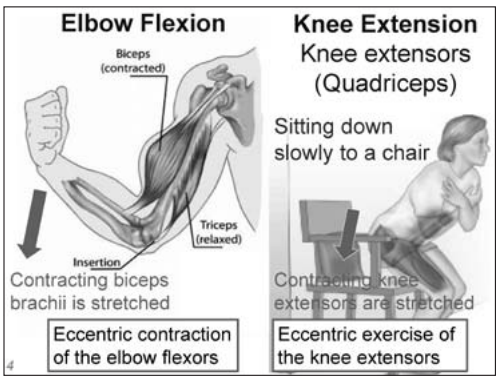
2017年度学術講演会報告

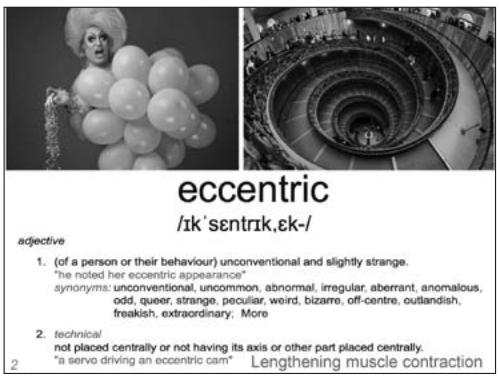
Let' Get Eccentric !

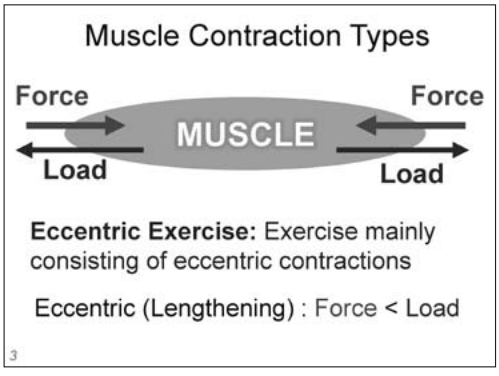
野坂　和則

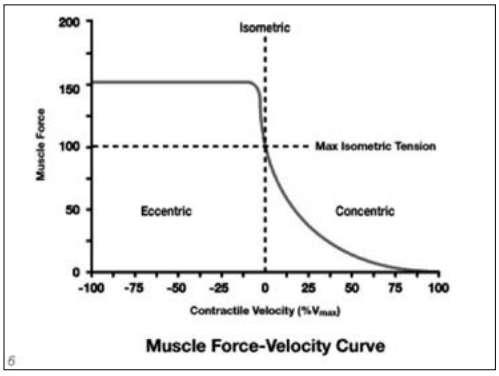
Let' Get Eccentric !

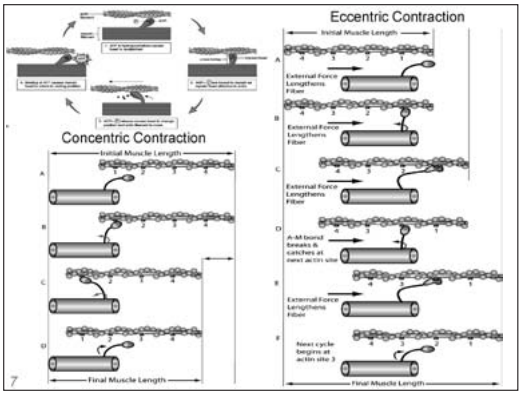
Kazunori NOSAKA



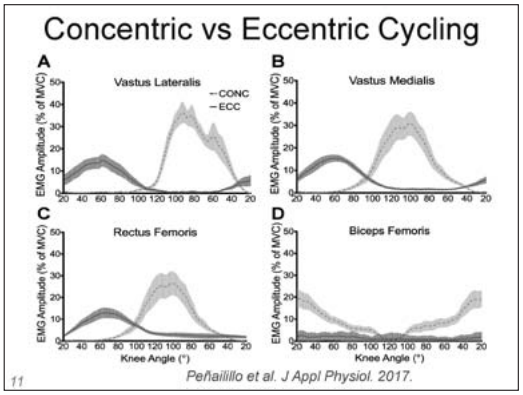




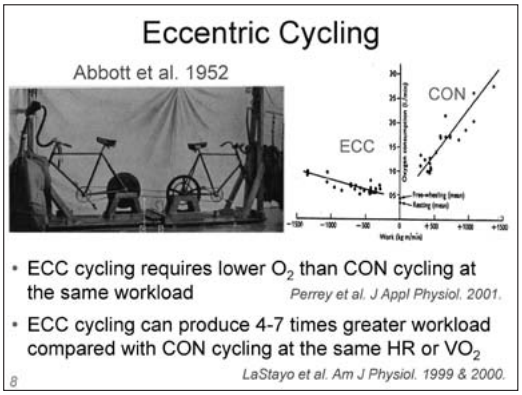




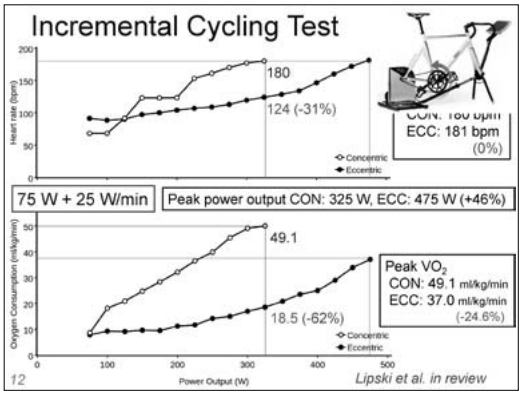
7



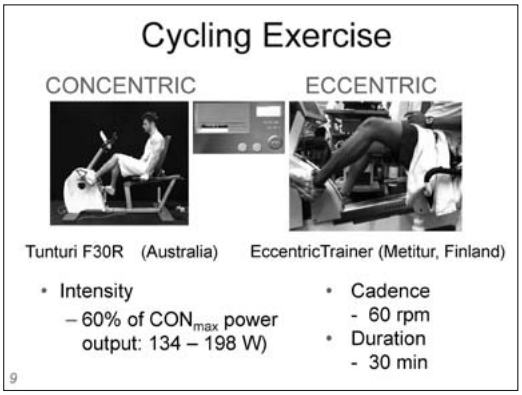
11



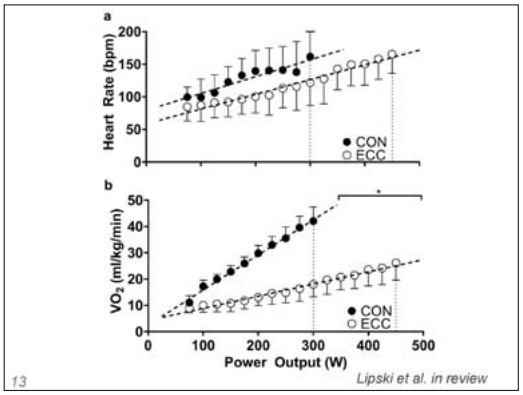
8



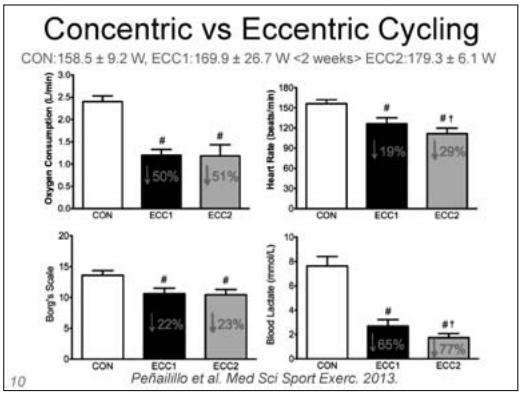
12



9



13



10

Maximal Cycling n=9

	CON	ECC	Dif (%)
Peak power (W)	300.4 ± 50.4 (200 – 375)	455.3 ± 118.1 (225 – 625)	149 ± 23 (138 – 188)
Peak HR (bpm)	184.4 ± 12.9 (155 – 196)	176.2 ± 20.4 (151 – 201)	83 ± 32 (79 – 106)
Peak VO_2 (ml/kg/min)	43.7 ± 7.6 (34.1 – 54.7)	31.2 ± 6.1 (21.7 – 40.7)	71 ± 11 (56 – 94)

