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

The Repeated Bout (Preconditioning) Effect in Exercise

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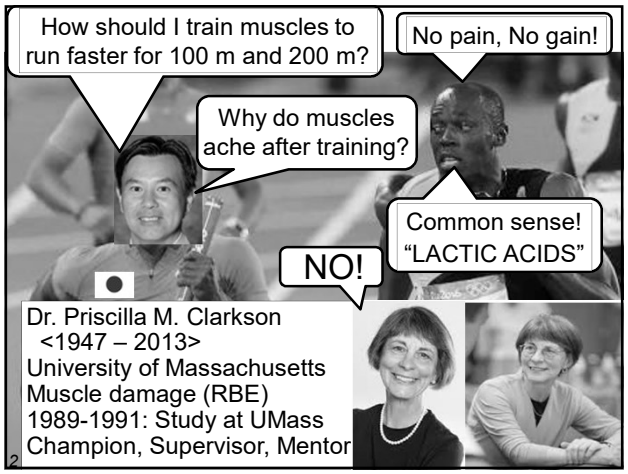


Dr. Priscilla M. Clarkson
<1947 – 2013>
University of Massachusetts
Muscle damage (RBE)
1989-1991: Study at UMass
Champion, Supervisor, Mentor

2

Type of Muscle Contraction

Isometric (Static) : Force = Load

Concentric (Shortening) : Force > Load

Eccentric (Lengthening) : Force < Load

3

Cycling Exercise

CONCENTRIC

ECCENTRIC

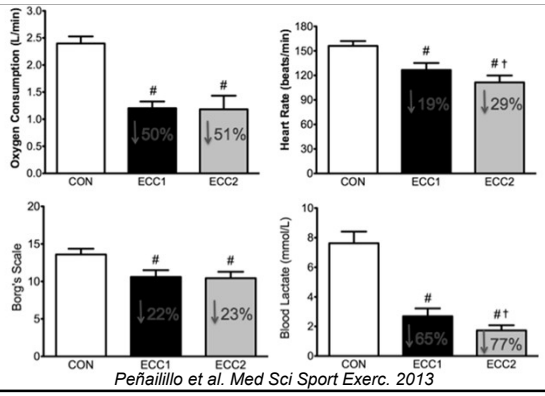
Tunturi F30R (Australia) EccentricTrainer (Metitur, Finland)

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

4

Concentric vs Eccentric Cycling

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



Peñailillo et al. Med Sci Sport Exerc. 2013

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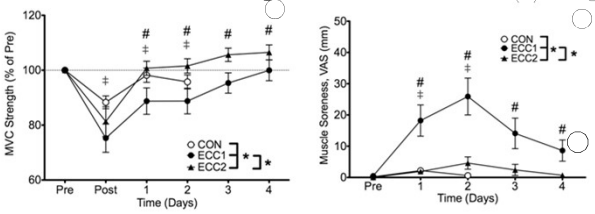
"Muscle Damage" after Cycling



Peñailillo et al. Med Sci Sport Exerc. 2013

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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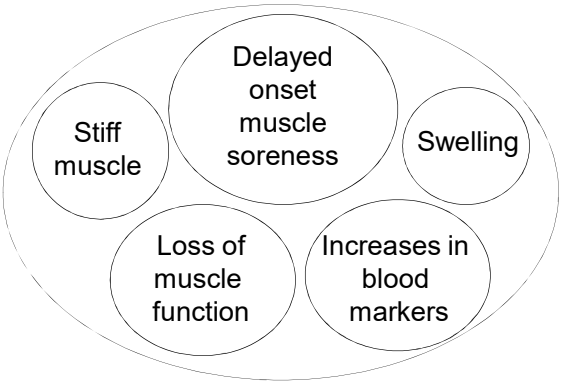
Indicators of Muscle Damage



