

NUTRITIONAL BIOCHEMISTRY

Nutritive and Calorific Value

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Energy

Just before the French revolution, Lavoisier and the physicist Laplace carried out some experiments to demonstrate the relationship between heat production and respiratory exchange. They placed a guinea pig in a very small chamber surrounded by ice and measured the amount of ice melted over a period of ten hours. They also measured the amount of carbon dioxide given out by the animal. Lavoisier further experimentally showed that oxygen consumption of men increased after food and exercise. This was the beginning of experiments relating to understanding the term energy, energy expenditure, energy transformations and energy balance in human nutrition.

Energy is defined as the capacity to do work. It is neither created nor destroyed. Energy is being changed from one form to the other and cycled throughout a system. In the human body the various metabolic and biochemical pathways convert the stored chemical energy in our food to other forms of energy for the body to perform various activities. In our bodies, energy is available in four basic forms for life processes: chemical, electrical, mechanical, and thermal.

The main source of energy in living organisms is the sun. During photosynthesis, cells in the green leaves use this energy to synthesize glucose using the carbon dioxide in the air and water in the soil. Proteins, fats and other carbohydrates are then synthesized from the glucose produced by the leaves to meet the needs of the plant. Carbohydrates are the main form in which plants store potential energy. Humans obtain carbohydrates, proteins and lipids and the energy contained in them by consuming plants or by eating the flesh of animals that may have consumed these plants. In humans and animals, the source of useful energy is the chemical energy supplied by food.

In the human body the food is converted to the basic energy unit i.e. glucose, which together with fatty acids is metabolized to release its energy to be transformed and cycled through body systems. Water and carbon dioxide, the initial materials used by plants, are released as end products of this process of oxidation in the body. And this cyclic procedure goes on.

Energy Transformation

On entering the body, the stored energy undergoes many processes of metabolism that convert it further to various metabolic products containing stored chemical energy to perform the body functions. This chemical energy is changed further to other forms of energy as body functions are performed. For example, chemical energy is changed into electrical energy in brain for transmission of impulses. For muscle contraction, the chemical energy is changed in to mechanical energy. It is used for body heat production and is thus changed into thermal energy. It also changes to different forms of chemical energy by the synthesis of new organic compounds. In all these activities of the body, heat is given off to the surrounding atmosphere and larger biosphere.

In human metabolism, as in any other system, the energy is always present either as free energy or potential energy. Free energy is the energy that is available. It is involved in the performance of a particular work. Potential energy is in the various chemical bonds that have a potential to become free energy whenever the need arises. For example, energy stored in sugar is potential

energy. When we eat it and it is metabolized, free energy is released and body work is accomplished.

Energy Balance

Energy balance is the balance between the energy input and output. Energy balance can be thought of as an equation: energy consumed minus energy expended.

$$\text{Energy Balance} = \text{energy consumed} - \text{energy expended}$$

A person is in positive energy balance when energy consumed is greater than energy expended. The result of a positive energy balance is the storage of excess energy, mostly in the form of triglycerides in the adipose tissue.

Whether the energy system is electrical, mechanical, thermal, or chemical, the supply of free energy is decreased and the stores of potential energy also slowly gets depleted during the process of the many reactions and essential work that the body performs. Thus, the energy in this system must be constantly added on from some outside source and in humans this can be done by eating food. This energy would be needed to support the body's basal metabolic needs and to meet physical activity requirements. In addition to what we see as energy being spent for physical activity, there is a large proportion of energy that we spend but do not see it being spent. This energy is being spent internally at all times to meet our basal or resting energy needs.

Energy Control in Human Metabolism

If all the energy produced in various reactions in the humans would be released at once, it would be destructive. Thus, some mechanism by which energy release is controlled in the human system must exist so that energy could be released when required and conserved otherwise for other processes. This is accomplished by chemical bonding and controlled reaction rates.

Chemical Bonding

The main mechanism controlling energy in the human system is chemical bonding. The chemical bonds that hold the elements in compounds together are energy bonds. As long as the compound remains constant, energy is being exerted to maintain it. When the compound is taken into the body and broken into its parts, this energy is released and available for body work. Three main types of chemical bonds transfer energy in the body.

1. Covalent bonds

These are regular bonds, based on relative valence of constituent elements, that link the elements of a chemical compound together eg. those that hold carbon atoms together in the core of an organic compound such as glucose.

2. Hydrogen bonds

Weaker than covalent bonds, these bonds are significant because they can be formed in large numbers. Also, the very fact that they are less strong and can be broken easily makes them important because they can be transferred or passed readily from one substance to another to help form still another substance. The hydrogen attached to the oxygen molecule in the carboxyl group of amino or fatty acids is an example of this type of bond.

3. High-energy phosphate bonds

A classic example of these high-energy phosphate bonds at work is the compound adenosine triphosphate (ATP), which is the unique compound the human body uses to store energy for its cell work. Like storage batteries for electrical energy, these bonds become the controlling force for ongoing energy needs.

Controlled Reaction Rates

The chemical reactions that are a part of the body's energy system must have regulations. Some chemical reactions or transformations if not catalysed take very long time for completion. Other reactions need to be regulated or controlled so that they do not proceed too fast or aimlessly and waste important body reserves. Control agents that regulate these cell activities are the enzymes, coenzymes, and hormones.

Enzymes

Enzymes are proteins that are produced in the cells under the control of specific genes. There are thousands of enzymes in each cell but each enzyme has a specific substrate. The enzyme and its substrate work together to produce a product, and the original enzyme is released, ready to do its specific work over and over again.

Coenzymes

Many reactions require another molecule to assist the enzyme in completing the reaction. These coenzymes are vitamins, especially the B-complex vitamins, or another compound. The enzymes cannot function without the help of these coenzymes. NAD^+ , FAD^+ are some examples.

Hormones

In energy metabolism hormones act as messengers to trigger or control enzyme action. For example the body's metabolic rate is controlled by the thyroid stimulating hormone (TSH) from the anterior pituitary gland. Another example is the controlling action of insulin from the beta cells of the pancreas on the rate of glucose utilization in the tissues. Steroid hormones also have the capacity to regulate the cell's ability to synthesize enzymes.

Types of Metabolic Reactions

The two types of reactions constantly going on in energy metabolism are anabolism and catabolism. Each requires energy. The process of anabolism synthesizes new and more complex substances. The process of catabolism breaks down more complex substances to simpler ones. These processes release free energy, but the work also uses up some free energy. Therefore there is a constant energy deficit, which must be supplied by food.

Energy Measurement

Units of measurement

The standard units of measurement is calorie which is the amount of heat energy required to raise the temperature of 1 ml of water (at 15 °C) by 1 degree Celsius. Because the amounts of energy involved in the metabolism of foodstuffs are fairly large a kilocalorie is commonly used.

- **Kilocalorie-** This is the amount of energy required to raise temperature of 1 kg of water from 15 to 16 ° C.
- **Joule** - The international system of energy measurement is the joule. It expresses the amount of energy expended when 1 kg of a substance is moved 1 m by a force of 1 Newton (N). It was named after James Prescott Joule (1818-1889), an English physicist who discovered the first law of thermodynamics. Since nutritionists are concerned with large amounts of energy kilojoules, megajoules or kilocalories are the most convenient units. Conversion from calories to joules is made by multiplying by 4.186 and this factor has been rounded off to 4.2 for many practical purposes.

Measurement of Energy Content of Food

The energy value of a particular food can be measured in two ways: calorimetry and calculation of the approximate composition.

Calorimetry

If foodstuff is placed in a small chamber or bomb of the bomb calorimeter and exposed to high pressure of oxygen catalysed by a platinum catalyst, it can be ignited by a small electric current. All the organic material is burnt and as a result of combustion heat is liberated which can be measured. The chamber is surrounded by water. As the food burns it gives off heat which raises the temperature of water surrounding the chamber. The increase in the temperature of water after the food has burned indicates the amount of energy in the food.

The bomb calorimeter provides values for the amount of energy that can be obtained from carbohydrates, proteins, lipids and alcohol. The average gross energy value of pure carbohydrates, fats and proteins by the bomb calorimeter are as follows:

1g carbohydrate yields 4.1Kcal
 1 g fat yields 9.45 Kcal
 1g protein yields 5.65Kcal

In the utilization of carbohydrates, fats and proteins in the body a certain percentage of these nutrients are lost in the process of digestion and the nitrogen of the protein is excreted in the urine as urea which contains some energy. The average losses in human subjects have been estimated to be 2% for carbohydrates, 5% for fats and 8% for protein. The physiological energy values calculated from the gross energy value of foods after allowing for the above losses in digestion and metabolism are: carbohydrates and proteins give 4 kcal/g, fats yield 9 kcal/g and alcohol 7 kcal/g. These are known as their respective fuel factors.

