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Endurance

Lecture - 178
Endurance : Concept, Types, Factors and Methods.

Introduction

Training is the process of preparation for some task. "Sports training is a pedagogical process, based on scientific principles, aiming at preparing sportsman for higher performances in sports competition".

Sports training is also essential to understand the meaning of the terms 'conditioning' and 'coaching'. Conditioning a process of gradually preparing the body for strenuous physical activity thus focusing attention on development of physical and motor fitness components(strength, endurance, speed, flexibility, co-ordinative abilities) and directly enhancing sports performance.

Endurance is directly or indirectly of high importance in all sports. It is however not easy to define endurance. Nabatnikowa (1976) brings this into focus by presenting definitions given by several experts. Disagreement among experts is much more regarding the definition of different types of endurance e.g., special endurance, speed endurance, strength endurance etc. but there is agreement regarding the following aspects of endurance.

Harre (1986) defines endurance as the ability to resist fatigue. Thiess and Schnabel (1987) also define endurance as the resistance ability to fatigue. Martin (1979) and Matweyew (1981) have also used the concept of 'ability to resist fatigue' for defining endurance. "endurance is the ability to do sports movements, with the desired quality and speed, under conditions of fatigue."

Concept

Endurance , like strength, is a conditional ability. It is primarily determined by energy liberation processes. The ability of the human body to maintain a certain level of energy production forms the physiological basis of endurance. Due to its high importance for health and training and competition and also due to its physiological determinants, which can be relatively easily studied, it is an ability which has been studied in great detail and depth by the physiologists.

Endurance is characterized by the maintenance of working capacity and by the degree of resistance of the organism against fatigue and against the influence of unfavourable environmental conditions. It is also characterized by the pace of recovery after a tiresome activity. Without an understanding of fatigue caused by training and competition load and the psycho-physiological systems involved in countering the effects of fatigue one cannot fully grasp the nature of endurance. But it is important to realize that endurance is as much a product of physiological functions as of psychic functions. This fact has been proved time and again by successful endurance athletes.

Types of Endurance

Endurance can be classified based on the nature of the activity and duration of the activity.
Keeping in mind the nature of the activity, endurance can be classified into following four types:
1. Basic Endurance
2. Speed Endurance
3. Sprint Endurance
4. Strength Endurance

Basic Endurance:

It is the ability of the organism to resist against fatigue in the case of endurance loads of medium intensity of stimulus and mainly aerobic muscular metabolism. E.g., jogging, swimming, walking at moderate speed for periods lasting more than 30 minutes. For sedentary and untrained persons the duration can be significantly less. As the activity is done at slow pace (below anaerobic threshold), therefore the energy is supplied predominantly by aerobic process of energy liberation. Due to this fact, it is also referred to as aerobic endurance. However, the term basic endurance is better as it reflects the psycho-motor nature of this ability better. Basic endurance activities do not result in appreciable lactic acid concentrations in the blood.

Basic endurance, as it depends on the aerobic process, forms the basis of all types of endurance. Without a sufficient level of basic endurance other types of endurance are difficult to improve. Local muscular endurance is a special form of strength endurance.

Speed Endurance:

It is the ability of the organism to resist against fatigue in the case of endurance loads of sub-maximum intensity of stimulus and mainly anaerobic gaining of energy and maximum loss of oxygen. This ability is required for cyclic activities lasting up to 45 seconds. The 400m sprint in track and field is a classical example of speed endurance ability. This ability is highly dependent on the power and capacity of glycolytic mechanism of energy production. The phosphogens (alactacid metabolism) also contribute significantly towards energy production. Glycolysis results in very high amount of lactic acid concentration in the muscles and as a result is one of the dominant fatigue producing factors in such activities. Very high amount of oxygen debt is recorded in speed endurance activities. A highly developed activity of the muscles, to continue contracting with required speed and force, other high lactic acid concentration is a primary prerequisite for good performance in speed endurance activities.

Sprint Endurance:

It is the ability of the organism to resist against fatigue during endurance loads of maximum intensity and motor frequency.