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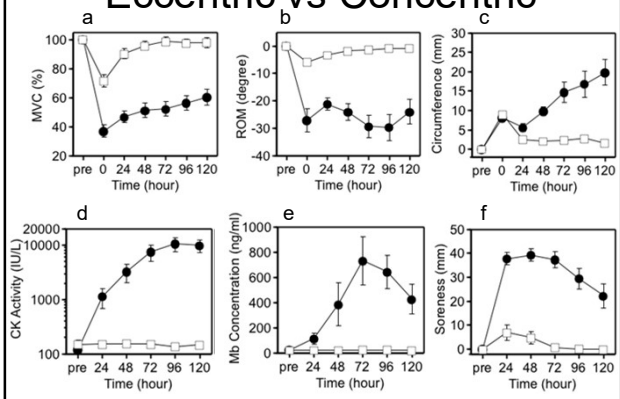
Eccentric vs Concentric



8 *Lavender & Nosaka. Eur J Appl Physiol. 2006*

−	Muscle Damage Magnitude	+
Low	**Intensity**	High
Small	**Repetition**	
~~Slow~~ Large	**Velocity**	Fast
Short	**Muscle length**	Long
Yes	**Preconditioning**	No
Yes	**Training**	No
Leg	**Muscle**	Arm
Child	**Age**	Old Adult Young
Female	**Gender**	Male

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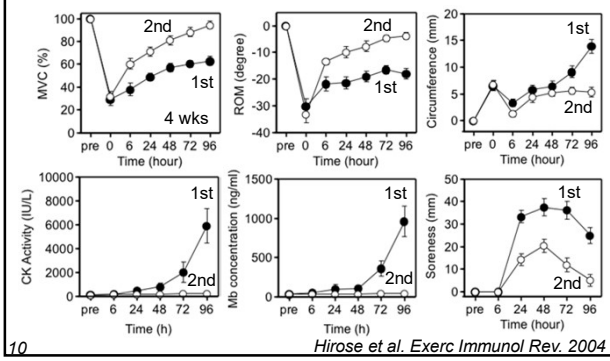
Repeated Bout Effect

