UNIT 17 SPORTS NUTRITION

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17.1 INTRODUCTION

By the time you are ready to do this unit, you have been exposed to a good deal of the basic knowledge of nutrition. We know that nutritional requirements vary according to age, sex and physical activity but would you like to know how much extra is needed for an athletic performance? Can the type of food we eat alter our endurance, strength and speed of performance? Do our carbohydrate, protein, fluid, vitamin and mineral requirements differ according to the kind of sport we want to engage in? When is the best time to eat and drink before the competition? What kind of foods to be consumed? Have you heard of ergogenic aids? Are you interested in learning about ergogenic aids and supplements?

In this unit, you shall learn about the application of nutrition knowledge in the field of sports and exercise. Also, we shall learn about body composition and the various ways of assessing it.

In this unit, we shall learn what kind of diet a sports person or an athlete should consume. Different types of sports differ in intensity and training; therefore, dietary requirements also differ from sport to sport. Further, we shall also learn about the general principles which should be followed as pre-game meal plan and post-game meal plan.

Monitoring body composition is equally important for athletes and non-athletes. In this unit, we shall also learn about what we mean by body composition and what are the various ways to assess body composition?

'Physical fitness' is the term we hear or use so many times. Here we shall learn about the scientific meaning of being physically fit and the components which need to be measured to declare a person physically fit or unfit.

Further, to enhance physical performance certain dietary or synthetic substances are ingested which are called ergogenic aids. We would learn about these substances, their ergogenic potential and psychological and physiological effects.

Objectives

After studying this unit, you will be able to:

- describe sports nutrition as a discipline evolved with integration of various subjects like exercise physiology, medicine, physical anthropology with nutrition,
- explain the basic principles of sports nutrition,
- apply nutritional recommendations to the needs of strength/power and endurance athletes and exercise in general,
- utilize appropriate tests for measurement of body composition and work capacity,
- identify, define and test various components of physical fitness, and
- discuss pros and cons of using nutritional ergogenic aids.

Let us first understand what we mean by sports nutrition.

17.2 WHAT IS SPORTS NUTRITION?

Sports nutrition is *a discipline which applies principles derived not only from nutritional but also biochemical and physiological scientific knowledge for the purpose of promoting optimal performance while remaining healthy*. As you read on, you will realize that sports nutrition blends knowledge from different fields like biochemistry, exercise physiology, physical anthropology etc.

Before we talk about sports nutrition and its components, it is very important to understand that sports nutrition does not restrict itself exclusively to sports, but also applies its principles to exercise in general. Let us be clear that times have changed and almost everybody today is concerned about health, fitness and longevity. Therefore, the goal of sports nutrition is not only to enhance performance of athletes but also to widen its scope for non-athletes by providing good health and physical fitness for all individuals.

Health and physical fitness centres are mushrooming. As you must have noticed, there is a gym at every nook and corner and people from all walks of life are joining them. There is a die hard competition amongst these centres to provide state of the art services to load muscles and burn off excess fat. Understanding of sports nutrition is essential to make these programmes successful.

If we talk about sports today, it is becoming increasingly competitive. More and more stress is being placed on how well one performs and wins medals. Along with training and motivation, adequate diet is equally important component for an athlete. Mere good nutrition may not generate good athletes but inadequate nutrition would reduce the ability of an athlete to play to his maximum potential. Without the right food, even physical conditioning and expert coaching are not enough to achieve the best results.

Let us next focus on how sports nutrition evolved and grew as a discipline.

17.3 EVOLUTION AND GROWTH OF SPORTS NUTRITION AS A DISCIPLINE

An academic discipline is basically *a formal body of knowledge discovered, developed, and disseminated through scholarly research and inquiry.*

Characteristics of an Academic Discipline

An academic discipline has:

- a body of knowledge,

- a conceptual framework,
- procedures and methods of inquiry, and
- both the process of discovery and the end result.

The concept of sports nutrition was evolved fundamentally with integration of different disciplines in order to collectively strive for a higher standard of care and education for counseling athletes. In this field, you will find connection between various disciplines of medicine, physiology, exercise, physical anthropology, nutrition and biochemistry. Time and again, it has been suggested that the name of this discipline be changed to exercise nutrition in place of sports nutrition, as the term exercise includes more than the word sports.

Although the quest of nutrition as applied to exercise and sports dates back to ancient civilizations and important discoveries in fields of chemistry, exercise, metabolism, nutrition and physiology are being made over past two millennia, it is unfortunate that no university or college is imparting a graduate degree or diploma in sports or exercise nutrition. Some Universities or Colleges offer sports nutrition as a subject or at some places it is offered merely as a chapter in the subject with the degree or diploma in physical education, sports science or dietetics.

The search for right kind of food for exercise and sports, building strength and endurance has been an ancient phenomenon. Initially, it seems that the only sportsmen who took nutrition seriously were the *body-builders*. They were years ahead of other athletes in their regard of nutrition and how it can affect performance. However, other sports caught up later. Now, in activities such as football, athletics, swimming, tennis and most others, nutrition is assuming the same importance as training.

Over the past fifty years, the biggest breakthrough was the discovery of how to load glycogen and sophistication in the methods of glycogen loading. Nitrogen balance studies also demonstrated a slight increase in the needs for athletes as compared to the non athlete. Past two decades were most exciting in the advancement of sports nutrition. The areas of growth also included evaluating the effects of exercise on protein utilization, thus the overall protein needs, meal timings to maximize the anabolic response. Newer, more reliable methodologies of body composition assessment, physical fitness assessment have given a helping hand in recommending nutrient intake and dietary recommendations. However, a lot of research still needs to be done in the areas of assessment of dietary needs for athletes engaged in different sports and recommendations of their dietary and nutrient intake.

17.4 ANTHROPOMETRIC AND PHYSIOLOGICAL MEASUREMENT

Various physiological and anthropometric measurements give us an indication of the present status of an individual based on which training and diet intervention programmes may be planned. Further, these form the basis of talent identification for various sports. Details of body composition and work capacity assessment have been discussed below. Let us proceed with our discussion.

Body Composition

You might have read in previous units that our body weight is composed of muscle, bone and fat. Segregating these components of body weight into different compartments gives an idea of body composition. Broadly, we can classify body composition into two components: the *fat mass* (FM) *and the fat free mass* (FFM). The fat free mass includes muscle, bone and water. The fat mass includes all of the fat stores in the body.

Two persons weighing 60 kg may differ in their body composition. One might have a higher percentage of body fat while the other may have a higher fat free mass.

It is the fat mass which is generally viewed with a negative image because of its detrimental effects on health and performance and efforts have been made to lay down normal levels of fat in the body. The average fat content of the body is 15% for men and 25% for women with a wider range of normal fatness, 10-25% for men and 18-32% for women. The body fat can be further categorized as essential fat, storage fat and non-essential fat.

For the body to function normally, certain amount of body fat is required. This is called *essential fat*. For women, average amount of essential fat is 12% and for men, it is 3% of the body weight. *Storage fat* consists mainly of fat deposited just under the skin or subcutaneous fat. For the average man, 12% of body weight is storage fat and for the average woman, 15% of bodyweight is storage fat. The third category of fats is the *non-essential fat,* which serves no purpose and may be harmful to health.

Thus, assessment of fat mass in general population can add to our understanding of energy metabolism and disease processes. Research has shown that an excessive body fat is associated with hypertension, elevated cholesterol and blood lipid levels, higher cardiovascular and diabetes risk factors. Also, there are strong chances of osteoarthritis and reduced balance and co-ordination with high body fat mass.

Effective nutrition and exercise intervention strategies can be planned to control FM and prevent loss of FFM associated with conditions such as malnutrition, ageing, injury etc. (also see section 17.6)

Importance of body composition assessment in athletes

Body composition and weight are two of the many factors that contribute to optimal exercise performance. Body weight can influence athlete's speed, endurance (stamina) and strength (power) whereas body composition can affect athlete's strength, agility (co-ordinating ability) and appearance. Low body fat percentages are often emphasized within many sports. However, too little body fat results in deterioration of health and performance. Thus, the primary reason for determining an athlete's body composition is to obtain information that may be beneficial in improving athletic performance. Body composition assessment is generally done in sports and exercise for the following reasons:

1) It can serve as the basis for interventions, such as training or diet.
2) It can act as a health screen.
3) It can be useful in identification of ideal physique for talent search within specific sports in which physique is likely to influence performance (morphological optimization). Specific parameters which may influence exercise performance, depending on the sport. For example, height matters in basketball and two athletes of similar body weight; one having higher body fat percentage may be good for swimming and the other one for athletic events.
4) It can determine healthy body weights for athletes. Optimal competitive body weight and relative fatness should be determined when an athlete is performing at his best.

Percentages of body fat values for athletes vary depending on the sex of the athlete and the sport itself. Male athletes participating in middle-distance and long-distance events and bodybuilders generally have the lowest body fat% (less than 6%), whereas male basketball players, cyclists, gymnasts, sprinters, jumpers and wrestlers average between 6% to 15% body fat. Male athletes involved in power sports such as football and hockey have slightly more variable body fat levels (6% to 19%). Female athletes

with the lowest body fat (6% to 15%) participate in body building, cycling, and running events; higher fat levels are found in female athletes participating in swimming, tennis and volleyball (10% to 20%).

Athletes should understand that they can perform well if they have the desired body fat% for their specific sport. In an attempt to attain body fat levels that are inappropriate, or have body-fat percentages below the minimal levels, they may adopt dangerous dieting pattern. Thus, they may be at risk for an eating disorder (anorexia or bulimia) or other health problems related to poor energy and nutrient intakes.

Having read about body conposition and its importance for assessment in athletes, next let us focus on the techniques we can use for measuring body composition.

17.4.1 Various Techniques for Measuring Body Composition

To study body composition, the body mass is subdivided into two or more compartments. Methods for assessment of body composition are based on either a 2-component or a multi-component model. Let us discuss in details about these models.

The Two-Compartment Model (2-C): The simplest body composition model, called the two-compartment (2-C) model, assumes that body weight (BW) can be divided into fat mass (FM) and fat-free mass (FFM), as illustrated in Figure 17.1

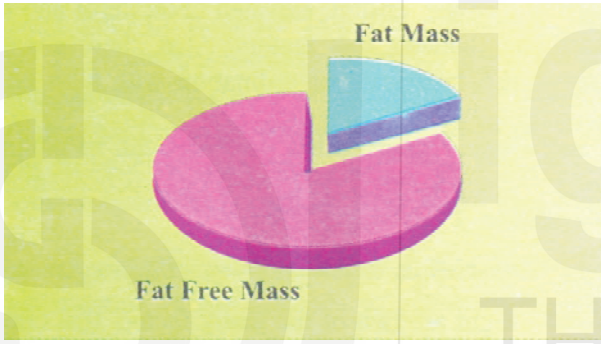


Figure 17.1: Two compartment model

It is relatively easy to obtain. The direct measurement of fat mass (FM) is not easy and remains a significant challenge for most body composition techniques. The alternative approach is to measure fat free mass (FFM), and then calculate FM as body weight minus FFM (FM = BW – FFM).

