Food fuels and the three energy systems

Chapter 5

pages. 133-141

Session Outline

• Welcome students and session goals	2 mins
• Agree or Disagree statements	15 mins
• Comparisons of the rate of ATP production and capacity of each energy system	10 mins
• Interplay of the energy systems	10 mins
• Training the energy systems	10 mins
• Predominant energy systems	10 mins
• Homework tasks	3 mins

Menu questions

Comparing the three energy systems

- The most obvious comparison to be made between the three energy systems is their energy production.
- A unit of measure for quantifying chemical compounds, called moles, is used to compare the amount of energy available from each of the three energy systems.
- One mole of ATP provides approximately 30 kilojoules of useful energy. As one mole equals 1000 millimoles, we have:
- 1 mol of ATP = 1000 mmol of ATP = 30 kJ of useful energy

(Malpeli, Telford, Whittle, & Corrie, 2010)

Energy Systems

ATP-PC

- Within the body's total muscle mass there are between 570 and 690 millimoles of ATP and PC, which can provide about 15 to 20 kilojoules of useful ATP energy.

Anaerobic glycolysis

- Can potentially resynthesise 3 moles (3000 millimoles) of ATP from 1 mole of glycogen (180 grams)

Aerobic system

- Yield a total of 38 moles of ATP from the breakdown of one mole of glycogen (or 87 to 98 moles of ATP from the breakdown of all the stores of glycogen in the muscles)

(Malpeli, Telford, Whittle, & Corrie, 2010)

Key characteristics of the three energy systems

5.7

Characteristic	ATP–PC energy system	Lactic acid energy system	Aerobic energy system
Alternative name (also known as)	Alactic system, phosphocreatine (PC) or creatine phosphate (CP) system, phosphagen system	Anaerobic glycolysis, lactacid system	Oxygen system, aerobic glycolysis
Fuel source	Phosphocreatine (PC or PCr) or creatine phosphate (CP) (These are different names for the same chemical.)	Glycogen	*At rest:* FFAs *At submaximal and maximal intensities:* • CHO • Fats (when glycogen sparing and when glycogen stores are diminished) • Proteins (only under extreme conditions such as starvation, extended illness of depletion of CHOs and FFAs
Intensity of activity	High intensity (>95% max HR)	• High intensity (>85% max HR) • Used for increases in intensity during long duration events when PC has not restored	• Resting • Submaximal intensity (<80% max HR)
Duration system is dominant during activity	Short duration 1–5 seconds	Intermediate duration 5–60 seconds	Long duration >75 seconds
Peak power	2–4 seconds	5–15 seconds	1–1.5 minutes
Amount of ATP produced	Extremely limited (0.7 ATP for every PC molecule)	Small amounts (2–3 ATP for each glucose molecule)	• Large amounts (endless) • Carbohydrates (38 ATP per glucose molecule) • Fats (441 ATP per triglyceride molecule)

(pg. 134)

(Malpeli, Telford, Whittle, & Corrie, 2010)

Characteristic	ATP–PC energy system	Lactic acid energy system	Aerobic energy system
Speed of production of ATP	• Explosive, instantaneous • Fast and simple chemical reactions	• Fast • Longer chemical reactions (12 of them) in the breakdown of glycogen compared to ATP–PC	• Medium • Complex chemical reactions • Availability of oxygen delays maximum power • Fats slower to resynthesise ATP than CHOs
By-products	• Inorganic phosphates (P_i) • ADP and AMP*	• Lactic acid • H^+ ions • ADP	• CO_2 • H_2O • Heat
Total duration during activity	0–10 seconds	10–75 seconds	>75 seconds (The major contributor of energy for events of more than 75 seconds in total duration)

(pg. 135)

(Malpeli, Telford, Whittle, & Corrie, 2010)

What energy system produces the most energy, that is, has the greatest capacity to supply ATP?