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



10 *Hirose et al. Exerc Immunol Rev. 2004*

4 Repeated Bouts

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

Study design/Exercise

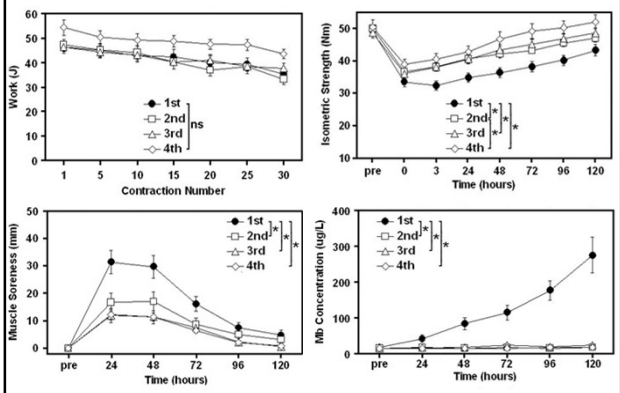
1st → 2nd → 3rd → 4th
4wk 4wk 4wk

Maximal eccentric exercise of the elbow flexors

Non-dominant arm
30 max ECC contractions
Rest: 10 s
ROM: 90 - 0º
Velocity: 90º/s

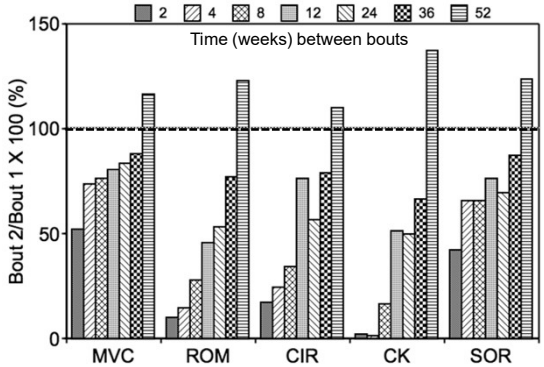
11

4 Repeated Bouts



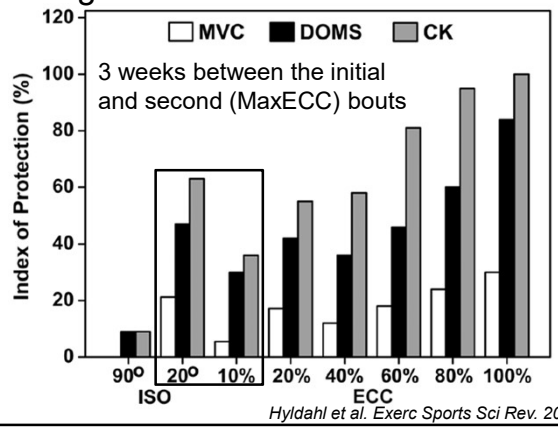
12 *Chen et al. Eur J Appl Physiol. 2009*

How long does the RBE last?



13 *Nosaka et al. Med Sci Sports Exerc. 2001*

Magnitude of the Protective Effect



14 *Hyldahl et al. Exerc Sports Sci Rev. 2017*

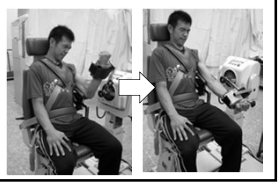
Low-Intensity Eccentric Exercise

10% bout: 10% load

- ✓ 5 sets of 6 contractions
- ✓ 3 s contraction (30º/s)
- ✓ ROM: 90-0º
- ✓ 10 s between contractions
- ✓ 2 min between sets

Dumbbell: MVC@90º

100% bout: Maximal isokinetic eccentric contractions



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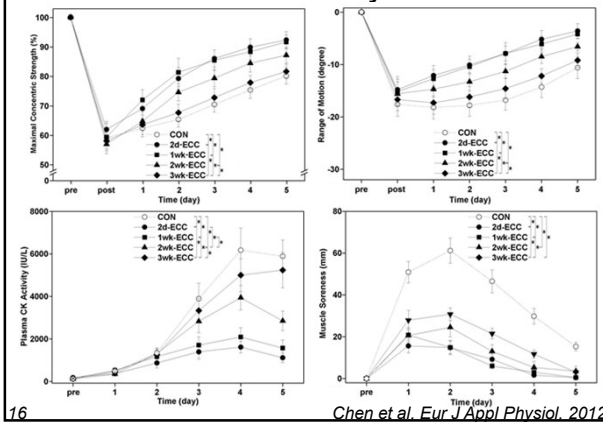
Protective Effect by 10% ECC



16 *Chen et al. Eur J Appl Physiol. 2012*

Isometric Contractions

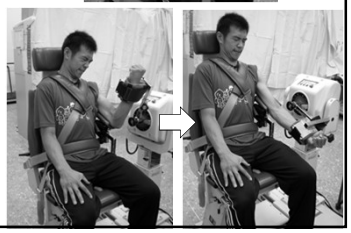
2 or 10 maximal isometric contractions

- ✓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



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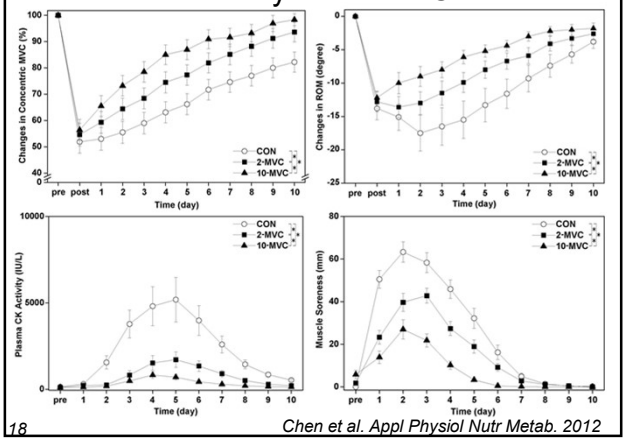
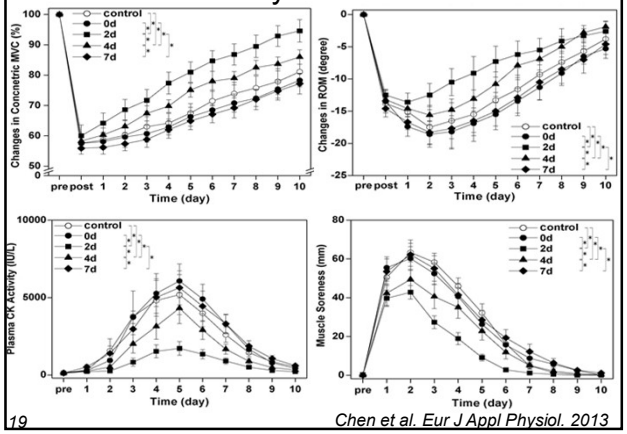
Protective Effect by Isometric Contractions



