Outline

- How work gets done
- Science of energy systems and fatigue
- Demands of rugby matchplay
- Practical considerations in ESD
- Effective methods of ESD
- Putting the pieces together
• Everything we do requires the transfer of energy
• ATP is our universal energy currency
• ATP $\rightarrow$ ADP + P$_i$ + work + H$^+$
• More power = more work = more ATP
• We have finite stores of ATP
• Energy systems continually replenish stores
Work

Rate of Energy Production
(power)

Duration of Energy Production
(capacity)

Total Potential of Energy Production
(biological power)

Energy Production

Energy Utilization

Central Governing Control
(power regulation)

Efficiency of Energy Expenditure
(skill & technique)

Neuromuscular Contractility
(mechanical)
• Any production in force must be accompanied by a concomitant increase in metabolic output
• Force without fuel is useless
• We maximise ESD when we:
  • ⬆️ ATP supply and/or ⬇️ ATP demand
• Fatigue occurs when ATP demand > supply
• A combination of power & capacity is required to increase intensity and repeatability of high intensity efforts
Energy systems

- **Alactic**- 2-10 seconds capacity
- **Glycolytic**- 10-60ish seconds capacity
- **Aerobic** hours of capacity
- **Power**: Alactic ➡ glycolytic ➡ aerobic
- **Sustainability**: Aerobic ➡ glycolytic ➡ alactic
- **Fuels**:
  - Alactic- creatine phosphate
  - Glycolytic- glycogen and blood glucose
  - Aerobic- fat, carbohydrate, lactate
Energy systems

- All 3 are always active
- Energy contribution varies according to intensity and duration of activity
- Inverse relationship between capacity and power of activity and system use
- Peak power:
  - Alactic- 6s
  - Glycolytic- 30s
  - Aerobic- 60s
Energy systems

- Anaerobic energy systems:
  - Highly inefficient
  - Very powerful and unsustainable
  - No oxygen delivery required
  - Production of inhibitory byproducts

- Aerobic energy systems:
  - Highly efficient
  - Low power but high sustainability
  - Oxygen delivery required
  - No production of inhibitory byproducts
The alactic system

- Maximal or explosive efforts: sprinting, jumping, kicking, tackling etc.

- Limited by:
  - Substrate availability (capacity)
  - Enzyme concentration (power)
  - CNS input and output (power + capacity)

- Fuelled by PCr hydrolysis

- Low trainability, high heredity
The glycolytic system

- Sustained high intensity bouts
- “Activated” by oxygen unavailability, fuelled by incomplete breakdown of carbohydrate
- Limited by:
  - Substrate availability (carbohydrates)
  - Enzyme concentration
  - CNS input and output
  - Lactate buffering and metabolism
- Fuelled by anaerobic glycolysis
- Low trainability, high heredity, training sucks
The aerobic system

- Sustained sub LT intensity bouts
- Fuels resynthesis of other 2 systems via complete breakdown of carbohydrate and fat
- Limited by LOTS of factors
  - Structural factors e.g. mitochondria, cardiac dimensions, capillarisation
  - Substrate availability (carbohydrates)
  - Enzyme concentration
  - CNS input and output
  - Hemoglobin and myoglobin affinity
- Low heredity, very high trainability
Old thinking

- Energy systems switch on sequentially
- Work is physiologically limited
- Lactic acid is the bad guy

![Graph showing energy systems over time](Image)
Old thinking

- “The ball is in play 30s”
- “Unfit players produce lots of lactate”
- “The game doesn’t last long enough to utilise the aerobic system”
- “The aerobic system makes you slow, small and weak”

Outcome: tons of glycolytic work, work till you feel sick, repeat, shy away from aerobic work
All energy systems are always working
The best players produce least lactate
Everything is more aerobic than we thought:
  Even a 200m race is 30% aerobic
  We are predominantly aerobic after 15-30s
  Aerobic development predicts running speed from 2 secs to 4 mins within 2.5%
Watch the player, not the ball
Updated thinking

- Aerobic system enhances alactic functioning
- Glycolytic functioning detracts from aerobic and alactic functioning
- Intervals become progressively more aerobic with each successive interval
- Decline in work is smaller than decline in anaerobic energy production (the aerobic system takes up the slack)
- Aerobic development is the strongest predictor of PCr resynthesis and repeat sprint average power output
- The most aerobic athletes maintain power the best
- The most glycolytic athletes maintain power the least
Rugby demands

- Ball in play: out of play approx 30s:40s
- Approx 70% walk/jog
- Approx 20% high intensity (sprint/cruise)
- Approx 10% running
- Average high intensity effort is 2-4s every 90s
- Approx 10 maximal sprints per match
- Generally speaking:
  - Backs sprint longer and less frequently
  - Forwards sprint shorter and more often
  - Elite athletes have higher variability
Game demands begin alactic and aerobic, lactate progressively rises

Fatigue occurs due to:

- Inability to resynthesise PCr via aerobic system
- Inappropriate expenditure of anaerobic energy
- Insufficient development of alactic system/CNS
- Insufficient development of aerobic system
- Higher development of the above delays fatigue
Fatigue

• Two theories: central vs peripheral

• Peripheral: substrate depletion & by product accumulation

• Central: exercise begins and ends with the brain

• My opinion:
  • Brain is the central governor but reflects physiological state
  • You cannot replace physiology with “toughness”

• Physiology first, psychology second
  • Physiology is your potential, psychology taps into your potential
Central fatigue

