How should I train muscles to sprint faster? Why do muscles become sore after training? No pain, no gain!

Exercise-Induced Muscle Damage

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Type of Muscle Contraction

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

Consciously: forced lengthening, controlled lengthening
Unconsciously: deceleration, shock absorption

Eccentric Exercises

Exercise Models of Muscle Damage in Human Studies

- Downhill running, walking, backward walking
- Bench stepping exercise
- Sitting exercise
- Plyometric exercises (e.g. Drop Jumps)
- Eccentric cycling
- Submaximal / Maximal Eccentric Exercise
  Elbow Flexors / Extensors, Wrist Extensors
  Knee Extensors / Flexors, and others

The magnitude of damage is dependent on the models, subjects (gender, age, conditions etc)

Elbow Flexor “Torture” Machine

“Manual” mode (Isotonic)
“Feel” resistance
Modify load
Slow action (5 s)
Full range of motion
Not “sophisticated”
But, worked well
Maximal Eccentric Contractions of the Elbow Flexors

ROM (Flex – Ext)
- full, partial
- 90°–60°, 60°–0°

Isokinetic mode
- angular velocity
  - (30°/s - 240°/s)

Isotonic mode

Muscle Damage

SYMPTOMS
- Weakness
- Muscle Pain
- Stiffness
- Swelling

MARKERS
- ↓ Muscle function
- ↓ Range of Motion
- ↓ Muscle Volume, Girth
- Abnormality in MRI/US
- ↑ Muscle proteins in blood

Histological changes

Ultrastructural Alterations

8 sets of 8 reps @80% 1RM Arm-curl exercise

Focal
Moderate x200
Extreme x1200

Number of fibres (% of total)
- Baseline
- Post-Exercise
- 48 h Post-Exercise


Muscle Damage

Extreme

Muscle Damage

Muscle Damage

Voluntary Contraction vs Electrical Stimulation

210 lengthening contractions of the knee extensors (8 men)

Maximal voluntary
Electrically stimulated

Disrupted Z-lines were greater for the stimulation
No significant difference in muscle soreness
Greater strength loss in the voluntary exercise

Desmin stain 8 days post

Changes in CK activity following Max ECC

Myoglobin peaks 3-4 days post exercise


CK and TnI


Inflammatory Markers after Mac ECC

No significant changes in CRP after Max ECC


No significant changes in the number of circulating lymphocytes, eosinophils, basophils, and small increases in neutrophils (12, 36, and 60 h post) and monocytes (8 h post)


Little or no changes in inflammatory mediators IL-1β, IL-1ra, IL-4, IL-6, IL-8, IL-10, IL-12p40, TNF-α, G-CSF, MPO, PGE₂, HSP60, HSP70


Muscle Soreness following Max ECC

Muscle Soreness

Visual Analogue Scale (VAS)

No pain 50 mm (100 mm) Very painful

Exercised
Control

4 days after ECC

Exercised: 48-mm
Control: 41-mm

Muscle Swelling following Max ECC

Changes in MRI (T2) following Max ECC

Changes in B-mode ultrasound images after elbow flexor eccentric exercise

Changes in ROM following Max ECC
Changes in MVC following Max ECC


Changes in Markers following Max ECC


Mononuclear cell infiltration

(Israel et al., J Physiol 379: 435-446, 1986.)

DOMS and Other Markers

No significant correlation


Muscle Damage by Non-ECC

- Isometric contractions at a long muscle length (e.g. elbow joint angle: >160°)
- Concentric contractions with fatigue
- Electrical stimulation
- Stretching
- Muscle cramp

Structural Damage by EMS

180 isometric contractions of the plantar flexors
EMS: 60 Hz, 300 µs, on-off 4–6 s
Lack of desmin fibres: 12%
CD68+ fibres: 13.6%

Desmin

CD68

48 h post EMS, gastrocnemius


EMS Protocol

Intelect Advanced Colour Stim (Chattanooga Group, USA)
2 positive electrodes over motor point of the VL and VM
2 negative electrodes over the proximal portion of the QF
75 Hz pulsed current, pulse duration: 400 µs, duty cycle: 5 s / 15 s
40 isometric contractions
Knee joint angle: 100°
Trunk angle: 110°