18 *Chen et al. Appl Physiol Nutr Metab. 2012*

Protective Effect by Isometric Contractions



19 *Chen et al. Eur J Appl Physiol. 2013*

Contralateral Repeated Bout Effect

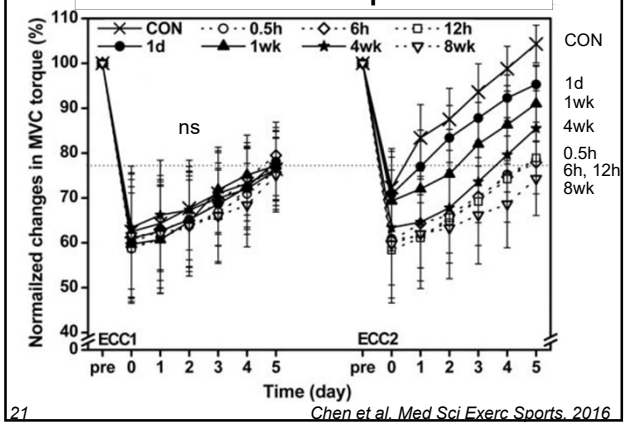
5 sets of 6 maximal eccentric contractions of the elbow flexors

1st Bout	Interval	2nd Bout	Group
Non-dominant Arm	2 weeks	Non-dominant Arm	CONTROL
Right (Left) Arm	0.5 hour	Left (Right) Arm	0.5h
	6 hours		6h
	12 hours		12h
	24 hours		24h
	1 week		1w
	4 weeks		4wk
	8 weeks		8wk

104 young "untrained" men — 13 men/group

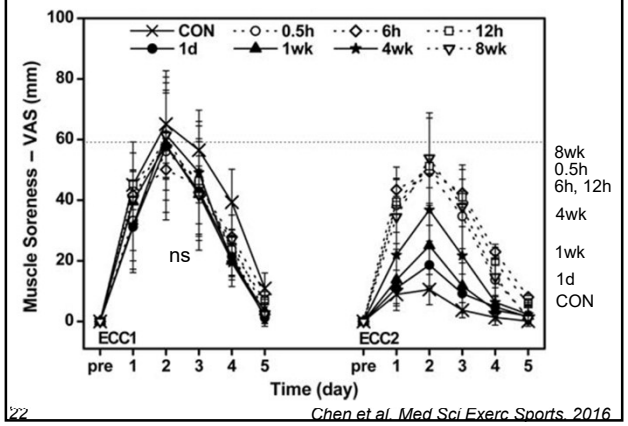
20

MVC Torque



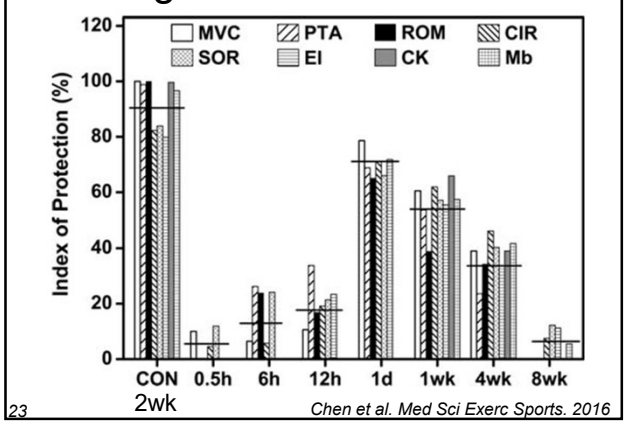
21 *Chen et al. Med Sci Exerc Sports. 2016*

