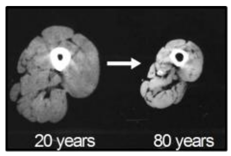
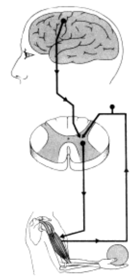
5th Congress of the Hellenic Society of Biochemistry and Physiology of Exercise
Athens · November 6-7th, 2015

Use of exercise training to reverse age-related changes in neuronal function and skeletal muscle morphology





Per Aagaard

Muscle Physiology and Biomechanics Research Unit,
Institute of Sports Science and Clinical Biomechanics,
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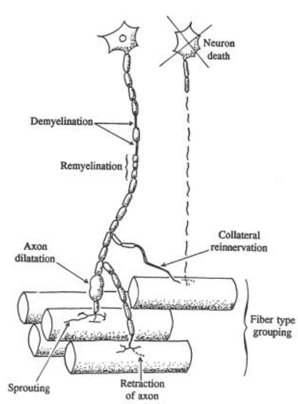
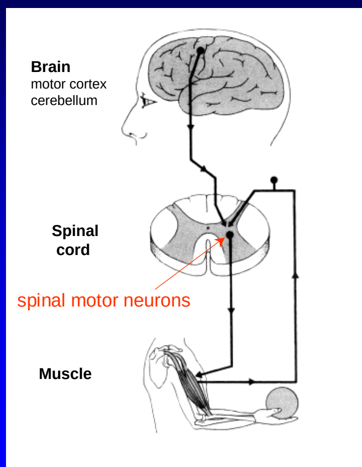
Age-induced changes in neuromuscular function:
Loss of motor neurons, MU reorganization



Ageing and neuromuscular function



Spinal motor neurons

reduced number of motor neurons in the spinal cord

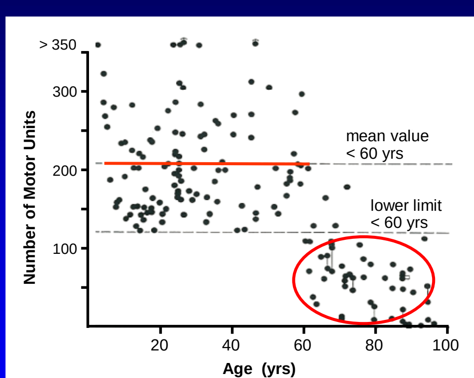
25% average loss of spinal motor neurons (lumbospinal segments L1-S3) from 20 yrs to 90 yrs of age

Tomlinson & Irving 1977

several subjects > 60 yrs showing ~ 50% less MN's compared to 20-40 yrs old

Tomlinson & Irving 1977

Ageing and neuromuscular function



Campbell, McComas et al. 1973
Extensor digitorum brevis (n=207, age=3-96 yrs)
AJ McComas: Skeletal muscle - form and function, 1996

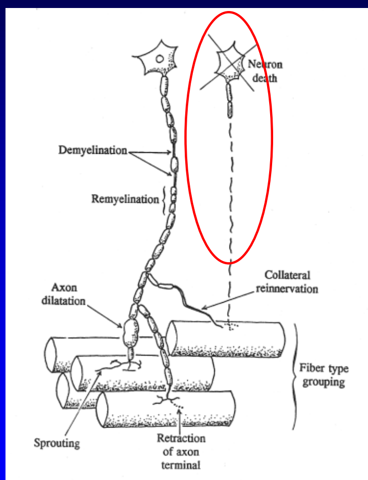
Motor Units

reduced number of excitable (i.e. functioning) MU's observed at 60-70 yrs of age

Brown et al. 1988, Doherty et al. 1993, Campbell, McComas et al. 1973

Number of excitable MU's in aged subject (60-95 yrs) ~ 1/3 of that observed in younger subjects (1-60 yrs)