(Malpeli, Telford, Whittle, & Corrie, 2010)

5.9 Rate of ATP production and yield of ATP for the three energy systems

Energy system		Fuel used	Rate of ATP (energy) production	Total amount of ATP (energy)
ATP–PC system		Phosphocreatine (PC) or creatine phosphate (CP)	Fastest 110	0.7–1.0
Anaerobic glycolysis or lactic acid (LA) system		Glucose	Fast 80	2–3
Aerobic system	Aerobic glycolysis	Glucose	Moderate 60	36–38
	Aerobic lipolysis	Fatty acids	Slowest 40	147

(pg. 136)

(Malpeli, Telford, Whittle, & Corrie, 2010)

Energy system interplay

Virtually all physical activities derive some energy from each of the three energy systems.

The three systems contribute energy sequentially but in an overlapping way, depending on the type of activity and exercise demands.

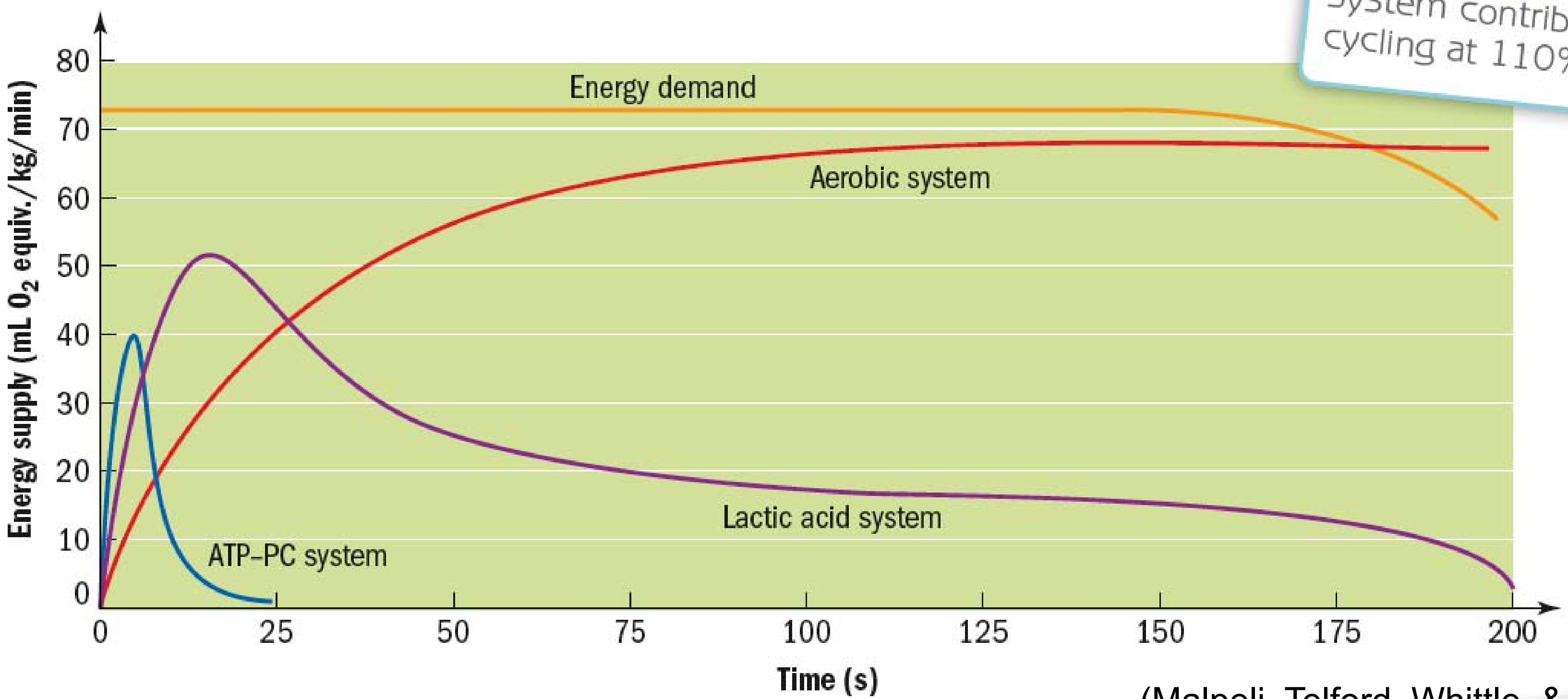
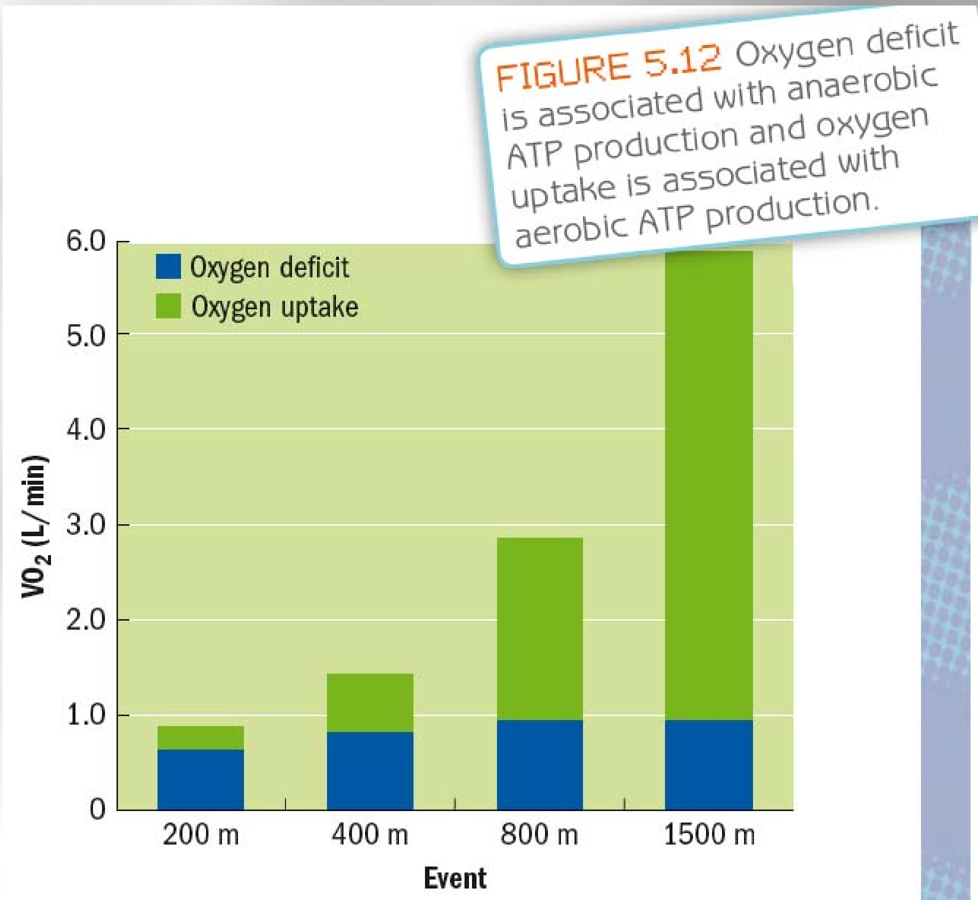