Muscle Soreness



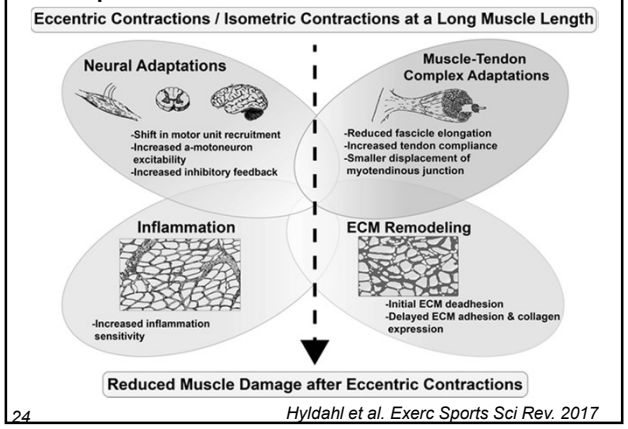
22 *Chen et al. Med Sci Exerc Sports. 2016*

Magnitude of Protection



23 *Chen et al. Med Sci Exerc Sports. 2016*

Repeated Bout Effect Mechanisms



24 *Hyldahl et al. Exerc Sports Sci Rev. 2017*

Modulating exercise-induced hormesis: Does less equal more?

Peake JM, Markworth JF, Nosaka K, Raastad T, Wadley GD, Coffey VG. *J Appl Physiol* 119:172– 189, 2015.

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 adaptations.

Is muscle damage necessary?

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.

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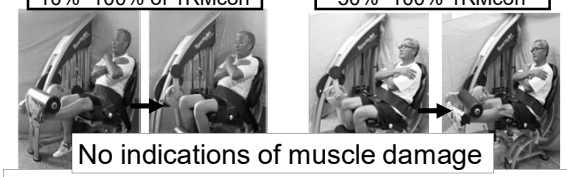
Knee Extensor Resistance Exercise Study

- 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

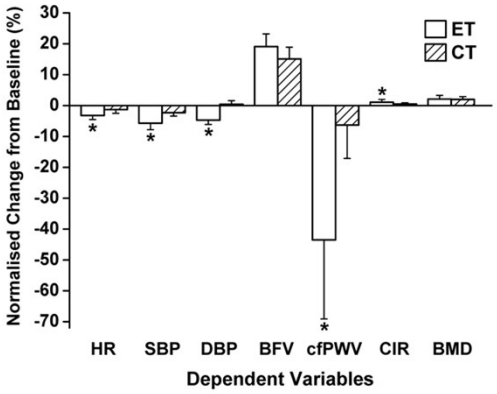
Concentric Exercise: 50%~100% 1RMcon



No indications of muscle damage

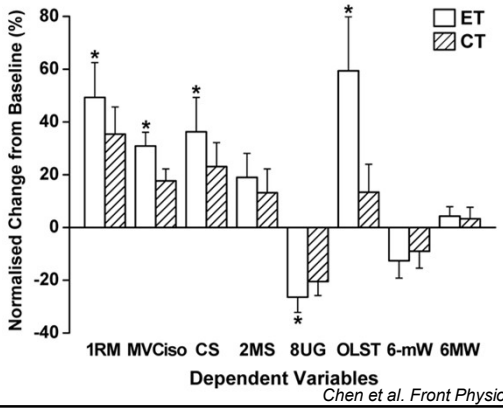
26 Once a week over 12 weeks, 12 training sessions for both legs

