LESSON 1 HUMAN BIOLOGY & AEROBIC FITNESS

To completely understand how aerobic exercise is performed and fitness is achieved, we need to know what happens from the moment we start to exert ourselves.

When a movement in the human body occurs, energy must be released to cause that movement. This energy release occurs via a chemical reaction where adenosine triphosphate (ATP) is converted to adenosine diphosphate (ADP) plus free phosphorus, and large amounts of energy.

The energy produced is primarily motion (i.e. the movement of muscles), and heat (which is lost). The body's use of energy is not particularly efficient since a lot of energy is usually lost during any movement.

The small amount of available ATP in muscles is only sufficient to support a single explosive muscle contraction - such as throwing a ball, or a golf swing. If a sport, or some other performance, demands repeated muscle contractions then the ATP required must be constantly replenished from other fuel sources in the muscle.

ADP can be reconstituted by adding energy to it - this converts it back to ATP.

ATP is stored in every cell of the body, and is able to be transported throughout the body.

SOURCES OF ATP

ATP can be supplied to the body by three different ways:

1) ATP-PC System

Here, the compound 'phosphocreatine' is broken down to produce ATP. When phosphocreatine breaks down it produces phosphorus, creatine and energy. The energy produced is then able to be used by ADP to create ATP. Phosphocreatine is then able to be reconstituted with the addition of energy (which comes from foodstuffs and not from stored ATP/ADP reactions). These sources of energy are quickly rebuilt after effort, to the extent that 50% of the energy source is available around 30 seconds later, and 80% of this energy is restored within 2 minutes.

2) Lactic Acid System

When a maximal effort is continued beyond the extent of the phosphate energy system, energy is provided from glycogen stored in the muscles. This system involves glucose (or glycogen) going through various chemical processes to produce ATP plus lactic acid. One glucose molecule is broken down into carbon dioxide and water in the presence of oxygen, and in turn, produces two ATP molecules.

The amount of ATP produced this way is small. This is a more complex procedure using only carbohydrates as its food fuel, and not requiring oxygen for the process.

This energy is used, for example, in 400 metre track races and 100 metre swimming events. Continuous activities which lead to exhaustion in 45-50 seconds result in maximal values for lactic acid accumulation. A problem with this process is that increased lactic acid levels can affect blood pH. Blood pH should be around 7.3, and never drop below 6.8. Nevertheless, the lactic acid system is self-limiting and so should not normally develop such problems. Generally, the result will be a feeling of fatigue which will cause an athlete (or someone doing heavy bursts of work) to slow down. Once lactic acid is produced, it requires 45 to 60 minutes to be removed, and for the athlete to recover.

3) Oxygen System

This process involves the formation of carbon dioxide, water and ATP - from fats, proteins and/or carbohydrates, in the presence of oxygen. This process can produce large amounts of ATP. One molecule of sugar can result in the production of 36 molecules of ATP.

This is more complex than the ATP-PC system. The only limiting factor for this system is usually the supply of oxygen.

The body will normally try to use this system, and only use other systems to produce ATP if oxygen is in short supply. The short supply of oxygen can occur when:

- Activity first starts.
- Activity is placing higher demands on oxygen than what can be supplied by breathing.

THE OXYGEN SYSTEM IS AN AEROBIC SYSTEM. THE ATP-PC AND LACTIC ACID SYSTEMS ARE ANAEROBIC SYSTEMS.

The body uses anaerobic systems for energy supply only when aerobic systems cannot meet the demand.

Example

If a person is running a marathon, breathing may not be supplying ample oxygen to produce ATP through this system. Hence, the lactic acid system may be used, resulting in a build-up of lactic acid - OR, the ATP-PC system may be used, resulting in a depletion of phosphocreatine in the muscles.

After completing exercise, there may be a lactic acid build-up, and if so, the body needs to remove this excess. This lactic acid removal requires energy which is supplied aerobically - hence extra oxygen may be required. This extra oxygen requirement (after exercise) is called the ‘oxygen debt’.

Krebs Cycle

This is one particular series of reactions occurring in the oxygen system.

Two main chemical reactions occur in this cycle:

1. Production of carbon dioxide.

2. Oxidation (i.e. removal of electrons).

Carbon dioxide produced in this cycle is eliminated from the body by breathing out.

The Krebs cycle can be explained as follows:

- Aerobic glycolysis produces pyruvic acid from glucose.
- This pyruvic acid enters the cycle, giving off carbon dioxide which is transferred to the lungs and breathed out.
- Electrons are removed from hydrogen to produce H+ ions, and electrons. These electrons enter the electron transfer system for further chemical reactions.
- Eventually water is formed from hydrogen ions and electrons removed in the Krebs cycle.
- Energy is released as electrons are transported in the Electron Transfer System, and this energy is used in the formation of ATP from ADP and free phosphorus.

The urea or Krebs cycle can be described in simple terms as follows:

1. Carbon dioxide (CO_2) and Ammonia (NH_3) combine (along with ATP and orthinine) to produce citrulline.
2. Citrulline with ammonia produces arginine.
3. Arginine produces urea and orthinine.
4. The orthinine produced in stage three completes the cycle by being used again in stage one.

