The Physiology of Fatigue
Can Fatigue be Measured?

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What is Fatigue?

- Temporary loss of strength and energy resulting from hard physical or mental work; "growing fatigue was apparent from the decline in the execution of their athletic skills"

- Feeling of tiredness or weariness usually associated with performance decrement
What is Fatigue?

- A feeling of tiredness or weariness resulting in a decreased capacity for physical and mental work

- A condition that results when the body cannot provide enough energy for the muscles to perform a task

- Physical weariness resulting from exertion
What is Fatigue?
What is Fatigue?

100 metres sprint
What is Fatigue?

100 metres sprint

Acceleration

Graph showing speed (metres/second) versus distance (metres) for a 100 metres sprint.
What is Fatigue?

100 metres sprint

Speed (metres/second) vs Distance (metres)

- Acceleration
- Peak Speed

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What is Fatigue?

100 metres sprint

- Acceleration
- Peak Speed
- Fatigue
What is Fatigue?
What is Fatigue?

The Marathon

[Graph showing speed and distance with a downward trend in speed over distance]
What is Fatigue?

The Marathon

![Graph showing speed over distance with a significant decline at the end.](image-url)

**Accelerate**

**distance (km)**

**speed (metres/second)**
What is Fatigue?

The Marathon

![Graph showing speed vs. distance with a highlighted section indicating fatigue.]

- Acceleration
- Distance (km)
- Speed (metres/second)
- Fatigue
- The Wall

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What is Fatigue?

The Marathon

Speed (metres/second) vs. Distance (km)

- Acceleration
- The Wall
- Fatigue

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When does Fatigue become Exhaustion?

Los Angeles Olympics
The Women’s Marathon
5 August 1984
Gabrielle Andersen-Scheiss
Switzerland
When does Fatigue become Exhaustion?

Twenty minutes after the winner crossed the finish line, Andersen-Scheiss (39) staggered into the stadium, suffering from heat prostration. Her right leg was stiff and her left arm was hanging limply by her side.

While spectators gasped in horror, doctors noted that she was perspiring and they let her continue. For 5 min and 44 s, she lurched along the final lap around the track, occasionally stopping and holding her head.

Finally she fell across the finish line and into the arms of waiting medics. Andersen-Scheiss finished 37th.

Remarkably, she recovered rapidly and was released by medical personnel only two hours later.
When does Fatigue become Exhaustion?

Valya Tsybulskaya, exhausted after completing the 10km walk
When does Fatigue become Exhaustion?
When does Fatigue become Exhaustion?
When does Fatigue become Exhaustion?

Wednesday

Saturday
**Fatigue versus Exhaustion**

**FATIGUE**
- Able to restart exercise after a short rest
- Physiologically normal
- Risk of pathology low

**EXHAUSTION**
- Not able to continue to exercise
- Physiological extremes
- Pathological changes
Definitions of Exhaustion

- Extreme fatigue
- Serious weakening and loss of energy
- The act of exhausting something entirely
- See *Fatigue*
- The depletion of energy stores resulting in muscle fatigue to the point where physical activity cannot be performed
What is Fatigue?

100 metres sprint

- Acceleration
- Peak Speed
- Fatigue
What is Fatigue?

Fatigue refers to the inability to continue exercise at a given intensity.
Fatigue

100 metres sprint

1st race
Fatigue

100 metres sprint

1st race
30 min rest
2nd race
What is Fatigue?

