**Session III**
General Biomedical Implications of Preconditioning
11:30 – 12:00

**The Repeated Bout (Preconditioning) Effect in Exercise**

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**Type of Muscle Contraction**

- **Isometric (Static):** Force = Load
- **Concentric (Shortening):** Force > Load
- **Eccentric (Lengthening):** Force < Load

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**Cycling Exercise**

**Concentric**

- Tunturi F30R (Australia)
- Intensity: 60% of CON_{max} power output: 134 – 198 W
- Cadence: 60 rpm
- Duration: 30 min

**Eccentric**

- EccentricTrainer (Metitur, Finland)
- Intensity: 60% of CON_{max} power output: 134 – 198 W
- Cadence: 60 rpm
- Duration: 30 min

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**Concentric vs Eccentric Cycling**

- CON: 158.5 ± 9.2 W, ECC1: 169.9 ± 26.7 W <2 weeks> ECC2: 179.3 ± 6.1 W

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**“Muscle Damage” after Cycling**

- Prolonged loss of muscle strength and delayed onset muscle soreness (DOMS) are peculiar to “unaccustomed” eccentric exercise
- Symptoms of muscle damage

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**Indicators of Muscle Damage**

- Stiff muscle
- Loss of muscle function
- Increases in blood markers
- Delayed onset muscle soreness
- Swelling

**Muscle Damage Magnitude**

<table>
<thead>
<tr>
<th>Low</th>
<th>Positive</th>
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<tbody>
<tr>
<td>High</td>
<td>Negative</td>
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<table>
<thead>
<tr>
<th>Small</th>
<th>Repetition</th>
</tr>
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<tbody>
<tr>
<td>Large</td>
<td>Velocity</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Short</th>
<th>Muscle length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Yes</th>
<th>Preconditioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Yes</th>
<th>Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Leg</th>
<th>Muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Child</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old</td>
<td>Adult</td>
</tr>
<tr>
<td>Young</td>
<td></td>
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</table>

**Gender**

| Female | Male |

**Repeated Bout Effect**

A bout of exercise confers protective effect against muscle damage in subsequent bout of similar exercise.

**4 Repeated Bouts**

Subjects: 15 young men (21.8 ± 1.9 yrs)
No resistance training 1 y prior to the study

Study design/Exercise

- Maximal eccentric exercise of the elbow flexors
- Non-dominant arm
- 30 max ECC contractions
- Rest: 10 s
- ROM: 90 - 0°
- Velocity: 90°/s

4 wk 4 wk 4 wk 4 wk

**4 Repeated Bouts**

- Maximal eccentric exercise of the elbow flexors
- Non-dominant arm
- 30 max ECC contractions
- Rest: 10 s
- ROM: 90 - 0°
- Velocity: 90°/s

**4 Repeated Bouts**

- Maximal eccentric exercise of the elbow flexors
- Non-dominant arm
- 30 max ECC contractions
- Rest: 10 s
- ROM: 90 - 0°
- Velocity: 90°/s
How long does the RBE last?

How long does the RBE last?

Magnitude of the Protective Effect

3 weeks between the initial and second (MaxECC) bouts

Low-Intensity Eccentric Exercise

10% bout: 10% load
- 5 sets of 6 contractions
- 3 s contraction (30°/s)
- ROM: 90-0°
- 10 s between contractions
- 2 min between sets

100% bout: Maximal isokinetic eccentric contractions

Protective Effect by 10% ECC


Isometric Contractions

2 or 10 maximal isometric contractions
- 20° flexion
- 3 s
- 45 s between contractions

Eccentric Exercise

5 sets of 6 maximal eccentric contractions
- Angular velocity: 90°/s
- ROM: 90-0°
- 10 s between contractions
- 2 min between sets

Protective Effect by Isometric Contractions


Protective Effect by Isometric Contractions


Contralateral Repeated Bout Effect
5 sets of 6 maximal eccentric contractions of the elbow flexors