Summary of The Aerobic Energy System

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O +$ energy

The above formula is a simplified version of what occurs when stored foods e.g. carbohydrates, fats, proteins or in this case the simple sugar molecule glucose, are oxidised to produce carbon dioxide (CO_2 - which is respired out of the body), water (H_2O) and energy. The energy is used to convert ADP to ATP.

ENERGY DEFINITIONS

Energy is the capacity to do work.

Work is the transference of a force over a distance (i.e. work = force x distance).

Power is a measure of work carried out per unit of time.

$$\text{Efficiency} = \frac{\text{Work Output}}{\text{Energy Input}} \times 100$$

THE NATURE OF ENERGY

- Energy cannot be created or destroyed - it simply changes form.
- All energy in a person's body is ultimately derived from solar energy.
- Chemical energy is an important form of energy for man.

Suggested Tasks: ▼

Throughout this course you will be provided with suggested tasks and reading to aid with your understanding. These will appear in the right hand column. Remember: these tasks are optional. The more you complete, the more you will learn, but in order to complete the course in 20 hours you will need to manage your time well. We suggest you spend about 10 minutes on each task you attempt, and no more than 20 minutes.

LEARN MORE »»»

Suggested Tasks

We have covered a lot of complex information here. Try summarising this information in another way, such as -

Flash cards

Mind Maps

Spider diagrams

Flow Charts etc.

UNITS OF MEASUREMENT

Work and power are measured as:

- Kilopond metre (i.e. kpm where 1 kilopond = 1 kilogram)
- Watts

Power is measured as work per unit of time (e.g. kilopond metres per minute)

Energy is expressed as:

- Kcal or calories (where 1 Kcal = 1000 calories)
- Kilojoules
- Litres of oxygen per minute (where 1l/O_2/min = 5 k/cal, but it can vary though).

ENERGY PRODUCTION PATHWAYS FROM DIFFERENT FOODS

1) Fats (triglycerides in the body)

- Hydrolysis of triglycerides produces glycerol and FFA.
- Beta oxidation of glycerol produces acetyl CoA.
- Acetyl CoA enters the Krebs cycle.

2) Carbohydrates

- Carbohydrates break down to glucose (simple sugar).
- Glycolysis of simple sugars produces pyruvic acid.
- Pyruvic acid produces acetyl CoA which enters the Krebs cycle.

3) Proteins

- Proteins break down into amino acids.
- Deamination may occasionally occur to produce keto acid, which in turn can move into the krebs cycle.

RESPIRATORY QUOTIENT (i.e. RQ or Re)

This is a measure of the relationship between carbon dioxide produced and oxygen consumed.

- If you are metabolising fats, the respiratory quotient = 0.7
- If you are metabolising glucose, the respiratory quotient = 1.0
- If you are metabolising protein, the respiratory quotient = 0.8

Note: This means if you are metabolising fat, you need more oxygen than if metabolising glucose or carbohydrate.

RESTING QUOTIENT

When resting it is normal for the body to be metabolising a combination of both fat and glucose.

- If you are metabolising 66% fat and 33% glucose, the respiratory quotient = 0.8

AEROBIC CAPACITY

This is determined by measuring a person's ability to extract and utilise oxygen.

- This measurement is called 'O_2 uptake' (i.e. VO_2 max).
- People can utilise fat deposits when energy consumption is less than 50% of VO_2 max.
- Energy must come from anaerobic sources when intensity is high.
- Running in excess of approximately 1 mile tends to be dominated by aerobic metabolism.
- The energy required for activity is determined by not just duration of exercise, but also the intensity.

WHAT HAPPENS DURING EXERCISE

As exercise starts:

- Heart rate and respiration rate increase.
- VO_2 increases.
- Lactate initially increases.
- RQ drops at first, then increases.

As intensity of exercise increases, the use of fat decreases and at 50% VO_2 max, fat use can reach zero.

BREATHING

During aerobic exercise we need to optimise our oxygen supply, and to do this two things are important:

1. The way you breathe.
2. The quality of the air which you breathe in.

By optimising the oxygen supply, the following can be achieved:

- Lung elasticity increases.
- Blood volume increases.
- Heart performance improves.
- Circulation of blood becomes better.
- Cell metabolism improves, hence muscle performance is better and waste products are removed more efficiently from the cells.
- The likelihood of hyperventilation during exercise is lower.

Practical Applications of Breathing

Breathing techniques may be incorporated into the warm up phase prior to aerobic exercise. Raising oxygen levels in the body in preparation for exercise to follow, will aid muscle activity and endurance.

Breathing exercises after a fitness routine can also aid in refreshing the body and easing the heart beat down to a normal rate.

1) The Way You Breathe

Consider how you breathe and its impact on your health:

- Deep or shallow? Deep breathing is considered better for overall health.
- Slow or fast? Slow breathing is important when relaxed.
- Through the nose or mouth? Breathing through the nose utilises the natural filtration system humans have in the nasal passage.