- The brain creates fatigue to prevent bodily harm and catastrophic ATP depletion
- The brain uses internal and external feedback to make predictions about the damage it can sustain
- Internal stimuli: lactate, H+, Pi, CK, O2, CO2, electrolytes, substrate depletion, temperature
- External stimulation: feedback, pacing, emotional state, psychological drive, desensitisation to feedback
- Fatigue (hazard) = RPE * time remaining
- Minimise RPE (more aerobic?)
- Additional info: higher % of VO2 narrows attentional focus. More aerobic, better skill execution?
ESD objectives

- Increase the intensity, sustainability and frequency of high intensity efforts
- Maximise alactic and aerobic development where possible to meet game demands
- Optimise physiological environment to minimise inhibitory feedback to CNS
- Exploit external feedback to maximise elasticity of CNS output in response to fatigue
ESD objectives: alactic-aerobic model

• Intensity = alactic system
• Frequency, sustainability = aerobic system
• The glycolytic system is neither, and detracts from the other 2, has extremely limited trainability, plus interrupts the high-low training schedule
• All glycolytic development comes from rugby training and matches
• Energy supply: maximise alactic and aerobic power and capacity
• Energy utilisation: use rugby training and matches to minimise effective energy demand and desensitise CNS to sensations of fatigue
Key aerobic concepts

1. Lactate threshold:
   - Highest intensity of predominantly aerobic energy production
   - Push the intensity higher and work is unsustainable
   - Strong predictor of endurance and repeat sprint performance
   - Highly trainable

2. Anaerobic capacity:
   - The total amount of work that may be performed above LT
   - Greater % of LT = shorter duration of work
   - Smaller % of LT = longer duration of work
   - Trainable but still finite
Oxygen debt

- Work undertaken by aerobic system to pay the debt of anaerobic work
- Greater depletion of anaerobic capacity = bigger debt
- Higher % of LT = more time required to repay debt
- Smaller depletion of anaerobic capacity = smaller debt
- Lower % of LT = less time required to repay debt
Oxygen debt
Have a bigger overdraft

- You can spend beyond your means for longer
- You still have to pay your debts back
- Your ability to pay the debt doesn’t improve
- Your ability to spend in the future isn’t improved
Make more money

- Less likely to get into debt in the first place
- You can pay your debts much faster
- You can spend bigger
- You can spend sooner
Practical example

Pre-training
- Alactic
- Lactic

A: Anaerobic training
- Alactic
- Lactic

B: Aerobic training
- Alactic
- Lactic
- Aerobic
Funnel periodisation

- Prep
- Power
- Capacity
- Realisation
Alactic development

- Prep: sub maximal efforts, technique, work capacity, anatomical adaptation
- Power: sprints, jumps, throws, wrestle
- Capacity: extended alactic and repeated efforts
- Realisation: play the game
Aerobic development

- Components within the aerobic engine
- Longer term, lower intensity adaptations first, higher general training
- Shorter term, higher intensity, specific adaptations later, higher specific training
- Adaptations: eccentric + concentric cardiac development, mitochondrial development (fibre + sarcoplasm), enzyme content, slow fibre hypertrophy and capillarisation
- Activity ➡ environment ➡ signalling ➡ adaptation ➡ performance
Aerobic development

• What is the adaptation I want?
• What is the physiological environment that triggers the adaptation?
• What exercise conditions trigger that physiological environment?
• How do I maintain these conditions within a session?
Eccentric cardiac hypertrophy

- Maximum diastole
- 130-150bpm (less for seated, less for older)
- Central adaptation: steady state activity
- 90+ mins per week, can be up to 14 sessions
Slow fibre hypertrophy

- Hypoxia, no lockout, constant tension
- Sub LT HRs
- 40s work: 40s rest
- Peripheral adaptation: squats, single leg squats, leg presses
- 5 to 15 sets per session, 1 exercise
- 1 to 3 sessions per week
Mitochondrial density (fibre)

- High force, low speed, continuous activity
- Moderate lactate production, HR < LT
- 10-20 minutes for 1-2 sets
- Peripheral adaptation: step ups, lunges, sled pushes, heavy bike
- 1 to 3 sessions per week
Mitochondrial density (sarcoplasm)

- High force, high speed, interval activity
- Moderate lactate production, HR < LT
- 5s maximal activity, 55s rest or HR ➡ 130
- Peripheral adaptation: Hills, jumps, heavy bike, sled pushes
- 20-50 reps per session
- 1 to 3 sessions per week
Enzyme content

- Maximal oxygen uptake
- LT +/- 10 beats per minute
- Peripheral adaptation: continuous or interval activity, LB dominant
- 20 minutes or more per session
- 1 to 2 sessions per week
Concentric cardiac hypertrophy

- Maximum contractility
- High lactate but creates aerobic adaptation
- High vascular resistance or circa max HR
- 4*4*4
- Central adaptation: whole body, high resistance work
- 1 to 2 sessions per week
Realisation work

- Highly game specific - game or game variations only
- Self discovery environment - learn to use what you have
- Manipulate feedback to increase fatigue
- Practice for average scenario and worst case scenario
- Consider the use of impossible tasks
• Low days: Eccentric cardiac hypertrophy: any modality at developmental load
• High days: Slow fibre hypertrophy- squat, RFESS, leg press
• 1-2 sessions of each per week
Phase 2- lower intensity adaptation

- Low days: Eccentric cardiac hypertrophy: any modality at developmental load
- High day 1: HICT- sled, bike, lunge, step up
- High day 2: HRIs- sled, bike, stairs, hills
Phase 3- high intensity adaptation

• Low days: Eccentric cardiac hypertrophy: any modality at retention load
• High day 1: LT- running, small sided games, drills
• High day 2: Concentric cardiac hypertrophy- whole body, high load, high fatigue
Phase 4- realisation of adaptation

• Low days: Eccentric cardiac hypertrophy: any modality at retention load
• High days: Rugby, rugby, rugby!
Questions?