The Marathon

**Graph**

- **Y-axis**: speed (metres/second)
- **X-axis**: distance (km)

The Wall

Fatigue
Development of Fatigue & Exhaustion

“Fit”  Fatigued  Exhausted
Development of Fatigue & Exhaustion

“Fit”  Fatigued  Exhausted

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Fatigue & Intensity

The higher the intensity, the earlier the onset of fatigue
Fatigue

Same effect, different mechanisms
Causes of Fatigue

1. Fatigue of energy generating systems within and external to muscle

2. Accumulation of metabolic by-products & failure of the muscular contractile mechanism

3. Disturbances to homeostasis

4. Central or peripheral nervous system dysfunction
Causes of Fatigue

1. Fatigue of energy generating systems within and external to muscle
   - Muscle glycogen depletion
   - Liver glycogen depletion

Snow et al. (1981)
Causes of Fatigue

1. Fatigue of energy generating systems within and external to muscle
   - Muscle glycogen depletion
   - Liver glycogen depletion
   - Depletion of fat stores
Causes of Fatigue

2. Accumulation of metabolic by-products & failure of the muscular contractile mechanism
   – Lactic acid accumulation
   – Phosphocreatine depletion and phosphate accumulation
   – Hypoxia/impaired of oxygen delivery
Causes of Fatigue

2. Accumulation of metabolic by-products & failure of the muscular contractile mechanism
   - Lactic acid accumulation
   - Phosphocreatine depletion and phosphate accumulation
   - Hypoxia/impaired of oxygen delivery
   - Disturbance to calcium metabolism
Causes of Fatigue
Disturbance to calcium metabolism

Nerve

Muscle

Mitochondria

Sarcoplasmic reticulum
Causes of Fatigue
Disturbance to calcium metabolism

- Mitochondrial dysfunction due to Ca++ uptake
- Reduction in Ca++ release from SR
- Both mechanisms thought to be important in development of fatigue during prolonged exercise
Causes of Fatigue

3. Disturbances to homeostasis
   - Electrolyte concentrations and their compartmentalisation
   - Concentrations of glucose in blood, muscle and other tissues (e.g. brain)
   - Muscle and systemic pH and osmolality
   - Temperature (especially muscle and brain)
   - Concentrations of FFA
   - Blood and plasma volume
   - Hormone concentrations
Causes of Fatigue

4. Central or peripheral fatigue

**Negative inputs**
- Pain (e.g. muscles, joints)
- Sensations of breathlessness
- “Fatigue”
- Low brain glucose

**Positive inputs**
- External stimulation
  - Crowd
  - Riders voice
  - Whip
  - Other horses
Cardiac Causes of Fatigue?
What factors affect the time to onset of fatigue?

- Intensity, duration and pattern of exercise
- Fitness
- Age
- Body Condition
- Environmental conditions
  - Heat, heat & humidity or cold
  - Altitude
  - Pollution
What is fatigue in an endurance horse?

- The horse that stops eating & drinking?
- The horse that will not canter?
- The horse that is reluctant to trot?
- The horse that will not walk?
Indicators of fatigue

- Ataxia, stumbling, unwillingness to exercise
  - Pain
  - Weakness
  - Hyperthermia
  - Low blood glucose
  - Hypovolaemia
  - Low BP
  - Nerve dysfunction
Indicators of fatigue

- Hypoglycaemia
  - Muscle glycogen depletion
  - Liver glycogen depletion

Marlin et al. (2002)
Indicators of fatigue

- Changes in muscle EMG output

Naeije & Zorn (1982)
Indicators of fatigue

- Dehydration
  - Hypovolaemia
  - Electrolyte loss
  - Acid-base disturbance

500kg horse

~300 litres total body water

5% dehydration

~275 litres total body water
Indicators of fatigue

- Dehydration

5% dehydration

~275 litres total body water

Lungs ~90%>

Blood~80%>

Brain ~70%>

Bone
Indicators of fatigue

- Synchronous diaphragmatic flutter (SDF) “Thumps”
  - Indicative of moderate to marked:
    - Dehydration
    - Electrolyte disturbance
    - Acid-base disturbance
    - Failure to maintain homeostasis
Indicators of fatigue

• Changes in the ECG
  – May be indicative of electrolyte and acid-base disturbance
  – Little or no published data on changes in equine ECG following endurance exercise
Indicators of fatigue

Worsening Clinical Picture

“Fit”  Fatigued  Exhausted

Mild dehydration  Electrolyte loss  Glycogen depletion  Marked dehydration  Low blood glucose

Recovery  Pathology  Death