FIGURE 5.11 Energy system contribution during cycling at 110% VO_2 max

(pg. 137)

(Malpeli, Telford, Whittle, & Corrie, 2010)

Figure 5.12 also demonstrates the changing contributions from the aerobic and anaerobic systems as the length of an event increases.



(pg. 137)

(Malpeli, Telford, Whittle, & Corrie, 2010)

Energy system interplay: all three systems working, but to varying amounts

Intermittent activity Team sport: Netball	Continuous activity Individual activity: Marathon
• Netball is characterised by repeated bouts of high-intensity action interspersed with periods of moderate activity and active rest (during play stoppages). When play starts, all three systems start contributing, but most energy in the first 3 to 5 seconds is derived from the ATP–PC system. At the same time, the LA system increases its contribution to energy production, but more slowly, due to more complex chemical reactions required to break down glycogen as compared to PC. If efforts above 85% max HR last for longer than 5 seconds, the LA system will increase its contribution.	• The marathon is a continuous activity that lasts for just over 2 hours at the elite level. At the start, all three systems supply energy but at a slower rate than required by someone who is working at a higher intensity, such as a netball centre. PC will be used at a slower rate and hence it will peak later (8–10 seconds). The LA and aerobic systems are also contributing to ATP production, and increase their contribution from the first step. However, because the activity will not exceed the anaerobic threshold in the early stages, the aerobic system quickly takes over as the major ATP producer.
• There is sufficient PC to 'power' efforts for up to 10 seconds, and following each explosive burst, this will deplete the ATP–PC system. Restoration of PC will occur at very low intensities, but until a break of 60+ seconds occurs (e.g. quarter time), this system is unlikely to rebuild or restore PC. Increasingly high-intensity efforts will be driven by the LA system as the match progresses, especially for mobile players such as centres, wing attack or defence, etc.	• During any surges in the range where the LA system increases its contribution, it still cannot produce the same amount of energy as the aerobic system (2–3 mole ATP compared with 30–36 mole ATP). During surges, the LA system isn't the major ATP provider; rather, it is the system that provides the extra energy required to allow an increase in intensity or work output.