Two-component models, developed by *Siri* (1961) and *Brozek et al* (1963) have been widely used to acquire reference measures of body composition and to validate body composition field methods and prediction equations. The Siri two-component model assumes the following:

1) the densities of fat (0.901 g/cc) and the FFM (1.10 g/cc) are similar for all individuals,
2) the densities and relative proportions of water, protein and mineral components in the FFM are constant for all individuals, and
3) individuals differ from the "reference" body only in the amount of fat.

Using these assumed proportions and their respective densities, *Siri* developed a conversion formula to estimate percentage of body fat% (BF%) from total body density (Db):

$$BF\% = [(4.95/Db) - 4.50] \times 100$$

The *Brozek et al.* (1963) two-component model conversion formula is based on a reference body with a specified total Db and assumes slightly different values for the density of fat (0.88876 g/cc) and the FFM (1.10333 g/cc):

$$BF\% = [(4.57/Db) - 4.142] \times 100$$

These two conversion formulas yield similar BF% estimates (within 0.5 to 1.0 BF%) for total body density (Db) ranging from 1.0300 to 1.0900 g/cc.

The Multi-Compartment Model (*M-C*): The multi-compartment model divides the body into fat, water, protein and mineral, as you can see in Figure 17.2.

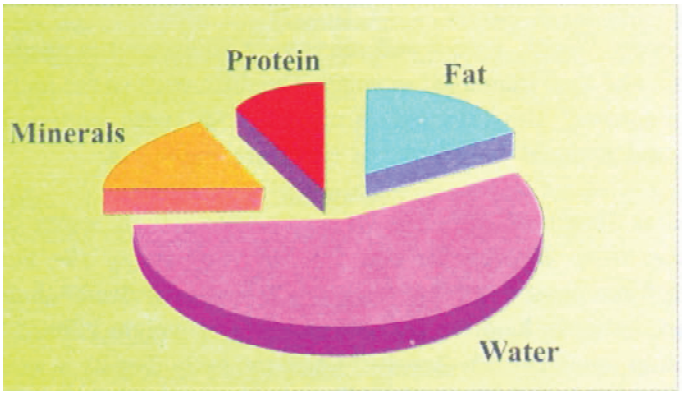


Figure 17.2: Multi compartment model

Three components are measured and the fourth i.e. fat is estimated. It provides a more accurate assessment of body composition. Hence, several measurements are made in combination to estimate body composition. These may be 3-C (three compartment) or 4-C (four compartment) models. In 3-C, two compartments are measured using two different methods and FM is calculated. Similarly in 4-C, three compartments are measured and FM is computed. These methods may include:

- body density based on underwater weighing (UWW),
- counting of gamma rays emitted from the body to derive total body potassium (TBK), and
- isotope dilution for the measurement of total body water (TBW).

Some of these methods can only be used in laboratory settings and require elaborate equipment. While some can be used in the field using portable equipments. However, field methods need to be standardized against more reliable methods in laboratory settings. Given herewith is the list of selected methods of body composition assessment:

- Total Body Potassium (TBK)
- Underwater Weighing (UWW)
- Air Displacement Plethysmography (ADP)
- Total Body Water Measurement (TBW): Isolope Dilution Method
- Dual Energy X-Ray Absorptiometry (DEXA)
- Bioelectrical Impedance Analysis (BIA)
- Skinfolds Thickness (SFT)
- Girth Measurements
- Body Mass Index (BMI)
- Anthropometric Indices (AI)

Let us review a few of these body composition assessment methods.

A) ***Underwater Weighing***

Underwater weighing or hydrostatic weighing is one of the most common body composition methods used in laboratory settings. It is based on densitometry i.e. the measurement of total body density (Db) and the estimation of body composition from

Db. Db is *the ratio of body mass to body volume* (BV); BV is measured by either water displacement or air displacement. The water displacement method, known as *hydro densitometry* or *hydrostatic weighing*, has been considered as a gold standard method because it gives a relatively small technical error in the measurement of body density.

To measure body density, a pool and measuring equipment is needed. The subject is weighed in air, and then immersed in water. The difference in the upthrust displacement by water is measured. Thus, the values of total body mass, underwater weight, water temperature and residual lung volume (RV) are measured.

This method is based on *Archimedes's principle* which states that *a submerged object is buoyed up by a force equal to the volume of the water it displaces*. This buoyant force causes the object to weigh less underwater than it does on land. The difference between land weight and underwater weight is used to calculate body volume and subsequently body density. Once the body density is measured, this value must be converted into body fat percentage using *Siri equation* (discussed above with 2-C model).

Hydrostatic weighing or underwater weighing requires considerable subject cooperation given that multiple trials need to be performed in order to obtain an accurate estimate of underwater weight. Let us get to know about these requirements.

Requirements:

- The equipment required to perform hydrostatic measurements is bulky and maintenance intense.
- A large tank of water, usually 1000 gallons, must be maintained at a constant temperature.
- Equipment to measure residual lung volume must be utilized.
- Calibrated autopsy scale or its electronic equivalent, connected to an underwater chair is also required.
- Test subjects are asked to exhale as much air as possible from their lungs and be immersed for 10 to 15 seconds for an underwater weight measurement to be taken. This procedure is repeated 7 to 10 times. Total test procedures may require 45 minutes to one hour.

Fear of immersion, fear of infection, obesity and infirmity are barriers to the hydrostatic measurement of accurate body composition analysis. There are also certain limitations, as well as, certain advantages of this method. Let us get to know about these.

Limitations:

- This method is expensive, time consuming and usually requires a lot of equipment and space.
- The subject needs to be totally submerged underwater and exhale all of the air from the lungs. This can be difficult for the subjects.
- Requires considerable subject co-operation given that multiple trials needed to obtain accurate estimate of underwater weight.
- Being submerged under water may be difficult and produce anxiety for some.
- Density of FFM assumed may vary if bone density is altered as in the case of elderly or certain disease conditions.

Advantages:

- This method is currently considered the "gold standard" in percent body fat measurement (with the coming up of DEXA, the debates are still on).

- Repeat measures usually prove consistent, and can be used to chart progress.
- Air Displacement Plethysmography (ADP)

Since the major drawbacks with UWW method are that the subject needs to be totally submerged underwater and exhale all of the air in his lungs, body volume and body density can be measured by Air Displacement Plethysmography (ADP) as an alternative. For this measurement, the subject sits in an air-filled chamber, which is attached to a reference chamber of a known volume. The subject's residual lung volume can be measured while in the chamber.

The major advantage of ADP is that the subject does not have to be submerged underwater, and it takes only a few minutes to complete.

At present, there is only one commercially available ADP instrument, called the *Bod Pod* and its software is still based on the 2-C model. The ADP technique is rapidly replacing the UWW approach as the preferred method for the measurement of body density.

B) ***Total Body Potassium (TBK)***

Potassium in the body is an index of body's total cell mass. A gamma counter measures the amount of a type of potassium which is assumed to be a proportion of FFM. The person lies on a bed for 15 minutes. Special detectors, above and below the bed, pick up and measure the naturally-occurring gamma signals that are emitted from the body. The equations are complex and the method is impractical and costly.

C) ***Dual Energy X-ray Absorptiometry (DEXA)***

Dual energy X-ray absorptiometry (DEXA) is a relatively new technology that is being identified as a reference method for body composition analysis. This method is based on three-compartment model that divides the body into total-body mineral, mineral-free lean and fat tissue masses.

A device emits X-rays at two different energy levels and a detector measures the reduction of energy through the body. From this, bone density and soft tissue can be calculated. The values of body fat mass and lean tissue can be estimated. DEXA provides segmental and regional measures of body composition. This method can also be used for showing distribution of fat on the body.

This is a very accurate and reproducible method, has good relationship correlation with other methods. DEXA is an alternative to hydro densitometry (UWW) as a reference method because it is rapid (a total body scan takes 20 minutes), safe, requires minimal subject cooperation and takes into account inter individual variability in bone mineral content.

D) ***Isotope Dilution Method***

The measurement of total body water (TBW) is based on the principle of *hydrometry*. You must be aware that water is the most abundant substance in the body accounting for 67% to 74% of the body's weight. The amount of water contained in cells varies with different types of tissues. Adipose tissues contain less water than do muscle cells, if one assumes that the distribution of water in fat and fat free tissues is consistent among individuals. The fat% can be estimated by measuring volume of water contained in the body.

This method assumes that the distribution and exchange of the isotope by the body are similar to the distribution and exchange of water. The subjects are given to drink deuterium or tritium. Deuterium is a rare, non-radioactive isotope of hydrogen and tritium is a rare, radioactive isotope of hydrogen. After approximately 3 hours of ingestion of isotope, a urine or blood sample is taken. The amount of isotope contained

in the sample is inversely proportional to the amount of water in the body, total body water is measured. The concentration of hydrogen isotopes (deuterium or tritium) in biological fluids (saliva, plasma and urine) is measured and used to estimate TBW.

In this method, it is also assumed that the hydration of the FFM is constant for all individuals (~ 73% of FFM). Because TBW fluctuates widely within and among individuals depending on age, gender, level of obesity, and disease, large errors may result when hydrometry is used with the two-compartment model to derive reference measures of body composition. Thus, there are potential sources of error, it's expensive and again it is not very practical. Moreover, technical expertise is required.

E) ***Bioelectrical Impedance Analysis (BIA)***

The difficulty of measuring total body water (TBW) by Isotope Dilution Method led to the search of Bioelectrical Impedance Analysis (BIA). The technique is based on the assumption that tissues that are high in water content will conduct electrical currents with less resistance than those with little water. Adipose tissue contains little water and is a relatively poor conductor of electricity, therefore, fat will impede the flow of electrical current. Fat-free tissue is a better conductor of an electrical current (contains water and electrolytes) than fat tissue. An electric current is passed through the body and, with equations, FFM and fat can be calculated. The resistance to current flow is inversely related to FFM. BIA and its accuracy is dependent on apparatus and valid choice of prediction equation used.

The BIA technique is considered to be a secondary measurement because it must be calibrated using a reference technique such as deuterium dilution for TBW. The increasing popularity of this technology can be attributed, in part, to the low cost of the instruments, their simplicity of operation and the high reproducibility obtained for the individual.

Bioelectrical impedance analysis (BIA) is a rapid, non-invasive and relatively inexpensive method for evaluating body composition in field or clinical settings. BIA method is preferred for the following reasons:

a) the method does not require a high degree of technical skill,

b) the method is more comfortable,

c) the subjects are not required to be given many instructions, and

c) this method can be used to estimate body composition of obese individuals.