Ageing and neuromuscular function



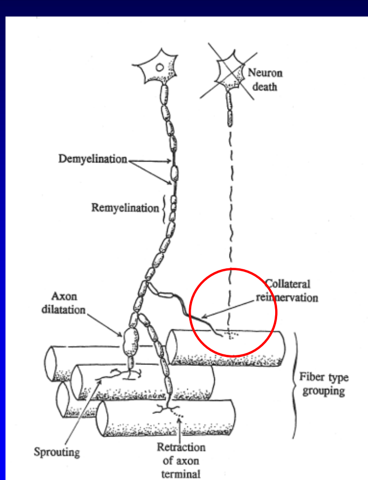
AJ McComas: Skeletal muscle
- form and function, 1996

↓ # motor neurons = ↓ # motor units at increasing age

ongoing process of denervation and reinnervation of skeletal muscle fibers late in life

Vandervoort 2002, McComas 1996

Ageing and neuromuscular function



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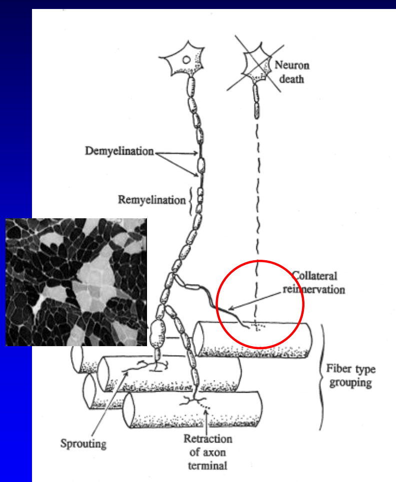
Ageing and neuromuscular function



AJ McComas: Skeletal muscle - form and function, 1996

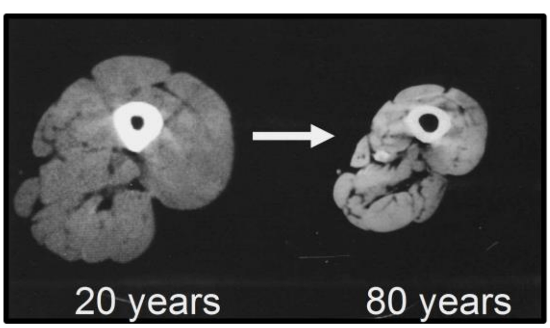
↓ # motor neurons = ↓ # motor units at increasing age

ongoing process of
denervation and reinnervation
of skeletal muscle fibers late in life

evidenced by
- histological findings of fiber type grouping
- elevated coexpression of MHC isoforms
- preferential atrophy of type II muscle fibers
- very large MUAPs, indicating ↑ innervation ratio

Vandervoort 2002, McComas 1996

Age-induced changes in neuromuscular function:
Loss of muscle mass with aging: sarcopenia



Picture courtsey Paolo Caserotti
Institute of Sports Science and Clinical Biomechanics
University of Southern Denmark

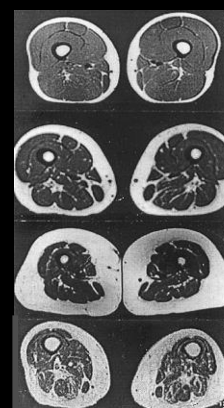
Loss of muscle mass with aging: **sarcopenia**

Reduced muscle cross-sectional area
(↓ 40% between the age of 20 and 80 yrs)

The decline seems to start in early adulthood and accelerate after the age of 50 years

↑ content of non-contractile tissue such as intramuscular fat and connective tissue

Vandervoort, Muscle & Nerve 25, 2002
McNeil et al, J Appl Physiol 102, 2007



Parise & Yarasheski,
Curr Opin Clin Nutr Metab Care, 2000

Sarcopenia
(loss of muscle mass)

Photo courtsey
Charlotte Suetta

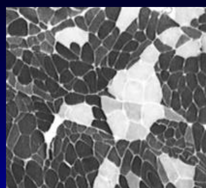
Sarcopenia is significantly associated with a