2) The Quality Of The Air You Breathe In

Consider the purity of the air you breath and how this may affect health:

- Air conditioning - these units can spread air-borne sicknesses.
- Pollen, dust, allergens - allergies to these and other irritants may impede breathing in many people.
- Value of exercise around vegetation (where oxygen levels are higher) - fresh air is important to all, especially for those involved in activities where oxygen is crucial.
- High altitude training (how much oxygen is in the air) - although used as a pre-season training method for some sports, the oxygen level gets lower as altitude increases.

RESISTANCE TRAINING

Resistance training increases muscle strength by pitting the muscles against a weight, such as a dumbbell or barbell. The muscle cells adapt to the extra workload by enlarging (hypertrophy) and recruiting greater numbers of nerve cells to aid contraction. Understanding the principles of muscle contraction can help you reach your fitness goals faster. It is important to pay attention to safety and good form to reduce the risk of injury. If you are overweight, over 40 years, have a pre-existing medical condition or haven't exercised in a long time it is important to consult with a doctor before starting any new exercise program.

The basic principles of resistance training include:

- Type of lift - you need to tailor your workout to address specific body areas. For example, if you want bigger and stronger arms, you need to use exercises that target those particular muscles.
- Intensity - the faster the lift, the greater the intensity.
- Volume - the greater the number of lifts, the more profound the increase in muscle size and strength. You can increase the volume by either training frequently (say, four times per week instead of two) or else training for longer per session (such as one hour instead of 30 minutes).
- Variety - switching around your workout routine, such as regularly introducing new exercises, challenges your muscles and forces them to adapt with increased size and strength.

- Progressive overload - gradually increasing your weights forces your muscles to grow stronger and larger.

- Rest - you need to rest between sets. If your goal is muscle size or endurance, rest for two minutes or so. If you want muscle strength, allow up to four minutes between sets.

- Recovery - muscle needs time to repair and grow after a workout. A good rule of thumb is to rest the muscle group for at least 24 hours to allow sufficient recovery time before working the same muscle groups again.

Principles of Exercise

FITT is an easy way to remember the variables of an exercise program that you can manipulate in order to constantly challenge yourself.

Frequency - how often you exercise
Intensity - how hard you exercise
Time - how long you exercise
Type - the type of exercise you're doing (i.e. running, walking, etc.)

When you workout at sufficient intensity, time and frequency, your body will improve (also called the 'Training Effect') and you will start to see changes. When your body adjusts to your current FITT levels, it's time to manipulate one of more of them. For example, if you've been walking 3 times a week for 20 minutes and you've stopped seeing improvement, you can change the following:

Frequency - Add one more day of walking
Intensity - Add short bursts of jogging, speed walking or hill training
Time - Add 10-15 minutes to your usual workout time
Type - Do a different activity such as cycling, swimming or aerobics

**Changing any of these variables every 4 to 6 weeks can help you keep that training effect going.*

Progressive resistance (the Overload Principle)

In order to improve your strength, endurance and fitness, you have to progressively increase the frequency, intensity and time of your workouts. A simple way to stimulate your body is to try different activities. If you normally walk on the treadmill, try riding the bike which will use different muscles and allow you to burn more calories. If you've been doing biceps curls with dumbbells, change to a barbell.

Specificity

Your training should be specific to your goals. For example, if you're trying to improve your racing times, you should focus on speed workouts. If your main goal is simply health, fitness and weight loss, you should focus on total body strength, cardio and a healthy diet. Make sure your training matches your goals!

Warm up and cool down also needs to be addressed in exercise.

Benefits of Resistance Training

A few of the benefits of regular resistance training include:

- Increased muscle strength, power, endurance and size
- Increased bone density and strength
- Reduced body fat
- Increased muscle-to-fat ratio
- Boosted metabolism (burning more kilojoules when at rest)
- Lowered heart rate and blood pressure after exercise (thought to reduce the risk of heart disease)
- Improved balance and stability

TYPES OF RESISTANCE TRAINING

Progression/Progressive Resistance

This means that the individual must exercise at intensity greater than his or her existing capacity if they wish to improve. It involves gradually increasing the number of repetitions (reps) done in an exercise from a “lower guide number” to the “upper guide number”. When the upper guide number is reached, more weight is added to the system, reps are reduced to the lower guide number, and the process is repeated. You are achieving *overload* by increasing resistance.

Example of progressive resistance:

You are required to do one set of 8-12 reps of a movement starting with 20kgs (or a safe weight for you - appropriate for your level of fitness). For example, bicep curls with a barbell.

Session days would be:

Day 1 20kg Barbell X 8 bicep curls

Day 3 20kgs X 9

Day 5 20kgs X 10

Day 7 20kgs X 10

Day 9 20kgs X 12

Once 12 repetitions are achieved, the weight can be increased to make the biceps work harder.

Day 11 25kgs X 8 (only 8 reps can be performed because the weight is now heavier)

Day 13 25kgs X 10

Day 15 25kgs X 12

This continues making sure the muscle group being worked can achieve a least 11 - 12 repetitions and then the resistance is increased.

Note: Weight training the same muscle group two days in a row will not allow that particular muscle group to rest. By not resting enough the muscles will not repair or adapt to the training performed (i.e.: grow in strength/size), overuse can also cause injuries.