Many bio impedance analyzers are available in the market which are less expensive, easy to use and portable equipments. The *Tanita analyzer* measures lower-body resistance between the right and left legs as the individual stands on the electrode plates. The *Body Stat* is another analyzer available which measures whole the body resistance. However, the validity and applicability of their prediction equations for diverse subgroups of the population needs to be looked into.

F) ***Anthropometry***

Anthropometry refers to the *measurement of the size and proportions of the human body*. Anthropometric prediction equations estimate body density, percent body fat (%BF) or FFM from combinations of body weight, standing height, skeletal diameters and circumference measures. These anthropometric techniques are relatively simple and inexpensive. The accuracy and precision of anthropometric measures, however, are affected by technician's skill. Therefore, standardized procedures should be strictly followed for locating measurement sites, positioning the skeletal anthropometer and tape measure and applying tension during the measurement.

The use of anthropomorphic girth (circumference) measurements also is a quick, easy and inexpensive method to estimate body composition. Using a standard calibrated

tape, girth and length measurements are taken from the body. The methodology is based on the assumption that body fat is distributed at various sites on the body such as the waist, neck and thigh. Muscle tissue, on the other hand, is usually located at anatomical locations such as the biceps, forearm and calf. The subjects' weight, height, girth size and ratios of various site comparisons are utilized in the calculations of percent body fat.

G) ***Skin Fold Thickness (SFT)***

Skinfold measurement is the most widely used field method of body composition assessment. The skinfold (SKF) is an indirect measure of the thickness of subcutaneous adipose tissue at a specified site. Most SKF equations use two or more SKF measurements to predict either body density (Db) or BF%. This method assumes that the thickness of the subcutaneous adipose tissue is proportional to the total amount of fat throughout the body. Equations for predicting fat mass from skinfolds have been developed.

A set of callipers is used to measure the skin folds at various sites on the body, most commonly triceps, biceps, subscapular and suprailiac. The 4 sites are summed and using logarithms, there is a linear relationship with total body density, age and gender specific. There are reference levels based on *Durnin* and *Wormesley* (1974) equations. These equations correlated well with the levels measured with under water weighing.

The accuracy and precision of SKF measurements is highly dependent on technician skill and type of SKF calliper. One needs to spend a lot of time and practice hard to develop skill as a SKF technician, and standardized procedures must be carefully followed.

SFT is an easy, quick, widely used and precise method. Thus, it is possibly the most useful measure of BF% in field. This is a convenient and only moderately invasive method of measuring BF%. Callipers are easily available.

One limitation is that the assessor needs to be experienced, as the exact location of the skin fold measurement needs to be consistent.

The obese population represents limitations for skin fold measurements. Skin fold callipers cannot open wide enough to measure the total fat thickness, thus tends to grossly under estimate body fat percentage in the obese population.

H) ***Body Mass Index (BMI) or Quetelet Index***

BMI is an *index measure of body fat used for the assessment of disease risk.* It is a figure which gives an indication of weight for height calculated by the equation:

$$\text{BMI} = \frac{\text{weight (in kilograms)}}{\text{height (in metres)}^2}$$

Thus, BMI is measured in kg/m^2. This index is simple, correlates to fatness, and applies to both men and women. *Garrow* and *Webster* (1985) proposed grades of obesity, as indicated in the Table 17.1.

Table 17.1: Grades of obesity based on BMI

	BMI
Underweight	< 19
Normal	19 - 24.9
Grade 1 (overweight)	25 - 29.9
Grade 2 (obese)	30 - 39.9
Grade 3 (morbidly obese)	> 40

BMI only indicates the degree of being over- or underweight. It makes no account for the distribution of obesity; indeed, where fat is distributed on the body, it has been linked to an increased risk of certain diseases. BMI is more reliable for assessing disease risk (such as cardiovascular diseases) when used in conjunction with waist-hip ratio (WHR).

$$\text{WHR} = \frac{\text{waist circumference (cm)}}{\text{hip circumference (cm)}}$$

WHR<1 — gynoid deposition of fat (pear shaped) and reduced risk of diseases

WHR >1 — android deposition of fat (apple shaped) and increased risk of diseases

BMI does not take into account skeletal size, amount of body water and, for the bodybuilder, muscle mass. Using the BMI scale in bodybuilding puts most as 'overweight' and in many cases 'obese', even if there is very low body fat. However, it is a simple, quick method which correlates to fatness and applies to both men and women.

With this, we end our study of body compositon assessment methods. Next, we shall focus on work capacity.

17.4.2 Work Capacity

There are generally two areas of work capacity that is relevant to sports nutrition; one is aerobic capacity and the other is endurance capacity.

Now first let us understand what is *aerobic capacity*? *The capacity to work at maximum exertion levels* is known as the *aerobic capacity* and is usually measured by oxygen uptake at a point at which the subject has achieved a level of maximum exertion or is completely exhausted. Thus, aerobic capacity is the ability to perform maximal physical work or to work up to one's maximal potential. Each individual has many different capacities such as aerobic and anaerobic, neuromuscular and functional capacity. In practice, aerobic work capacity (VO_2 max) is the capacity most often considered. It is basically a measure of the individual's capacity for work at maximum exertion levels. The most commonly used equipment to measure this capacity is the *tread mill*.

The other capacity of relevance is the *endurance capacity* which means *maximum length of time for which a submaximal work load can be sustained*. Let us understand the meaning of 'Endurance', the word which will be referred to frequently in the discussion ahead. 'Endurance' can be defined as *the maximum time an individual can carry on a particular sub maximal workload* or in other terms, it is usually defined as *percentage of his/her maximum oxygen consumption* (% VO_2 max) or in simpler words, it is the *stamina*.

You might know that during most of the exercises, the body is dependent upon oxygen to provide energy. Oxygen is extracted from inhaled air by the lungs, and is transported via blood to working muscles. As the level of exercise increases, there is a corresponding increase in the demand for oxygen by the muscles.

An individual's maximal aerobic capacity or VO_2 max is the maximum amount of oxygen that can be extracted from the air breathed in, and transported to the working muscles. It is usually measured in millilitres of oxygen per kilogram of body weight per minute (ml/kg/min).

You might have come across terms like aerobic exercises and anaerobic exercises. Let us here understand what these exercises are. We shall begin our discussion with aerobic exercises.

- *Aerobic Exercise or Aerobic Energy System*

To produce necessary energy, the body uses an aerobic pathway and an anaerobic pathway. *Exercise that relies heavily on oxygen for the provision of energy* (Aerobic pathway, Citric Acid Cycle) *is called an aerobic exercise*. These are generally exercises like running, swimming etc. For better performance, high VO_2 max is desirable. Athletes with a high VO_2 max maintain high intensity exercise using aerobic metabolism, thus avoid high levels of fatigue (accumulation of lactic acid) associated with anaerobic exercise.

At a point where the intensity of the activity increases to such a point where the oxygen demand of the working muscles cannot be met and muscles have to obtain the extra energy through anaerobic metabolism, using reactions that do not require oxygen. When oxygen demands exceed oxygen supply (oxygen debt) during and following prolonged exertion, lactic acid accumulates within muscle tissue and sets in fatigue. The greater the exercise intensity, greater is the lactic acid accumulation. Following maximum exercise, it may take an hour or longer to attain resting levels. Therefore, the main disadvantage of anaerobic metabolism is that it can only sustain high rates of energy production for a short period of time.

- *Anaerobic Exercise/Energy System*

Thus, exercises which are done for short bursts of time lasting only for few seconds (less than 120 sec) use only anaerobic system of energy. These are called *anaerobic exercises* and examples are sprinting (100 m run), skipping etc.

Next, let us consider what determines as individuals work capacity.

What determines an individual's Work Capacity or VO_2 Max?

Both aerobic and anaerobic mechanisms determine an individual's performance capacity. VO_2 max is determined by the constituents of the Oxygen Transport System which include:

- Pulmonary ventilation (Efficiency to breath in or breath out)
- Haemoglobin concentration
- Blood volume and cardiac output
- Peripheral blood flow
- Aerobic metabolism

Having studied about work capaicty, let us next look at physical capacity tests.

Physical Capacity Tests

Aerobic capacity has already been defined. Aerobic capacity is usually measured using a *tread mill test* in which the intensity of the exercise is progressively increased until maximum exertion levels are reached and at this point oxygen uptake is measured. Aerobic capacity is expressed as VO_2 max, i.e. volume of oxygen in ml consumed per unit time at maximum exertion level.

A field test that has been used extensively in nutrition studies to assess aerobic capacity measures Heart Rate responses to sub maximal work loads. A decreased heart rate for a given work load indicates superior aerobic capacity. The test has taken the form of a standard step test such as the *Harvard Step Test*. These concepts are further described under specific tests.

Endurance capacity, on the other hand, is measured by *standard running tests* in which time to exhaustion is taken as the endurance capacity. One can also measure endurance capacity by using other equipments, the main criterion being that the work load is sub maximal and time to exhaustion is generally the indicator.

The physical work capacity tests include common tests like *running staircases* (Step test) or using a *bicycle ergometer* or *treadmill*. The oxygen consumed at different levels of work load is measured and VO_2 max is either measured directly or predicted using equations.

Direct measurement of VO_2 max is determined by having the subject perform exercise at increased loads, for 12 to 15 minutes. A *stationary bicycle* or a *treadmill* is used. The test starts with a moderate work load which is maintained for a few minutes. The load is increased gradually every few minutes until reaching the maximum level that the subject can tolerate. This is done by increasing the cycling resistance or the speed and grade of the treadmill. The oxygen uptake measured at the maximal load is the subject's VO_2 max. The higher the VO_2 max, the more work one can perform; thus, the better the level of aerobic fitness. These tests are expensive, and are beyond the reach and capability of most people.

Heart Rate (HR) Method: An alternative method for determining aerobic capacity involves the measurement of heart rate. Heart rate is linearly associated with maximum oxygen uptake. The available methods to predict VO_2 max consist of HR measurements during the performance at sub-maximal exercise with a treadmill or cycle ergometer. At least three 3 to 5-minutes of testing at each load has to be performed. Since a fit person shows a lower HR than an unfit one when exercising at the same load (same oxygen uptake) and the maximal HR for each age group is known, the oxygen uptake-HR curve can be drawn to extrapolate maximal HR where it represents VO_2 max. Age and sex differences in HR have to be considered.

Harvard Step Test: In this test, the subject steps on and off an 18-inch platform at a rate of 30 times per minute. The evaluator records the subject's pulse rate at 30 seconds, 1 minute, 2 minutes, and 3 minutes after the exercise. The following formula is then applied:

$$\text{Physical Efficiency Index (PIE)} = \frac{\text{Duration of exercise in seconds} \times 100}{2 \times \text{sum of any 3 pulse counts during recovery}}$$

The higher the index, better is the person's status. There are many variations to this test and is easy to perform. Used as a field method, it gives an idea of aerobic fitness of the subject.

