Running Economy

• ________ by itself is not a good predictor of endurance performance.

• ___________ may be more important.
  – _____________________________________
  _____________________________________.
  • ml/kg/min for a given speed

Running Economy

• The amount of oxygen consumption for a given speed.

Running to cover a distance aerobically

<table>
<thead>
<tr>
<th>Speed (m/s)</th>
<th>Energetic Cost (ml/kg/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Running</td>
</tr>
<tr>
<td></td>
<td>Walking</td>
</tr>
</tbody>
</table>

Hreljac, 1993, MSSE
Holt, Hamill, & Andro, 1991 MSSE
Factors that Affect Running Economy

- Running style
  - Up/down movement
  - Biomechanical factors
  - Technique / type of activity

Rate of Oxygen Consumption
at different speeds with different stride lengths

- SF changes slightly
- "U-shaped" curve
- Little change in VO₂ near PSF.
- PSF important as velocity increases.
Factors that Affect Running Economy

- Muscle capacity to store energy
  - ________________ (i.e., springs)
    - Tendon, titan, ...

- Fitness and training
  - ________________
  - ~1-4% improvement without changes in VO2max

- Age
  - ________________
  - But become more economical with age.
    - Training, weight gain, running mechanics, elastic

Factors that Affect Running Economy

- Fatigue
  - Maybe due to damage to elastic material.
    - Stretch-shortening cycle
Factors that Affect Running Economy

• Gender
  - 
  - ...but because body composition varies between gender, maybe women would be more economical if this was controlled.

• Ethnicity
  - May be a factor … but not clear if ethnicity or culture effect.
  - African pygmies were about 10% more economical than Caucasians when running but not when walking.

Factors that Affect Running Economy

• Added weight (clothing and shoes)
  - Running economy is influenced by what is worn.
  - Adding weight
    - 0.5 kg added to the thigh
    - 0.5 kg added to the foot
    - ~1% increase in RE for every 100 g added to the foot.
  - Shoes weigh about 160 g (racing flats) to 310 g (trainer)
  - Orthotics weigh about 80 g

Factors that Affect Running Economy

• Environmental conditions
  - Running uphill
  - Running surface
    - Sand, snow, soft surfaces
      - worse RE
    - "tuned" track?
Factors that Affect Running Economy

Environmental conditions:

• Wind
  \[ D = \frac{1}{2} (\rho \cdot C_d \cdot A \cdot V^2) \]
  - \( \rho \): Density
  - \( C_d \): Coef. of drag
  - \( A \): Frontal area
  - \( V \): Velocity
  - \( \sim 8\% \) of energy is used to overcome air resistance
  - 6 m/s or 4 min 30 s min/mi
  - Drafting reduces energy cost
  - Greatest effect at speeds 18 kph (11.2 mph)
  - Follow within 1 m (i.e., as close as possible)
  - On TM, set grade to 1-2 %

• Grade
  \[ VO_2 = v(0.2 + \text{grade} \times 1.8) + 3.5 \]

Summary: Part 2

• Running Economy
  - vs. VO2max
• Factors that influence RE
  - Running style
  - Fitness/training
  - Age
  - Fatigue
  - Gender
  - Ethnicity
  - Added weight
  - Environmental conditions
    - Grade, surface, wind

Suggestions to Improve Running Economy

• Training can improve RE more so than VO2max
• Training increases the running speed at the LT
  - The %VO2max that can be sustained increases
• Noakes hypothesizes that \( \text{_____________} \) is reduced with training
• It is not clear what training program is best for improving RE
• Practical suggestions:
  - Minimize shoe and clothing weight
  - Aerodynamics (e.g., tight fitting clothing)
Predicting Running Performance

• Noakes: VO2max is an ______________ of athletic performance
  – It is a measure of VO2 at the ______________ (i.e., speed, grade)
  – It is not possible to run at VO2max for more than a few minutes
  – Trained runners can sustain a speed that elicits 80-95% of VO2max
• The ________________ at VO2max
• The work rate at the lactate turnpoint
• ______________
  – Use this to test how prepared you are for a marathon

Limits to Performance

• No one knows what limits performance
• Sprint vs. Endurance performance
  – ______________________________
  – Sprinters can transform energy from chemical to mechanical at high rates but are not fatigue resistant
  – Endurance runners are fatigue resistance but do not transform chemical energy to mechanical at high rates

Limits to Endurance Performance

• Noakes: ______________ contribute to running performance
  – Superior heart and skeletal muscle function
    • Allows fastest athletes to maximize muscle power output
  – Ability to resist fatigue during prolonged exercise
    • Endurance performance limited by ______________ of cardiac muscle
      – Response to heat?
      – Glycogen stores?
      – Blood glucose levels?
      – Skeletal muscle damage?
Prediction Tables

- Based upon
  - past performances
  - Knowledge of VO2max and running economy (i.e., the percent VO2 that can be sustained)
- Do not account for
  - Environmental conditions
    - Grade, wind, temperature
  - Differences in subjects