<table>
<thead>
<tr>
<th>1st Bout</th>
<th>2nd Bout</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-dominant Arm</td>
<td>Non-dominant Arm</td>
<td>CONTROL</td>
</tr>
<tr>
<td>2 weeks</td>
<td>0.5 hour</td>
<td>0.5h</td>
</tr>
<tr>
<td>0.5 hour</td>
<td>6 hours</td>
<td>6h</td>
</tr>
<tr>
<td>12 hours</td>
<td>24 hours</td>
<td>24h</td>
</tr>
<tr>
<td>1 week</td>
<td>1 week</td>
<td>1w</td>
</tr>
<tr>
<td>4 weeks</td>
<td>4 weeks</td>
<td>4wk</td>
</tr>
<tr>
<td>8 weeks</td>
<td>8 weeks</td>
<td>8wk</td>
</tr>
</tbody>
</table>

104 young "untrained" men
13 men/group


MVC Torque

CON 1d 4wk 0.5h 6h 12h 8wk

Muscle Soreness

CON ns 1d 4wk 8wk 0.5h 6h 12h


Magnitude of Protection


Repeated Bout Effect Mechanisms

Hormesis encompasses the notion that low levels of stress stimulate or upregulate existing cellular and molecular pathways that improve the capacity of cells and organisms to withstand greater stress. This notion underlies much of what we know about how exercise conditions the body and induces long-term adaptations.

During exercise, the body is exposed to various forms of stress, including thermal, metabolic, hypoxic, oxidative, and mechanical stress. These stressors activate biochemical messengers, which in turn activate various signaling pathways that regulate gene expression and adaptive responses.

**Knee Extensor Resistance Exercise Study**
- **Participants:** 26 healthy elderly men
  - Age: 60-76 (65.9 ± 4.7) y, Height: 164.7 ± 5.0 cm, Body Mass: 70.5 ± 8.0 kg, Body Fat: 25.9 ± 2.4 %, BMI: 29.4 ± 7.8, MVC-CON Torque: 120.6 ± 4.9 Nm
- **Study Design:** 2 group (n=13 / group)
  - Eccentric Exercise: 10%~100% of 1RMcon
  - Concentric Exercise: 50%~100% of 1RMcon
- **No indications of muscle damage**
  - Once a week over 12 weeks, 12 training sessions for both legs

**Cardiovascular and Other Parameters**
- HR, SBP, DBP, BFV, ePVW, CIR, BMD
- Normalised Change from Baseline (%)
- ET vs CT

**Muscle Function and Physical Fitness**
- 1RM MVC, CS, 2MS, 8UG, OLST 6mW, 6MW
- Normalised Change from Baseline (%)
- ET vs CT

**Insulin Sensitivity and Blood Lipids**
- GLU, INS, HOMA, HbA1C, OGTT, TG, TC, LDL, HDL
- Normalised Change from Baseline (%)

**Eccentric Exercise is Hormesis**
- **Negative aspect**
  - Muscle damage
  - DOMS, Prolonged loss of muscle function
- **Positive aspects**
  - Less metabolic demand
  - Muscle function
  - Muscle mass
  - Muscle coordination
  - Balance
  - Flexibility
  - Bone mineral density
  - Insulin sensitivity
  - Blood lipid profile
  - Cardiovascular function
  - Brain health

**Not** no pain no gain

Minimize muscle damage, Maximize eccentric contractions
SUMMARY

- Muscle damage characterized by a prolonged loss of muscle function and DOMS is induced by unaccustomed eccentric exercise
- The magnitude of muscle damage is reduced when the same or similar eccentric exercise is repeated, and even for the contralateral homologous muscle
- Low-intensity eccentric contractions or a small number of maximal isometric contractions at a long muscle length also confer preconditioning effects
- The underlying mechanisms of the repeated bout and preconditioning effect are not fully understood
- Eccentric exercise is hormesis: using it appropriately is beneficial for health and QOL

Stair Walking Study

- Participants: 30 elderly obese women >60 y, BMI: >25, Body fat: >30%
  - Age: 66.4 ± 6.8 y, Height: 154.8 ± 5.0 cm
  - Body mass: 62.7 ± 4.7 kg, BMI: 26.2 ± 1.0
  - Percent Body Fat: 34.8 ± 4.0%
- Groups – Ascending vs Descending
  - n=15 per group (ASW, DSW)
  - No significant difference in any baseline measures

