

ATHLETICS OMNIBUS – ENERGY PRODUCTION IN MUSCLES

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1. INTRODUCTION

Similar to an engine that needs high octane “fuel” to move the components of an engine, muscles need “energy” to function.

The capacity of the human body to move mainly depends on the capacity of the muscles to contract (to become shorter). Generally the muscles need oxygen in the muscles to be able to contract. It is however possible for the muscles to contract for short periods of time without the presence of oxygen in the muscles.

At times, the contraction of muscles needs to be quick, explosive contractions such as in the sprints, jumps and throwing events. In these events the muscle contractions are so fast, that oxygen cannot reach the muscles in time to manufacture “fuel” to be used by the muscles. During these events the muscles will use “fuel” that was stored in the muscles before the start of the event.

In the case of running a long distance event, the contractions of the muscles need to be slower to ensure muscle contractions over longer periods of time. If the contractions are slow enough, the muscles will be able to manufacture enough “fuel” for sustained muscle contractions.

2. ENERGY USED IN THE BODY

The type of energy that is used to produce contractions in the muscles is an energy source called Adenosine Triphosphate (ATP). ATP is a molecule, (a so-called high octane fuel), that releases the energy needed for muscle contraction.

3. ENERGY SYSTEMS

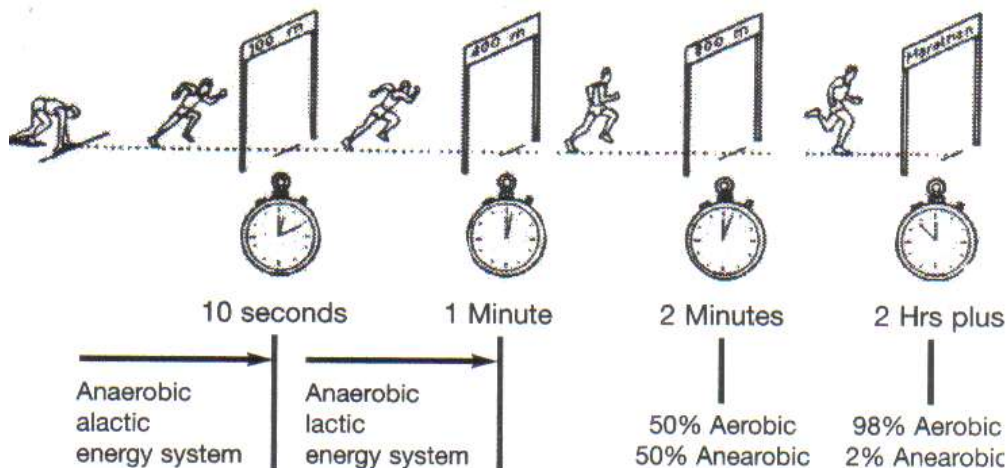
The same type of “fuel” Adenosine Triphosphate (ATP) is needed in all types of events. The type of energy that will be used to manufacture the required “fuel” will largely depend on the volume, the intensity and the time it takes to complete a competition.

The body uses 2 systems to provide the “fuel” needed for muscle contractions. The:

- 3.1. Anaerobic System is an oxygen free “fuel” manufacturing process generally needed during quick, explosive contractions e.g. in sprints
- 3.2. Aerobic System is an oxygen based “fuel” manufacturing process generally needed in slower muscle contractions over longer periods such as the Marathon.

The diagram indicates two primary time frames.

The time frames mark a shift in the emphasis from anaerobic energy to aerobic energy.



For events that require maximum force, two time frames is clearly defined where the shift from one type of energy providing system to another takes place is at 10 seconds and 2 minutes.

For events that require low intensity force, two time frames is clearly defined where the shift from one type of energy providing system to another takes place is at 2 minutes and 2 hours.

How this conclusion was made will become clear in the explanation of how the anaerobic and aerobic energy systems operate.

3.3. THE ANAEROBIC SYSTEM

The Anaerobic System can be divided into 2 oxygen free energy providing systems that will produce energy to the muscles:

3.3.1. THE ANAEROBIC ALACTIC SYSTEM

The anaerobic alactic system operates as a start-up system in the muscles. The anaerobic alactic system will use a "high octane fuel" called Adenosine Triphosphate (ATP) that is stored in the muscles during rest periods.