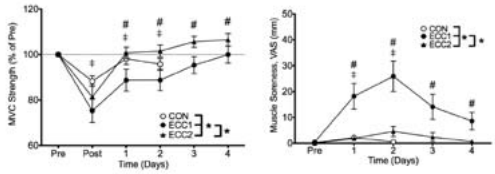
Cycling @ 200 W

	CON	ECC	Dif (%)
HR (bpm)	139.7 ± 31.8 (92 – 176)	100.2 ± 24.8 (64 – 125)	74 ± 16 (50 – 103)
VO_2 (ml/kg/min)	29.9 ± 3.0 (23.5 – 34.8)	13.1 ± 3.2 (8.7 – 18.3)	42 ± 11 (31 – 62)

Lipski et al. in review

14

"Muscle Damage" after Cycling

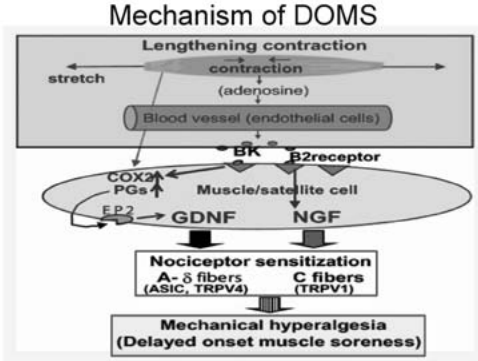


Peñailillo et al. Med Sci Sport Exerc. 2013

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

15

Mechanism of DOMS



19 *Mizumura & Taguchi. J Physiological Sci. 2016*

Eccentric Exercise-Induced Muscle Damage

SYMPTOMS	INDICATORS	VARIABLES
Weakness	Muscle Function	Maximal voluntary contraction strength Isometric, Concentric, Eccentric Optimal angle, Muscle endurance, RFD Electrical stimulation (e.g. twitch force) Magnetic stimulation (e.g. MEP) Conduction velocity, Ca^{2+} sensitivity
Fatigue	Exercise Economy	Oxygen consumption, RPE, Heart rate
Stiff muscle	Muscle Stiffness	Relaxed, Flexed, Extended joint angles Muscle hardness, Muscle stiffness
Sore muscle	Muscle Pain	Pain scale (e.g. VAS, VRS, Likert, CR-10) Pressure / Electrical pain threshold
Swelling	Limb Volume	Circumference, Cross sectional area Muscle thickness (ultrasound)
	Muscle Proteins in Blood	CK, Myoglobin, Structural proteins
	MRI / B-mode Ultrasound Images	MRI (T2 relaxation time, Diffusion) Ultrasound echo-intensity
Direct marker	Histology	LM, EM: Myofibre, Myofilaments, Plasma membrane, SR, Inflammatory cells, Extra cellular matrix, Capillary, Nerves

16

Visual Analogue Scale (VAS)

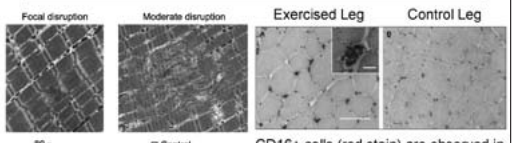
no pain — 50 mm (100 mm) — **very painful**

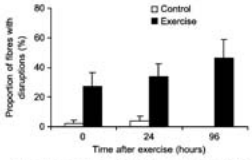
Pressure Pain Threshold

Electronic Algometer (Somedic, Sweden)

20

30 sets of 10 maximal eccentric contractions of the **Knee Extensors**

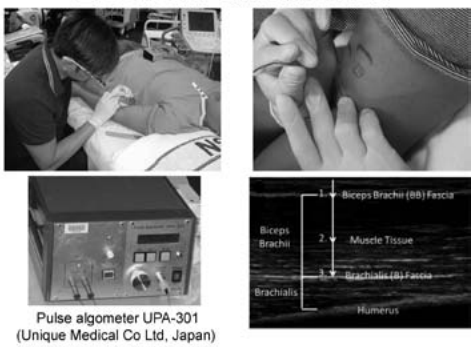




CD16+ cells (red stain) are observed in the interstitial spaces of the exercised leg but not the control leg (vastus lateralis) at 96 h after exercise; the inserted picture shows CD68+ cells (red) inside a muscle cell (scale bar = 50 µm).
Intracellular infiltration was observed occasionally (0.2-1.35% of myofibres)

17 *Raastad et al. Med Sci Sports Exerc. 2010. Paulsen et al. Med Sci Sports Exerc. 2010.*

Electrical Pain Threshold



Pulse algometer UPA-301 (Unique Medical Co Ltd, Japan)

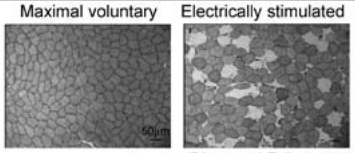
21

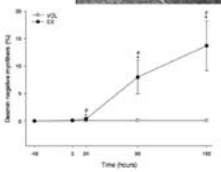
Voluntary Contraction vs Electrical Stimulation

210 max eccentric contractions of the knee extensors

Maximal voluntary — Electrically stimulated

Desmin stain 8 days post



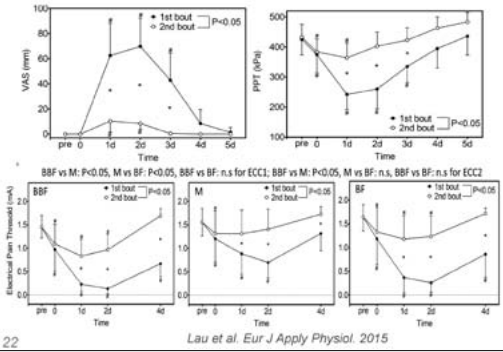


- Disrupted Z-lines were greater for the stimulation
- No significant difference in muscle soreness
- Greater strength loss in the voluntary exercise
- Histological changes do not represent "symptoms"

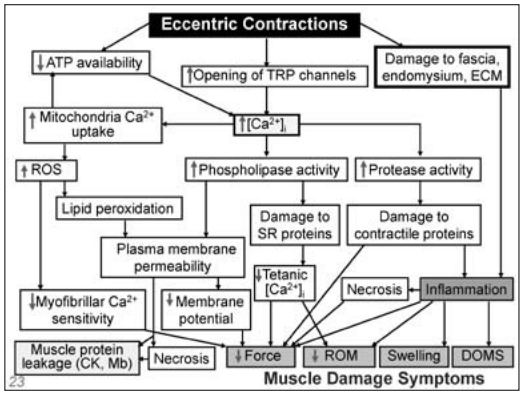
Crameri et al. J Physiol. 2007.