Exercise

- 10-story building (22 [11 x 2] stairs per floor)
- 5 floors: 110 stairs, 17-cm per stair, 1 step / s
- Lift: Ascending (6th-1st), Descending (1st-6th)
- 2 reps / week, 1st week: 2 reps (10 floors) - 5 min, 12th week: 24 reps (120 floors) - 60 min
- 2 sessions per week, 12 weeks (24 sessions)
- Total number of floors: 1,560 in 12 weeks

Thank you very much


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k.nosaka@ecu.edu.au
Responses to Exercise

<table>
<thead>
<tr>
<th></th>
<th>ASW</th>
<th>DSW</th>
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<tbody>
<tr>
<td>RPE (6-20)</td>
<td>9.6 ± 1.0</td>
<td>8.1 ± 0.9*</td>
</tr>
<tr>
<td>Heart Rate (bpm)</td>
<td>113.7 ± 10.9</td>
<td>88.6 ± 7.8*</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>133.7 ± 10.1</td>
<td>119.4 ± 7.4*</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>68.8 ± 4.6</td>
<td>68.0 ± 5.9</td>
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No signs of muscle damage: *: significantly (P<0.05) different from ASW

Muscle Function and Physical Fitness

<table>
<thead>
<tr>
<th></th>
<th>MVC</th>
<th>CS</th>
<th>2MS</th>
<th>8UG</th>
<th>5MW</th>
<th>TW</th>
<th>EOFs</th>
<th>EOSs</th>
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<tbody>
<tr>
<td>ASW</td>
<td>1.90</td>
<td>1.12</td>
<td>0.48</td>
<td>0.47</td>
<td>0.54</td>
<td>2.78</td>
<td>1.27</td>
<td>1.36</td>
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<tr>
<td>DSW</td>
<td></td>
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Muscle Length Changes During Eccentric Contractions of the Elbow Flexors
- Aloka SSD-a10 with a 10-MHz probe (6 cm)
- Frame rate: 47 Hz

Insulin Sensitivity and Blood Lipids

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<thead>
<tr>
<th></th>
<th>GLU</th>
<th>INS</th>
<th>HOMA2</th>
<th>H/A/C</th>
<th>OGT/T</th>
<th>TC</th>
<th>LDL/C</th>
<th>HDL/C</th>
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<tbody>
<tr>
<td>ASW</td>
<td>0.84</td>
<td>2.77</td>
<td>1.91</td>
<td>2.52</td>
<td>1.14</td>
<td>1.12</td>
<td>0.82</td>
<td>0.69</td>
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<tr>
<td>DSW</td>
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Anthropometric and Cardiovascular Parameters

**Distal MTJ Displacement Over Sets**


**Muscle Fascicle Behavior during Eccentric Cycling**

**Fascicle Length – Torque and Tendinous Tissue Length – Torque Relationship during Eccentric Cycling**


**Exercise, Diabetes, Dementia**

Metabolic Syndrome: abdominal obesity, high blood pressure, high glucose, triglycerides, low HDL in the blood

- Prevent, delay development
- Improve quality of life

Diabetes

Hypertension

Atherosclerosis

Eccentric

Dementia

Alzheimer’s Disease

- Prevent, delay development
- Maintain cognitive demand
- Prevent development
- Reverse symptoms

**“Eccentric” Exercise**

Muscle Damage, Muscle Pain

Neuromuscular Fatigue

Interventions for fatigue, damage and pain

Eccentric Cycling / Eccentric Training

Cold water immersion

Therapeutic modalities (e.g. vibration, massage)

Stretching

Supplementation

Electrical / Magnetic stimulations (IDCS, TMS, NMES)

Muscle cramp

Exercise Medicine: Application for chronic diseases (e.g. Diabetes, Stroke), anti-ageing

Exercise Rehabilitation: Injury prevention and treatment, injury risk assessments

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