ymca
awards

YMCA Awards

Level 3 Applied anatomy and physiology

2018

Level 3 Applied anatomy and physiology

Energy systems

Learning outcomes

By the end of this session you will be able to:

- Identify which energy systems are used according to type, duration and intensity of exercise and how they may interact
- Explain how the by-products of the three energy systems can affect performance
- Explain the effect of different types of training on the production of fuel for exercise

Energy – Carbohydrate

- 4kcal per gram
- 50% of daily calorie intake
- Stored in muscle and liver cells in the form of glycogen
- Glycogenolosis
  - Conversion of glycogen into glucose

Energy – Fat

- 9 kcal per gram
- No more than 35% daily calorie intake
- Stored as adipose tissue
- Lipolysis
  - Breakdown of triglycerides into fatty acids

Energy – Protein

- Used as the building material for growth and repair
- 4kcal per gram
- 0.75-1.8 grams/kg bodyweight intake daily
- Gluconeogenesis
  - The breakdown of proteins into amino acids, then amino acids into glucose, in the liver

Energy is released in the body by the breakdown of carbohydrates, fat and protein to produce:

- Adenosine Triphosphate (ATP)
- The body's energy 'currency'

The energy systems

- Phosphocreatine system
  - Used for high intensity / short duration activities
  - Anaerobic
  - Energy supplied by creatine phosphate

Creatine kinase

$$\text{CP} \xrightarrow{\text{Creatine kinase}} \text{ADP} + \text{C} + \text{P} = \text{ATP} + \text{C}$$

Phosphocreatine system

- Adaptations to training:
  - Increased stores of creatine phosphate
  - Faster breakdown of creatine phosphate
  - Increased production and release of creatine phosphate in the liver

How the system works

- Creatine phosphate is stored in the sarcoplasm of muscle cells. There are very limited stores of CP in the muscle cells. The energy released from the breakdown of CP is used in the endothermic reaction to reattach a free phosphate to the adenosine diphosphate to reform adenosine triphosphate. Since the supplies of CP are so limited, this re-synthesis will only last up to 10 seconds before the supplies of CP are used up

How the system works

- Fast twitch muscle fibres (FG) will use the phosphocreatine system for energy production. Their low aerobic ability means that they need to use an energy system that can provide energy without the use of oxygen (anaerobically). Their suitability to short bursts of intense activity also means that the best energy system for them to utilise is the phosphocreatine system

The energy systems

- Lactic acid system
  - Used for moderate to high intensity / short duration activities (about 90 seconds)
  - Anaerobic
  - Energy supplied by glycogen

Glycolysis

ADP + P + GLYCOGEN = ATP + LACTIC ACID

Lactic acid system

- Adaptations to training:
  - Increased subjective tolerance to discomfort of lactate build up
  - Increased glycogen storage
  - Improved anaerobic glycolysis
  - Improved lactic acid removal
  - Increased anaerobic threshold and point of OBLA
  - Work harder for longer

How the system works

- 10 complex chemical reactions are required to convert glycogen into pyruvic acid (from which energy can be derived)
- The lactic acid system requires considerable effort for a relatively low yield of ATP
- In the absence of oxygen, the by-product of the lactic acid system, pyruvic acid, combines with hydrogen ions to form lactic acid
- The presence of lactic acid in the blood is experienced as a cramping/burning sensation in the muscles, which impedes performance and cannot be tolerated for long

How the system works

- The lactic acid system is sustainable for about 2–3 minutes
- The point at which lactic acid begins to accumulate faster than it can be removed is called onset of blood lactate accumulation (OBLA) or anaerobic threshold
- At this point blood lactate concentration levels are approximately 4mmol (raised from ~1mmol), although this can vary between individuals
- Onset of blood lactate accumulation is directly related to exercise intensity

The energy systems

- Aerobic system
  - Used for low to moderate intensity / longer duration activities (greater than 90 seconds)
  - Aerobic
  - Energy supplied by glycogen and fatty acids

Glycolysis

$$ADP + P + O_2 + GLYCOGEN + FATTY\ ACIDS = ATP + CO_2\ H_2O$$

Aerobic system

- Adaptations to training:
  - Increased uptake and utilisation of oxygen in the muscle
  - Improved capillarisation
  - Increased size and number of mitochondria
  - Increased fat metabolism
  - Increased glycogen and myoglobin stores
  - Raised aerobic and anaerobic threshold
  - Increased VO2 max

How the system works

- When oxygen is available the by-product of anaerobic glycolysis, pyruvic acid, enters the mitochondria and is converted to acetyl coenzyme A
- Coenzyme A then combines with oxaloacetic acid to form citric acid
- The Kreb’s cycle is also sometimes called the citric acid cycle
- The Kreb’s cycle produces enough energy to re-synthesise two molecules of ATP. By-products of these reactions include hydrogen ions which are transported through an electron transport chain by carrier molecules

How the system works

- The electron transport chain produces 34 molecules of ATP
- This is a far greater and more productive yield than any other system
- Carbon dioxide (CO_2) is another by-product of the Kreb’s cycle that is exhaled by the lungs
- The process is termed a cycle because the starting product, oxalacetic acid, is also the end product, so the process is able to repeat itself over and over again

The effects of the energy system by-products on performance

Phosphocreatine system

- Combined, the ATP-PC system can sustain all-out exercise for bursts. During this time the potential rate for power output is at it's greatest. It does, however require an extended recovery time to replenish (3 plus minutes)

Anaerobic glycolysis

- Lactic acid production allows for high intensity activity to be prolonged but produces a painful sensation resulting in a physiological need to slow down
- The contribution of the anaerobic glycolytic system (Lactic acid system) increases after the initial ten seconds of intense exercise and phosphates from the ATP and PC begin to run out
- At around 30 seconds of sustained activity energy comes from the anaerobic glycolytic system

Aerobic system

- Exercise beyond 45 seconds to 1 minute has a growing reliance on the aerobic energy system
- The by-product of carbon dioxide does not hinder activity, however the Aerobic system is the slowest system to ‘kick in’ to provide energy

The effect of different types of training on the production of fuel for exercise

- Phosphocreatine system

Examples of exercise that train this system include maximal effort short-duration exercise such as:

- Lifting the heaviest weight possible for one or two repetitions (power lifting)
- Sprinting as fast as you can for 50 – 100 metres with 2-3 minute recovery intervals

Anaerobic glycolysis

Examples of exercise that train this system include prolonged, repeated bouts of high intensity activities appropriate recovery such as:

- Resistance training - 3 sets of 10 reps of any resistance exercise performed relatively slowly (5 secs per rep) with up to 3 minutes rest between sets (1:3 ratio)
- Gym circuit class with 45 seconds on each station and 15 seconds rest to move to the next station
- Sprint repeats – 10 reps of 30 second sprints as fast as possible with 15 seconds recovery between each sprint (2:1 ratio)

Aerobic system

Examples of exercise that train this system include longer duration activities at lower levels of intensity below the anaerobic threshold such as:

- Run of two minutes at mod/high intensity, followed by two minutes at low intensity (active recovery) repeated for 30 minutes
- 30 minutes (or more) of low/moderate intensity activity such as cycling, swimming or jogging without change in intensity

ymca
awards