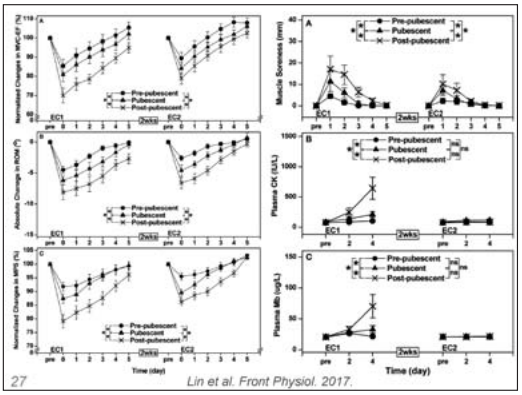
18

Changes in VAS, PPT and EPT



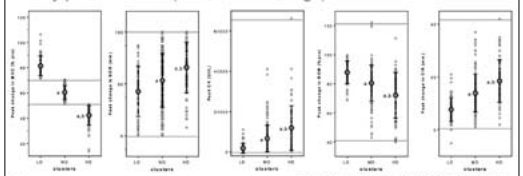
22 *Lau et al. Eur J Apply Physiol. 2015*





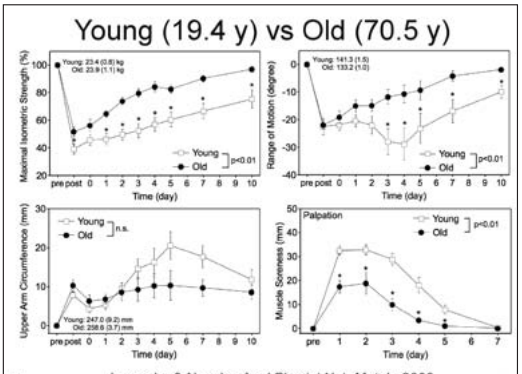
Relationship among Indirect Markers of Muscle Damage

- "Untrained" young men (n=286)
- 30 maximal "isokinetic" eccentric contractions of the elbow flexors
- Indirect markers: MVC torque, Muscle soreness (VAS: 100 mm), CK activity, Range of motion, Upper arm circumference
- Clusters based on the magnitude of decrease in MVC torque 1 day post-exercise (Low, Medium, High)



24 Damas et al. Int J Sports Med. 2016.

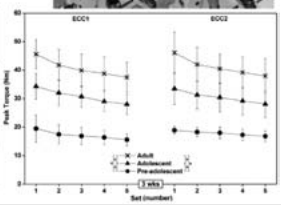
Young (19.4 y) vs Old (70.5 y)



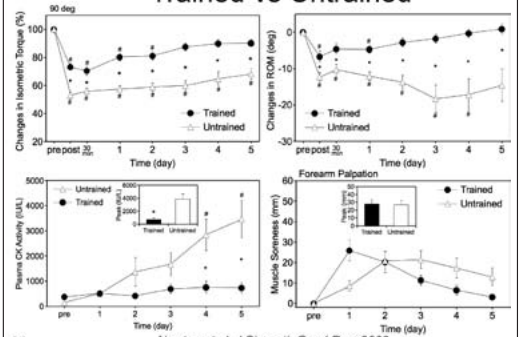
Muscle Damage in Children

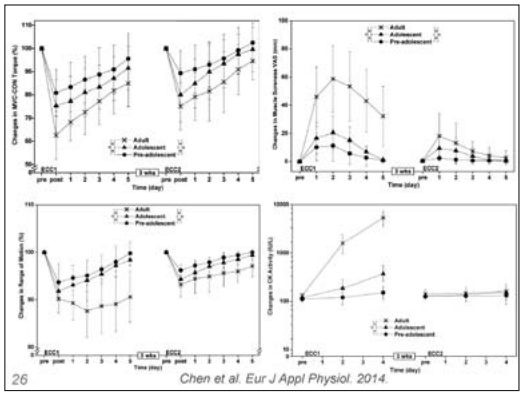
- Non-dominant arm
- 5 sets of 6 maximal ECC
- ROM: 90 - 0° (90°/s)
- 10 s between contractions, 2 min between sets

	MVC (Nm)	Peak ECC (Nm)
Adult (20-25 y)	35.3	40.9
Adolescent (14-15 y)	25.1	30.7
Pre-adolescent (9-10 y)	8.9	17.5

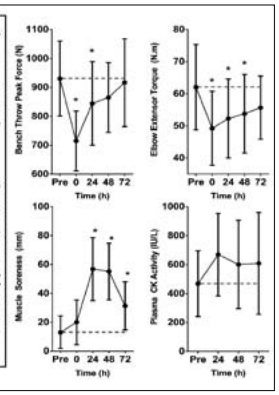


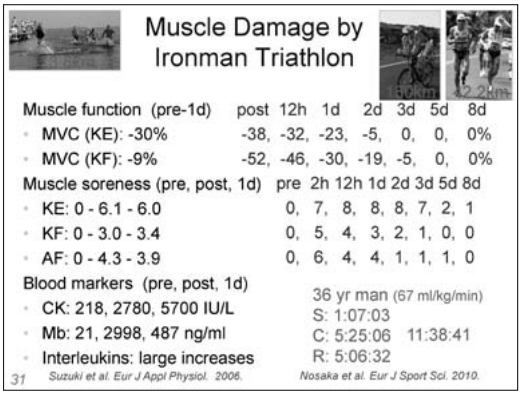
Trained vs Untrained

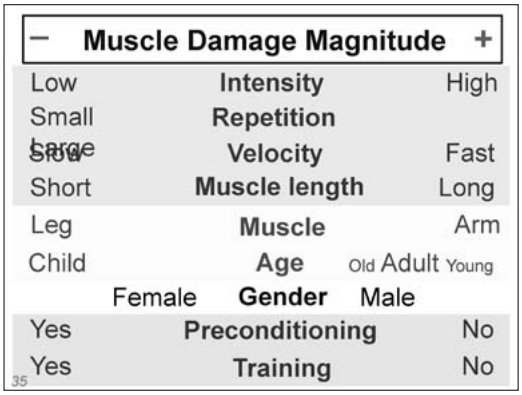




- 10 male bodybuilders Training: 4–9 y, Contest participation, Age: 23 ± 2 y, Height: 176 ± 4 cm, Body mass: 85 ± 8 kg
- A series of 5 exercises (3–4 sets x 8–12 reps @56-70%1RM) and 4 exercises to volitional failure (3 circuits x 1 set each @40–67%1RM) targeting the pectoral muscles (60–70 min)







Muscle Damage after an Official Basketball Match

Brazilian National Female Basketball Championship

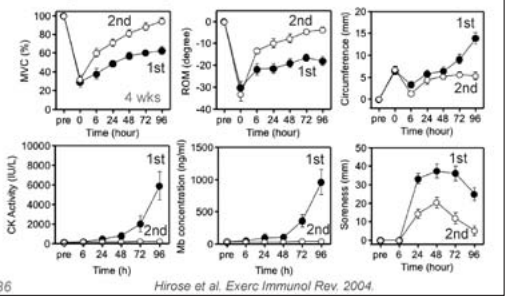
Professional team members (> 5y)
Age: 27.4 ± 4.8 y, Height: 179.5 ± 5.5 cm, Body mass: 72.0 ± 7.8 kg
10-12 training sessions per week