More tests of measuring aerobic fitness have been discussed in sub-section 17.5.2.

Check Your Progress Exercise 1

1) Fill in the blanks:

   a) ……is the commonest method to assess body composition.

   b) ……..…. is the commercially availably instrument for measuring body density.

   c) DEXA method is based on a 3-C model that divides the body into ……., ……. and …….

   d) The measurement of TBW is based on the principle of ……..

   e) …… is the most widely used field method of body composition assessment.

2) Enumerate any two limitations and advantages of underwater weighing.

   .....

   .....

3) What is the assumption on which BIA method is based upon? Why is it preferred over other methods?

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4) What do you understand by the term 'physical work capacity'? What are the factors that determine it?

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5) Name any two physical work capacity tests.

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17.5 PHYSICAL FITNESS

Physical fitness is a general term we come across quite often and use it to describe an individual if he or she is able to carry out a variety of physical tasks without feeling fatigued. It enables us to perform up to our potential and capabilities. Different authors define physical fitness in different ways. Let us have a look at these.

According to W.H.O. (1994) "Fitness is the ability to perform muscular work satisfactorily".

According to *Davis*, *Bull*, *Roscoe* & *Roscoe* (1994) Physical fitness is "the ability to carry out our daily tasks without undue fatigue".

Lamb (1984) defines "Physical fitness is the capacity to meet successfully the present and potential physical challenges of life".

American Medical Association defines fitness as "the general capacity to adapt and respond favourably to any physical effort".

Rusby (2001) also states that physical fitness is "the ability to meet physical demands placed upon us, either generally in the terms of everyday life or the specific demands of a sport or physical activity".

With the health point of view, physical fitness is the attainment or maintenance of physical capacities that are related to good or improved health and are necessary for performing daily activities and confronting expected and unexpected physical challenges.

As you can see, the term fitness and its definitions are dependant upon how you look at it. Thus, looking at all these definitions, it can be said that an individual is physically fit when he is able to carry out daily tasks with vigour and alertness without feeling tired and still have energy left for leisure and recreational activities and for unpredicted situations.

It is the ability to endure, bear up, withstand stress and carry on in circumstances where an unfit person cannot continue. Thus, physical fitness involves the performance of heart, lungs and muscles of the body. And, since physical efforts also influence mind, fitness affects qualities such as mental alertness and emotional stability. To put it briefly, we can say that physical fitness is a major basis for good health and well-being.

Fitness varies from a person to person. It is influenced by age, sex, heredity, personal habits, exercise and eating practices. The first three factors cannot be controlled. However, the later three viz, habits, exercise and diet are within one's capacity to improve.

Fitness plays a vital role in any field of human endeavour and influences the efficiency of a person. For this reason, fitness consciousness has become a phenomenon all over the world. People from all walks of life now feel that fitness is necessary for health, appearance and work performance.

There are certain measurable parameters of fitness. What are these? Let us read about it in the following sub-section.

17.5.1 Parameters of Fitness

There are five basic components of physical fitness, which involve heart, lungs, strength, endurance and flexibility. To improve the overall fitness, an individual has to participate in specific programmes to develop each one of these basic components. There is a general impression that parameters of fitness are only necessary for athletes and individuals who hold jobs that require heavy muscular work or great appearance. However, by now it must be very clear to you that components of total physical fitness are important for all and is an integral part of everyone's day-to-day life. Shopping, catching the bus, all household chores at peak hours, long working hours in the office, socializing, child bearing and rearing, fitness matters everywhere.

In physical fitness, there are five measurable components:

i) *Cardiovascular endurance*: In our previous section on work capacity, concepts of aerobic capacity/VO_2 max were described. Cardiovascular endurance, in fact, is *an individual's aerobic capacity or aerobic power, which is the ability to supply oxygen to the working muscles during physical activity*. Or in other words, cardiovascular endurance is *the ability of the heart, lungs and blood vessels to supply oxygen and nutrients to the muscles and to remove wastes during long period exercises such as running, cycling or swimming.* Hence, all these terms are synonymous and used interchangeably.

   Thus, moderately strenuous activity done over a period of time determines cardiovascular endurance. For example, jogging, continuous running, cycling, dancing, aerobics done for 20-30 minutes or longer are the activities of cardiovascular endurance. It reflects how well your heart and lungs work together to supply oxygen and nutrients to your body during exercise and exertion. Long runs and swims are among the methods employed in measuring this component. Longer the time taken for exhaustion, better is the cardiovascular endurance.

ii) *Muscular strength*: It is *the ability of a muscle to exert force for a brief period of time*. Upper-body strength, for example, can be measured by various weight-lifting exercises. It is possible to have muscular strength in one area, say your arms, while lacking strength in another area such as legs. Strength is crucial for daily activities such as sitting, walking, running, lifting and carrying objects, doing household work etc. When you increase your strength, you are also increasing the size of muscles, as well as, strengthening connective tissues. This, in turn, helps to avoid injuries and you are stronger and healthier. Strength is also of great value in improving personal appearance and self-image.

iii) *Muscular endurance*: *It is the ability of a muscle, or a group of muscles, to sustain repeated contractions or to continue applying force against a fixed object*. This is the ability to hold a particular position for a sustained period of time or repeat a movement many times. This could be explained as the capability required to hold a specific weight above your head for five minutes or the effort required to lift that weight 20 consecutive times. *Push-ups* are often used to test endurance of arm and shoulder muscles. Muscular endurance depends to a large extent on cardiovascular endurance. Weak muscles cannot repeat an action several times, nor sustain it for a prolonged period of time.

iv) *Flexibility*: It refers to *the ability to move joints and use muscles through their full range of motion; the elasticity of the muscle*. This means how elastic you are. The *sit-and-reach test* is a good measure of flexibility of the lower back and backs of the upper legs. An individual's flexibility depends on many factors including joint structure, ligaments tendons, muscles, skin, tissues, body temperature, gender and age.

v) *Body composition*: It refers primarily to *the distribution of muscle, fat, bone and other tissues in the body*, and its measurement is often considered as a component of fitness. It is different from body weight in that it refers to the build of the body in terms of lean body mass (muscle, bone, vital tissues and organs) and fat mass. An optimal percentage of fat to lean mass is an indication of fitness. It is often represented as a two compartment system; lean body mass and fat mass. The fat mass is then expressed as a percentage of total body weight (BF%).

The above parameters of fitness are related to athlete, as well as, non-athlete and people of all age-groups and are of prime importance for health and wellness of one and all. There are a few more motor skill-related aspects of fitness which are of greater significance only in sports. These include balance, co-ordination, reaction time and speed. While these components are important in achieving success in athletics, they are not crucial for the development of better health.

Now that you are well aware of the components of physical fitness, let us have a look at the various fitness tests which can be used to evaluate these components.

17.5.2 Fitness Tests

Testing is an important evaluation tool for the sports performer as it gives them an insight into their current physical condition and the effectiveness of their training. Physical fitness of both athletes and non-athletes may be tested for a number of reasons, as listed below:

1) *To assess pre-training fitness status*: Before beginning an exercise programme and allow the exercise, intensity and duration to be set at the correct level, as these are important in assessing the persons' initial fitness level.

2) *To assess post-training fitness status*: Fitness tests are applied to assess fitness level to evaluate performance after initiation of training programme and predict future performance.

3) *To assess loss due to injury*: After injury or illness, fitness testing is done to determine the amount of fitness loss.

4) *To assess suitability for an occupation*: Suitability of an individual for a particular occupation (e.g. armed forces, police and fire brigade) is seen based on fitness testing.

5) *To assess recovery from health problems*: Fitness tests are also used by medical practitioners to assess our recovery from specific health problems such as coronary heart disease.

Physical fitness tests examine the components of physical fitness such as endurance, speed, strength, flexibility and body composition. There are various tests applied for each component and various norms exist for each test. But in this unit we shall only restrict ourselves to one or two tests commonly used to test each parameter of fitness. These are dealt with in detail in this section.

1) *Tests of Cardiovascular Endurance*

Cardiovascular endurance or aerobic fitness is *the ability to exercise continuously for extended periods without tiring*. It can be measured either at maximal and submaximal levels. The direct measurement of aerobic capacity is done using either *treadmill* or *bicycle ergometer*. The testing can also be done at submaximal level, which means that the individual does not exercise till the maximal level of exhaustion and the results at below exhaustion are used to predict maximal volume of oxygen consumed (discussed in the work capacity section). It includes *Astrand Bicycle Ergometer test, PWC170 test* and *tri-level aerobic test*. We would get to know about these in details consequently.

There are other series of step tests which are based on the assumption that the person having a better aerobic capacity will have lesser increase in the resting pulse rate after step exercise of a specified period of time. These step tests include *Harvard Step Test*, *Queens College Step Test*, *Chester Step Test*. These are field methods and can be easily administered at a reasonable cost. While there is a simple step test, that can be done at home, these include certain walking tests such as *Rockport Walk Test* and *2 km Walk Test*. Let us discuss about a few of these in detail.

- *Measuring Direct Aerobic Fitness (VO_2 max)*

For direct measurement of VO_2 max, the subject is asked to perform exercise for 12 to 15 minutes. A stationary bicycle or a treadmill is typically used. The test starts with a moderate work load which is maintained for a few minutes. The load is increased gradually every few minutes until reaching the maximum level that the subject can tolerate. This is done by increasing the cycling resistance or the speed and grade of the treadmill. The oxygen uptake measured at the maximal load is the subject's VO_2 max. The subject works until VO_2 max is reached, indicated by max heart rate, VO_2 max plateau (or over peak), respiratory exchange ratio of 1.15 (or greater) or voluntary exhaustion.

The higher the VO_2 max, the more work one can perform; thus, better the level of aerobic fitness. The disadvantage of these laboratory methods to determine aerobic fitness is that these require maximal work till exhaustion and are expensive. The advantage of this method is that it is most accurate to indicate aerobic capacity. VO_2 max ratings can be assessed from Table 17.2 for men and Table 17.3 for women.

