A SIMPLIFICATION OF ENERGY SYSTEMS IN THE BODY

Running,like all other forms of movement is made possible by the action of our muscles. Tendons connect bone to skeletal muscle and by the action of our muscles alternately contracting and relaxing give rise to joint movement

A muscle contraction whether it is strong or weak is a result of a complex chain reaction which requires energy. Ultimately ,we derive energy from converting foodstuff at the muscle cell level into a high-energy compound known as Adenosine Triphosphate ***(ATP)*** *which is then stored in the muscle cell*

ATP is the body's main source of energy for muscle contractions since it is held together with high energy phosphate (P) bonds

ATP,as its name suggests,consists of one molecule of adenosine and three molecules of phosphate.

The hydrolysis(splitting of the phosphate group from the ATP) produces an immediate source of muscular energy

High-energy ATP --- > broken down *into* ***ADP + P (adenosine diphosphate + phosphate).As one phosphate bond is broken into ADP +P, energy is released.***

However there is only a small amount of ATP stored within our muscles that would last for around four seconds if we exercised flat out thus we must continually replenish ATP supplies to facilitate ongoing physical activity

Think of an ATP tank-an analogy can be made to putting petrol in the tank of a car,if not enough fuel is put in the car it will come to a halt. So it is with the ATP tank,this tank must be kept full at all times or nearly full(never below 60% of resting level) for muscular activity to continue. It is probably not likely to happen since we have this overwhelming desire to eat and cannot forget about it unlike putting petrol in the car. This is achieved by the transfer of the chemical energy found in fats,carbohydrates and proteins,from our foodstuffs. The foods are broken down into Glucose which can be stored in the muscle and liver in the form of Glycogen and then utilised in energy production pathways to rebuild the ATP molecule

Training,be it sprint,endurance,interval or resistance(weights) does not increase our resting ATP concentrations. Instead training improves our ability to maintain ATP resynthesis. Provided we can produce ATP at the same rate it is needed by the muscles for contraction,we can delay the onset of fatigue. As soon as we fail to produce ATP at the rate at which we are using it,fatigue sets in. Thus,the maintenance of ATP levels within muscle tissue is the primary goal of athletic training. Our ability to resynthesise ATP within the muscle cells in order to support continued exercise relies upon three energy systems:

- *Anaerobic ATP-CP or Creatine Phosphate System*
- *Anaerobic Glycolysis or Lactic Acid System*
- *Aerobic or Oxygen system*

The three systems should not be thought of as operating independently of each other. The situation does not exist wherebye one system is used as the other becomes exhausted.The three systems are constantly making some contribution to the body's energy requirements. The major feature that distinguishes these energy systems is the speed at which they function and the total amount of ATP resynthesised by each series of chemical reactions. The greater the intensity of effort,the greater the rate of ATP turnover,the greater the reliance on anaerobic glycolysis and creatine phosphate

A second important point is that the 'trigger' which initiates the chemical reactions necessary for the transfer of energy from fats,carbohydrates and proteins for ATP resynthesis is a decrease in a cell's ATP concentration. As soon as resting ATP levels fall (which has to occur when muscles contract) the chemical reactions immediately begin

CREATINE PHOSPHATE SYSTEM

The most immediate source of new ATP, after the use of the initial stored ATP, is to be found in a substance called Creatine Phosphate

Creatine Phosphate is in practical terms similar to ATP. When an enzyme(which is a substance responsible for controlling chemical reactions) splits creatine from phosphate,energy is released and transferred for ATP resynthesis. A transfer of a phosphate(P) from CP to ADP generates the necessary ATP.

Muscle cells have relatively low stores of CrP and reserves are normally depleted within 8-10 seconds. Energy from this splitting (CrP) is provided very quickly and requires only one anaerobic chemical reaction(ie,a reaction which is not dependent on oxygen) This system is also referred to as ***Anaerobic(without oxygen) Alactic (without lactate)***

It is the chief source of energy for extremely quick and explosive activities such as 100m dash,weightlifting and throwing events in track and field since it provides energy quickly in large amounts, but as we see, the stores are exhausted quickly. Through restoration,low intensity exercise or complete rest the body recovers and replenishes energy stores to preexcercise conditions. Through its biomechanical means, the body attempts to return to physiological balance(homeostasis),which is when it has the highest efficiency. Phosphagen restoration occurs rapidly. In the first 30secs it reaches 70% and in 3-5 minutes it is fully restored. This is why sprinters have longer recovery bouts between sprints,more often than not, when training

To produce more ATP the muscles will now have to break down one or two fuels available in the body,either carbohydrates or fats. Carbohydrates can be broken down to produce ATP with oxygen present, referred to as ***AEROBIC METABOLISM*** *or without oxygen present, referred to as* ***ANAEROBIC METABOLISM****. Fats and protein on the other hand can only be broken down by the aerobic process*

ANAEROBIC GLYCOLYSIS or LACTIC ACID SYSTEM

Anaerobic Glycolysis,which is sometimes referred to as the lactic acid system relies on chemical reactions to break down glycogen(stored carbohydrate) in the muscle cells and the liver,releasing energy to resynthesise ATP from ADP +P. Due to the absence of oxygen during the breakdown of glycogen,a by-product called lactic acid forms.