	Time (min)	RPE (0-10)	ΔCK IU·L⁻¹	ΔMb ng·mL⁻¹	ΔHS (mm)	ΔPM (mm)	1RM-LP (%)	1RM-BP (%)	T test (%)
1-Guard	18	3	82.5	25.1	22	16	-4.5	5.3	-0.2
2-Guard	20	3	160.3	166.3	33	6	-3.8	0.0	0.7
3-Centre	4	3	205.7	75.8	13	7	8.0	0.0	-4.3
4-Centre	18	6	297.6	46.1	17	10	0.0	0.0	-1.9
5-Centre	20	4	548.4	230.2	29	20	0.0	-13.0	-0.5
6-Centre	25	7	587.7	301.6	37	6	-2.4	0.0	4.0
7-Centre	17	4	147.1	122.5	5	12	7.0	0.0	-3.8
8-Forward	6	2	10.7	39.0	9	8	2.4	0.0	-2.8
9-Forward	22	4	29.3	66.9	2	0	-4.3	0.0	-2.3
10-Forward	20	4	65.6	83.3	18	15	0.0	4.0	-2.5
11-Forward	30	4.5	211.1	127.6	43	22	-12.0	5.7	1.7
Mean	18.2	4.0	213.3	116.8	20.7	11.5	-0.9	0.2	-1.1
SD	7.5	1.5	195.1	86.2	13.4	6.4	5.8	5.0	2.5

Moreira et al. Biol Sport. 2014.
32

Repeated Bout Effect

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



Hirose et al. Exerc Immunol Rev. 2004.
36

Muscle Damage after a Tennis Singles Match

Brazil Tennis Academy Young Tennis Players

Age: 17.6 ± 1.4 y, Height: 179.0 ± 3.6 cm, Body mass: 70.2 ± 7.1 kg
National junior ranking: 10-45, Training: 20-30 h per week

Simulated 3-hour tennis match play (3 x 1-hour)

Players	Session RPE (0-10)	Peak DOMS (mm)	Peak CK (IU·L⁻¹)	Peak Mb (ng·mL⁻¹)	1RM (%) post	1RM (%) 24h	SJ (%) post	SJ (%) 24h	CMJ (%) post	CMJ (%) 24h
1	8	20	498	150	-47.6	-13.3	-7.8	-4.1	-12.9	-5.3
2	8	21	367	121	-33.3	-18.6	-7.0	-5.5	-8.5	-7.1
3	4	18	336	112	-33.3	-14.3	-14.5	0.7	-11.7	-0.5
4	3	10	105	81	-18.2	0.0	0.0	0.0	-2.6	1.6
5	7	9	157	106	-26.7	0.0	-2.9	1.6	-5.9	2.9
6	4	18	149	101	-27.3	-9.0	-0.6	-3.4	-3.6	1.6
7	8	29	299	139	-50.0	-14.0	-12.1	-8.0	-15.4	-0.3
8	5	15	490	100	-38.8	-8.3	-4.2	-7.1	-9.7	-1.5
9	6	20	290	115	-30.0	-15.0	-3.2	-4.0	-6.0	-2.7
10	7	20	409	175	-46.7	-15.1	-17.5	-5.6	-23.5	-9.5
Mean	6.0	18.0	310.0	120.0	-35.2	-10.8	-7.0	-3.5	-10.0	-2.1
SD	1.9	5.7	136.8	27.6	10.4	6.4	6.0	3.3	6.3	4.1

Gomes et al. Biol Sport. 2014.
33

4 Bouts of Maximal ECC

Subjects: 15 young men (21.8 ± 1.9 yrs)
- Height 1.74 ± 0.06 m, Body weight: 64.9 ± 9.2 kg
- No resistance training 1 y prior to the study

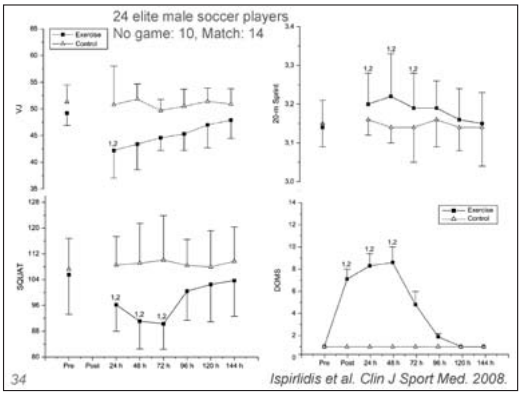
Study design/Exercise

1st → 2nd → 3rd → 4th
4wk 4wk 4wk

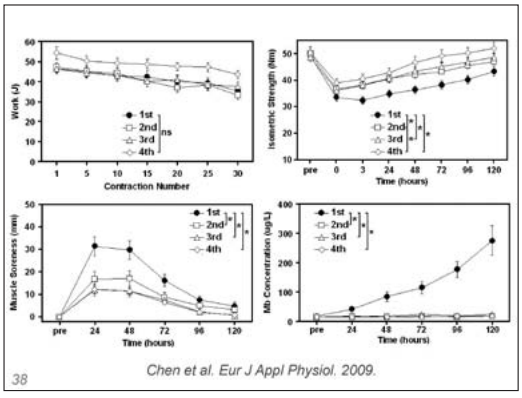
Maximal eccentric exercise of the elbow flexors

Non-dominant arm performed all bouts
- 30 max lengthening contractions
- Rest between contractions: 10s
- ROM: 90-180°
- Velocity: 90°·s⁻¹
- Torque, Work (Biodex System 3)

37

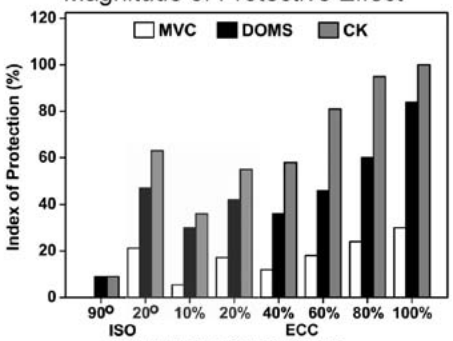


Ispirlidis et al. Clin J Sport Med. 2008.
34



Chen et al. Eur J Appl Physiol. 2009.
38

Magnitude of Protective Effect



39 Hyldahl et al. Exerc Sports Sci Rev. 2017.

Eccentric Exercise

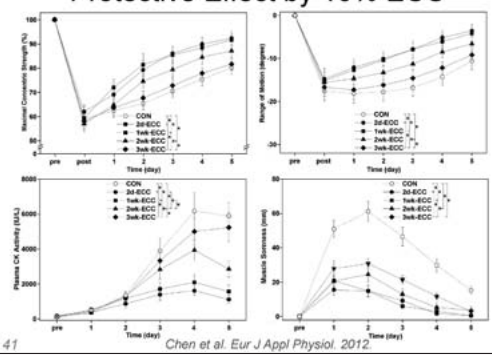
- **100% bout:** Maximal isokinetic eccentric contractions