These energy figures have to be adjusted for

a) Digestibility

b) Substances in foods such as waxes and fibrous plant parts that would burn in a bomb calorimeter as they have an organic composition but are not usable by the human body to yield energy. The figures are then rounded off to whole numbers.

Calculation of the Approximate Composition

Alternatively food energy can be calculated using the fuel factors as mentioned above for calculation.

Measurement of Human Energy Expenditure: Heat Loss Plus External Work Performed

All of the energy transformed within the animal body can be accounted for as heat eliminated from the body and as work done by the animal. In the resting animal (that is, when no external work is being performed), essentially all of the energy transformed within the body is dissipated as heat. This state is referred to as the resting metabolism. It applies to energy expenditure under normal life conditions while at rest. Heat loss thus includes both the heat produced from inefficient transfer of the energy of oxidation and final degradation of internal work into heat. For example, the work of the heart and lungs is converted into heat by the friction of blood in the capillaries and the movement of air in and out of the body.

When external work is performed, energy expenditure is equivalent to the heat produced plus the work done. All forms of work, however, are not easily measured. Lifting a known weight to a known height or riding a stationary cycle ergometer are forms of work that can be calculated easily as heat energy. The heat equivalent of work energy is 1 kcal to 427 kilogram meters of work where $\text{kilogram meters} = \text{weight} \times \text{distance}$.

If, conceivably, a large-size calorimeter could be constructed and an individual allowed to perform all his or her usual activities within, the total amount of heat measured should be quite close to the individual's actual energy expenditure. In certain instances, such as lifting an object, a small amount of energy would reside in the object lifted; in other instances, such as freely riding a bicycle, heat is produced by friction of the wheels. Heat produced during the latter activity therefore emanates from the object, not from the individual.

The amount of energy generated by the body can be assessed by direct and indirect methods.

Direct calorimetry

It is easy theoretically but difficult in practice. It requires monitoring the amount of heat produced by a subject placed inside a structure large enough to permit moderate amounts of activity. The method provides a measure of energy expended in the form of heat but provides no information on the fuel being oxidized. Its use is limited by expense and lack of facilities.

However, direct measurement of heat loss is expensive and complicated in operation and is rarely used in practical human calorimetry.

Indirect calorimetry

The calculation of energy expenditure in kcal from oxygen consumption is known as indirect calorimetry. It measures the metabolic rate by determining with a spirometer the oxygen consumption and carbon dioxide production by the body over a given period of time. In practice only oxygen consumption is measured and carbon dioxide released is estimated.

Technically, this is a far better procedure than measurement of heat. It is based on the fact that when an organic substance is completely combusted either in a calorimeter or human body, oxygen is consumed in amounts directly related to the energy liberated as heat.

This equipment has the advantage of low cost and mobility and may be applied when the subject is at rest or engaged in various activities. It also has an added advantage of measuring the total energy- resting metabolism plus work performed.

The first instrument to be used to measure this was the respiration calorimeter which was a chamber similar to that of direct calorimetry. However, for many years now, mobile, lightweight and versatile instruments are being used for the measurements of respiratory exchange. These instruments consist of masks and attachments that can be strapped to the subject for collection of gas and allow easy movement of the subject.

The heat equivalent of respiratory exchange is not calculated from oxygen consumed and carbon dioxide expired but also is dependent on the ratio of moles of carbon dioxide produced to oxygen consumed or the Respiratory Quotient (RQ)

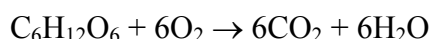
$$RQ = \text{Moles of CO}_2 \text{ expired} / \text{Moles of O}_2 \text{ consumed}$$

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

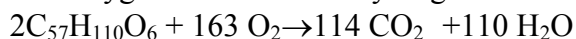
The RQ varies when carbohydrate, fat and protein are oxidized because of the difference in the composition of the foodstuffs that determine the amount of oxygen required for complete oxidation and thus, the volume of carbon dioxide let off.

The RQ for the oxidation of glucose is 1 because the same number of carbon dioxide molecules are produced as oxygen molecules consumed.

The oxidation of glucose is shown below:



Fats require more oxygen than carbohydrates for combustion because the fat molecule contains a low ratio of oxygen to carbon and hydrogen. For fat the RQ may be represented as follows:



$$\frac{CO_2}{O_2} = \frac{114}{163} = 0.70$$

The approximate RQ for fat is 0.7.

Calculation of RQ for protein is a little more difficult because protein is not completely oxidized and both carbon dioxide and oxygen are excreted in the urine as urea. After adjusting for urinary excretion the ratio of carbon dioxide produced to oxygen consumed is 1:1.2 and thus equivalent to an RQ of 0.82. The RQ for a mixed diet is generally accepted to be 0.85.

The RQs for individual carbohydrates, fats, and proteins differ slightly, but the average figures of 1.0, 0.7, and 0.8, respectively, are accepted as representative of the foodstuffs. The RQ for an ordinary mixed diet consisting of the three foodstuffs is approximately 0.85. Obviously, it is impossible to make assumptions about the relative amounts of foodstuffs undergoing oxidation except at extremes of the RQ range. For example, if the RQ is nearly 1.0, one can safely assume that the foodstuff consists mainly of carbohydrate. Similarly, an RQ of about 0.7 indicates a predominantly fatty acid metabolism. At intermediate levels of RQ, no safe assumption can be made.

Since the nature of the foodstuff consumed in cellular respiratory processes determines both oxygen consumption and carbon dioxide formation (that is, the RQ), the caloric equivalent for a given volume of oxygen or carbon dioxide also will vary with the RQ. Caloric equivalents of oxygen and carbon dioxide for RQ values between 0.7 and 1.0 are shown in Table 1 below. It is obvious from the table that when fat is oxidized, heat production represented by 1 liter of oxygen consumed is only 0.3 kcal less than when carbohydrate is oxidized, a difference of about 6 percent. The variation in caloric equivalent for carbon dioxide, however, is on the order of 30 percent. These figures apply only to mixtures of carbohydrate and fat and therefore represent what is referred to as the non protein RQ.

For work requiring great accuracy, the extent of protein oxidation can be calculated from urinary nitrogen, and the nonprotein R.Q. can then be estimated. In practice, the error incurred by ignoring protein metabolism is relatively small and, particularly in short term studies, no correction is made for the effect of protein metabolism on R.Q. Calculation of heat production is made as if only fat and carbohydrate were oxidized.

Factors Contributing to the Total Energy Requirement

The determination of energy needs requires a separation of the total energy expenditure into physiological entities that can be defined and measured. The most significant factors that affect the total energy requirements of an individual are:

1. Basal metabolism
2. Calorigenic effect of food or food intake effect
3. Activity-physical activity

Basal Metabolic Rate

When a subject is at complete rest and no physical work is being done, energy is required for the activity of the internal organs and to maintain the body temperature. This energy is called basal or resting metabolism. It is thus, a sum of all the internal chemical activities that maintain the body at rest.

The basal metabolic rate (BMR) is a measure of the energy required for activities of resting tissue and is determined experimentally when the subject is lying down at complete physical and mental rest, wearing light clothing in a room comfortably warm and is in the post prandial state (12-16hrs after a meal).

Table 1: Caloric values of oxygen and carbon dioxide for non protein RQ

Non protein RQ	Caloric value of 1 Liter of O₂	Caloric value of 1 Liter of CO₂	Percentage of total O₂ consumed by fat	Percentage of total heat produced by fat
0.707	4.686	6.629	100.0	100.0
0.71	4.690	6.606	99.0	98.5
0.72	4.702	6.531	95.6	95.2
0.73	4.714	6.458	92.2	91.6
0.74	4.727	6.388	88.7	88.0
0.75	4.739	6.319	85.3	84.4
0.76	4.751	6.253	81.9	80.8
0.77	4.764	6.187	78.5	77.2
0.78	4.776	6.123	75.1	73.7
0.79	4.788	6.062	71.7	70.1
0.80	4.801	6.001	68.3	66.6
0.81	4.813	5.942	64.8	63.1
0.82	4.825	5.884	61.4	59.7
0.83	4.838	5.829	58.0	56.2
0.84	4.850	5.774	54.6	52.8
0.85	4.862	5.721	51.2	49.3
0.86	4.875	5.669	47.8	45.9
0.87	4.887	5.617	44.4	42.5
0.88	4.899	5.568	41.0	39.2
0.89	4.911	5.519	37.5	35.8
0.90	4.924	5.471	34.1	32.5
0.91	4.936	5.424	30.7	29.2
0.92	4.948	5.378	27.3	25.9
0.93	4.961	5.33	23.9	22.6
0.94	4.973	5.290	20.5	19.3
0.95	4.985	5.247	17.1	16.0
0.96	4.998	5.205	13.7	12.8
0.97	5.010	5.165	10.2	9.51
0.98	5.022	5.124	6.83	6.37
0.99	5.035	5.085	3.41	3.18
1.00	5.047	5.047	0	0

(Source: From N Zuntz and M Schumberg with modifications by G Lusk, EP Cathcart and DP Cuthberton, *J Physiol* 72: 349(1931)

Certain active tissues like the brain, liver, heart, gastrointestinal tract and kidneys comprise a very small proportion(less than 5%) of the total body weight but they contribute about 60% to the basal metabolic activity.