Sprinters will depend upon anaerobic glycolysis to supplement their limited CrP reserves during sprinting. The longer the sprint the greater the reliance on aerobic glycolysis to provide energy

So infact for all intensive events up to approximately 40-60 seconds(200m, 400m) the ATP-CP system first provides energy up to 8-10 seconds and then the lactic acid system provides the further energy needed

Although anaerobic glycolysis provides quick energy,lactic acid can accumulate within the muscles. To a limited extent muscles can cope with a mild accumulation of acid. However,if lactic acid production is great,as it is during longer sprints,acidity(acidosis) increases and is believed to be a major cause of fatigue and can be quite painful

High intensity Interval and Repetition training will clearly improve an athlete's ability to use anaerobic glycolysis with the greater tolerance developed to the lactic acid build up

Full restoration of glycogen requires a long time,even days, depending on the type of training and diet but in general allow 24-48 hrs depending on fitness levels. A good aerobic base can reduce the time necessary to replenish glycogen stores.

Interestingly, it is the aerobic system which allows removal of the lactic acid and again helps the muscle to return to normal. Thus,as with the CrP recovery of the muscle they are oxygen -dependent

AEROBIC SYSTEM

The aerobic system,also known as the oxygen energy system,can only function when oxygen is supplied to the muscles. When oxygen is available,fat(in the form of free fatty acids),carbohydrate(in the form of glycogen) and protein can be broken down inside a cell structure within the muscle known as the mitochondria. It is the availability of oxygen that creates the combustion with these nutrients to produce ATP.

Aerobic chemical reactions are relatively slow compared to those in the glycolytic pathway,the aerobic system requiring 60 to 80 seconds to produce energy for resynthesising ATP from ADP + P

However,considerably more energy becomes available aerobically than through either of the two anaerobic energy pathways. The slower rate of ATP resynthesis is due to the necessary transfer of fuel between different compartments in the cell. The aerobic system also depends upon oxygen delivery from the lungs,which is governed by blood flow from the heart,to the lungs,back to the heart and then to the muscles. All these processes take time – time the sprinter simply does not have but the endurance athlete does

The aerobic system is the primary energy source for events lasting between 2 minutes and 2 to 3 hours(all track events from 800m up, cross country and long distance running or walking). Prolonged work beyond 2 to 3 hours may result in the breakdown of fats and proteins to replenish ATP stores as the body's glycogen supply depletes. In any of these cases,the breakdown of glycogen,fats or protein produces the by-products of carbon dioxide(CO_2) and water(H_2O), both of which are eliminated from the body through respiratory and perspiration

The rate at which athletes can replenish ATP is limited by their aerobic capacity, or the maximum rate at which they can consume oxygen, the intensity of the run having a direct effect on enough oxygen being available

Those who derive most benefit from the aerobic system are distance athletes and it follows that endurance training then improves the function of the aerobic system

SUMMARY

The body uses or depletes energy sources during exercise according to the intensity and duration of the activity. Except for very short activities, most sports employ both energy systems to varying degrees. Therefore,in most sports the anaerobic and aerobic systems overlap

A good indicator of which energy system contributes the most in an exercise is the level of lactic acid in the blood. Blood samples may be taken and lactic acid levels measured. The threshold of 4 millimoles of lactic acid indicates that the anaerobic and aerobic systems contributed equally to the resynthesis of ATP. Higher levels of lactic acid indicate that the anaerobic or lactic system dominates, and lower levels indicate that the aerobic system dominates. The equivalent threshold heart rate is 168-170 beats per minute,although individual variation exists. Higher heart rates indicate that the anaerobic system predominates, and lower rates indicate that the aerobic system predominates

Summary of the Energy Systems

ATP- PC (phosphagen) System produced without the presence of O_2	***Anaerobic Glycolysis or lactic acid system produced without the presence of O_2***	***Aerobic or oxygen system produced in the presence of O_2***
Anaerobic Very Rapid Chemical fuel : PC	*Anaerobic Rapid Fuel : glycogen*	*Aerobic Slow Fuels: glycogen, fats,protein*
Very limited ATP Production	*Limited ATP production*	*Unlimited ATP production*
Muscular stores limited	*By- product,lactic acid causes muscular fatigue*	*No fatiguing by-products*
Primary use with sprint or any high-power: Short duration activity 0-10 seconds	*Primary use in intense activities Duration 10s-70s*	*Primary use in endurance or long-duration activities*

To conduct an effective training program athletes must understand energy systems,the energy fuel used by each system and how much time is needed to restore energy fuels used in training and competition. A good understanding of restoration time for an energy system is the foundation for calculating rest intervals between training activities during a workout,between workouts and after competition

The more comfortable you are with these concepts, the more effective you are in organizing and leading a training program

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