- **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

40

Protective Effect by 10% ECC



41 Chen et al. Eur J Appl Physiol. 2012.

Isometric Contractions

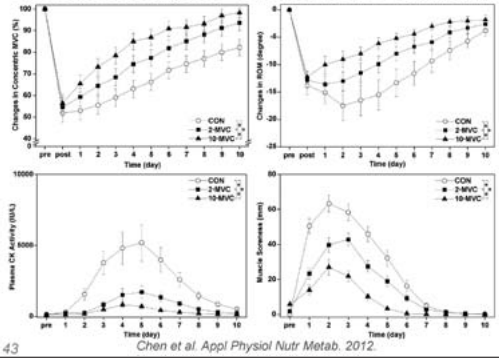
2 or 10 maximal isometric contractions
- ✓20° flexion
- ✓3 s
- ✓45 s between contractions

Eccentric Exercise

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

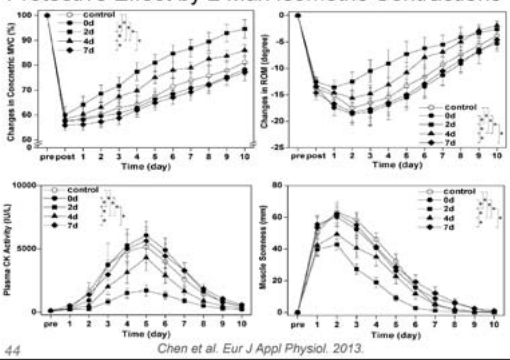
42

Protective Effect by 2 or 10 Max Isometric Contractions



43 Chen et al. Appl Physiol Nutr Metab. 2012.

Protective Effect by 2 Max Isometric Contractions



44 Chen et al. Eur J Appl Physiol. 2013.

Contralateral Repeated Bout Effect

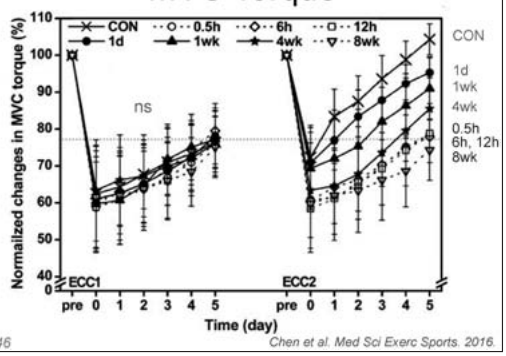
5 sets of 6 maximal eccentric contractions of the elbow flexors

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

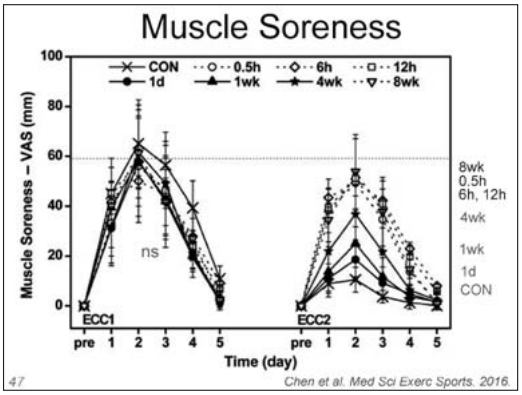
104 young "untrained" men — 13 men/group

45

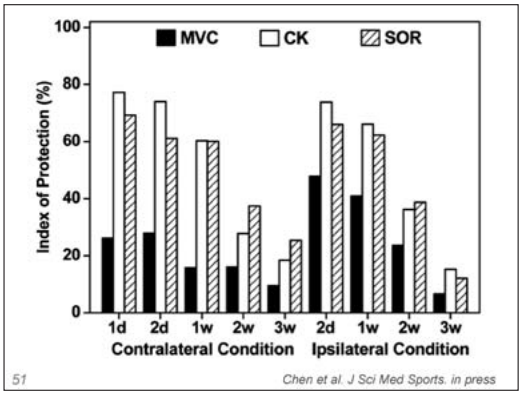
MVC Torque



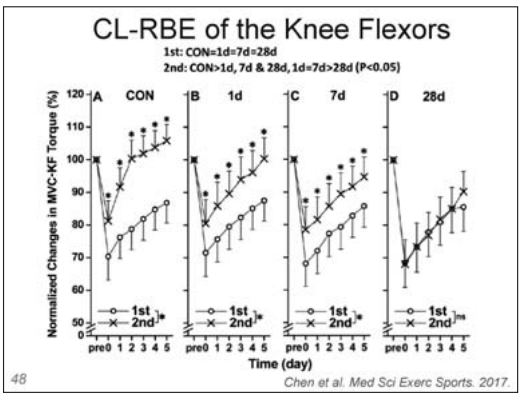
46 Chen et al. Med Sci Exerc Sports. 2016.



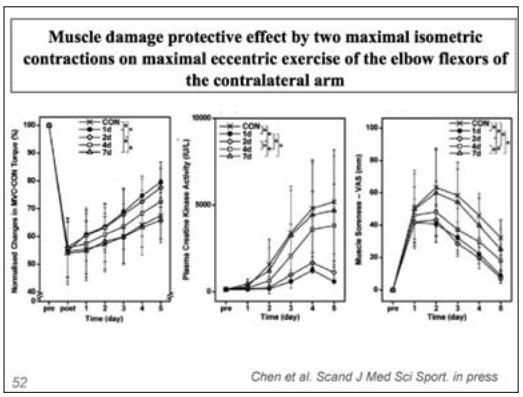
47 Chen et al. Med Sci Exerc Sports. 2016.



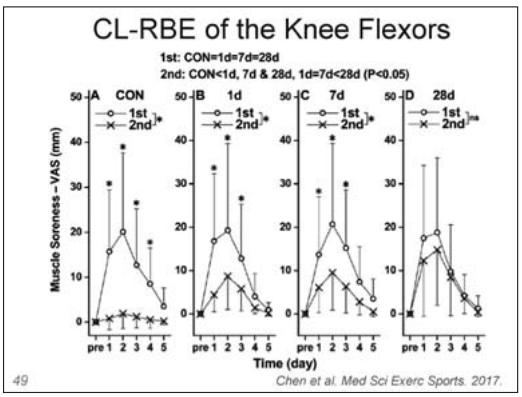
51 Chen et al. J Sci Med Sports. in press



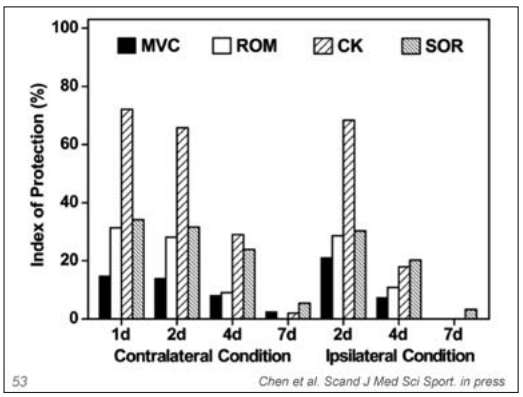
48 Chen et al. Med Sci Exerc Sports. 2017.