The BMR is the largest component of energy expenditure in humans making up about 60-70% of the daily energy expenditure of most people.

Measurement of Basal Metabolic Rate

The BMR can be measured by both direct and indirect methods of calorimetry as discussed above.

1. Direct calorimetry

In this method a person is placed in a large chamber and the body's heat production at rest is measured. This instrument is large and costly and its use is limited to research studies.

2. Indirect calorimetry

This involves the measurement of oxygen consumption and is a far simpler procedure than measurement of heat. In this method a portable instrument called a respirometer is brought to the side of the bed or chair on a cart. The person at rest breathes into the instrument through a mouthpiece or by means of a ventilated hood, and the exchange of gases in respiration, the respiratory quotient (CO_2/O_2). The metabolic rate can be calculated with a high degree of accuracy from the rate of oxygen utilization, because more than 95 % of the energy expended by the body is derived from metabolic reactions with oxygen. The energy expenditure (BMR) measured in this manner is equivalent to the heat released by the body.

3. Indirect laboratory tests

Because the thyroid hormone thyroxine regulates BMR, thyroid function tests are used in clinical practice to serve as indirect measures of BMR and thyroid function. These tests include measures of serum TSH and thyroxine levels, both triiodothyronine (T₃) and thyroxine (T₄), as well as the radioactive iodine uptake test. T₃ and T₄ are produced in the final two stages of thyroid hormone synthesis and reflect the relative functioning of the thyroid gland and the amount of hormone activity influencing the BMR.

Factors Influencing Basal Metabolic Rate

Some of the factors affecting the BMR are:

1. **Fat Free Mass Or Lean Body Mass (LBM)** - LBM, including muscle cells and vital body organs, is the major factor influencing BMR because of its greater level of metabolic activity when compared with the less active tissues of fat and bones. The elderly have a lower BMR because of the loss of lean tissue that occurs as we age.
2. **Sex** - Women have a lower BMR as compared to men. Differences in metabolic requirements between women and men are primarily related to the generally lower amount of muscle mass and higher amount of body fat in women compared with those in men. However, when based on lean body mass the BMR of both males and females is not very different.
3. **Growth** - Growth during childhood and pregnancy and milk production during lactation require anabolic work under the influence of growth hormone. This affects the BMR. The BMR is higher in infants and young children as compared to adults.
4. **Fever and disease** - Fever increases BMR by about 7% for every 1° F rise in body temperature above 98.6°F or 13% for each degree Celsius above 37°C.

Diseases involving increased cell activity such as cancer, certain anemias, cardiac failure, hypertension, and respiratory problems such as chronic obstructive pulmonary disease generally result in an increase in the BMR. Patients with Parkinson's disease appear to have increased metabolic energy needs because of involuntary muscle movements and thus show a decrease increase in BMR

5. Climate - BMR varies with the surrounding temperature and rises in response to lower temperatures to produce heat to maintain body temperature. The reverse is true for people living in tropical climates since they show an increase in BMR.
6. Fear and nervous tension - During test conditions BMR is seen to increase due to fear and nervous tension. This is because of secretion of adrenaline that increases BMR.
7. Under nutrition and starvation - starvation and protein-energy malnutrition lower BMR because LBM is reduced
8. Sleep - During sleep the metabolic rate falls approximately 10% below that of levels measured while the person is awake and reclining. This drop is because of muscle relaxation and by decreased activity of the sympathetic nervous system.

Food Intake Effect

Food ingestion stimulates metabolism and requires energy to meet the multiple activities of digestion, absorption, metabolism, and storage of nutrients. The overall metabolic stimulation is called the thermic effect of food (TEF). About 10% of the body's total energy needs are used in activities related to metabolize food.

Physical Activity Needs

Exercise performed in work and recreation or in physical training and competition accounts for wide individual variations in energy requirements. Effects of various activities on energy metabolism have been measured by the oxygen consumption method of direct calorimetry.

Total Energy Expenditure

In summary, the basic components of energy expenditure when body weight is remaining constant are:

1. BMR, the energy demands of the involuntary process of the body-about 70% of the total;
2. the TEF- about 10% of the total; and
3. the variable requirements of physical activity. Another factor called adaptive thermogenesis is sometimes added.

Energy Requirements

Energy Requirements during Growth

The energy intake of children during growth at different ages must allow for satisfactory growth and physical development, and for the high degree of activity characteristic of healthy children. Recommendations are based on observed intakes of normally growing children. ICMR has given energy requirements of infants based on the energy intake through breast milk (850 ml/day) by infants of well nourished mothers. For the first year of life, energy requirements are related to body weight. Energy requirement per kg of body weight is more than double that of adult but falls slowly as the rate of growth per unit of body weight falls with age. ICMR has recommended the adoption of energy allowances given by FAO/WHO with necessary adjustments of body weights of healthy well nourished Indian children who had no dietary constraints. For undernourished children ICMR suggested that energy should be provided on the basis of ideal weight for age.

In children of all ages, there are wide individual variations in activity which can lead to extremely high energy expenditure for active and very low for inactive children. Hence in dealing with feeding problems of children, account must be taken of activity as well as of size and age.

Energy Requirements during Pregnancy

During pregnancy additional energy is required to support the growth of the foetus, development of placenta and maternal tissues and to meet the needs for increased BMR. According to ICMR, for a reference Indian woman, whose body weight is 50 kg, the total energy cost of pregnancy includes the energy expenditure during normal pregnancy as well as the energy needed for deposition of 4 kg body fat to be utilized later during lactation. An increased amount of 120 kcal/day during the second and third trimesters is enough to meet the needs of increased energy expenditure, but does not allow for deposition of body fat. Based on this, the Nutrition Advisory Committee has recommended an additional intake of 300 kcal/day during the second and third trimesters.

Energy Requirements during Lactation

Lactating mothers need additional energy for the production of milk which is computed from the volume of milk secreted, its energy content and the efficiency of conversion of food energy into milk energy. Based on an optimal milk output of 850 ml and conversion efficiency of 80%, the additional energy allowance recommended by ICMR during the first 6 months of lactation is 550 kcal/day. This computation has taken into account the energy contribution from the fat stores deposited during pregnancy. Since Indian mothers continue to lactate beyond 6 months, although the milk output is reduced, an extra allowance of 400 kcal/day is recommended for the period from 6 to 12 months of lactation.

Energy Requirements of Average Man and Woman

Age, sex, activity and body weight largely determine the nutrient requirements of an individual. The energy needs are affected by a number of factors. These include

- a) *Basal or resting* energy requirement for vital functions as respiration, circulation etc.
- b) The energy required for the actual *physical activity* of the individual. These include the type of activity related to essential economic or occupational activities as well as the discretionary or non-occupational activities (including household tasks, exercise). For the sake of computation of energy requirements occupations have been classified as light, moderate and heavy.
- c) *Calorigenic effect or SDA* which includes the metabolic response to the food ingested (i.e. the use of energy in digestion, absorption and metabolism of the ingested nutrients).

For all practical purposes, since the energy expenditure associated with the calorigenic effect merges into measurements related to the cost of physical activity only two principal components of energy expenditure i.e. BMR and physical activity are considered.

In most individuals nearly half the energy expenditure is accounted for by the BMR. During sleep, energy expenditure is nearly equal to BMR and this factor also known as *Resting Energy Expenditure* has been taken as 1.0.

ICMR has assessed the energy requirements of different groups by factorial approach and the energy cost for activity has been expressed as a factor of BMR or as BMR units for arriving at the energy requirements of Reference Indian Man and Woman. A Reference Indian man is between 20-39 years of age, weighing 60 kg, 163 cm height free from disease, physically fit for active work, employed in moderate activity for 8 hrs, 8 hrs in bed, 4 to 6 hrs sitting and moving about and 2 hrs walking or active recreation. A reference Indian woman is defined as an adult woman between 20-39 years of age, weighing 50 kg, 151 cm tall, engaged for 8 hours in general household work or any other moderately active work, spending 8 hours in bed, 4–6 hours in light activity or moving around and 2 hours in walking, active recreation or household duties. The BMR factors for Indian man and woman engaged in sedentary, moderate and heavy activity are 1.6, 1.9 and 2.5 respectively.