Davies-Thompson

- Must know
  - VO2max
  - Percent that can be sustained
- Example
  - VO2max = 60 ml/kg/min
  - %VO2max: 50% (i.e., 30 ml/kg/min)
  - Running speed (km/h) = (%VO2 + 7.736) / 3.966
    - 9.5 km/h could be sustained

1. Osler and 2. Gardner-Purdy

- Prediction tables that include ‘quality’ of performance
  - Quality is not on a linear scale with time
Mercier-Leger-Desjardins

- Nomogram
  - Connect two race times with a straight line
  - Estimate VO2max
  - Estimate other times
  - Determine ‘quality’ of performances

Summary of Prediction

- VO2max is not necessarily a great predictor of endurance performance
  - This might be because VO2max is a result of performance vs. a determinant of performance.
- Past performances are the best predictor of endurance performance.
  - 10 K
    - Time for 42 km = 5.48 x (10K in min) – 28 (min)
    - 10 K = 40 min
    - 5.48 x 40 – 28
      - 191.2 min or 3.2 hrs or 3 hours and 12 mins

Summary of Prediction

- The ability to predict endurance performance is dependent on identifying the fatigue resistance an athlete has.
  - The % VO2max is important
    - Or, the % of max work rate
  - An athlete can use the prediction tables to determine his/her level of fatigue resistance.
    - Monitor training progress
    - Identify overtraining, detraining
Changes with Aging

• Reduction in VO2max
  – 10% reduction per decade
  • Maybe 5% per decade for trained
  • Why?
    – Reduced blood flow to the heart
    – Reduced cardiac output
    – Decreased permissible mass of skeletal muscle that can be recruited
    – Reduction in skeletal muscle contractility

Changes with Aging

• Muscular components
  – Especially at ages greater than 50/60 yo
    • Muscle strength is somewhat maintained up to about 50.
      – 15% loss per decade up to 70, then a 30% loss per decade
    • Type I and II fibers both lost
      – Type I retain normal size; Type II are smaller
      – Oxidative capacity decreases with age but is reversible with training
    • The number of motor neurons decreases after 60,

Changes with Aging

• Body composition
  – _______ with aging has a negative impact on VO2max
    • Training helps reduce increase in body fat
    • …remember, muscle mass is decreasing
Changes with Aging

• Training changes
  – General reduction in training volume and intensity accounted for 28% and 35%, respectively, in variance of VO2max (Marti and Howald, 1990).
  • Which comes first?
    – Reduced training leads to reduced VO2max
    – Reduced VO2max leads to reduced training
  • Athletes who are genetically better endurance athletes may have a reduced decrement of VO2 (and reduced training)

Changes with Aging

• Capacity to absorb landing forces
• Capacity to attenuate landing forces
• Capacity to absorb impact energy

Changes with Aging

• The body has to manage the impact while also generating the right amount of force to generate the next stride.
Changes with Aging

- Do elite runners damage skeletal muscle in such a way that they cannot be competitive at an older age?
- Noakes hypothesizes that high volume and intensity can only be sustained for about 15 years.

Changes with Aging

- Case study: Basil Davis
  - Completed 122 marathons
  - 34 Comrades marathons
  - 56 ultramarathons
- Training log
  - After age 50, he recorded he always "seems to be stiff."
  - After age 45, his marathon performance deteriorated at a fast rate.
  - In later years, he could not predict his marathon time based on his 10K time.

Changes with Aging

- Does __________________ accumulate over time?
- Is there a breakdown of the elastic behavior of the lower extremity?
  - Muscle contraction is important to maintain the tension on the connective tissue.
  - Is exhaustion (at any age) a simulation of aging?
  - Is "hitting the wall" a function of the breakdown of elastic tissue?
- Noakes hypothesizes that when the ______ are damaged the central governor will force the body to run at a slower pace to protect the muscles and joints.
<table>
<thead>
<tr>
<th>Changes with Aging</th>
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<tbody>
<tr>
<td>Sharwood et al. (2000)</td>
</tr>
<tr>
<td>– 20 marathon and ultramarathon performers</td>
</tr>
<tr>
<td>– Runners who accumulated more than 5000 km in racing used a different muscle recruitment strategy than those who raced less.</td>
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<td>The ability to recover from intense exercise is impaired with aging.</td>
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<td>Runners get injured</td>
</tr>
<tr>
<td>Are older runners more susceptible to injuries?</td>
</tr>
<tr>
<td>Aging does not seem to negatively influence adaptation to training</td>
</tr>
<tr>
<td>Volume and Intensity may be reduced with aging</td>
</tr>
</tbody>
</table>

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<tr>
<th>Summary of Changes With Aging</th>
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<td>Reduction in VO2max</td>
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<td>Muscular components</td>
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<td>Body composition</td>
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<td>Training changes</td>
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<tr>
<td>Capacity to absorb landing forces</td>
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<tr>
<td>Recovery</td>
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<tr>
<td>Chronic orthopedic disabilities</td>
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<td>Ability to adapt to training</td>
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