- 3-4 times greater risk of physical disability
- 2-3 times greater risk of balance abnormality
- 2-3 times greater risk of falls

Baumgartner RN 1998, 1999

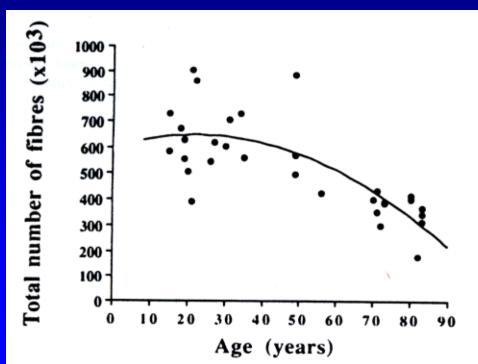
In frail elderly persons with advanced sarcopenia but without circulatory or pulmonary diseases, muscle weakness is typically more limiting for daily functioning than aerobic fitness.

Jesper L. Andersen



Reduced muscle mass with ageing

Loss of skeletal muscle fibers



Elderly male subjects (70-75 yrs) show ~40% fewer muscle fibers than young subjects (19-30 yrs)

VL muscle, Lexell et al. 1983

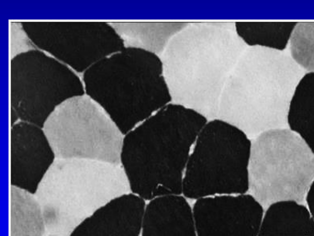
Very old male subjects (>80 yrs) ~60% fewer fibers compared to young subjects

VL muscle, Lexell et al. 1988

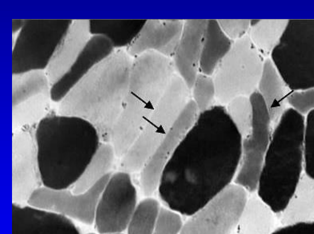
Reduction in muscle fiber size with aging

courtsey C Suetta

Young subject (31 yrs)



Old subject (79 yrs)



VL muscle
Jesper L. Andersen, CMRC

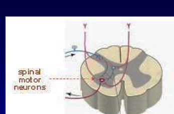
Age-related reductions in skeletal muscle fiber size

Vandervoort, Muscle & Nerve 25, 2002

Study	Gender	Age (years)	Percent reduction		
			Type I		Type II
Larsson et al., Acta Physiol. Scand. 103, 1978	M	22-65	1	<<	25
Essen-Gustavsson and Borges, Acta Physiol. Scand. 126, 1986	M	20-70	15	≈	19
	F	20-70	25	<<	45
Lexell et al. J. Neurol. Sci. 84, 1988	M	15-83	1	<<	29
Hakkinen et al. J. Gerontol. 53B, 1998	M	29-61	+8	<<	10
Fiatarone Singh et al. Am. J. Physiol. 277, 1999	M, F	72-98	+7	<<	60
Hikida et al. J. Gerontol. 55, 2000	M	58-78	24	<<	40

VL muscle

Neuronal and Muscular changes induced by Ageing



Motor Unit remodeling

↓ Motor unit number

↓ # Spinal motor neurons

↑ Motor unit size

↑ innervation ratio (# fibers/neuron)

↓ Muscle strength/power

Reduced muscle mass ('sarcopenia')

↓ cross sectional area

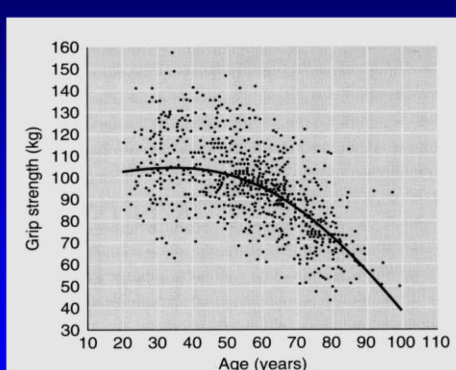
↓ Total muscle fiber number

↓ Muscle fiber size (pref. type II)

Age-induced changes in neuromuscular function:
Impairments in mechanical muscle function

Decreased Muscular Strength With Aging

CROSS-SECTIONAL DATA



Spirduso, Physical dimensions of aging, 1995

Isometric muscle strength

Is preserved to ~50-60 yrs of age (cross sectional data)

Decreases at a rate of 1-1.5% per year from 60-65th year

Substantial individual differences !