Since energy requirements are related to body weight also, ICMR has given energy needs for men and women with different body weights (Table 2). Moreover males who are usually taller, heavier and have more active tissue mass than females, have higher energy requirements than women of the same activity level.

Table 2: Recommended energy requirements for adult man and woman

Group	Body weight (kg)	Energy (kcal)
Man		
Sedentary	60	2425
Moderate		2875
Heavy		3800
Woman		
Sedentary	50	1875
Moderate		2225
Heavy		2925

Specific Dynamic Action of Foods (SDA)

This term is used to describe the effect of food in raising the metabolic rate above the value found when fasting. Traditionally referred to as SDA, it is now more commonly called the Calorigenic effect of food or dietary induced thermogenesis. This effect studied initially by Rubner et al established that food might increase metabolism by as much as 30 per cent and 'that meat ingestion raises the metabolism most, fat next and sugar least of all foodstuffs'. On normal diets the overall effect amounts to no more than 5 to 10 per cent of the basal metabolism over 24 hrs.

The causes of the thermogenic effect remain uncertain. It can be accounted for by the work necessary for the secretion of gastric juice, digestion and absorption of food and also related in some way to protein synthesis.

Planning of Dietary Regimes

Planning of Dietary Regimes during Pregnancy

Optimum nutrition is critical during pregnancy and lactation due to special nutritional needs associated with physiological changes. The expectant or the nursing mother not only has to nourish herself, but also the growing foetus or infant who is being breast fed.

Foetal development is accompanied by many physiological, biochemical and hormonal changes occurring in the maternal body which influence the need for nutrients. These changes include:

- i. Increased basal metabolic rate
- ii. Gastrointestinal changes
- iii. Hormonal changes
- iv. Changes in body fluids
- v. Cardiovascular and renal changes
- vi. Weight gain

Nutritional Considerations during pregnancy

Increased nutritional requirements due to the high anabolic activity and associated biological and physiological changes are characteristic of this period. An increased nutrient intake has been suggested mainly in the second and third trimesters of pregnancy, since there is no significant increase in size of the foetus during the first trimester. However a qualitative improvement has been recommended during this period.

- **Energy** - Additional energy is required to support the growth of the foetus, development of placenta and maternal tissues and to meet the needs for increased BMR. Provision is also made for deposition of 4 kg body fat to be utilized later during lactation. ICMR has thus recommended an additional intake of 300 kcal/day during the second and third trimester.
- **Protein** - Additional protein is necessary for the growth of the foetus, development of placenta, enlargement of maternal tissues, increased maternal blood volume and formation of amniotic fluid. Hence an additional level of intake recommended by ICMR is 15 g/day.

- **Calcium** - Additional calcium is needed for growth and development of bones and teeth of foetus. ICMR has recommended a total of 1g calcium/day which takes care of the total calcium needs of the mother and the additional needs of pregnancy.
- **Iron** - Increased iron is necessary for foetal growth, expansion of maternal tissues, iron content of placenta and the blood losses during parturition, ICMR has recommended an amount of 38 mg/day.
- **Iodine** - Due to increase in BMR, the iodine needs are enhanced during pregnancy.
- **Vitamin A and Vitamin C** - No additional allowance has been suggested by ICMR.
- **Thiamine, Riboflavin and Niacin** – These need to increase corresponding to additional needs of energy.
- **Folic Acid** - ICMR has recommended an additional intake of 300 µg/day because of increased haematopoiesis.
- **Vitamin B₁₂** - In order to cover the foetal demands, an additional intake of 0.5 µg has been suggested.
- **Vitamin B₆** - ICMR has suggested a level of 2.5 mg/day to meet the increased pyridoxine needs.

To meet the increased nutrient needs of the pregnant woman the following considerations have thus to be kept in mind:

Considerations for Diet Planning

The basic meal planning principles remain the same as for normal adults.

- To meet the increased energy requirements during the second and third trimester, the mother needs to consume extra food.
- Increased protein needs can be met by including protein of good quality like milk, meat, eggs, fish. Combination of plant protein (Khichri: rice-pulse combination, paratha: wheat flour–pulse combination) improves the protein quality.
- To meet the additional iron need, food stuffs like whole grain cereals, whole pulses, leafy vegetables like bathua, mustard leaves, soyabean, eggs, organ meats should be consumed.
- Small frequent meals about 5-6 are beneficial with balanced nutrient distribution to facilitate intake of additional food needs.
- Easily digestible foods are suitable, strongly flavored and highly spiced foods should be avoided.
- Avoid fried foods since it leads to excessive weight gain which is not desirable.
- Morning sickness and nausea are common in early pregnancy, hence suitable selection of high carbohydrate foods like biscuits, bread and rusk as first food in the morning helps relieve nausea.
- Constipation is a common complication due to foetal pressure, hence large quantities of foods rich in dietary fiber, i.e. fresh fruits and vegetables, whole grain cereals, whole pulses and plenty of fluids are advised.
- Alcohol should be avoided during pregnancy since alcohol can lead to Foetal-Alcohol-Syndrome which can cause prenatal mortality.
- Smoking should also be abstained from, since nicotine and carbon monoxide act together to produce chronic hypoxia in the foetus, and pose a greater risk of spontaneous abortion in the infant.

- o Caffeine intake (from, coffee, tea, colas) should not be excessive since caffeine crosses the cell membrane, is a CNS stimulant and can lead to low birth weight and birth defects if consumed in high doses.
- o Abnormal cravings for substances that have little or no nutritional value (PICA) are harmful and should not be indulged in.

Table 3: Food Plan for a Pregnant Woman: Vegetarian / Non- Vegetarian

Food Group	Amount (g)	Energy (kcal)	Protein (g)
Milk	625	425	20
Meat/Paneer	40	70	7
Pulses	60	200	14
Cereals	300	1050	30
Veg A	200	40	2
Veg B	300	120	4
Fruit	200	80	-
Fat	40	360	-
Sugar	45	180	-
Total		2525	79

Planning of Dietary Regimes for Infancy

Infancy, the period from birth to one year is a period of rapid growth. A healthy well growing infant (approx 3 kg at birth) doubles his birth weight by 5-6 months and trebles it by 1 year. This growth and development, which is an extremely pleasant experience for the child and the parents, is accompanied by a number of important physiological changes. These include:

1. Change in body size.
2. Change in body composition.
3. Development of gastro-intestinal system.
4. Development of functional capacity of kidneys by one year.
5. Rapid increase in mental functioning.
6. Changes in feeding behaviour.

The nutritional requirements are thus very high and their fulfillment is critical to ensure normal growth and development.

Nutritional Considerations

In view of the fact that Indian infants from well-to-do families who do not have any dietary constraints can attain weights and heights comparable to the NCHS standards, the ICMR Expert Committee has based the nutrient recommendations for Indian infants on the NCHS reference values.

Table 4: Recommended dietary allowances of various nutrient for infants

	Age (months)	
	0-6	6-12
Energy (kcal)	108/kg	98/kg
Protein (g)	2.05/kg	1.65/kg
Calcium (mg/d)	500	
Retinol (µg/d)	350	
Beta carotene (µg/d)	1400	
Thiamine	55µg/kg	50µg/kg
Riboflavin	65µg/kg	60µg/kg
Niacin	710µg/kg	650µg/kg
Vitamin C (mg/d)	25	
Folic acid (µg/d)	25	
Cyanoco-balamin (µg/d)	0.2	

Nutritional requirements for infants have largely been based on breast milk intakes of well nourished population combined with contributions from supplements introduced into the child's feeding regime from 4-5 months of age. The mother's milk alone is not sufficient for the infant after that age.

The Recommended Dietary Allowances of various nutrients for infants are from 0-6 months and 6-12 months of age.

Energy - The energy requirements of infants are mainly based on the energy intake through breast milk by infants of well nourished mothers. Based on an average secretion of about 850ml of milk/day by a well nourished mother, ICMR has recommended the levels of energy allowance for infants as in Table 4.

From birth onwards, the child meets its energy requirements from mother's milk alone, but after 5-6 months of age, a part of the energy needs should be met by supplements introduced into the feeding schedule of the child.

Protein - Protein allowances for infants should not only meet the need for maintenance but also for the rapid growth which occurs during the first year of life. In the case of infants beyond six months, breast milk alone is not able to satisfy the protein needs and supplementary foods have to be introduced into the child's feeding schedule. Since in India, infants are given food supplements based on vegetable proteins, protein allowances for infants between 6 to 12 months of age are made in terms of both breast milk protein and vegetable protein.