Cardiovascular and Other Parameters



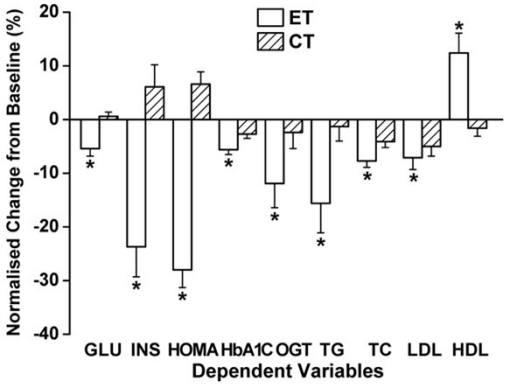
27 *Chen et al. Front Physiol. 2017*

Muscle Function and Physical Fitness



28 *Chen et al. Front Physiol. 2017*

Insulin Sensitivity and Blood Lipids



29 *Chen et al. Front Physiol. 2017*

Eccentric Exercise is Hormesis

Negative aspect

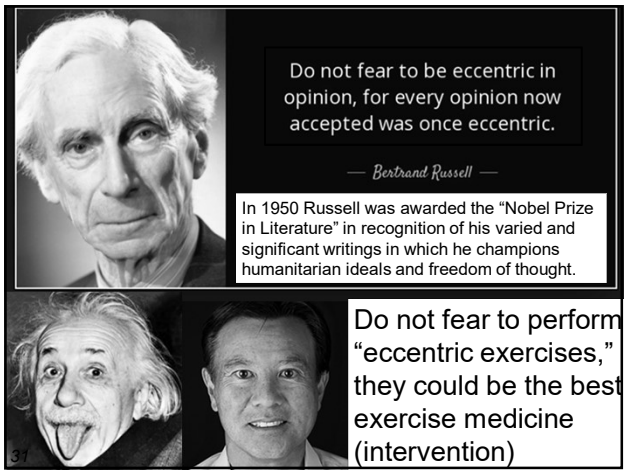
- **Muscle damage**
  DOMS, Prolonged loss of muscle function

Muscle damage can be minimised by using "pre-conditioning exercise" and gradually increasing the intensity and volume Muscle damage does not appear to be the stressor required for adaptations
"Not" no pain no gain

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

30 **Minimize muscle damage, Maximize eccentric contractions**



Do not fear to perform "eccentric exercises," they could be the best exercise medicine (intervention)

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Eccentric-Only Gym

32 Treadmill: Downhill walking / running

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

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Thank you very much

Questions?
Comments?
Suggestions?
Collaboration?

Ken Nosaka
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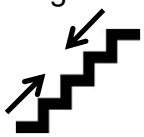
Stair Walking Study

- Participants: 30 elderly obese women >60 y, BMI: >25, Body fat: >30%

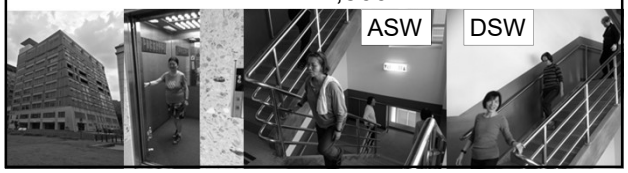
Age: 66.4 ± 6.8 y, Height: 154.8 ± 5.0 cm
Body mass: 62.7 ± 4.7 kg, BMI: 26.2 ± 1.0
Percent Body Fat: 34.8 ± 4.0%

- 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

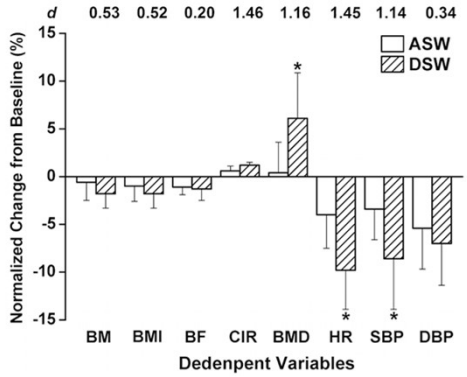


Responses to Exercise

	ASW	DSW
RPE (6-20)	9.6 ± 1.0	8.1 ± 0.9*
Heart Rate (bpm)	113.7 ± 10.9	88.6 ± 7.8*
Systolic BP (mmHg)	133.7 ± 10.1	119.4 ± 7.4*
Diastolic BP (mmHg)	68.8 ± 4.6	68.0 ± 5.9