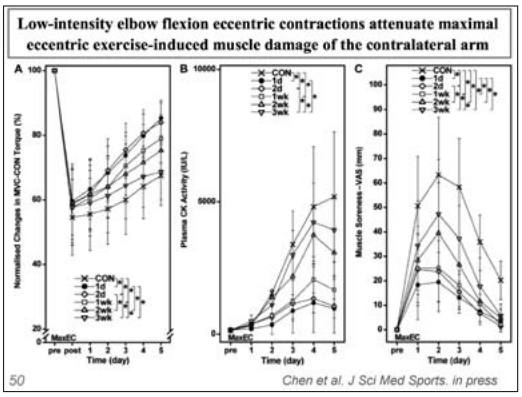
52 Chen et al. Scand J Med Sci Sport. in press



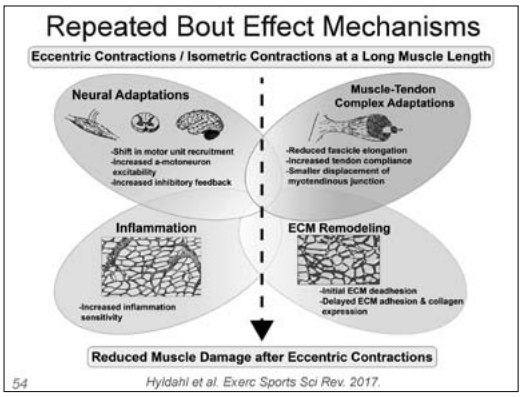
49 Chen et al. Med Sci Exerc Sports. 2017.



53 Chen et al. Scand J Med Sci Sport. in press



50 Chen et al. J Sci Med Sports. in press

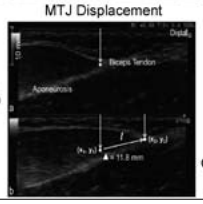


54 Hyldahl et al. Exerc Sports Sci Rev. 2017.

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



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

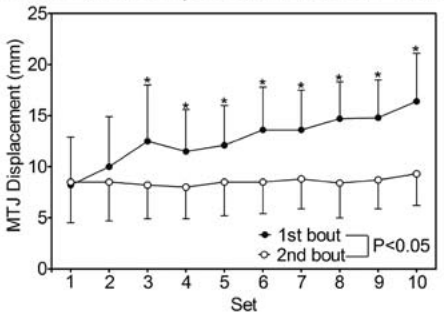
55

Douglas et al. Sports Med. 2016.

Key Points
Eccentric training can improve muscle mechanical function to a greater extent than other modalities.
Novel muscle-tendon unit adaptations associated with a faster (i.e. explosive) phenotype have been reported.
Eccentric training may be especially beneficial in enhancing strength, power and speed performance.

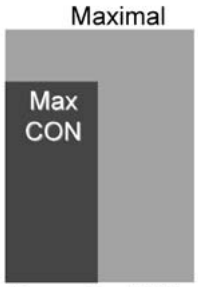
59

Distal MTJ Displacement Over Sets



56 *Lau et al. Am J Physiol. 2015*

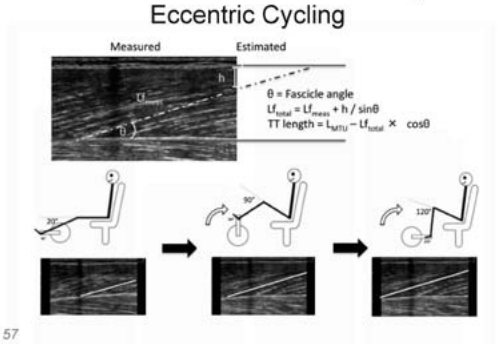
Variety of Eccentric Exercises



Supra-max ECC
Accentuated ECC
Prolonged ECC
ECC-biased Endurance ECC
Low-intensity ECC

60

Muscle Fascicle Behavior during Eccentric Cycling



57

Low-intensity Eccentric Training

Subjects: 26 untrained young men
(Age: 21.4 ± 1.7 y, Height: 172.9 ± 6.3 cm, Weight: 67.2 ± 11.1 kg)

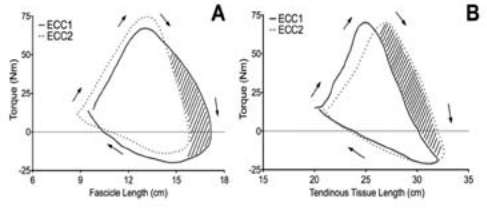
Training: Low-intensity (10% of maximal isometric contraction strength @ 90º elbow flexion

4wk group: 2 bouts/wk for 4 wk
8wk group: 2 bouts/wk for 8 wk

- 5 sets of 6 reps
- ROM: 90-0º
- 3 s contraction
- 10 s between contractions
- 2 min between sets

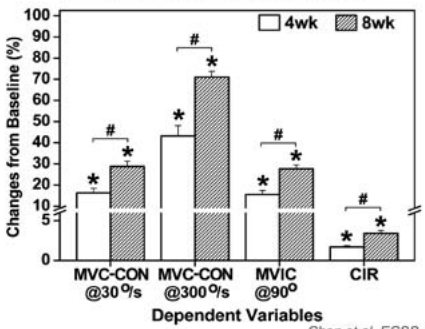
61

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



58 *Peñailillo et al. Med Sci Exerc Sports. 2014.*

10%EC Training Effects



62 *Chen et al. ECSS. 2017.*

Eccentric vs Concentric Cycling Training

18 men (35.2 ± 11.9 y)
- HI-EC (High-intensity eccentric cycling): n=10
- HI-CC (High-intensity concentric cycling): n=8

60 rpm
2 / wk for 8 weeks
Periodised

HI-EC: 70% P_{max}
HI-CC: 36% P_{max}
Both: 9/10 effort

7x2min ON
30s OFF

HI-EC: 45% P_{max}
HI-CC: 30% P_{max}
Both: 7/10 effort

x2min ON
1min OFF

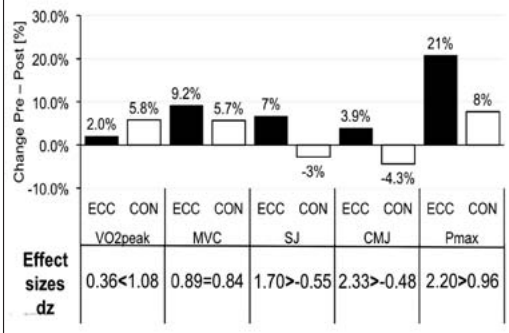
63

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

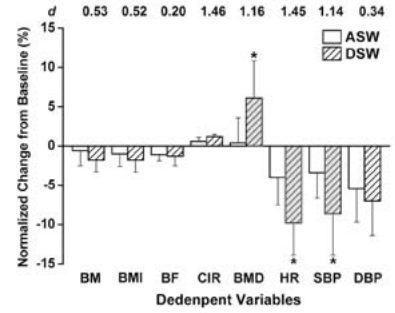
No signs of muscle damage　*: significantly (P≤0.05) different from ASW

67



64　*Lipski et al. in preparation*

Anthropometric and Cardiovascular Parameters



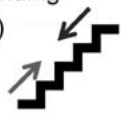
68　*Chen et al. Med Sci Sport Exerc. 2017.*

Stair Walking Study

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

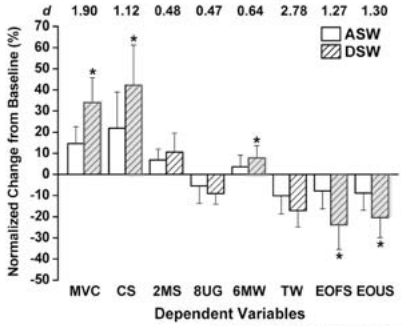
Age: 66.4 ± 6.8 y, Height: 154.8 ± 5.0 cm
Body mass: 62.7 ± 4.7 kg, BMI: 26.2 ± 1.0
Percent Body Fat: 34.8 ± 4.0%