(pg. 138)

(Malpeli, Telford, Whittle, & Corrie, 2010)

• The aerobic energy system supplies only a small portion of the energy needed during initial intense efforts, but its contribution increases as PC has less time to resynthesise, providing most of the energy during moderate activity after the 2-minute mark. It is critical for efficient recovery during stoppages, breaks and time on the bench. Once the aerobic system has established itself as the major ATP producer, it contributes more ATP than the LA system (which can only produce one-fifth to one-seventh as much ATP), even if high-intensity efforts are required.	• Once PC is depleted it does not have the chance to replenish itself, so the ATP–PC contribution is limited to the first few seconds of the race. The aerobic system is not only important to producing ATP during the race, but also plays an important role in breaking down any metabolic by-products that accumulate when the LA system increases its contribution. It also converts any accumulated LA back into glycogen to be used either aerobically or anaerobically.
• At the 5-second stage, the contribution from the three systems might be: ATP–PC 90%, LA 5–7%, aerobic 3–5%.	• At the 5-second stage, the contributions might be: ATP–PC 80%, LA 15%, aerobic 5%.
• At the 2-minute stage, the contributions might be: ATP–PC 25%, LA 15%, aerobic 60%.	• At the 1-hour stage the contributions might be: ATP–PC 0%, LA 5%, aerobic 95%.

For any activity, rather than consider the overall contribution of the three energy systems, it is probably more accurate to consider the energy system contribution and interplay at various stages of performance. This involves considering the key factors of *intensity*, *duration* (how far into the activity the event has progressed) and *availability of fuels.*

(pg. 138)

(Malpeli, Telford, Whittle, & Corrie, 2010)

Training the ATP-PC system

- Short-interval, sprint training or plyometrics are favoured training methods to develop the capacity of the ATP–PC system.
- Alternatively, resistance or weight training can be used, where maximal effort occurs up to 5 seconds.

(Malpeli, Telford, Whittle, & Corrie, 2010)

Training the anaerobic glycolysis system

- Training sessions occurring above the anaerobic threshold
- Ideally, anaerobic threshold training should include a work-to-rest ratio of 1:1.

(Malpeli, Telford, Whittle, & Corrie, 2010)

Training the aerobic system

- Training the aerobic system can be divided into high- or low-intensity bouts and can use continuous or long-interval training sessions.
- High-intensity aerobic training works best with interval training, which should range from about 80 to 90% max HR.
- Like most training, more is not necessarily better.

(Malpeli, Telford, Whittle, & Corrie, 2010)

table 5.11

Training intensity, type of recovery and recommended work-to-rest ratio for the energy systems

Energy system	Training or exercise bout	Intensity	Work:rest ratio	Recommended recovery
ATP–PC	Up to 10 seconds	Maximal	1:3 → 1:5	Passive
Lactic acid	10–90 seconds	>85% max HR	1:2 → 1:3	Active
Aerobic	Interval: about 2–3+ minutes	70–85% max HR	1:0.25 → 1:0.5	Active
	Continuous: about 30 minutes			Passive

(pg. 141)

(Malpeli, Telford, Whittle, & Corrie, 2010)

Predominant energy systems

Road Cyclist

(pg. 112)

What energy system(s) would be predominant for this athlete?
With the person next to you, discuss a training session for your sport targeting the predominant energy system.

(Arkinstall, Dawson, Johnson, & Zahra, 2010)

Weightlifting

(pg. 109)

What energy system(s) would be predominant for this athlete?
With the person next to you, discuss a training session for your sport targeting the predominant energy system.

(Arkinstall, Dawson, Johnson, & Zahra, 2010)