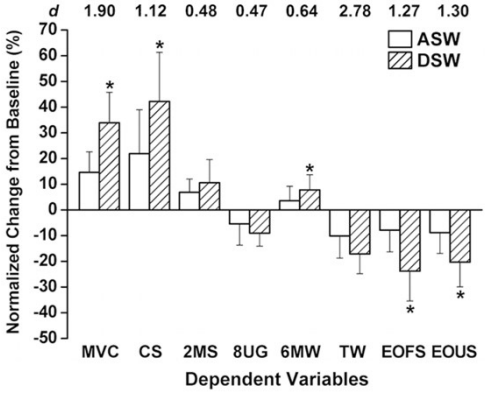
No signs of muscle damage *: significantly (P≤0.05) different from ASW

Anthropometric and Cardiovascular Parameters



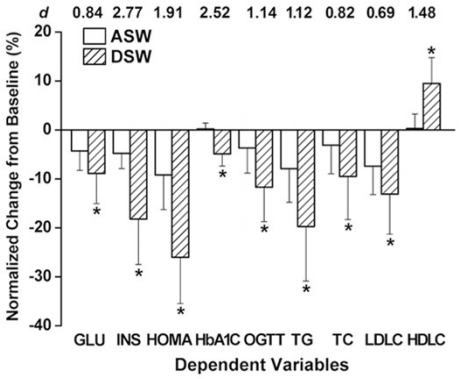
Chen et al. Med Sci Sports Exerc 2017

Muscle Function and Physical Fitness

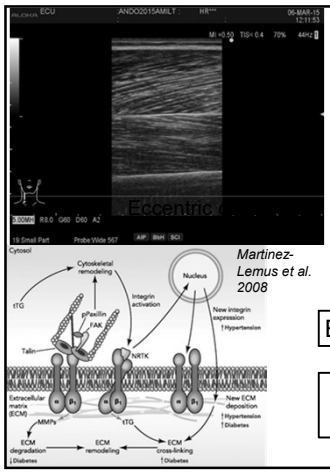


Chen et al. Med Sci Sports Exerc 2017

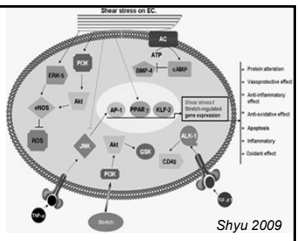
Insulin Sensitivity and Blood Lipids



Chen et al. Med Sci Sports Exerc 2017



Martinez-Lemus et al. 2008



Shyu 2009

Eccentric contractions

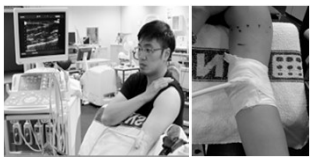
Stretch ⇩ Stimulate

Extracellular Matrix (ECM)

Muscle cells	Vascular cells	Nerve cells

Adaptations

Muscle Length Changes During Eccentric Contractions of the Elbow Flexors



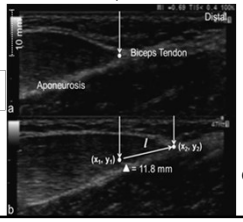
- Aloka SSD-α10 with a 10-MHz probe (6 cm)
- Frame rate: 47 Hz