Biodex isokinetic dynamometer
Torque during Exercise

9 men (31.3 ± 4.7 y)

Interval between bouts: 2 weeks

Maximal Voluntary Isometric Contraction Strength @ 100°

Faster recovery after 2nd than 1st bout

Muscle Soreness

During squat
Similar results for palpation

Smaller increases after 2nd than 1st bout

Plasma CK Activity

Smaller increases after 2nd than 1st bout

Alternating Current vs Pulsed Current

2.5 kHz @ 75 Hz
Sinusoidal
Pulse duration: 400 μs
Duty cycle: 5 s / 15 s
Maximal tolerance

75 Hz
Biphasic, rectangular

Torque during EMS

12 men (31.2 ± 5.5 y)

Stimulation intensity: 60 – 80 mA

25-30% MVC
Maximal Voluntary Isometric Contraction Strength

Strength loss: 100° > 70° > 40°

Plasma CK Activity

Peak CK activity
PC: 1,677 ± 491 IU/L
AC: 1,262 ± 339 IU/L

Muscle Soreness

Voluntary vs EMS (Elbow Flexors)

12 men
Arm1: Voluntary Max isometric
Arm2: EMS-induced isometric
50 intermittent (5s /15s rest)
contractions@180°
EMS: 75 Hz, 200μs

Peak torque over 50 contractions
VOL: 44-28 Nm, EMS: 15-20 Nm

Greater changes after EMS than VOL
Greater increases after EMS than VOL

Factors influencing muscle damage

Effect of Number of Eccentric Actions

Short vs Long Muscle Length

Trained vs Untrained Subjects

Japanese vs Caucasian

Effect of Exercise Intensity
**Muscle Damage / DOMS in Children**

- Limited information is available
- No DOMS for infants?
  - no DOMS for 3-5 yr (parents’ observation)
- Little DOMS before 10 yrs?
  - little DOMS for 6-7 yr (questionnaire)
  - no DOMS after eccentric exercise (Exp)
  - 1/3 of 11-12 yr had DOMS (questionnaire)
  - less DOMS and muscle damage for 9-10 yr

**Eccentric Exercise of 4 Different Limbs**

- EF = EE > KF > KE
Flexible subjects are less susceptible to muscle damage

MVC - 5d ROM

Peak CK ROM

MVC - 5d OA

Peak CK OA

Effect of Wrist Position

Supinated

Neutral

Muscle Damage after Downhill Running

<table>
<thead>
<tr>
<th>Factors influencing Muscle Damage</th>
<th>pre</th>
<th>1 h</th>
<th>1 d</th>
<th>2 d</th>
<th>3 d</th>
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<tbody>
<tr>
<td>Contraction type</td>
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</table>

<table>
<thead>
<tr>
<th>Factors influencing Muscle Damage</th>
<th>Magnitude of Muscle Damage</th>
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</thead>
<tbody>
<tr>
<td>M/C 496.7 ± 21.2</td>
<td>391.2 ± 36.1</td>
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<tr>
<td>Peak CK 104.5 ± 28.5</td>
<td>226.6 ± 46.3</td>
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<tr>
<td>Mb 19.8</td>
<td>1006.6 ± 127.3</td>
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</tbody>
</table>

MVC: Maximum Voluntary Contraction

Peak CK: Peak Creatine Kinase

M: Mass

*Significant differences from control
Ironman Triathlon

Muscle function (pre-1d)

- MVC (KE): -30%
- MVC (KF): -9%
- SJ: -29%
- CMJ: -20%

Muscle soreness (pre, post, 1d)

- KE: 0 - 6.1 - 6.0
- KF: 0 - 3.0 - 3.4
- AF: 0 - 4.3 - 3.9

Blood markers (pre, post, 1d)

- CK: 218, 2780, 5700 IU/L
- Mb: 21, 2998, 487 ng/ml
- Interleukins: large increases


3.8km
180km
42.2km

Thank you very much


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