Unfortunately only a small quantity of ATP is stored in the muscle for use during the initial stages of movement. The stored ATP amounts to 5kj of energy only, which is equal to about ¼ litre of oxygen. The ATP can therefore act as fuel for the muscles for not more than 4 – 6 seconds.

Because the ATP was stored in the body for use by the anaerobic alactic system, no oxygen was needed during the chemical reactions to create energy for the muscles. Because no oxygen will be used during the energy creating chemical reaction, no disposables called lactic acid will be created as well.

3.3.2. THE ANAEROBIC LACTIC SYSTEM

To form ATP, limited re-synthesis (production of chemical compounds) in the body can take place from another high-energy phosphate compound called Creatine Phosphate (CP).

Unfortunately the amount of Creatine Phosphate (CP) available in the muscles is also low and the re-synthesis process can produce only about 15kj of energy, the equivalent of about ¾ litre oxygen.

Jointly the ATP and CP can provide a total of 1 litre of oxygen but will last no longer than 1 minute in total.

The ATP-CP energy systems powers the initial seconds of movements where maximum force is needed, such as in the sprints, field events and weight lifting in the gym. This system is readily available for high intensity short duration exercise.

If muscular exercise at maximum force is to continue for longer than a few seconds, continuous replenishment of the ATP is necessary.

The replenishment is achieved primarily by the re-synthesis of ATP from CP in the mitochondria of the muscle cells. (The mitochondrion is a structure in which energy production takes place and exists in large numbers in the muscle cells).

The process of replenishment (re-synthesis) requires oxygen. The replenishment process is responsible for an oxygen consumption rate of 5 – 7 times faster than in a state of rest. This explains the out of breath sensation, irrespective the fitness level, after running full speed for 200m.

During the re-synthesis process, lactic acid is produced as a disposable. The lactic acid build-up in the muscles is very quickly and is responsible for the feeling of stiffness and soreness of the muscles after training.

3.4. THE AEROBIC SYSTEM PRODUCE ATP BY BREAKING DOWN GLYCOGEN

The Aerobic System can be divided into 2 oxygen based systems that will produce energy to the muscles:

3.4.1. THE AEROBIC GLYCOLITIC SYSTEM

The muscles will use the Aerobic Glycolitic System when muscle activity is of long duration and low intensity.

ATP production will take place during the breakdown of glycogen in the presence of sufficient oxygen that is supplied by the cardiovascular and respiratory systems.

This energy system is predominantly active during physical activities lasting between 2 minutes up to 2 hours.

The Aerobic Glycolitic System produces glycogen from sugar. It can produce large amounts of ATP, but the process is slower and needs oxygen.

The Aerobic Glycolitic System also produce lactic acid as a disposable, but the lactic acid build-up in the muscles is much slower than the ATP-CP re-synthesis process in the Anaerobic Lactic System.

3.4.2. THE AEROBIC LIPOLITIC SYSTEM

The muscles will use the Aerobic Lipolitic System when muscle activity is of long duration and low intensity.

ATP production will take place during the breakdown of fat in the presence of sufficient oxygen that is supplied by the cardiovascular and respiratory systems.

The Aerobic Lipolitic System only start functioning when the Aerobic Glycolitic System experiencing difficulty to produce glycogen from sugar.

The Aerobic Lipolitic System will start metabolizing fat aerobically after about 2 hours of low intensity physical activity.

Fat is used as substrate to be metabolized completely in the presence of sufficient oxygen supplied by the cardiovascular system to supply large quantities of ATP.

The rate of ATP production of the Aerobic Lipolitic System is low, but can be supplied for several hours.

4. ENERGY SYSTEMS NEEDED FOR SPECIFIC CONDITIONS

The table below indicates the type of energy required under specific conditions. The table can be used as a guideline to prepare training programmes for athletes according to the distance, duration or intensity of the event.