Strength Endurance:

It is the ability of the muscle to get over resistance in the case of loads of medium intensity of stimulus for as long time as possible. Keeping in mind the duration of different games and sports, endurance can be classified into following three types:

1. Short Time Endurance: This ability is required for cyclic activities which last from 45 seconds to 2 minutes. These activities result in high amount of lactic acid concentration in the blood and muscles. Because of comparatively longer duration of activity the lactate values can exceed those found in speed endurance activities. To perform well in short time endurance activities, speed endurance and strength endurance are important pre-requisites. Examples of short time endurance are 400m run, 800m run few events of swimming, selected combative sports namely wrestling, judo etc.

2. Middle Time Endurance: This ability is needed for cyclic activities continuing between 2 to 8 minutes. In this activities also, there is a high amount of lactic acid concentration in the blood and muscles. Speed endurance and strength are important motor components required for good performance. E.g., 1500m run, 3000m run, few events in swimming, selected combative activities etc. The contribution of alactacid metabolism is practically nil. For oxidation the source of energy is muscle glycogen which due to limited duration of acitivity cannot be depleted to significant extent and as a result is not a limiting factor for performance. Due to involvement of glycolysis in medium time endurance activities, lasting up to eight minutes, high concentrations of lactic acid are produced.
3. Long Time Endurance: This ability is essential for all games and sports and activities continuing for more than eight minutes. For long time endurance

activities, the main source of energy is the glycogen stores in muscles and liver. Energy is produced by the oxidation of glycogen. For activities continuing upto 30 minutes, energy production is achieved from oxidation of glycogen whereas for activities lasting for more than 30 minutes, the energy is produced as a result of fat metabolism. As the duration of activity increases, production of lactic acid in the muscles and blood reduces. E.g., long distance events in track and field and swimming, racket games, kabaddi, kho-kho etc. Depending on the nature of energy production as a result of duration of activity long time endurance can be divided into three types as given in Tabular form.

For good performance in long time endurance activities, especially of type II and type III the glycogen stores in the muscles and liver assume great importance. These often become limiting factors as low level of muscle glycogen and blood sugar can reflexibily accelerate the onset of fatigue. The performance here also depends significantly on several psychic factors like will power, motivation, ability to tolerate pain and agony. The long time endurance particularly of type II and type III, is dependent to a great extent on basic endurance.

Factors Determining Endurance

Endurance is one motor ability which has been a subject of keen study by experts of sports physiology. As a result we have a much better insight into the factors and prerequisites which determine endurance ability. But the study of psychic factors of endurance is still lagging behind. The study of psychic aspect of endurance is crucial for further improvement of endurance performances.

The list of factors which determine endurance is very exhaustive. For the sake of presenting these factors systematically all the factors can be grouped into four major factors. They are under as follows:

1. Aerobic capacity

To enable a person to continue an activity for a prolonged period, continuous flow of oxygen has to be ensured to the working muscle for liberation of energy. The aerobic capacity of a person can be measured by the maximum amount of oxygen consumed by the working muscles in one minute (VO_2 max).
The human body gets oxygen from the atmosphere and is then transported to the muscles where it is consumed. But as energy liberation has to continue for long periods, therefore, the energy reserves are also important constituents of aerobic capacity.

a. Oxygen intake

Oxygen intake is the amount of oxygen which can be taken into the blood stream from the atmosphere. If oxygen intake is more, then there are favourable chances of achieving higher VO_2 max. Oxygen intake depends on the vital capacity which further depends on the lung size, number of active alveoli, strength of respiratory muscles, size of the chest cavity etc. Once the oxygen is inside the lungs it has to be absorbed into the blood through diffusion. The rate and amount of oxygen diffusion from the lungs to the blood depends on several factors e.g., temperature, partial pressure of oxygen in the lungs and blood, the amount of haemoglobin in the blood and so on.
It is generally agreed that oxygen intake is not a limiting factor for endurance performance in healthy and well trained sportsmen.

b. Oxygen Transport

The amount of oxygen taken into the blood from the lungs has to be transported to the working muscles. More oxygen transport means more oxygen available to the muscles for comsumption. The oxygen transport depends on two things. The amount of oxygen which the blood has absorbed from the lungs and the ability of the cardio-circulatory system to carry this quickly to the muscle for comsumption.

c. Oxygen Update

The oxygen from the blood has to be taken up by the muscle cells and then consumed. The oxygen uptake depends on the rate of diffusion which is further determined by the speed of blood flow, temperature and partial pressures of oxygen in the blood and of carbon-dioxide in the muscle cell. The oxygen uptake is facilitated if capillarisation is good. The speed and amount of oxygen consumption also depends on the number, size and metabolic capacity of the mitochondria.