Table 17.2: VO_2 max ratings (ml/kg/min)

Men (aged 20-69 years)

Fitness	Very Poor	Poor	Average	Good	Very Good
Age (years)					
20 - 29	38	39 - 43	44 - 51	52 - 56	57
30 - 39	34	35 - 39	40 - 47	48 - 51	52
40 - 49	30	31 - 35	36 - 43	44 - 47	48
50 - 59	25	26 - 31	32 - 39	40 - 43	44
60 - 69	21	22 - 26	27 - 35	36 - 39	40

Table 17.3: VO_2 max ratings (ml/kg/min)

For women (aged 20-56 years)

Fitness	Very Poor	Poor	Average	Good	Very Good
Age (years)					
20 - 29	28	29 - 34	35 - 43	44 - 48	49
30 - 39	27	28 - 33	34 - 41	42 - 47	48
40 - 49	25	26 - 31	32 - 40	41 - 45	46
50 - 56	21	22 - 28	29 - 36	37 - 41	42

- *Astrand Cycle Test*: This is a submaximal test done on *cycle ergometer*. In this test, comparatively lower wattages are set. For example, for males less than 35 years of age are given to exercise on 100-150 watts and for females between 100-125 watts. For older adults, the wattage is further declined. Whether to use upper limit or the lower limit depends upon the body weight and prior fitness level of the person. The person is asked to pedal at 60 rpm for 6 minutes at chosen loading, taking pulse every minute. Your pulse rate should be steady state (130-160 beats per minute). If pulse is not in target range (above or below), after 2 minutes, adjust loading by 25 watts accordingly for remainder of the test. At the end of minute 6, pulse and resistance loading is recorded. VO_2 max in L/min is then converted to ml/kg/min by multiplying it by 1000 and dividing by body weight (kg).

  The advantage of this test is that it is simple to do, reasonably accurate and easy for ECG monitoring. However, the disadvantage of this test is that test is less accurate with advancing age.

- *Cooper's Run (12 minute run)*: To undertake this test, a 400 metre running track is required-marked every 100 m and a stop watch. The test comprises of noticing how far an athlete can run/walk in twelve minutes. The total distance covered to the nearest 100 metres is recorded and VO_2 max is predicted using the equation given below.

  VO_2 max (ml/kg/min) = (35.97 × miles) – 11.29

  This test is easy to administer to large groups.

- *Queens College Step Test*: This test can be administered to large groups or those who are incapable of doing a test up till exhaustion. For this test, a bench (41 cm high), stopwatch, metronome are required. *Metronome* is an apparatus which sets beats and pace for up and down process during stepping. Different paces at slower or faster rate can be adjusted with metronome. Stepping pace in this test for women is 22 steps/min and for men it is 24 steps/min. Subjects step using a four-step cadence, 'UP-UP-DOWN-DOWN'. This implies that the subject first keeps right foot on the 41cm high bench then left foot up, then right foot down and finally left foot down. This is repeated continuously for 3 minutes and then immediately their pulse for 15 seconds is taken, 5-20 seconds into recovery. Multiplying this 15 second reading by 4 will give beats per minute figure of the subject. Using the prediction equations based on linear relationship between heart rate and oxygen consumption the subjects one minute end test pulse reading can be used to predict a value for their Max VO_2.

  For men: VO_2 max = 111.33 – (0.42 × step test pulse rate beats/min)

  For women: VO_2 max = 65.81 – (0.1847 × step test pulse rate beats/min)

With this, we come to an end of our discussion on tests of cardiovascular endurance. Next, let us move on to the tests which we can use to measure muscular strength and endurance.

2) Tests to Measure Muscular Strength and Endurance

It is important to first understand the difference between muscular strength and endurance. To know the muscular strength, how much load a person can lift or resist is measured but it does not take time or repetitions into consideration. While when the person is able to sustain certain degree of tension over the period of maximum time or repeats identical muscular movements for maximal number of times, this is called as *muscular endurance*. The different test for muscular strength includes *Isokinetic strength tests*, *Hand-grip strength test* and *Abdominal strength test*. The different tests that are used for evaluating muscular endurance include *pull-up, push-up test, Bent-knee curl up test* and *Bench-press test*.

Thus, as strength is the force exerted by a muscle or muscle groups during a single contraction, it can be measured for specific muscle groups. For this purpose, equipment called *dynamometer* is used. 'Handgrip' and 'Back & Leg' dynamometers are most commonly used. A dynamometer measures the amount of force that particular muscles groups can exert with very little movement. The best of three attempts is recorded and the highest of these reading is taken as a score. When the subject is asked to repeat his possible maximum grip strength for as many times as possible or say in one minute, it will test his muscular endurance.

So, let us start with our discussion on these tests.

- *Push-ups*

Push-ups is another test done to measure muscular strength, as well as, endurance and done on a parallel bar. The subject stands between the parallel bars with the arms a shoulder-width apart, and the back, buttocks and legs straight from head to heels. Grasping one bar in each hand, the subject jumps upwards so as to make his arms straight. How well is he able to complete the test, scoring is done on this basis. When the subject performs as many correct push-ups as possible in one minute this will test his muscular endurance. Higher the number, better is the endurance.

- *Pull-ups*

This test is also done to measure upper body strength or endurance by maximum number of pull-ups completed. Subject hangs from a horizontal bar at a height he can hang from, with arms fully extended and feet free from floor, using an overhand grasp (palms facing away from body). The subject raises body until chin clears the bar and then lowers body to full-hang starting position. As many correct pull-ups as possible are performed.

- *Flexed-arm Hang*

Persons who cannot do one pull-up may do the flexed-arm hang. Using the same hand position as in pull-ups, subject takes flexed-arm hang position with chin clearing the bar. Subjects may be lifted to this position and they are required to hold this position as long as possible.

- *Sit-ups*

To measure muscular endurance, bent knee sit-ups can be done. Sit-ups begin with the subject lying flat on their backs with their knees bent at approximately a 90-degree angle and feet flat on the ground. Other individuals hold subject's ankles to the ground with their hands. The subjects may interlock their fingers behind their heads or cup their hands over their ears. Applicants begin by raising the upper body forward to the vertical position, touching the elbows to the knees, and then lowering the upper body until the upper portion of the back has touched the ground. This is one repetition. Subjects perform as many correct sit-ups as possible in one minute. Higher the number, better is the muscular endurance.

With this, we finish our discussion on the various tests of measuring muscular strenght and endurance. Next, let us get to know about different tests to measure flexibility.

3) *Tests to Measure Flexibility*

The flexibility component measures *the elasticity or range of motion around a joint*. This component of physical fitness enables the person to have free body movements, better co-ordinated movements requiring lesser work and to handle greater stress with lesser chances of injury. The various tests include indirect measures such as *sit and reach test, calf muscle flexibility test, shoulder flexibility test* and *90/90 hamstring test*; and direct measures that involve use of a *goniometer* and *flexometer*. Let us have a look at one of these in brief.

- *Sit-and-Reach Flexibility*

The subject sits on a mat with legs extended straight ahead. Legs should be at right angles to a taped line or box, with feet flat against a box with a ruler on top of it. Keeping the knees straight, the subject slowly tries to reach forward, extending both hands as far forward as possible, momentarily holding the position. The length of the stretch is measured in centimetres at the fingertips. Past the toe line is a positive reading. Not reaching the toe line is a minus reading. The flexibility score is the best of three attempts. This test is simple to administer but measures only hamstring flexibility. For this test, a testing box or flexomeasure and a yard stick is required.

Methods of measuring body composition have been discussed in detail in sub-section 17.4.1.

Check Your Progress Exercise 2

1) What do you understand by the following terms:

a) Physical fitness

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b) Cardiovascular endurance

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c) Muscular strength

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d) Flexibility

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e) Muscular endurance

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2) Why are fitness tests important?

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3) Mention any two tests for the following:

a) Cardiovascular endurance

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b) Muscular strength and endurance

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c) Flexibility

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17.6 NUTRITIONAL DEMANDS OF SPORTS AND DIETARY RECOMMENDATIONS

There is a strong relationship between nutritional status and physical training. Whether it is to maintain health or to achieve success in sports, both depend upon meeting adequate nutritional needs. There are some basic dietary recommendations for health and fitness. These apply to athlete and non-athlete alike. They are to:

- maintain healthy body weight and body composition by modifying food intake and regular exercise,
- increase intakes of complex carbohydrates and fibre foods including liberal intake of fruits and vegetables,
- reduce dietary fat intake to an average of 30% of total caloric needs or less and specifically saturated fats less than 10%,
- reduce intake of refined sugars and high sugar products, and
- reduce salt intake and foods high in salt.

For general population, inclusion of above mentioned dietary modifications along with 30-40 minutes of regular brisk walk is beneficial in reducing fat mass and increasing fat free mass. However, over and above these general recommendations, athletes have certain critical areas of nutrition. Owing to extra caloric expenditure during exercise, requirements for most nutrients are increased depending upon the nature of sports.

Nutrition and Sports

The physical fitness and performance of an athlete is affected by both current and previous nutritional status. The capacity for exercise training is improved if energy, fluid and other nutrient needs are met on a consistent basis. In sports and exercise, nutrition should be aimed at:

- maintaining ideal body weight and body composition as desired of a particular sport,
- maintaining adequate pool of nutrients,
- providing diet that helps in achieving performance up to one's potential,
- clarifying facts and fallacies related to food,
- introducing athlete to competition diets, and
- encouraging healthy nutritional practices amongst athletes.

Although sports nutrition basics are similar for all athletes, important differences exist for individual athletes in various sports. For example, nutritional needs of a gymnast would be different from a long distance runner and the needs of a tennis player would be different from weight-lifter or judo player.

Basically the intensity, duration and type of exercise training determines what, how much and when to eat. The sports events, as we have discussed in previous sections, are classified as endurance or strength.

Next, let us move on to the nutritional recommendations for athletes.

a) *Energy*: You are familiar with the fact that body needs energy to maintain body temperature, to meet metabolic demands, maintain electrolyte balance and to support growth and physical activity. The major variations in the energy needs of different individuals of the same age, sex and body weight is mainly due to differences in the physical activity pattern. In sports nutrition, physical activity is even more important as there are wide variations in energy needs between different individuals. Exercise intensity and duration are the main factors that influence exercise energy expenditures.

An athlete's success at meeting energy requirements depends on accomplishing these two goals:

1) *Matching energy intake to energy expenditure*: To be in energy balance, an athlete needs to consume about the same number of calories that he or she expends on a daily basis. Energy intake needs to be adjusted during off season and peak season.

2) *Maintaining body weight and body composition at levels that are compatible with good health and athletic performance*: We have understood that body composition is one of the many factors that affect athletic performance. High ratios of FFM/FM are associated with better athletic performance in most sports. Endurance athletes tend to have lower percentages of body fat than non-endurance athletes because body fat limits endurance, speed and movement through space. Within most sports, the percent body fat of males is lower than that of females.

The Table 17.4 shows how body fat percentage of different sports differs. If you look at the table carefully, you will notice that athletes participating in long distance running have the lowest body fat percentage. A swimmer of same body weight will have higher body fat percentage because fat has lower density which helps in floating in water. Thus, to maintain the appropriate body composition for a particular sport is also a challenge for sports nutritionists.

Table 17.4: Various body fat % according to the sport

Sport	BF % (males)
Swimming (Endurance)	8.5
Gymnastics (Strength/Power/Flexibility)	5.0
Long distance Runner (Endurance)	3.8
Middle distance Runner (Endurance)	12.5
Football (Endurance, team game)	13.5
Weight-lifting (Strength)	9.8

Monitoring body weight is a practical way to assess energy balance. Weight stability, particularly during periods of heavy training and competition, indicates that energy requirements are being met. If body weight loss or weight gain is desired to enhance athletic performance, it is best addressed in the off-season. Weight loss during the

competitive season places athletes at-risk for inadequate energy, carbohydrate and fluid intake. Weight gain in the form of body fat adversely affects endurance, speed and power. The suggested allowances for sports persons are given in Table 17.5.