Vandervoort & McComas 1986
Spirdoso 1995

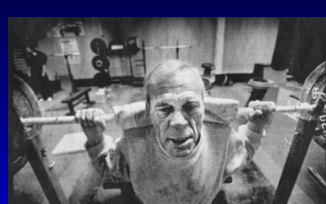
Decreased Muscular Strength and Power with Aging

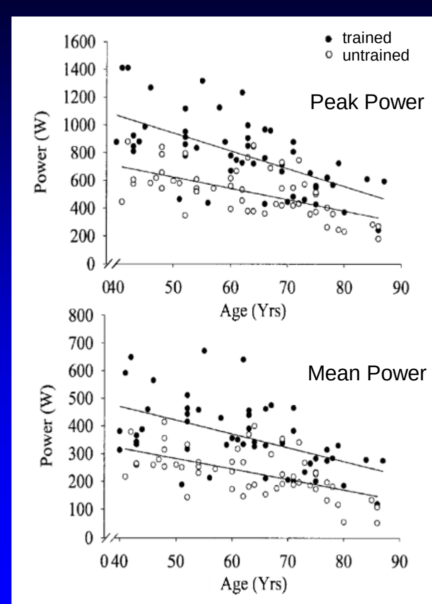
Decreased maximal muscle force and contractile power from > 65 years

Loss of strength: 1.5% per year
Loss of power: 3.5% per year

Young & Skelton, Int. J. Sports Med. 15, 1994

Muscle function in elite master weightlifters

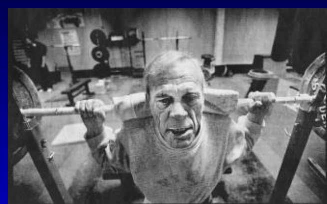




Trained (closed circles) and untrained (open circles) individuals demonstrated similar age-related decline rate in peak power (1.3% vs 1.2% per year, respectively)

Pearson, Harridge et al;
Med Sci Sports Exerc 2002

Muscle function in elite master weightlifters



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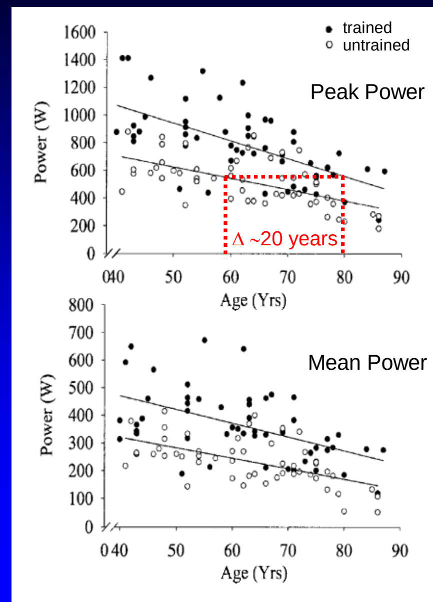
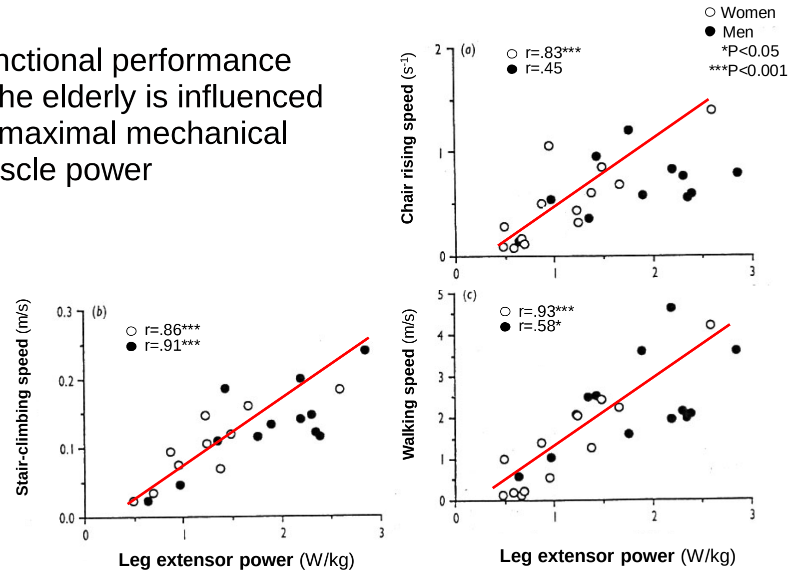