d. Energy Reserves

The amount of muscle glucogen has a decisive effect on activities lasting longer than 30 minutes.The muscles store glucose in the form of glycogen. When the activity is to be done at moderate speed then the energy is largely derived from the oxidation of muscle glycogen. The depletion of muscle glycogen beyond a certain level results in the onset of fatigue. The activities which last for very long periods (e.g., marathon) lead to extreme depletion of muscle glycogen. The discovery of the role of muscle glycogen in endurance performance has led to introduction of diet manipulation before and during long duration activities. During sports activities the muscle can use three substances as fuel for energy production. These substances are: phosphogens, carbohydrates and fats these, however, are used differently for activities depending on the speed or pace of activity.

2. Anaerobic Capacity

Anaerobic capacity is the ability of the organism to perform an activity in the absence of oxygen. For these activities energy production comes either from breakdown of phosphogens (ATP and CP) or from glycolysis of muscle glycogen. In the muscles the total amount of store phosphogens is only sufficient for acitivities with maximal intensity lasting upto 8-10 seconds. Hence, alactacid mechanism is of crucial importance for speed performances.

The glycolysis process during anaerobic work primarily aims at rapid resynthesis of creative phosphate which is further required for rapid re-synthesis of ATP (adenosine triphosphate). The end product of glycolysis is lactic acid. The glycolytic processes achieve is maximal values after 40-45 sec of maximal value and inhabit muscle contractions. Therefore lactic acid is the limiting factor in speed endurance activities.

The anaerobic capacity is required to a lesser or greater extent for all sports performances depending on endurance. Even in long time endurance activities the anaerobic capacity is needed for sudden bursts of short duration at the beginning or end or in between. The anaerobic capacity depends on the following factors:

a. Phosphogen Stores

Stores of ATP and CP are crucial for anerobic capacity. This is so because muscle derive energy only from ATP which is stored in very less amount in the muscles. Therefore ATP has to be rapidly resynthesized by CP the stores of which are also limited. CP is re-synthesised by glycolysis. But larger stores of ATP and CP relieve pressure on the glycolysis thereby resulting on lesser amount of lactic acid production. The phosphogen stores can be increased significantly through training. Alongwith the phosphogens certain non-oxydative enzymes are also crucial for anaerobic energy production. The amount of these enzymes can also be increased by training.

b. Buffer Capacity

As discussed earlier high concentration of lactic acid are detrimental for endurance performance of short duration as it tends to inhabit muscle contraction. To avoid this, lactic acid is quickly pushed into the blood where it lowers the blood pH value i.e., makes blood more acidic. The maintenance of blood pH value within a range of 7.1 to 7.5 is crucial for the normal functioning of the body. Therefore, the incoming lactic acid has to be neutralized or converted into something which is less acidic. This is done by some substance in the blood which are collectively refered to as alkali reserve. The total capacity of the alkali reserve to counter the effects of lactic acid in blood is called buffer capacity. A higher buffer capacity will ensure longer duration of glycolysis which is indispensable for endurance performance of short duration. The alkali reserve, however, cannot be improved significantly through training.

Some amount of lactic acid can be removed from blood by oxydation but this process is very slow and can be effective for removal of lactic acid during recovery break.

c. Lactic Acid Tolerance

In endurance performances of short duration the ability to effectively tolerate higher concentrations of lactic acid is of very high importance. Due to limited amount of alkali reserve the lactic acid is of very high importance. Due to limited amount of alkali reserve the lactic acid concentration inevitably increases in the blood and the body is forced to work under highly acidic condition of blood. High lactate values in blood also slow down the removal of lactic acid from the working muscles. As a result muscle lactate values also increase rapidly. Now only the ability to tolerate high lactate concentrations can enable the sportsman to continue the activity with the same speed. Fortunately through training the lactic acid tolerance can be significantly improved. The performance in 400, 800m and 1500m in track and field depends significantly on lactic acid tolerance.

d. Aerobic Capacity

The anaerobic capacity depends, to a significant extent, on aerobic capacity. During speed endurance and short time endurance performance the total energy required is produced by a certain combination of alactacid, lactacid and oxidative metabolic processes. A higher level of aerobic capacity has a sparing effect on glycolytic (i.e., lactacid) and alactacid mechanisms. This fact is demonstrated by higher anaerobic threshold levels in endurance trained sportsmen. In untrained persons the lactic acid production begins at work rates of about 60%-65% of VO_2 max. This happens in case of highly endurance trained sportsmen at about 85% VO_2 max. or even higher.