Fat - Adequately breast fed infants receive nearly 30g fat/day. Breast milk would, thus, meet the EFA (essential fatty acids) needs of infants, which is about 6en%. During weaning, care should be taken that the diet provides about 25% energy as fat, which should be a blend of invisible and visible fat, so as to reduce the bulk.

Calcium - ICMR has recommended an amount of 500mg of calcium daily during the entire period of infancy.

Iron - The basal iron needs of infants are the same as for other age groups, i.e., 14µg/kg body weight. The need for growth, expansion of blood volume and for improving iron stores in the body has been estimated to be 65µg/kg.

However, ICMR has not suggested any recommended allowance of iron for infants because

- i. An infant born to a mother with a satisfactory iron status has a high haemoglobin level of 17g/100ml of blood which falls to a normal level of 11g/100ml in two weeks. The iron released from the breakdown of haemoglobin is stored in the infant's body to be used subsequently.
- ii. Breast milk, though not a rich source of iron contains sufficient amount of bio-available iron to meet the needs of exclusively breast fed infants for 3-4 months of life.
- iii. Losses of iron in infants are not known precisely and therefore the amounts needed to replace these losses are difficult to assess.

Vitamin A - On the basis of vitamin A ingested by breast fed infants in well-nourished communities, ICMR has recommended a daily allowance of 350µg of retinol upto the age of 6 months. In the absence of specific data on the needs of infants from 6 to 12 months, the same level of retinol has been recommended during the second half of infancy also.

Thiamine -Thiamine requirements of infants upto 6 months of life can be calculated on the basis of the amount of this vitamin ingested through breast milk.

The recommended allowance as given by ICMR is 55µg/kg body weight and 50µg/kg body weight for the infants of 0-6 months and 6-12 months, respectively.

Riboflavin - The recommended allowances of riboflavin as given by ICMR are 65µg/kg body weight for infants of 0-6 months of age and 60µg/kg body weight for infants of 6-12 months of age.

Niacin - On the basis of the average body weight of infants, the recommendations for niacin are 710µg/kg and 650µg/kg body weight for the infants of 0-6 months and 6-12 months respectively.

Pyridoxine - In the absence of precise data, ICMR has based its recommendations of the levels of pyridoxine in the breast milk of western mothers and has suggested an amount of 0.1 mg and 0.4mg of pyridoxine per day for the infant of 0-6 months and 6-12 months, respectively.

Folic acid - Folic acid requirements during infancy are mainly based on the vitamin level of breast milk. Breastfed infants normally receive about 25 to 30µg of folic acid/day, most of which is absorbed easily. ICMR has, therefore, recommended 25µg of folic acid per day for infants.

Cyanocobalamin (Vitamin B₁₂) - A daily allowance of 0.2µg has been considered adequate for this group by ICMR to prevent Vitamin B₁₂ deficiency and show normal haemopoiesis.

Ascorbic Acid (Vitamin C) - ICMR has suggested 25mg/day for infants in view of the beneficial effect of vitamin C on non-haem iron absorption.

Considerations for diet planning

To meet the high nutritional requirements of an infant, good nutrition throughout infancy is very important.

Documented evidence has shown that infants grow well on exclusive breast feeding for first 4 to 6 months of life. During this period, the baby does not even need water supplements. The various advantages of breast feeding, e.g., natural method of feeding, nutritionally “tailor made” for the baby, source of natural immunity, having ant-infective and anti-allergic properties, economical, natural contraceptive and facilitator of mother-child bonding, are well established.

Weaning

Weaning is the process of gradually introducing foods other than breast milk in the child's feeding schedule. This process starts when any food besides mother's milk is introduced in the child's diet and is completed only when the child has been put entirely off the breast. The introduction of supplementary foods not only ensures the fulfillment of nutritional requirements but also introduces the child gradually to the normal family eating patterns.

Nutritional Guidelines

- Weaning is started first with strained liquid foods, which may be progressed to thicker gruels, followed by semisolid soft foods low in fibre. By one year, the child can be progressed to easily digestible, bland adult foods, with limited soft fibre.
- Complementary foods may be in the form of premix or may be freshly prepared. Indigenous premixes may be prepared using roasted and powdered cereal pulse combinations in a proportion ranging from 4:1 to 1:1, with or without nuts and dehydrated powdered vegetables. These should be stored in air tight containers and reconstituted when needed, in required amounts, with water or milk, based on the income group. Sugar/Jaggery and fat should be added at the time of reconstitution. This improves the shelf life of the premix.
- Fresh complementary foods may be prepared from a suitable combination of cereals, dehusked pulses/milk, vegetables/fruit, nuts, fats and sugar to provide the energy, protein, vitamin and mineral requirements of the infant.
- The complementary foods should be energy dense but not bulky.
- Malted cereals rich in amylase (ARF) may be used to reduce bulk of the complementary foods, as also nuts, oilseeds and fat (contributing approximately 25% energy), which increase energy density and reduce bulk.
- While introducing complementary foods, the following considerations are important:
 - Introduction of only one food at a time.
 - Starting with very small amounts of any new food and gradually increasing the quantity as the child develops a liking.
 - Do not force feeding the infant. If a child dislikes a particular food remove it from his diet and reintroduce at a later stage.

Table 5: Weaning foods for infants

Infant's age	Foodstuffs	Form in which given	Amount to be given	Type of supplement
6 months	Fruit juices	Juice mixed with a little sugar	Start with 1 to 2 spoons and increase to about 30 to 50 ml	Liquid
	Green leafy vegetables	Soups in milk	Start with 1 to 2 spoons & increase to about 50ml	Liquid
6-7 months	Cereals	Cooked in water or milk	Cook about 2 tsp of cereal in a cup of milk or water, for example suji kheer,	Semi-solid
7 months	Egg yolk	Half boiled egg yolk	Start with ½ tsp and increase to 1 yolk	Semi-solid
	Starchy vegetables and fruits	Boiled and mashed potato with butter or milk, mashed banana with milk	Start with small amounts & increase to 40 to 50g	Semi-solid
7-8 months	Vegetables & pulses	Well cooked vegetables, thin khichri	Starting with small amounts, increase the quantity gradually	Semi-solid
10-12 months	Whole egg including the egg white	Soft boiled egg, scrambled egg, Custard.	One egg	Semi-solid
	Meat, vegetables, fruits	Well cooked, raw or cooked (chopped)	Starting with small amounts increase gradually	Solid

- Gradual introduction of different foods to make the infant get used to a variety of foods and flavours.

- Using bland/smooth textured low fibre foods with only salt as the seasoning. No spices or fried foods.
- Serving food at lukewarm or body temperature.
- Introduction of a new food when child is hungry.
- Use of salt (iodized) and sugar in moderation.
- Variety should be introduced in the child's diet to make it more appealing.
- Strict hygienic measures and cleanliness are critical in infant feeding.
- The meal frequency can be 5-7 feeds/day at 2 ½ to 3 hour intervals.

Planning of dietary regimes for old age

Aging is a continuous process that begins with conception and ends with death. It is an irreversible biological change that occurs throughout an individual's life. A number of physiological, biochemical and socio-psychological changes occur in old age which affect planning of nutrient needs.

- **Body composition** - With aging, a progressive decline in the water content and lean body mass is accompanied by an increasing proportion of body fat. The amount of collagen increases and it becomes more rigid; the skin loses its flexibility, the joints creak, and the back becomes bent.
- **Function of the gastrointestinal tract:** The senses of taste and smell are less acute in later years so that some of the pleasure derived from food is lost. Less saliva is secreted so that swallowing becomes more difficult. Because of tooth decay and periodontal disease more than half of persons over 70 years have lost some or all of their teeth. Consequently, these persons eat more soft, carbohydrate-rich foods that fail to provide adequate intakes of protein, minerals, vitamins and fiber.

Digestion is affected in a number of ways. Hiatus hernia leads to increased complaints of heartburn and intolerance to foods. A reduction of the tonus of the musculature of the stomach, small intestine, and colon leads to less motility so that the likelihood of abdominal distention from certain foods is greater, as well as the prevalence of constipation. The volume, acidity, and pepsin content of the gastric juice is sometimes reduced. In turn there is interference with the absorption of calcium, iron, zinc, and vitamin B₁₂. Fats are often poorly tolerated as they further retard gastric emptying. The pancreatic production of lipase is inadequate for satisfactory hydrolysis and chronic biliary impairment may reduce the production of bile or interfere with the flow of bile to the small intestine.