Table 17.5: Average body weight and Energy allowances

Group	Average body weight (kg)	Type of Activity	Energy Allowances (Kcal/kgBW/day)	Total energy Requirement (Kcal/d)	Calories Ratio CHO : Protein : Fat
I	85 (80-90)	Power events of higher weight category including throwers, boxers, weight-lifters, judo, power lifting, kabaddi and wrestling	70	6000	55 : 15 : 30
II	65 (60 - 70)	Endurance Events – Marathon, long distance running, walking, cycling, long distance swimming (>200m), rowing, canoeing.	80	5200	60 : 15 : 25
III	65 (60 - 70)	Team Events like basketball, football, hockey, volleyball, and Power Events of middle weight category (60-80 kg), Judo, swimming (< 200m),	70	4500	60 : 15 : 25 64 : 15 : 21
IV	60	Events of light weight category-Gymnastics, table-tennis, yatching, Power Events of light weight category (60 kg and below)	60	3600	65 : 15 : 20
V	60	Skilled Events like shooting, archery, horse-riding.	50	3000	55 : 15 : 30

CHO: Carbohydrate

Source: Nutrition and Hydrotion guidelines for excellence in sports performance; ILSI, NIN, SAI; 2007

b) *Carbohydrate Requirements*: Carbohydrate is the primary fuel for high intensity exercise. Increased intake of carbohydrate on a consistent basis enables endurance athletes to undertake more training with less fatigue. Because carbohydrate stores (liver and muscle glycogen) are relatively small and muscle glycogen depletes after hard training and competition. This leads to fatigue and decreases the ability to exercise at high intensity. Therefore, it is essential to have sufficient stores of glycogen before competition and to replenish glycogen stores to pre-exercise values within 24 hours. The research has shown that higher carbohydrate intake, exercise times to exhaustion increases. Thus, the endurance capacity of an athlete is enhanced.

Carbohydrates also provide ample amount of substrates for fatty acid oxidation.

How much of energy should come from carbohydrates again depends upon the type of exercise. Carbohydrate requirements may range from 55% in an average training diet to up to 70% of total energy intake for endurance athletes. They yield more energy per unit of oxygen consumed than fats.

The type of carbohydrate consumed also affects the fuel stores and the overall nutritional status. You already know that carbohydrates can be classified as – simple and complex. Simple sugars occur naturally in fruits, vegetables, honey, milk and other foods, as well as, in a refined state, such as table sugar or sucrose. Complex carbohydrates are a complex chain-like structure of many simple sugar units like starches and dietary fibre as found in cereals, grains, fruits, vegetables and foods such as noodles, potatoes etc.

Complex carbohydrates should constitute a chunk of total carbohydrates consumed. A variety of fruits, vegetables and grains should be consumed. Whole-grain breads and

cereals, peas, fruits and vegetables are generally low in fat, contain no cholesterol and are rich in fibre, which facilitates proper bowel function and can reduce symptoms of chronic constipation. In addition to this, these are generally good sources of vitamins and minerals. Simple sugars in moderation can be taken to add to energy levels needed for large fuel stores. Amount and type of carbohydrates before, during and after exercise is also given in Table 17.6.

c) *Protein Requirements*: Proteins provide energy to the body. Since exercise may increase an athlete's need for protein, depending on the type and frequency of exercise. The ADA recommendation is protein intake of 10-12% of total calories.

Protein requirements of athletes, particularly those engaged in strength and power events, may be increased above those of sedentary people for the following reasons:

1) Amino acids are used to repair muscle trauma that results from repeated muscle contractions and the repairs to injuries to muscle fibres protein requirements are increased.

2) To remodel muscle tissue in response to strength training. There is an increase in muscle bulk due to resistance training. Protein requirements of the beginner strength athletes to maintain nitrogen balance appear to be at the higher end of the range compared to that of elite strength athletes. Research shows that those who are adapted to strength training may not need a very high intake of protein.

3) Prolonged exercise increases oxidation of amino acids for fuel. Protein use as an energy substrate increases during high intensity, long duration endurance activity. Protein makes a greater contribution to total energy production during endurance exercise when muscle glycogen levels are low.

Protein intake equal to 15-20% of total calories will meet the protein requirements of most athletes. ICMR 1985 recommends 12-14% of total energy requirements and upper limit could be placed at 2 g/kg body weight.

Protein intakes above 2.0 g/kg BW do not improve strength gains compared to intakes of 1.4-1.8 g/kgBW. Consuming more protein than 2.0 g/kg BW results in increased protein oxidation, urea formation, diuresis and can increase risk for dehydration.

The type of sport and total calorie intakes influence protein requirements. Eating sufficient foods to meet high energy requirements ensures that athletes will meet their protein requirements. However, high protein diets increase the water requirement necessary to eliminate nitrogen through the urine. Also, an increase in metabolic rate can occur and therefore, increased oxygen consumption.

A diet providing good quality protein from animal sources or vegetable sources (supplementation with first class protein or using complementary sources together) in the amount constituting 15-20% of total calories is sufficient for an athlete. No supplementation above this level is required for any kind of sport.

d) *Fat Requirements*: Fats are the body's other major energy source. It is a well known fact that fat is a highly concentrated source of energy and the primary fuel at rest and during low intensity physical activity. However, fats cannot be used exclusively as an energy source and a small amount of carbohydrate must always be available. High rates of fat oxidation can occur during aerobic exercise. Aerobic training increases the ability of the body to use fat as an energy source. Thus, for athletes who require high energy intakes, fat is an important fuel and adds to daily energy requirements. Fats must be present in adequate amounts, too less or too much both may have adverse effects. Most athletes eat moderately low fat diets.

Low fat diets for long periods may not obtain sufficient fat-soluble vitamins, including vitamin E, which has antioxidant functions. Restrained eating and extreme fat restriction increase the risk for eating disorders that ultimately impair exercise performance.

Keeping fat intake below 30 percent of the total calories has been shown to be beneficial in protecting against various diseases. Concerning cardiovascular health, consuming no more than 30% of total calories from fat is recommended. Moreover, high fat intake impairs insulin sensitivity and glucose utilization.

Fats may contribute as much as 75 percent of the energy demand during prolonged aerobic work. There is an evidence that the rate of fat metabolism may be accelerated by ingesting caffeine prior to and during endurance performance. However, insomnia, restlessness and ringing of the ears can occur.

Thus, total energy provided by fat may range from 20-30% including both visible and invisible fat with the ratio of 2:1. The proportions of saturated fat, mono-unsaturated fats and poly-unsaturated fats also needs to taken into consideration. Thus, the diet should be a blend of oils from palm, soyabean, mustard and other vegetable sources.

e) *Vitamins and Minerals*: Vitamins and minerals perform the same essential functions for athletes and non-athletes alike. However, owing to increased energy requirements and exercise-induced production of free radicals, higher amounts of B-vitamins and vitamins with anti-oxidant properties are required for athletes. Though there is no evidence that taking more vitamins than is obtained by eating a variety of foods will improve the performance.

Therefore, athletes with high energy expenditures (3000-6000 Kcal) may need 1mg/1000 Kcal of thiamine and riboflavin and 10-20 mg/1000 Kcal of niacin. Carbohydrates and protein foods are excellent sources of these vitamins. Intake of retinol may be placed at 1000-2000 micrograms per day. Vitamin E, which is an antioxidant, should be taken at the level of 10-20 IU. Vitamin C which is also essential for iron absorption, its intake should be 100-200 mg/day.

There is an increased risk of stress fracture among athletes which is associated with lower calcium intake and lower bone density. Female athletes should have an adequate supply of calcium to avoid calcium loss from bones. The calcium intake of 1-2 mg per day is recommended or it may exceed even up to the level of 3 mg per day. Dairy products, especially low-fat choices are the best sources of calcium.

Iron carries oxygen and is another important mineral for athletes. It also affects oxygen transport and aerobic metabolism as a component of haemoglobin, myoglobin, and oxidative enzymes. Immune function is dependent on iron-containing enzymes. Consuming adequate amounts of iron is essential for an optimal aerobic endurance performance especially for the female athletes and athletes between 13 and 19 years of age. Female athletes, who train heavily, have a high incidence of amenorrhea and thus, conserve iron stores. In any case, iron intake should not be less than 50-75 mg for sportsmen and 60-100 mg for sportswomen.

Vitamins and minerals work together with nutrients in food. While antioxidant vitamins E and C and beta-carotene should be obtained by habitual consumption of foods high in antioxidant value (fruits, vegetables, whole grains). Hundreds of antioxidants, some of which act synergistically, are available in foods. Supplementing is unlikely to help.

Thus, the key to obtain the adequate vitamins and minerals is to eat a wide variety of nutrient-dense foods in amounts that will maintain energy balance. Fruits and vegetables are particularly rich in vitamins and antioxidants as well. Supplements are not replacements for food.

Vitamin supplements are commonly used by athletes to make up for less than optimal diets. It is well known that vitamin and mineral deficiencies impair physical performance. However, research indicates that if there are no deficiencies, supplementation above nutritionally adequate sports diet does not improve physical work capacity, endurance, oxygen consumption, cardiovascular function, muscle strength, or resistance to fatigue.

Consuming an excess of any mineral can interfere with digestion and absorption of other minerals and lead to mineral imbalances. In large enough doses, all minerals can be toxic. Hence, one should be very careful in taking vitamin and mineral supplementation and the intake should be discontinued periodically to prevent toxic effects.

So by now you must have understood that success in sports relies on many aspects, and nutrition is one of them. Thus, to excel in sports it is very important to strategically plan the pre-event meal, to maintain fluid and electrolyte balance during the game and to build up a post-game recovery strategy. What is a pre-event meal? What must be the nutrient intake so as to prevent unfavourable conditions during the event? Let us proceed with our discussion.

Pre-Exercise or Pre-Event Meal

Suitable foods in adequate quantities at all times should be consumed but before the event, strategies to fuel up the energy system and proper hydration are amongst the primary goals. Conditions like hunger, fatigue, weakness, light-headedness should be prevented and a comfortable gastrointestinal state is desirable. Thus, the goals of pre-event meal are:

1) *To fuel up muscles and brain*: As explained earlier that energy for high intensity endurance physical activity is supplied by muscle glycogen. Therefore, adequate glycogen stores are crucial to optimal athletic performance.