3. Economy of Movement

All the movement are to be efficiently executed and unwanted movements are to be avoided so that activities are performed with minimum expenditure of energy. To achieve this, complete technical efficiency is to be ensured.

In some endurance sports like long distance swimming, rowing, cycling etc. the role of technique for energy conservation assumes very high significance. In these sports poor technique leads to a lot of energy wastage, thereby markedly affecting the performance. Technique in endurancesports,therefore,aims at movement economy.Sajiorskij (1987)found that in long distance events in sportsmen with good running technique spend less energy than those having poor technique. The good runners raise their C.G.less higher,their unnecessary movements are less and they conserve and utilize kinetic energy for running. Fox and Costill (1972)found that marathon runners require 5-10% less energy than the middle distance runners when running at same speed.

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4. Psychological Factors

The contribution of psychic factors towards endurance performance can hardly be over estimated. Endurance performances, because of high degree of fatigue involved, are always a result of sportsman's fight and resistance against the uncomfortable and painful sensations and feelings which are an inevitable part of endurance activity. Endurance performance, in addition to physiological factors, certain psychological factors namely motivation, will power, ability to tolerate pain and discomfort etc. are also important in enabling a sportsperson to continue activity for a prolonged period. These qualities of head and heart are important for endurance competition as well as for endurance training. Endurance athletes are characterized by qualities of hard work, perseverance, determination and by a distinct type of temperament and personality. Fortunately, many of the psychic factors important for good endurance performance can be significantly improved through training and other means.

Method of Endurance Training

Duration of Load Method

This training method includes those methods of endurance training in which uninterrupted medium to sub-maximum intensity loads are maintained for a relatively longer period of time.

(a) Constant Method

This method involves continuous loads administered for a long prolonged period of time. In as much as the loads are continued for a long time, the intensity of running is low. This method has three variations.

(i) Slow Constant Method
(ii) Fast constant Method
(iii) Varied Pace Method

(b) Alternating Method

In this method of endurance training also the load is uninterrupted but the intensity of running is changed. The change of intensity is fixed by the coach. In view of the fact that intensity of running and its changes is planned by the coach, this method has not become popular.

(c) Fartlek

Fartlek is a Swedish term meaning "speed play". This method was developed in Scandinavia to provide an alternative to constant running. It is used to described cross country runs where the steady speed of ordinary cross country running is changed into a mixture of faster and slower phases, each covering a different distance over natural terrain according to the individual approach of the sportsperson. The change of intensity is done depending upon the surface of running, surroundings, condition of the sportsperson, climate and

the like. This method is effective for developing both aerobic and anaerobic capacities of sportspersons.

Interval Running Method

It is perhaps the most versatile method of endurance training which involves repeated efforts art at the relatively faster pace, separated by measured intervals of incomplete recovery. The intensity of each bout of running should be such that the heart rate increases from normal to between 170 to 180 beats per minutes. The bouts of loads are repeated when the heart rate comes down from the above value to about 120 beats per minutes. The training load method is best maintained by repeatedly checking the heart rate.

Repetition Training Method

This method involves loads of high intensity (90% to 100%) of stimulus separated by intervals of complete recovery. It is considered as the best method for developing speed endurance and pace judgement. This method enhances anaerobic capacity thus improving phosphogen stores, lactic acid tolerance and non oxidative enzymes.

Competition and Test Method

Endurance performance depends upon experience tactical efficiency and psychic factors.
They can be improved through participation in competitions. Test and time trial are also good for specific endurance.

Conclusion

Endurance is an important component of various conditional abilities, skill and tactical actions. Exercises involving competitive movement and done with additional weights e.g. hurdling with weight jacket on, kicking in soccer with ankle weight collars on etc.
Endurance loads cause numerous changes in the functions and structure of the organism. These changes refer to the performances of heart, circulation, respiration, metabolism, hormonal system and bio-chemical changes in the muscle cells. Endurance enables sportspersons to successfully complete training schedules of high loads.