- **Cardiovascular and renal function** - The progressive accumulation of atheromatous plaques leads to narrowing of the lumen of the blood vessels and loss of elasticity. There is a decline in cardiac output, an increased resistance to the flow of blood, and a lessened capacity to respond to extra work. As the rate of blood flow is reduced, the absorption and distribution of nutrients is retarded. A reduced blood flow together with a smaller number of functioning nephrons lessens the glomerular filtration and the tubular reabsorption so that the excretion of waste and sometimes the return of nutrients to the circulation is less efficient.
- **BMR** - From age 40 years, the basal metabolism decreases about 5 percent for each decade owing to the increasing proportion of body fat and the lesser muscle tension. The

decline in basal metabolism is less in persons who remain healthy and pursue vigorous activity in their later years. The ability to maintain normal body temperature is also lessened, and hypothermia in the elderly can be especially dangerous.

- **Fat metabolism** - With increasing age the blood cholesterol and blood triglyceride levels gradually increase. The kind and amount of fat and carbohydrate in the diet, the degree of overweight, the stresses of life, and many other factors are believed to be responsible for these changes.
- **Decreased neuromuscular coordination** - As a result the holding of utensils and proper eating of food becomes difficult. This may lead to significant dietary changes and frequent nutritional inadequacies.
- **Socio-psychological factors** - These include loneliness, depression and social isolation which powerfully affect food intake. Upon retirement some elderly lose their sense of worth, some are neglected, live far away from children, have little desire to prepare meals, erratic eating habits, which perpetuates the mental depression.
- **Economic aspects** - Among many elderly individuals, financial constraints often limit their food intake leading to dietary inadequacies.

Nutrition Related Problems in Elderly

- **Obesity** - Very often the elderly fail to make adjustments in the energy intake for their decreased needs associated with a sedentary life style and lowered basal metabolic rate.
- **Under nutrition and malnutrition** due to various physiological and socio-psychological changes. Deficiencies of iron, folic acid and vitamin C are common.
- **Osteoporosis** characterized by a significant decrease in bone mass leading to easy fractures with prolonged healing time. This is more common in women.
- **Cardiovascular diseases** like hypertension, atherosclerosis, angina, myocardial infarction and congestive cardiac failure.
- **Diabetes**, perhaps due to decreased sensitivity of the cells to insulin.
- **Cancers** of the GIT, skin, lungs, prostate (men), breast and cervix (women).

Nutrient Needs and Recommended Dietary Allowances

Nutritional needs of the elderly are influenced not only by the present physical state and activity of the individual but also by the long standing food habits and many social, environmental, emotional and physiological stresses to which a person has been subject to throughout his life.

Energy - With the advancement of age beyond 30 years, energy requirements decrease. For computing the energy requirements for different age periods as in the case of adults, BMR factors for various activity levels are used. For the elderly, aged 60 years and above, the energy requirements for males and females with different body weights, engaged in sedentary activity are as follows:

**Table 6: Energy requirement of elderly males and females with different body weights
(Kcal/24 hr)**

Body Weight (kg)	Age 60 years and above (Sedentary Activity)	
	Males	Females
40	-	1544
45	1664	1624
50	1768	1704
55	1872	1784
60	1976	1864
65	2072	1944
70	2176	2024
75	2280	-

(Source : ICMR 1990)

Protein - In respect of protein requirements, values given for adult male and females have been retained, i.e., one gram per kg body weight.

Fats and Essential Fatty Acids (EFA) - These requirements for the aged have not been dealt with by ICMR. With the advancement of age, since the energy requirements are reduced, the requirement of energy giving nutrients i.e. carbohydrates and fats also need reduction.

Calcium and Phosphorous - Same level as adults, i.e., 400mg of calcium for both elderly men and women of all ages has been recommended.

Iron - Aging does not affect the iron needs of men and therefore, the same level, as for adult males has been recommended for the elderly. However, among women after menopause, i.e., around the ages of 45 to 50 years, menstrual losses of blood no longer take place. Hence, the iron needs of elderly women become quite similar to those of the elderly or adult men.

Vitamin A - Requirement of this vitamin is not affected by aging, therefore, the same levels as for adults, i.e., 600µg of retinol or 2,400 µg of β carotene can be considered adequate for elderly men and women of all ages.

Thiamine, Riboflavin and Niacin - Thiamine, riboflavin and niacin requirements are related to energy intake for all ages including the elderly. However, with the advancement of age, since the energy needs are reduced, there is a corresponding reduction in the total amounts of thiamine, riboflavin and niacin required by the aged.

Other B Group Vitamins - Just like adults, for the elderly of both the sexes, the daily recommended allowances for pyridoxine can be considered to be 2.0mg per day, for folic acid 100µg per day and for cyanocobalamin 1.0 µg per day.

Ascorbic acid (Vitamin C) - As for adults, a daily intake of 40mg of ascorbic acid has been recommended for the elderly by ICMR

Diet and Feeding Pattern

Since good nutrition is of immense significance during old age, care should be taken that the diets of the elderly are nutritionally adequate and well balanced. With the advancement of age, the energy needs are reduced, as a result the total quantum of food intake is lowered while the requirement of most of the other nutrients remains unaltered. Therefore, it becomes all the more important to provide adequate amounts of all the nutrients within the decreased energy levels. In addition to the general factors to be considered while planning balanced meals, other factors to be kept in mind include:

- Intake of energy rich foods like sweets, cereals and starches needs to be reduced while liberal amounts of milk and milk products, fresh fruits, vegetables particularly green leafy vegetables, should be included to meet the vitamin and mineral needs.
- Fried foods, foods rich in saturated fats should be avoided and instead oils containing high level of polyunsaturated fatty acid (PUFA) such as sunflower oil, soybean oil, etc., should be used to prevent and control the conditions of hypertension and other cardiovascular diseases. Similarly, the intake of simple sugars should be reduced as these provide only empty calories.
- An adequate intake of calcium, in particular, should be ensured to compensate for its losses due to gradual demineralization of bones associated with aging.
- Since sufficient exposure to sunshine is essential to meet the body's needs for vitamin D, in case of elderly individuals confined to bed, supplements of this vitamin need to be provided.
- Since dietary fibre has a beneficial effect in various conditions associated with aging such as constipation, diabetes and cardiovascular diseases, adequate amount of foods rich in dietary fibre should be included in the diet.
- Sense of smell and taste are less acute. Food should be palatable without excessive use of spices which are irritants.
- Swallowing may be difficult due to decreased secretion of saliva. So very dry meals should be avoided.
- With the advancement of age, the capacity to digest and tolerate large meals often decreases. Therefore, the quantity of food given at a time needs to be decreased. If required, the number of meals may be increased as per the individuals' tolerance.
- Due to the loss of teeth, particularly if dentures are not used, modifications in consistency need to be done. The diet should be soft, well cooked and should include foods that need little or no mastication such as milk and milk products, soft cooked eggs, tender meats, gruels, soft cooked vegetables, grated salad, fruit juices, soft fruits like banana or stewed fruits.
- The food for the elderly should be colorful and tasty, should be served in pleasant surroundings so as to arouse their interest in the food.
- Elderly should be advised to continue with their physical activity and light exercise to keep fit and prevent occurrence of diseases like arthritis, gout and obesity. Regular health checkups and weight monitoring also help in physical fitness and early detection of complications.

Table 7: Diet Plan for a 70-year-old man

Meal	Food Group	Amount(g)	Menu
Bed tea	Milk Sugar	25 5	Tea
Breakfast	Milk Meat Cereal Fruit Fat Sugar	125 40 40 100 5 7.5	Broken Wheat porridge Poached egg Toast with butter Apple
Mid-Morning	Milk Cereal Sugar	25 10 2.5	Tea Biscuits
Lunch	Milk Pulse Cereal Vegetable A Vegetable B Fruit Fat Sugar	125 30 70 100 100 100 10 7.5	Lentil Dal Palak Saag Salad Chappatis Fruit Custard
Tea	Milk Cereal VegetableB Fat Sugar	25 30 50 10 2.5	Vegetable Upma Tea
Dinner	Milk Pulse Cereal Vegetable A Vegetable B Fat	100 15 70 100 75 10	Lauki kofta curry Cauliflower and Potato (dry) Boondi Raita Grated Carrot Salad Rice/Chappati
Bed Time	Milk Sugar	150 2.5	Milk

Malnutrition

Malnutrition in its simplest sense “is an impairment of health resulting from a deficiency, excess or imbalance of nutrients”. It is “a state in which the physical function of an individual is

impaired to the point where he or she can no longer maintain adequate bodily performance processes such as growth, pregnancy, lactation, physical work, and resisting and recovering from disease.”

Existing literature amply illustrates that malnutrition predominates among the rural, tribal as well as the urban poor.

Malnutrition is usually indicated by growth failure. Malnourished children are shorter and lighter than they should be for their age.

Protein-Energy Malnutrition (PEM) is the most common form of malnutrition occurring among infants and young children. Mild PEM manifests itself mainly as poor physical growth, whereas individuals with severe PEM have high case fatality rates.