   Energy for the brain is supplied by glucose from the blood. Blood glucose is replenished from liver glycogen stores. During sleep, breakdown of liver glycogen and release of glucose into the blood keeps blood glucose levels normal. By morning, liver glycogen levels are low. Therefore, eating carbohydrate-containing foods before exercise refills liver glycogen stores and can "top off" muscle glycogen stores. Hence, before the event, following tips should be followed:

   - As the glycogen stores may be used up during night, a high carbohydrate snack on the morning of the event may be required to replenish liver glycogen stores.
   - Snack should comprise high-carbohydrate and low-fat foods providing 500-1000 Kcal should be consumed.
   - High sugar foods must be avoided as they lead to dehydration, cramping, nausea and diarrhoea.
   - On regular training days, instead of large meals, small meals or a snack every 2-3 hours should be taken.
   - Meals should be taken about 2-4 hours before exercise.
   - Eat less food if eating within two hours of exercise.
   - Dinner on the previous night of the competition is also important. The meal should be such that it ensures proper sleep and adequate fuelling up.
   - Familiar and easily digestible foods should be consumed. Any newer food or foods with known allergies or known to cause gastrointestinal upsets should be avoided.
   - Foods heavy on stomach like fried foods or high fibre foods should be avoided on the day prior to competition.

- Too much of protein intake should also be avoided as it increases water excretion leading to a state of dehydration. Moreover, protein is digested more slowly.
- Liquids or a small snack an hour before exercise can be taken.

For endurance events like sprinting (100 m run), football, hockey, the carbohydrate intake can be placed at 7-10 g per kg body weight. While for endurance events lasting more than 90 minutes, carbohydrate loading may be required.

Carbohydrate loading is based on the principle of *depletion-repletion* (first depleting the glycogen stores by lowering carbohydrate intake and increasing training schedules and then after few days increasing carbohydrate intake and tapering down of training).

However, currently the regime of carbohydrate loading being followed begins 6 days before competition. The athletes are asked to consume carbohydrates providing 50-55% of total calories and to taper down exercise slowly for the first three days. In the last three days of this regime, the tapering down of exercise continues, while carbohydrate intake is increased up to the level of 60-70%. This increases glycogen stores in the body. Care should be taken to choose carbohydrate sources. Complex carbohydrates including grains and fruits are better choices than simple or refined sugars.

2) *To prevent dehydration*: Maintaining optimal hydration status along with sufficient muscle glycogen stores delays the onset of fatigue and enables the athletes to exercise longer before exhausting.

High intensity games lead to heavy sweat losses resulting in fluid and electrolyte imbalance. Hence, sufficient amount of fluids to maintain water and electrolyte balance and to control body temperature need to be consumed particularly in hot climatic conditions. Prior to the competition, adequate hydration must be ensured by consuming fluids at the regular intervals.

Water is the best suitable fluid for this purpose. At all time drinking, 150-250 ml water every 15 minutes depending upon the exercise intensity and environmental conditions, would prevent dehydration. Up to 500 ml of fluid 10-15 minutes may be taken. Exact amount of fluid required by an athlete can be computed from Table 17.6

Dehydrating oneself for the purpose of reducing weight in order to get placed into lower weight categories is a common practice in sports where weight category matters. This practice must be prohibited. Besides affecting performance, the state of dehydration increases the risk of gastrointestinal distress. Excessive salt intake should be avoided to avoid diuresis.

Now that you have well understood the nutritional needs of an athlete and the goals of pre-event meal planning, let us focus now on the main event.

During Exercise: Addressing the nutritional needs during training is essential for optimal performance. The focus should be to:

- maintain water balance and body temperature control,
- maintain normal blood sugar levels,
- fuel muscles and brain, and
- delay fatigue.

Maintaining normal body temperature during exercise is essential. Heat is a by product of muscular work, and excess heat must be dissipated. The higher the intensity of the exercise, the more the athlete sweats to cool the body. Water lost by sweating needs to be replaced during exercise or the athlete's core temperature will rise and cause his

body to overheat. Even being a little dehydrated can weaken the performance. Mental and physical fatigue results from dehydration. During the limited time available between the events like in tennis, athletic events, boxing, the consumption of adequate carbohydrate and fluids may be taken care of. In shorter breaks, carbohydrate rich foods like banana, juices, carbohydrate based drinks or simply water may be taken. Carbonated beverages that contain caffeine must be avoided.

As the duration of high intensity events continues, muscle glycogen levels diminish. For endurance athletes, carbohydrate rich solids or liquid meals are recommended during exercise lasting longer than two hours. Refer to Table 17.6.

Table 17.6 : Requirement for Athletes pre, during and post exercise

Exercise	Amount of Fluid Required	Amount of Carbohydrates, Sodium & Potassium	Type of Carbohydrate
Pre Exercise			
2-4 hrs prior	5-7 ml/kg/ BW	CHO: 1-4 g/kg/BW Na: 20-50 mmol/L	Moderate GI Foods
2 hrs prior	3-5 ml/kg/BW*	-	-
10- 20 min	200 -300 ml	-	
During Exercise			
<45 min		CHO and Na: Not Required	-
45-75 min	0.4-0.8 L/hr	CHO: Small amounts including mouth rinse	Single or multiple transportable carbohydrates*
1–2.5 hrs		CHO: 30-60 g/hr; Na: 20-80 mmol/L; K: 4-8 mmol/L	Single or multiple transportable carbohydrates
>2.5 -3 hrs		CHO: 90 g/hr; Na: 20-80 mmol/L; K: 4-8 mmol/L	Only multiple transportable carbohydrates
Post Exercise			
<1 hr	1.25 -1.5 L/kg body weight lost	CHO:1-1.5g kg/BW for first 30 min, and again every 2 hours for 4-6 hours	Moderate to High GI foods

Source: Sawka *et al.* (2007)[22]. American College Sports Medicine Position Statement.

*if athlete is not hydrated.

* Multiple transportable carbohydrates (MTC) refers to combination of saccharides that rely on distinct transporters (that aid in absorption of particular carbohydrate source) for better intestinal absorption. For example, Oxidation of glucose alone at high rates is not much beacause of its particular transporter gets saturated early. On the other hand, oxidation is maximum by using combination of glucose and fructose in such a way that total amount of saccharides is same as was in case of glucose alone because of the involvement of different transporters.

During Recovery: Here, let us discuss what should be the nutritional goals based on the physiological aspects involved.

Goals: The main emphasis must be on the following:

- replace fluids lost during exercise.
- refill carbohydrate stores (muscle and liver glycogen)
- replace electrolytes (sodium, potassium, chloride)

The principle of 3R's should be followed after the event. Rehydration, refuelling, and rest facilitate the recovery process.

Recovery is the phase where muscle glycogen needs replenishment, and muscle repair and gains occur. For this purpose, rest is required. The recovery phase begins immediately after exercise ends.

First of all, the fluid lost during exercise must be replaced to restore fluid balance. Because restoration of normal fluid levels takes time, rehydration needs to begin during exercise and continue after exercise ends. Also, drinking more fluid than is lost is recommended because some of the fluid consumed in recovery is eliminated as urine. Achieving adequate rehydration before the next training session is crucial for quality training. Amount required by an athlete within an hour of performing exercise is 1.25-1.5 L/kg body weight lost as shown in Table 17.6.

Athletes benefit from consuming high carbohydrate foods immediately after ending repeated intervals of intense exercise or prolonged exercise. The body replaces the glycogen energy stores in the muscle within first few hours of exercising. The amount and type of carbohydrate to be administered can be assessed from Table 17.6. Milk, sugarcane juice, sports drinks and fruit juices are ideal choice after an exercise.

In addition to immediate consumption, continued consumption of carbohydrates and liquids during the recovery period is needed for optimal liver and muscle glycogen repletion.

Check Your Progress Exercise 3

1) Discuss the nutritional goals in case of sports and exercise?

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2) Briefly discuss the dietary recommendations for different nutrients.

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3) What is a pre-event meal? Enlist any five tips to be kept in mind.

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4) Highlight the principle of 3R's in facilitating the recovery process.

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17.7 ERGOGENIC AIDS FOR TRAINING AND COMPETITION

There is always our desire to work with the body more than its capability. This is more so in case of athletes. They wish to do better than what their body is capable of doing. In this attempt, they come across various substances that claim to enhance the performance. These substances are called *ergogenic aids*. An ergogenic aid is defined as *any substance, food, chemical or a training method that helps the body perform better and work harder*.

The 'ergon' is a Greek word which means *work* and is defined as *to increase work or potential for work*. Thus, ergogenic aids are *the substances, devices or practices that enhance energy use, production or recovery*. The most commonly used and talked about ergogenic aids include *anabolic steroids, human growth hormone, caffeine* and *creatine*.

Nutritional ergogenic aids are defined as *substances found in the diet or cells that are ingested in an effort to produce improved or enhanced sport, exercise and physical performance*. Over the ages, there has been a steady increase in the substances tested for their ergogenic potential.

Ergogenic drugs are potentially more detrimental as compared to the dietary supplements. The essential difference is that natural food supplements work with the body, while drugs work on the body.

As stated in the beginning that besides proper training, motivation and determination; a good judicious diet is all that is needed to excel in active sports.

There is no one "miracle food" or supplement that can supply all nutritional needs. Certain foods supply mainly proteins, other foods contain vitamins and minerals, and so on. The key to balancing diet is to combine different foods so that nutrient deficiencies in some foods are made up by nutrient surpluses in others. Eating a variety of foods is the secret.

No substance on its own outside the drug field makes a dramatic difference to physical or mental capabilities. However, nutritional supplements are marketed to athletes to improve performance, recovery time required after a workout or to build muscles. The following points need to be clarified, before we actually look into the ergogenic potential and usage of dietary supplements available for use. Let us go through these first.

- Dietary supplements do not "speed up" a child's growth and development.
- There is no scientific evidence that mega doses of supplements improve athletic performance, give athletes a competitive advantage or compensate for a lack of training or natural athletic ability.
- The full short- and long-term impact of dietary supplements (vitamin/mineral supplements, ergogenic aids, and herbs) is virtually unknown.
- Large doses of vitamins and minerals can actually be dangerous, and growing children and adolescents are at a greater risk of experiencing adverse effects.
- Supplements create false impressions and encourage bad eating habits.
- For example, an athlete may erroneously associate improved performance with whatever supplements he happens to be taking instead of attributing his progress to training, hard work and a balanced diet.
- This type of false reinforcement may also lead the young athlete to try other types of supplements and substances (such as drugs and steroids), with potentially disastrous consequences.

- These may be expensive.

The nutritional ergogenic aids may be categorized as follows:

A) *Water and Electrolytes*: As discussed above, water and electrolytes are important for exercise performance as they maintain blood volume and osmolality, thermoregulation to prevent danger of overheating and for shock absorbing and lubricating properties. Ingestion of water and electrolytes often improve performance or prevent fatigue. The level of water intake should be adjusted according to the climatic conditions. Hyperhydration during exercise in heat has been found to improve performance and delay adverse effects of dehydration; however, its effects are detrimental if only water without electrolytes is consumed for ultra marathon events.

