with the values in the FAO/WHO/UNU 1985 report, energy requirements proposed by FAO/WHO/UNU 2004 consultation are about 12 percent lower in the first three months of life, 17 percent lower from three to nine months, and 20 percent lower from nine to 12 months. The requirements for breastfed infants are 17, 20 and 22 percent lower than the 1985 estimates at ages 0 to three, three to nine and nine to 12 months, respectively.

4) The two conditions arising due to energy imbalance are chronic energy deficiency and obesity. Consequences of inadequate energy intake during the childhood and adolescence of an individual result in a reduced body size and a low BMI. In the presence of concomitant repeated infections in childhood and adolescence, an individual with CED, will also show stunting, reduction in muscle mass leading to reduced skeletal muscle performance,The health risks associated with obesity include increased mortality, hypertension, cardiovascular disease, diabetes mellitus, gallbladder disease, some cancers, and changes in endocrine function and metabolism.