PEM covers a wide spectrum of pathological conditions, the extremes being ‘nutritional marasmus’ and ‘kwashiorkor’ and intermediate cases referred to as ‘marasmic kwashiorkor’.

Nutritional marasmus, occurring usually in children less than 1 year, is identifiable by severe weight loss or wasting, loss of subcutaneous fat and, absence of oedema, protuberant belly. Such children have good appetite, are quite often alert and if treated correctly have a good prognosis.

Kwashiorkor, generally present in the older child, is characterized by oedema, or fluid accumulation in the body, loss of appetite and mental changes resulting in a child who is apathetic and irritable. The hair is sparse, dispigmented with swollen cheeks giving a characteristic moonface appearance.

In addition to the malnutrition due to deficiency of macronutrients (energy, protein), micronutrient deficiency (Hidden hunger) is one of the most critical factors which needs to be dealt immediately along with overall control of malnutrition. Three micronutrient deficiencies are most common-due to lack of iron (anaemia), iodine (goiter and cretinism) and Vitamin A (xerophthalmia).

Causes of Malnutrition

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

Malnutrition is not synonymous with a lack of food. In an individual, malnutrition is the result of inadequate dietary intake, or infection, or a combination of both. These in turn derive from a combination of food, health, and care related causes at the household and community level. Severe malnutrition, especially, increases the incidence, duration, and severity of infectious disease. The most common types of disease suffered by young children are: diarrhea, acute respiratory infections, measles, and malaria. All of these conditions may contribute to malnutrition through loss of appetite, mal-absorption of nutrients, loss of nutrients through diarrhea or vomiting, or through an altered metabolism (which increases the body’s need for

nutrients). This vicious cycle in which disease and malnutrition exacerbate each other is known as “malnutrition-infection complex”.

Malnutrition, or the risk of becoming malnourished, may be transmitted from one generation to another. Small women give birth to small babies, who, in turn, are more likely to become small children, small adolescents and ultimately, small adults. While smallness may be genetically inherited, the vast majority of small individuals in most poor countries are small because they have suffered, or are currently suffering, from malnutrition. This is the intergenerational cycle of malnutrition and, hence, when considering approaches to combating malnutrition, it is important in the long-term to adopt a life-cycle approach

Priority should be to prevent malnutrition from occurring among the 6-24 month old children because:

- o growth failure cannot be significantly corrected later; and
- o consequences of malnutrition are most serious at this age.

Implications of Malnutrition

Malnutrition represents a massive drain on human and societal resources. It is a major obstacle of socio economic development. It has an immense impact on the health of the population (with high social and public costs), learning ability (with a vast loss of human potential) and productivity (with greatly reduced work capacity). These deficiencies contribute to a vicious cycle of malnutrition, underdevelopment and poverty affecting already under privileged groups.

Malnutrition not only blights the lives of families and individuals but also reduces the returns on investment in education and acts as a major barrier of social and economic progress.

Effect during Intrauterine Period, Infancy and Childhood

- Small for date (SFD) babies and low birth weight.
- Intrauterine growth retardation.
- Perinatal, infant and under 5 mortality.
- Direct effects of deficiency of vitamin A manifested as xerophthalmia, iron manifested an anaemia.
- Improper development of brain and defective neuro-integration leading to lowered motor and mental performance.
- Permanent effects on cognition and future productivity of children.

Effect on Pregnant and Lactating Women

- o High maternal mortality and morbidity.
- o Intrauterine and subsequent growth retardation of the foetus.
- o Osteomalacia, incapacitation and development of bony deformities.
- o Anaemias.
- o Proneness to infections.

Impact of Malnutrition on National Development

- o Reduced capacity for physical work.
- o Reduced mental efficiency.
- o Reduced potential of women.
- o Slower national economic growth.

Prevention of Malnutrition

The factors responsible for PEM are multiple and some act synergistically. All the causative factors are related to underdevelopment; they include poverty, lack of education, poor environmental sanitation and personal hygiene, qualitatively and quantitatively inadequate food supply, poor housing, too many children, insufficient spacing between births, poor distribution of food within the family, and a disrupted family life. Prevention of PEM must take all these factors into consideration.

A variety of nutrition intervention programmes have been launched by the government to combat both macro and micronutrient deficiency. These are:

- ICDS, which holistically addresses health, nutrition, and development, needs of young children, adolescent girls and pregnant and lactating mothers across the life cycle. This has a strong supplementary nutrition component to meet calorie/protein gap of 300 kcal, 8-10 g protein.
- Nutrient deficiency control programmes
 1. National programme for prevention of blindness due to vitamin A deficiency
 2. National anemia control programme (NACP)
 3. National iodine deficiency disorders control programme (NIDDCP)
- Mid day meal programme (MDM) organized by the department of Education not only to improve the nutritional status of school children (6-11 years) but also to improve school enrollment.

The 10th plan has chalked out focused and comprehensive interventions to prevent malnutrition and improve the nutritional and health status of the vulnerable groups. It envisages a paradigm shift from

- o Household food security and freedom from hunger to nutrition security for the family and individual.
- o Untargeted food supplementation to vulnerable groups to screening of all from these groups, identification of those with various grades of under nutrition and appropriate management.
- o Lack of focused interventions on prevention of over-nutrition to promotion of appropriate lifestyles and dietary intakes for prevention and management of over nutrition and obesity.

Intervention will be initiated to achieve:

- o Adequate availability of food stuffs by
 - Ensuring production of cereals, pulses and vegetables to meet the nutritional needs
 - Making them available at affordable cost throughout the year

- More cost effective and efficient targetting of PDS
- Improving people's purchasing power through appropriate programmes including food for work schemes.
 - o Prevention of under nutrition through nutrition education.
 - o Operationalizing universal screening of all pregnant women, infants, preschool and school children for under-nutrition.
 - o Operationalization of nutrition interventions for the management of undernutrition through
- Targeted food supplementation and health care
- Effective monitoring
- Utilizing Panchayati Raj Institutions for effective inter sectoral coordination and convergence of services.
 - o Prevention, early detection and appropriate management of micronutrient deficiencies.
 - o Promotion of appropriate dietary intake and lifestyles for prevention and management of obesity and diet related chronic diseases.
 - o Nutritional monitoring and surveillance.

The entire intervention strategies come under four major categories:

1. Dietary diversification.
2. Supplementation.
3. Food fortification.
4. Public health measures.

Strategies selected should be appropriate to the need, existing delivery mechanisms and available technologies. A combination of measures may be often needed. For elimination of micronutrient deficiencies supplementation and food fortification are commonly adopted. These could be either short term or long term.

Breastfeeding and complementary feeding

Breastfeeding is the optimal method of infant feeding and should be initiated as soon after delivery as possible. The many advantages of breast milk over other foods for early infant feeding and the hazards of artificial milks and bottle feeding, especially in developing countries, are well established. In developing countries beset by poverty and adverse living conditions, breastfeeding is vital for infant health. Because access to modern contraceptive methods may also be limited, breastfeeding plays an important role in child spacing, which benefits both maternal and child health. In addition, the purchase of imported milk products has a negative economic impact at both the household and national level. Thus, breastfeeding is the simple solution for the health risks and economic costs associated with formula feeding.

Breast milk is the preferred form of nutrition for all infants including those born preterm or otherwise ill. It provides almost all the necessary nutrients, growth factors and immunological components that a healthy term infant needs. Other advantages of breastfeeding include reduction of incidences and severity of infections; prevention of allergies; possible enhancement of cognitive development; and prevention of obesity, hypertension and insulin-dependent diabetes mellitus.

Breastfeeding offers numerous health benefits for the mother, including a decreased risk of cancers. Health gains for breastfeeding mothers include lactation amenorrhea, early involution of the uterus, enhanced bonding between the mother and the infant, and reduction in incidence of ovarian and breast cancer. From the economic perspective, breastfeeding is less expensive than formula feeding as formula feeds are highly priced and beyond the reach of a common man in developing countries.

Despite the many benefits of breastfeeding, a decline in its use in the past two decades had been observed throughout the world. Breastfeeding in developing countries is associated with lower income, lower social class and rural living. The greatest decline in breastfeeding had been amongst the urban elite mothers who had higher levels of education and more likely to be employed in the modern sector. In some societies, feeding infant formula is associated with being modern and progressive, whereas breastfeeding is regarded as 'primitive' and backward.

While breastfeeding is a natural act, it is also a learned behaviour. An extensive body of research has demonstrated that mothers and other caregivers require active support for establishing and sustaining appropriate breastfeeding practices. To promote, protect and support breastfeeding, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) in 1991, developed the Baby-Friendly Hospital Initiative (BFHI) with the aim of increasing rates of breastfeeding. "Baby-Friendly" is a designation a maternity site can receive by demonstrating to external assessors compliance with the Ten Steps to Successful Breastfeeding. The Ten Steps are a series of best practice standards describing a pattern of care where commonly found practices harmful to breastfeeding are replaced with evidence based practices proven to increase breastfeeding outcome. The BFHI has been implemented in about 16,000 hospitals in 171 countries and it has contributed to improving the establishment of exclusive breastfeeding world-wide.