DEVELOPMENT OF THE 3 ENERGY SYSTEMS UNDER THE FOLLOWING TRAINING CONDITIONS

	ATP	ATP-CP	AEROBIC
Intensity	Maximal	90% - 100%	50%-75%
Duration	0-10 secs	10 secs – 1 min	1 min and longer
Distance	20m-80m	80m-400m	300m and longer
Repetitions	3-4	1-5	3-20
Recovery between reps	1½ - 3 mins	2-10 mins	1-3 mins
Sets	1-4	1-4	1-4
Recovery between sets	8-10 mins	10-2 mins	5-8 mins

THE IMPORTANCE OF ENERGY SYSTEMS DEVELOPMENT ACCORDING TO THE EVENTS

ENERGY SYSTEMS	EVENTS																	
	100m	200m	100mH	110mH	400m	400mH	Jumps	Throws	800m	3000m Sc	1500m	3000m	5000m	10000m	15000m	5000m Race Walk	10km-50km Race Walk	Marathon
Weight factor: Very important = 3 Important = 2 Helpful = 1 Least helpful = 0																		
Anaerobic (ATP)	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	0	0	
Anaerobic (ATP-CP)	2	3	3	3	3	3	3	3	3	2	2	2	2	3	1	1		
Aerobic glycolytic	0	1	1	1	1	1	1	2	3	3	3	3	3	3	3	3		
Aerobic lipolytic	0	0	0	0	0	0	0	0	0	0	0	2	2	2	3	3		

5. HOW TO DEVELOP EACH ENERGY SYSTEM CAPACITY.

5.1. The development of explosive energy

- 5.1.1. Sprint starts (0m-30m)
- 5.1.2. Maximal sprints (less than 6 seconds) with complete recovery (3-5min)
- 5.1.3. Resistance gym training with heavy weights, low repetitions. (3 sets of 3-5 repetitions @ 95% of maximum rate)

5.2. The development of lactate tolerance

- 5.2.1. Sprint repetitions of less than 30 seconds duration (3 to 5 min rest between repetitions)
- 5.2.2. Resistance gym training with lighter weights. (3 sets of 10 - 15 repetitions @ 80 - 85% of 1 repetition maximum)

5.3. The development of maximum aerobic energy and the development of fatigue resistance

3 types of workouts can be distinguished

5.3.1. Development of lung capacity to absorb oxygen

75% effort lasting between 2 and 15 minutes with equal rest periods - 1 to 6 repetitions depending on the maturity of the athlete

5.3.2. Anaerobic threshold sessions

- 5.3.2.1. Maximal steady state running for 20 to 60 minutes of duration, e.g.
- 5.3.2.2. 5 to 8 km time trail or 5 to 10km races.

5.3.3. Aerobic sessions

Easy running for 30 minutes to 3 hours.

5.4. The development of endurance and fatigue resistance

Long steady running at a tolerable pace for 1,5 to 4 hours.

6. THE USE OF HEART RATE MONITORING AND THE ENERGY SYSTEMS

Heart rate is of no use during high intensity training when the anaerobic systems are used. The energy is supplied from chemical sources and the heart rate gives no indication of the intensity or the efficiency of a particular work out.

Heart rate can be of help during aerobic training sessions to determine the intensity and therefore the energy system that is being taxed.

The following table can be of help.

Type of training session	Heart rate as % of maximum heart rate
Lung capacity to absorb oxygen	97-100%
Anaerobic threshold	85-90%
Aerobic glicolytic	80-85%
Aerobic lipolytic	75-80%

7. FIELD-TESTS TO EVALUATE THE VARIOUS ENERGY SYSTEMS.

7.1. The development of explosive energy.

30 to 50 meter sprint.

7.2. The development of lactate tolerance.

7.2.1. Sprint 400m + 200m with 30 sec rest between the sprints.

7.2.2. Sprint 500m + 300m with 30 sec rest between sprints.

7.3. Lung capacity to absorb oxygen

1 min sprint, 3min rest, 1 min sprint, 2min rest, 1 min sprint 1min rest, 1min sprint.

7.4. Anaerobic threshold.

5 km to 8 km time trial.

7.5. Aerobic capacity

Heart rate remain stable during 10 km easy run

8. DIETARY DEMANDS ON ENERGY SYSTEMS

8.1. The development of explosive energy.

Sufficient protein intake and Creatine loading.

8.2. The development of lactate tolerance.

Sufficient protein intake and Creatine loading.

8.3. Aerobic capacity

Carbohydrate loading prior to the event and sufficient carbohydrate and fluid intake during competition.

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