Is maximal muscle power important in elderly individuals ?

YES !

Functional performance in the elderly is influenced by maximal mechanical muscle power



Bassey et al, 1992
Nursing Home residents

Aging

loss of motorneurones

loss of muscle fibers

muscle fiber atrophy

⇓

reduced muscle strength, RFD and Power

⇓

Impaired function in tasks of daily living (stair walking, rising from chair, etc)

Aging

loss of motorneurones

loss of muscle fibers

muscle fiber atrophy

⇓

reduced m… …gth, RFD and Power

Strength/power training used as a countermeasure?

Impaired function in tas… …y living
(stair walking, rising from c… …ir, etc)

Aging

loss of motorneurones

loss of muscle fibers

muscle fiber atrophy

⇓

reduced muscle strength, RFD and Power

Aging & strength training

Aging

loss of motorneurones
loss of muscle fibers
muscle fiber atrophy

⇓

reduced muscle strength, RFD and Power

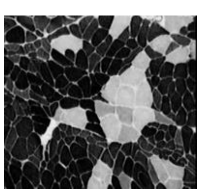
Aging & strength training

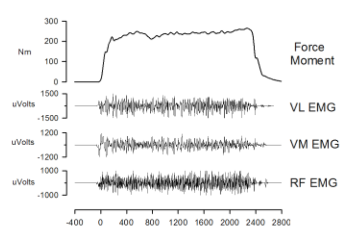
muscle fiber hypertrophy
improved neuromuscular function

⇓

Marked gains in muscle strength, RFD, Power
improved function in everyday activities

Age-induced changes in neuromuscular function:
Adaptive alterations in neuromuscular function with strength/power training

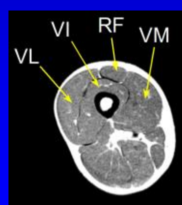




Percentage increases in Muscle Size (CSA) and Maximal Muscle Strength (MVC) with Strength Training in old vs young adults

Population	Training Duration (weeks)	ΔMVC (%)	ΔMVC /day (%)	ΔCSA (%)	ΔCSA/day (%)	Reference
Young adults	24	26.8	0.16	6.8	0.04	Häkkinen 1985
Young adults	12	15.0	0.18	5.7	0.06	Jones & Rutherford 1987
Young adults	24	29.6	0.18	19.0	0.11	Narici 1996