MTJ Displacement

60°

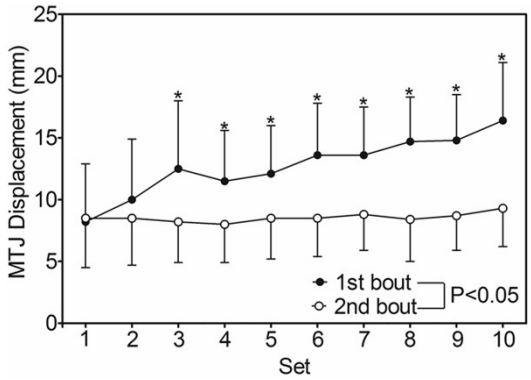
Eccentric Contraction

0°



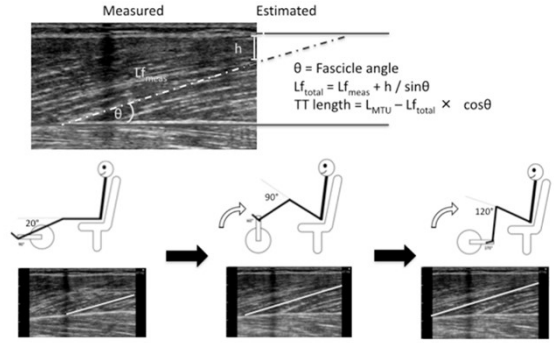
10 sets of 6 maximal eccentric contractions (60°/s) of the elbow flexors (ROM: 60°-0°)

Distal MTJ Displacement Over Sets

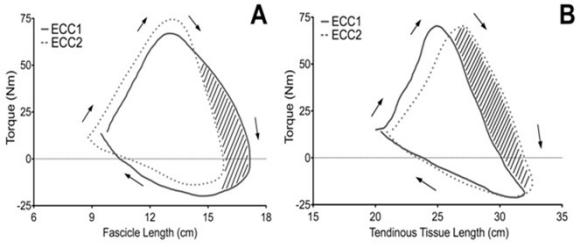


Lau et al. Am J Physiol 2015

Muscle Fascicle Behavior during Eccentric Cycling

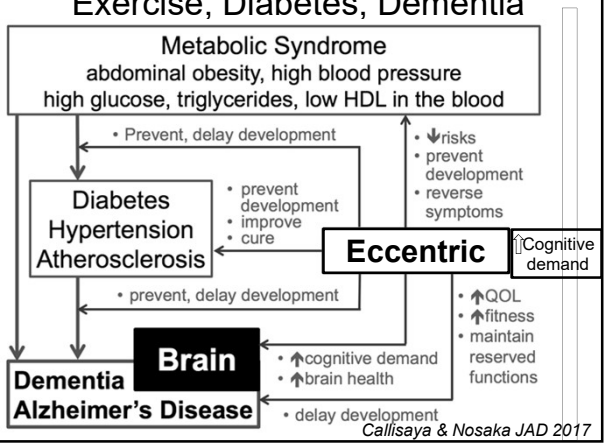


Fascicle Length – Torque and Tendinous Tissue Length – Torque Relationship during Eccentric Cycling



Peñaillilo et al. Med Sci Exerc Sports 2014.

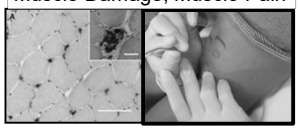
Exercise, Diabetes, Dementia



Callisaya & Nosaka JAD 2017

"Eccentric" Exercise

Muscle Damage, Muscle Pain

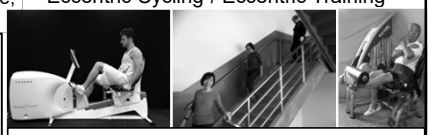


Neuromuscular Fatigue

Interventions for fatigue, damage and pain

Cold water immersion
Therapeutic modalities (e.g. vibration, massage)
Stretching
Supplementation
Electrical / Magnetic stimulations (tDCS, TMS, NMES)
Muscle cramp

Eccentric Cycling / Eccentric Training



Exercise Medicine: Application for chronic diseases (e.g. Dementia, Diabetes, Stroke), anti-ageing
Exercise Rehabilitation: Injury prevention and treatment, Injury risk assessments