After research established enough evidence on the advantages of exclusive breastfeeding, WHO and UNICEF recommend exclusive breast-feeding for the first 6 months of life. Thereafter infants should receive complementary foods and continued breastfeeding up to 2 years of age or beyond.

To enable mothers to establish and sustain exclusive breastfeeding for 6 months, WHO and UNICEF recommend:

- Initiation of breastfeeding within the first hour of life
- Exclusive breastfeeding – that is the infant only receives breastmilk without any additional food or drink, not even water
- Breastfeeding on demand – that is as often as the child wants, day and night
- No use of bottles, teats or pacifiers

The advantages of breastfeeding are many and the composition of breast milk is best suited for infant needs. The comparative approximate composition of colostrum, mature human milk, cow's milk and typical modern formula milk are given in Table 8.

Table 8: Approximate composition of colostrum, mature human milk, cow's milk and typical modern formula milk

	Colostrum	Human milk	Cows milk	Formula milk ¹
Energy (kJ/L)	- ²	2856	2730	2800
Protein (g/L)	100	9	31	15
Whey	840	600	200	210
Casein (G/kg TP) ³	160	300	800	789
Lactose (g/L)	53	70	49	72
Fat (g/L)	32	42	38	36
Poly and Mono unsaturated FA (g/kg total FA)	590	470	250	498
Sodium	21	6.5	20	10
Chloride mM	17	12	30	15
Calcium mM	8	9	30	16.5
Phosphorus mM	5	5	30	14.5
Vitamin A (µg/L) ⁴	1260	600	540	600
Iron (µM)	28	12.5	9	12.5
Vitamin C (mg/L)	70	38	10	80
Vitamin D ((µg/L)	18	0.4	0.3	10

¹Adapted from Poskitt, 1994

²Energy content difficult to measure because much of protein is not absorbed

³Total protein

⁴1 mg retinal equals 1 retinol equivalent

Protein

The amino acid composition of human whey is different to that of cows milk. Cows' milk-based formulas, in which the total protein and whey content have been modified to be similar to human milk, still have a different overall amino acid composition.

Human milk whey protein is predominantly α -lactalbumin, lactoferrin, secretory immunoglobulin (sIgA) and enzymes, especially lysozyme and bile-stimulated lipase. α -lactalbumin binds calcium and may increase its bioavailability. The immunological functions of breast milk including the protective roles of sIgA, have been known for some time. Convincing epidemiological data shows that the risk of dying from diarrhoea in developing countries is reduced 14-24 times in breastfed infants. By mechanisms which are still unclear, evidence also

suggests that breastfeeding promotes post-natal development of secretory immunity and enhanced secretory as well as systemic immune response to oral and parenteral vaccines.

Cows' milk whey proteins are mainly lactoglobulins, β -lactoglobulin is one of the proteins responsible for cows' milk-protein intolerance. Cows' milk-protein intolerance is now more widely recognized, but whether this is a real increase in prevalence or due to higher concentrations of β -lactoglobulin in modern formula, better diagnosis of the disease or some other factor is not known.

Carbohydrate

Lactose is the predominant carbohydrate in both human and cows' milk. The presence of lactose in milks facilitates calcium and magnesium absorption, however the reason why is not clear. The lactose contents of human milk is higher than that of cows' milk, however the lack of facilitated absorption of calcium with cows' milk may be overcome by the overall higher levels of calcium in cows' milk.

Modern formulas do have added carbohydrate which may be lactose and/or other carbohydrates, to increase their energy content.

Fat

Human milk contains the essential fatty acids, linoleic acid (18:2 n-6) and linolenic acid (18:3 n-3) and the very-chain polyunsaturated fatty acids (PUFA), arachidonic acid (20:4 n-6), eicosapentanoic acid (EPA) (20:5 n-3), and docosahexanoic acid (DHA) (22:6 n-3). Linoleic and linolenic acids are not inter-convertible and are the parents of the n-3 and n-6 series of fatty acids. They play important roles in providing PUFA, which act as components of cellular membranes and are particularly important in eye and brain development. They are also precursors of other metabolites such as prostacyclins and prostaglandins. Cows' milk contains more saturated fat than human milk, less of the essential fatty acids and no PUFA.

Human milk has high levels of cholesterol (100-159 mg/L). It is speculated that giving infants high dietary cholesterol early in life equips them for metabolizing cholesterol efficiently, thus reducing the risks of hypercholesterolaemia and arteriosclerosis in later life.

Carnitine is absent from cows' milk but present in high concentrations in human milk. Newborn infants can synthesize carnitine, but when growth and fat deposition are rapid it is possible that endogenous carnitine synthesis may limit rates of metabolism. Lower levels of plasma carnitine have been found in normal full-term formula-fed infants but no clinical effects have been identified.

Vitamins

Breast milk provides an adequate source of vitamins. However, differences in the composition of milk from the left and right breast, differences in the fore and hind milks, diurnal and seasonal variation as well as the stage of lactation may all introduce variation into the estimated vitamin concentration. Other problems include vitamin stability, for example vitamin C and riboflavin and method of extraction and detection, for example folate and vitamin A. Of greatest practical

importance is the bioavailability of vitamins in breast milk. A major determinant of bioavailability is the efficiency of absorption, which can be affected by factors such as current nutrient status, nutrient digestion and gastrointestinal integrity. There are virtually no comparative studies of the bioavailability of vitamins in formulas and human milk but there are some *in vitro* data that suggest there may be differences for some vitamins.

Table 9 summarizes the range of concentrations of vitamins in formula for term infants (0-6 months) compared to levels in breast milk.

Table 9: Range of concentrations of vitamins in formula for term infants from birth to 6 months compared to levels in human milk

Vitamin	Formula/L	Human milk/L
Thiamin (mg)	0.39-1	0.14-0.28
Riboflavin (vitamin B ₂) (mg)	0.53-1.5	0.4-2.87 ³
Niacin (mg)	3.4-9	1.8-3.9
Pyridoxine (vitamin B ₆) (mg)	0.33-0.65	0.23-0.4
Folic acid (µg)	33-110	30-137
Vitamin B ₁₂ (µg)	0.33-2.2	0.23-1.8
Ascorbic acid (vitamin C)(mg)	66-90	33-110
Pantothenic acid (mg)	2-4	2.6
Biotin (µg)	10-20	5.2
Vitamin A (mg retinal equivalents (RE)	0.6-1	0.49-0.77
Vitamin E (mg α-tocopherol equivalents)	4.6-10	1.1-8
Vitamin D (µg)	10-11	13-17
Vitamin K (µg)	26-100	13-130

(Source: *Nutrition in the infant: Problems and practical procedure*, ed Pready V, Grimble G and Watson R ; Greenwich Media Ltd, London)

Minerals and Trace Elements

In the manufacture of demineralized whey, the concentration of the minerals and trace elements are reduced to very low levels and these are subsequently adjusted to levels which are close to human milk. All infants formulas have higher levels of iron to compensate for the relatively poor absorption of iron compared to that from human milk . Lactoferrin is a major iron-binding protein in human milk and is thought to facilitate iron absorption. Not all trace elements reach levels found in human milk (e.g., zinc and selenium), and absorption may also be reduced where

they are present in bound forms. Table 10 gives a summary of typical concentrations of minerals and trace elements found in casein-based formula.

Table 10: Example of the mineral and trace element content of casein-based infant formula

Minerals/trace elements	Per 100 ml prepared formula
Sodium (mg)	25
Calcium (mg)	76
Phosphorus (mg)	46
Iron (mg)	0.7
Magnesium (mg)	8
Zinc (mg)	0.5
Iodine (µg)	9.1
Potassium (mg)	97
Chloride (mg)	63
Copper (µg)	30
Manganese (µg)	8

Although concentrations of minerals in formula are adjusted to the requirements of the infant, there are other factors that determine absorption and bioavailability and all these may not be available to the infant.

Thus, breastfeeding is an unequalled way of providing food for a healthy growth and development of an infant and must be encouraged under all circumstances. Our aim should be to revitalize efforts to promote, protect and support appropriate infant and young child feeding since infant and young child feeding are a cornerstone of care for childhood development. World-wide about 30% of children under five are stunted as a consequence of poor feeding and repeated infections. Even in resource poor settings, improved feeding practices can lead to improved intakes of energy and nutrients, leading to better nutritional status so our endeavour should be to encourage breastfeeding.

Suggested Readings

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