Aagaard et al,
J Physiol 2001



Narici et al,
J Musculoskel Neron Interact 2004

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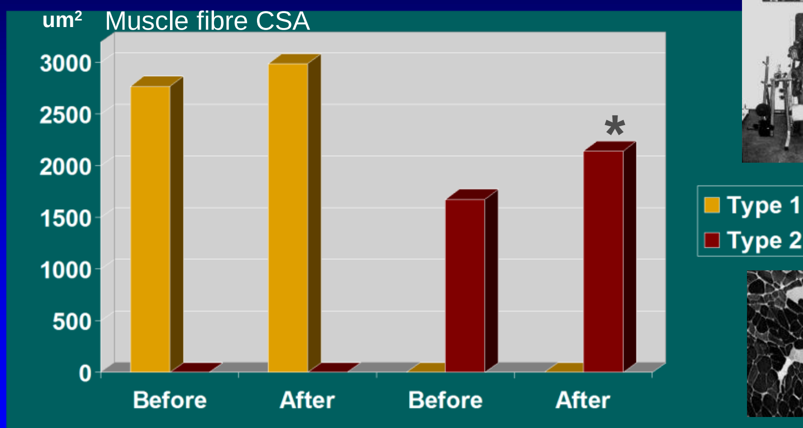
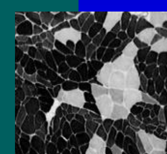
Young adults	24	29.6	0.18	19.0	0.11	Narici 1996
Elderly (65-81 yrs)	16	19.0	0.17	7.4	0.07	Ferri 2003
Elderly (60-72 yrs)	12	16.7	0.20	9.3	0.11	Frontera 1988
Elderly (61 yrs)	10	17.0	0.25	9	0.12	Häkkinen 1998
Elderly (85-97 yrs)	12	37	0.44	10	0.11	Harridge 1999

Narici et al,
J Musculoskel Neron Interact 2004

Heavy-resistance strength training also induces muscle fiber hypertrophy in the very old (85-98 yrs, mean age 89 ± 3 yrs)

Loading 80% 1RM, 3/week, 12 weeks





Kryger & Andersen,
Scand J Med Sci Sports 2007

Heavy-resistance strength training also induces muscle fiber hypertrophy in the very old (85-98 yrs, mean age 89 ± 3 yrs)

85+ year old discharged geriatric patients

12 weeks of resistance exercise

knee ext. 3 x weekly, 3 x 8 rep, >70% 1 RM

Results

Type IIa fibre CSA	↑ 22% *
Quadriceps muscle CSA	↑ 10% *
Quadriceps strength	↑ 40-45% *
Chair rising time (5 reps)	30% faster *
Maximal walking speed	25% faster *

* p<0.05

Kryger & Andersen,
Scand J Med Sci Sports 2007

Increases in muscle fibre size in older individuals following high-intensity dynamic leg strength training. Based on biopsy samples obtained from vastus lateralis

Vandervoort, Muscle & Nerve 25, 2002

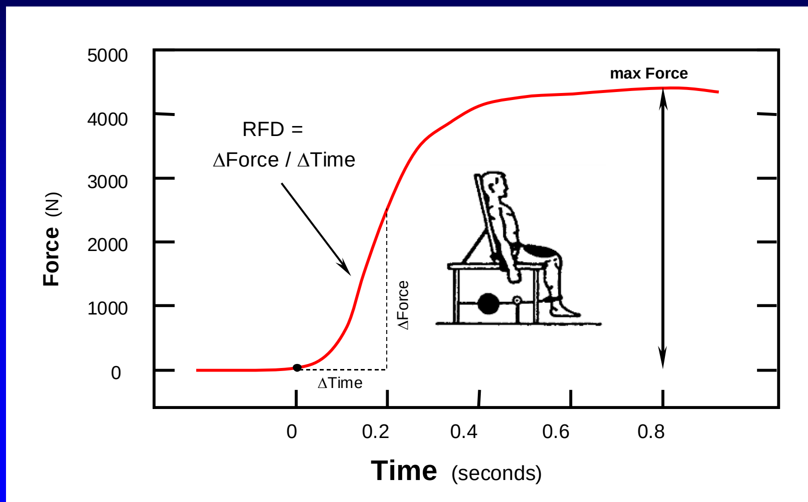
Muscle fiber size increase (%)