Electrolyte repletion is needed when high rates of sweating occur. Electrolyte needs (sodium and potassium) are discussed in Table 17.6. This increases dietary need of sodium, potassium and chloride. Small amounts of table salt may be added to meals which will prevent losses of sodium chloride which are detrimental to performance. Excessive use of salt tablets or salt (>10 g/d) is to be discouraged to prevent potassium excretion and loss.

Potassium supplement helps prevent muscle cramps and heat stroke. However, high potassium intake (>10 g/d) is known to be harmful for health. Fresh fruits and vegetables are rich in potassium and their consumption is to be encouraged before resorting to potassium supplements.

Thus, water is an important and essential ergogenic aid, however, hyperhydration works only in certain cases of excessive heat otherwise it hampers performance. In cases of heavy losses of electrolytes through sweat, sodium, potassium and chloride replenishment is needed.

B) *Carbohydrates*: In the previous unit, we came to know that availability of glucose is the major factor in exercise performance. Hence, carbohydrate manipulation is generally done by either increasing glycogen stores before the event or by consuming carbohydrates during the event (Refer to Table 17.6). Few days before the event, generally carbohydrate loading procedure is adopted by the athletes but this procedure is recommended only for events lasting more than 90 min or repetitive events occurring in single or multiple days. Events like sprinting, runs <10 km, weight lifting, hockey games etc. have lesser benefits of carbohydrate loading. When an event lasts more than one hour, an athlete may benefit from consuming carbohydrates during exercise. Drinks, such as diluted fruit juices or sports drinks, which contain less than 24 g of carbohydrate per cup, may be the best form for this. It is important to eat a high carbohydrate snack after an exercise session to replace muscle glycogen stores.

Some potential side effects of carbohydrate loading are:

- Muscle stiffness
- Diarrhoea
- Chest Pain
- Depression
- Lethargy

Carbohydrate supplement powders should be used only if athletes have problems consuming the needed amount of carbohydrates in their diet because of large volume of food they may need.

C) *Proteins*: Proteins are basically taken for their ergogenic properties of enhancing endurance and increasing or maintaining muscle mass to improve strength and size. The research has shown that if endurance activity extends beyond 90

minutes, the protein requirement is higher to achieve nitrogen balance. Protein and amino acid supplements are however, more popular with body-builder and strength-training athletes.

Each amino acid has unique metabolic properties and many of these have been hypothesized to enhance or improve exercise performance. Ingesting high amounts of single amino acids is contra indicated because they can affect the absorption of other essential amino acids and produce nausea or impair training and performance.

D) *Vitamins (A, D, K and B-Complex)*: Vitamins A, D and K have been found to have no ergogenic effects. Ingesting large doses of these vitamins have toxic effects.

Most scientific evidence shows that B-complex supplementation seldom enhances performance. In fact, high doses of niacin (>50 mg) can cause flushing. Thus, supplementation with single B vitamin or a mixture of B vitamin supplementation have more effects on mental performance than physical performance and only gives the sense of 'feeling better'.

E) *Antioxidants*: Antioxidants like ascorbic acid (vitamin C), tocopherols (vitamin E), selenium, glutathione (GSH) supplementation (singly or in combination) to athletes has been associated with improvements in antioxidant status and improve indicators of oxidative damage induced by exercise. Submaximal exercises do not produce any oxidative stress but exercises till exhaustion produce oxidative stress and hence antioxidant supplementation may be beneficial.

F) *Minerals*: Mineral supplementation, particulary iron in cases of iron deficient athletes is beneficial. Similarly, magnesium and chromium supplementation is also promising only if it corrects deficiencies. Phosphate salts enhance endurance when consumed at doses more that 4 g/d over 4 days.

G) *Caffeine*: Caffeine is found in coffee, tea, colas and chocolates. Its doses at 3-6 mg/d have been known to increase muscle contractility and aerobic endurance and also enhances fat metabolism. Caffeine in levels more than 15 mcg/ml in urine is unacceptable and will disqualify athletes. This level can be reached with the doses of 9-10 mg/kg. Therefore, care must be taken by athletes undergoing drug testing not to consume excessive amounts of caffeine before the event.

H) *Intermediary metabolites*: Coenzyme Q10 - for the physically active, Co-Q10 activates cell energy. When you perform any physical act; run, jump, throw, lift a weight etc., you are able to do so because you can contract muscle fibres. The harder the contraction, the greater power you can exert – up to a point. The substance that stimulates this contraction is ATP. Co-Q10 assists the body in producing ATP. Every cell in the body contains this substance, and an athlete may find that supplements of Co-Q10 will enable him to train harder and generate more power. Co-Q10 is also considered beneficial to the heart. The recommended dose is 30-60 mg per day.

I) *Creatine*: Over the past couple of years, creatine has been described as a 'legal steroid'. That's not true. Creatine has no anabolic properties. The users are athletes, footballers and women tennis players. Creatine is found in meat, but not in sufficient quantity to make much difference to athletic performance. In fact, creatine is very much like Co-Q10 just discussed and does the same thing. It increases the amount of ATP in muscles, thereby allowing for greater contraction and consequently, increased strength and power. Numerous double blind tests have proved that it can add strength and energy to an athlete, particularly those in explosive events, as opposed to events requiring endurance. What has been debated most is the amount to take daily. Safe daily intake is given at 3 grams per day. There are no reported side effects at this level, but excessive amounts well above this may cause muscle cramp.

Compounds such as bee pollen, glycine, carnitine, lecithin, brewer's yeast and gelatin are also claimed to improve strength or endurance. Although popular with some athletes because of this perceived ergogenic benefit, scientific research has failed to substantiate the claims for these products or inadequate research has been undertaken with these supplements.

However, because of the placebo effect, some athletes are convinced that certain foods, dietary regimens, or supplements improve performance. These substances may provide certain psychological benefits rather than proven physiological benefits. However, when use of these substances replaces a sound nutrition programme, health and performance may be compromised, resulting in serious consequences.

Check Your Progress Exercise 4

1) What are ergogenic aids? Give 2-3 examples.

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2) 'There is no one miracle food or supplement food that can supply all nutritional needs'. Discuss.

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3) How are nutritional ergogenic aids classified? Discuss potential side effects of carbohydrate loading and excess protein intake.

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17.8 LET US SUM UP

In this unit, we learnt about the concept of sports nutrition, how it developed and is currently developing as a discipline and its inter-relationship with a wide variety of disciplines such as medicine, exercise, physiology, physical anthropology, nutrition and biochemistry.

After a brief insight into the course of development of sports nutrition as an important area in nutrition, we learnt about various anthropometric measures and their relevance in sports. We also got to know about various techniques to measure these. Next, we moved on to the physical fitness, what is meant by it and what are its parameters. Then we had a discussion on the various nutritional requirements based on physiological demands before the event, during the event and post event activities. Finally, we got to know about what are nutritional ergogenic aids for training schedules and competitions.

17.9 GLOSSARY

Athlete : a person possessing the natural or acquired traits such as strength, agility and endurance that are necessary for physical exercise or

sports, especially those performed in competitive contexts.

Flexometer : an instrument which is attached to the limb and the change in angle on the flexometer is noted from one.

Goniometer : an instrument used to measure the range of motion at a joint.

Non athlete : a person who had never been involved in athletic activities.

Pulmonary ventilation : the total volume of gas per minute inspired or expired, measured in litres per minute.

17.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1) a) Underwater weighing or hydrostatic weighting
   b) Bod-pod
   c) Total body mineral, mineral-free lean, fat tissue masses
   d) Hydrometry
   e) Bioelectrical Impedence Analysis
2) The limitations and the advantages are given in sub-section 17.4.1. Look up the text and answer this question on your own.
3) The BIA technique is based on the assumption that tissues that are high in water content will conduct electrical currents with less resistance than those with little water. BIA method is preferred for the following reasons:
   a) the method does not require a high degree of technical skill,
   b) the method is more comfortable,
   c) the subjects are not required to be given many instructions, and
   d) this method can be used to estimate body composition of obese individuals.
4) Physical work capacity is the ability to perform maximal physical work or to work up to one's maximal potential. The factors that determine it are: Pulmonary ventilation (efficiency to breath in or breath out), haemoglobin concentration, blood volume and cardiac output, peripheral blood flow, and aerobic metabolism.
5) The two physical work capacity test include heart rate method and step test.

Check Your Progress Exercise 2

1) a) Physical fitness is the attainment or maintenance of physical capacities that are related to good or improved health and are necessary for performing daily activities and confronting expected and unexpected physical challenges.
   b) Cardiovascular endurance is the ability to supply oxygen to the working muscles during physical activity.
   c) Muscular strength is the ability of a muscle to exert force for a brief period of time.
   d) Flexibility refers to the ability to move joints and use muscles through their full range of motion; the elasticity of the muscle.

e) Muscular endurance is the ability of a muscle, or a group of muscles, to sustain repeated contractions or to continue applying force against a fixed object.

2) Look up sub-section 17.5.2 and answer on you own.

3) a) Measuring direct aerobic fitness, Astrand Cycle Test, Cooper's run, Queens College Step Test

b) Push-ups, pull-ups, sit-ups, flexed arm hand

c) Sit and reach flexibility, calf muscle flexibility test, shoulder flexibility test

The different tests that are used for evaluating muscular endurance includes pull-upset, push-up test, Bent-knee curl up Test and Bench-press test. The different test for muscular strength includes 1-RMN Tests, Isokinetic strength tests, Hand-grip strength test and abdominal strength test.

Check Your Progress Exercise 3

1) Nutrition goals in care of sports and exercise include:

- maintaining ideal body weight and body composition as desired of a particular sport,
- maintaining adequate pool of nutrients,
- providing diet that helps in achieving performance up to ones potential,
- clarifying facts and fallacies related to food,
- introducing athlete to competition diets, and
- encouraging healthy nutritional practices amongst athletes.

2) The dietary recommendations for different nutrients are presented in section 17.6. Read the text and answer on your own.

3) The tips for preveent meal are presented in section 17.6. Look up these tips and write this answer on your own.

4) The principle of 3R's should be followed after the event. Rehydration, refuelling, and rest facilitate the recovery process. Recovery is the phase where muscle glycogen needs replenishment, and muscle repair and gains occur. For this purpose, rest is required. The recovery phase begins immediately after exercise ends.

Check Your Progress Exercise 4

1) Ergogenic acids are substances, devices, or practices that enhance energy use, production, or recovery. The most commonly used and talked about ergogenic aids include anabolic steroids, human growth hormone, caffeine and creatine.

2) Certain foods supply mainly proteins, other foods contain vitamins and minerals, and so on. The key to balancing diet is to combine different foods so that nutrient deficiencies in some foods are made up by nutrient surpluses in others. Eating a variety of foods is the secret.

3) Refer to section 17.7 and answer on your own.