- Groups – Ascending vs Descending
  - n=15 per group (ASW, DSW)
  - No significant difference in any baseline measures



65

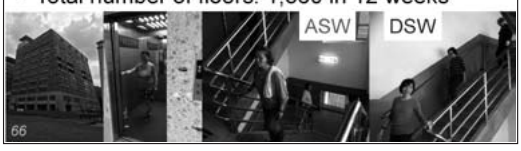
Muscle Function and Physical Fitness



69　*Chen et al. Med Sci Sport Exerc. 2017.*

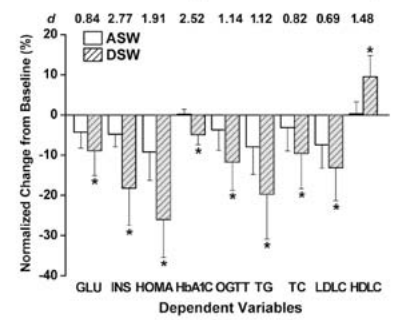
Exercise

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



66

Insulin Sensitivity and Blood Lipids



70　*Chen et al. Med Sci Sport Exerc. 2017.*

Knee Extensor Resistance Training Study

- Participants: 26 healthy elderly (60-76 y) men
- Study Design: 2 group (n=13 / group)

Eccentric Exercise: 10%~100% of 1RMcon

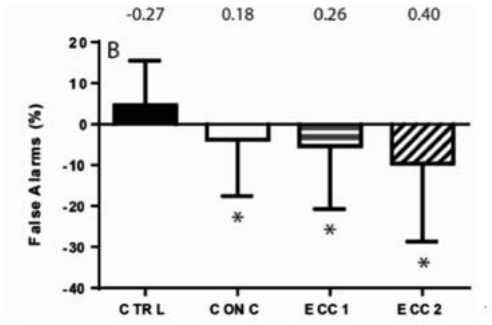
Concentric Exercise: 50%~100% of 1RMcon

Once a week over 12 weeks, 12 training sessions for both legs
ECC: 10% → 20% → 40% → 60% → 75% → 90% → 100% of one repetition maximum of concentric knee extensor strength (1RMcon), 3 or 6 sets of 10 contractions

No indications of muscle damage

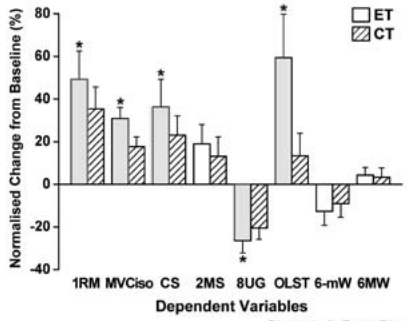
71

Cognitive Load during ECC vs CONC Cycling



75 *Kan et al. in review*

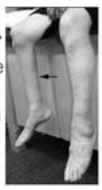
Muscle Function and Physical Fitness



72 *Chen et all. Front Physiol. 2017.*

Other Implication of Eccentric Training

Minimise atrophy strength loss better



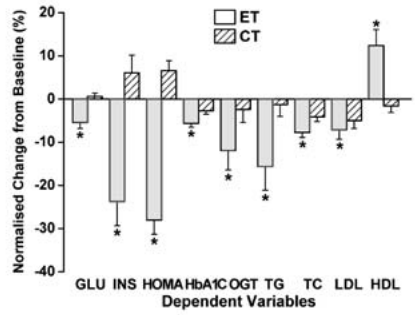
Atrophy
↓Muscle strength
↓ROM
Long recovery time

Eccentric Training
V
Concentric Training

Greater cross-transfer effect

76 *Kidgell et al. Neurosci. 2015.*

Insulin Sensitivity and Blood Lipids



73 *Chen et all. Front Physiol. 2017.*

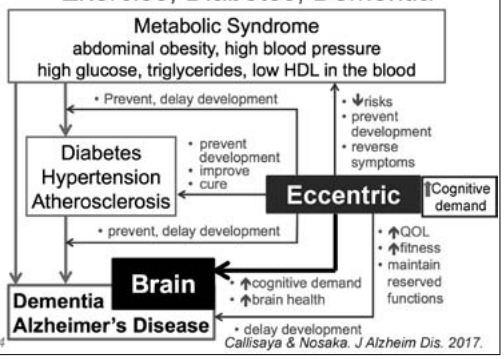
Eccentric Exercise

Negative aspect	Positive aspects
• **Induce muscle damage** DOMS, Prolonged loss of muscle function	• Less metabolic demand • ↗ muscle function • ↗ muscle mass • ↗ muscle coordination • ↗ balance • ↗ flexibility • ↗ bone mineral density • ↗ insulin sensitivity • ↗ blood lipid profile • ↗ cardiovascular function • ↗ brain health

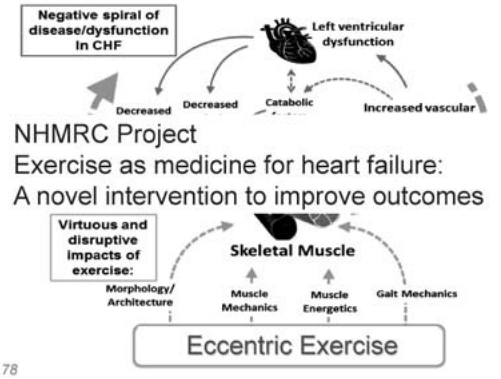
Muscle damage can be minimised by using "pre-conditioning exercise" and gradually increasing the intensity and volume
Muscle damage is not necessary!
Not NO PAIN, NO GAIN

77 **Minimise muscle damage, Maximise eccentric exercises**

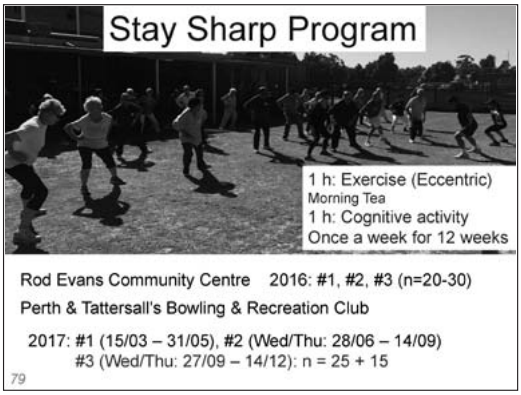
Exercise, Diabetes, Dementia

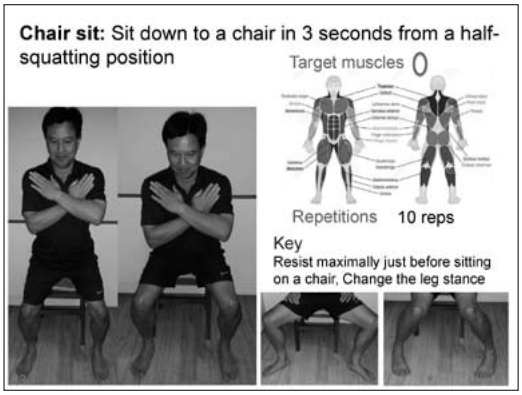


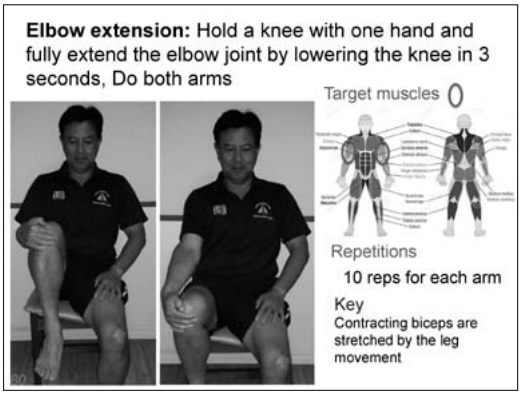
74 *Callisaya & Nosaka. J Alzheim Dis. 2017.*

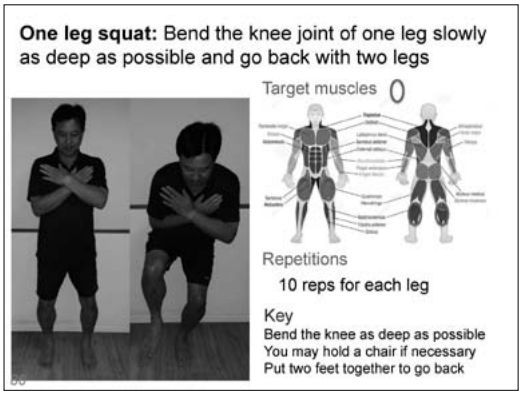


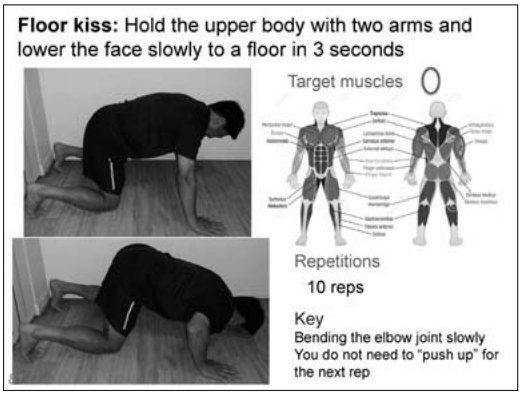
78

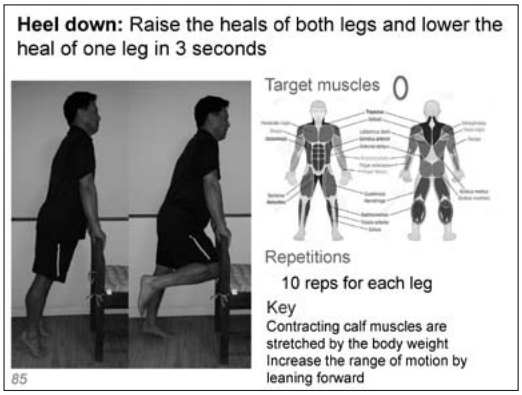


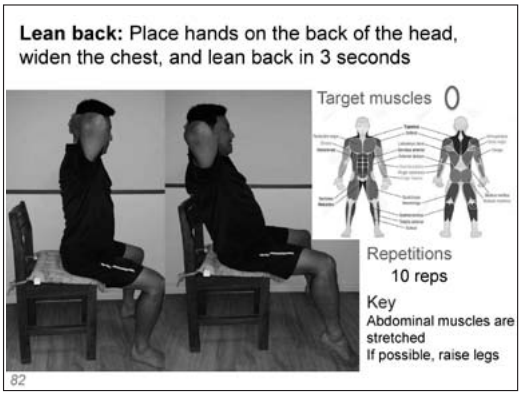












Effects of Eccentric Exercises

N=32 (M:10, F:22), 61 – 87 y, more than 2 ECC / week

	Pre	Post	Change
One leg stand (s)	26.2 ± 16.7	37.2 ± 19.5	42%↑
2.5-m up and go (s)	5.4 ± 0.9	5.1 ± 0.9	6%↑
30-s chair stand (reps)	16.1 ± 5.9	19.8 ± 4.8	23%↑
2-min Step (reps)	111.8 ± 11.9	120.6 ± 14.4	8%↑

Comments: easy to move around, stronger, more flexible, better balance, prevented falling, knee pain is gone, "sharp"

86

Importance of Eccentric Training

Eccentric Contractions

↓ Strength, Power, Endurance ↑

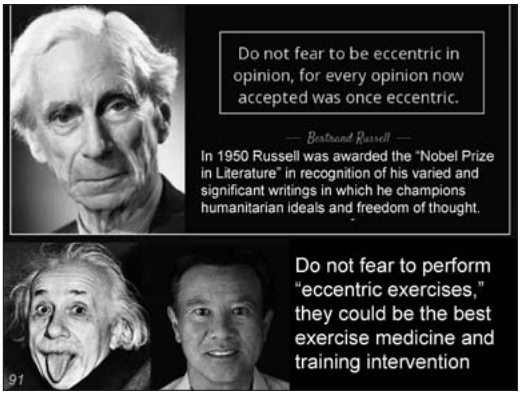
Muscle Damage

↓ Performance ↑

Eccentric Training

Muscle Adaptation

87



Is eccentric training effective for improving running performance?

Runners who performed downhill running appear to improve their middle and long distance running performance

88

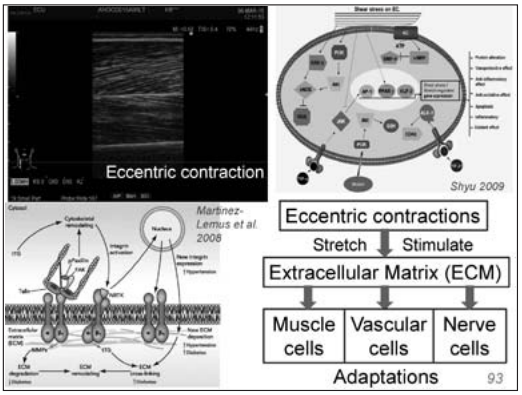
Eccentric-Only Gym

Is eccentric training effective for improving endurance performance?

350-500 W

Eccentric cycling training appears to be effective for improving cycling performance

89

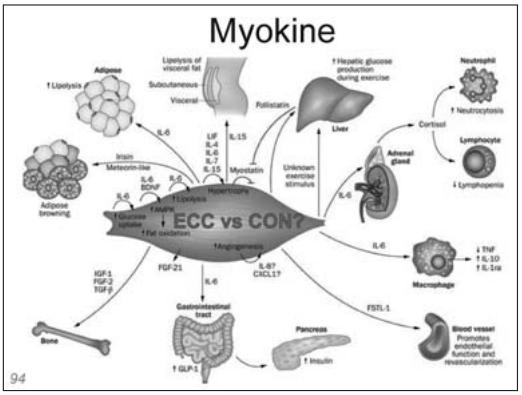


Rugby 7s Malaysia Team

29th SEA Games 2017

90

Myokine



Let's get ECCENTRIC

Make-up by Cocolo Nosaka

Let's do Eccentric Exercises

Let's do more "Eccentric" research

95

Challenges

- Visualise yourself **5 years** from now and set goals to achieve
- What kind of person do I want to be?
- How can I make a difference?
- What should I do today and now?
- How can I do it differently tomorrow?
- How can I progress to the "next" level?
- How can I maximise my potential?

96

Today is the first day of the rest of your life

Never too late

The 10,000 h Rule

6 h / day x 365 days x 5 years

You could be a person who you want to be in **5 years**

97

Thank you very much

Question?
Comment?
Suggestion?
Collaboration?

Ken Nosaka
k.nosaka@ecu.edu.au

98