Study	Type I		Type II
Frontera et al., J. Appl. Physiol. 64, 1988	34	≈	26
Charette et al., J. Appl. Physiol. 70, 1991	7	<	20
Grimby et al., J. Appl. Physiol. 73, 1992	8	≈	5
Häkkinen et al. J. Gerontol. 53B, 1998	23	≈	27
Fiatarone-Singh et al. Am. J. Physiol. 277, 1999	5	>	-12
Hunter et al., J. Appl. Physiol. 86, 1999	14	<	23
Hikida et al. J. Gerontol. 55, 2000	46	≈	43

Changes in explosive muscle strength (rate of force development, RFD) induced by strength training in the elderly

RFD Rapid force capacity ['explosive muscle strength']

Maximal rate of force development (RFD) in elderly vs young individuals



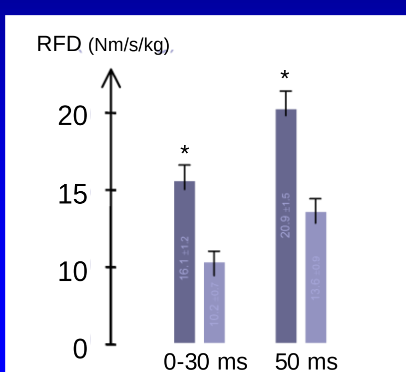
Aagaard et al, J Appl Physiol 2002

RFD Rapid force capacity ['explosive muscle strength']

Maximal rate of force development (RFD) in elderly vs young individuals

Contractile RFD is <u>substantially reduced</u> in healthy aging individuals compared to young individuals

Clarckson et al 1981, Häkkinen et al 1995, Izquierdo et al 1999, Barry et al. 2005, Korhonen et al 2006, Klass et al 2008, Suetta, Kjær, Hvid et al 2010



Quadriceps muscle
- maximal isometric MVC efforts

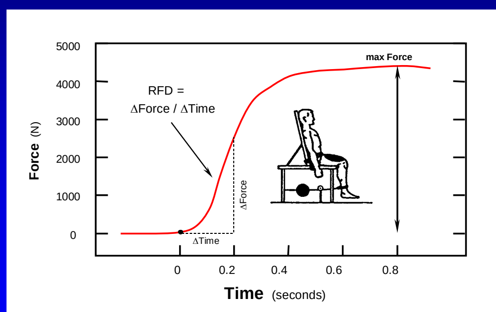
Young (24 yr, n=9)
Old (67 yr, n=11)

* Y < O (p<0.05)

Suetta, Kjær, Aagaard et al, J Appl Physiol 2009

RFD Rapid force capacity

Effects of resistance training on RFD in the elderly?



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SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS

Explosive heavy-resistance training in old and very old adults: changes in rapid muscle force, strength and power

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Corresponding author: Paolo Caserotti, PhD, Centre of Applied and Clinical Exercise Sciences, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark. E-mail: pcaserotti@health.sdu.dk

Accepted for publication 13 July 2007

Age-related decline in muscle power predicts falls, motor impairments and disability. Recent guidelines suggested that training programs should be tailored to maximize muscle power. This study investigated the effects of 12 weeks of explosive-type heavy-resistance training (75–80% of 1 repetition maximum) in old (60–65 years, TG60) and very old (80–89 years, TG80) community-dwelling women. Training was performed with maximal intentional acceleration of the training load during the concentric movement phase. Maximal isometric voluntary muscle strength (MVC), rapid force capacity, assessed as rate of force development (RFD), and impulse, maximal muscle power during a countermovement jump (CMJ) and during unilateral leg extension task (LEP) were evaluated. RFD, impulse and MVC increased by 51%, 42% and 28% in TG80, and by 21%, 18% and 18% in TG60, respectively. CMJ jump height increased by 18% and 10% in TG80 and TG60, respectively, while jump peak power increased in TG60 (5%). Finally, LEP increased 28% in TG80 and 12% in TG60. These findings demonstrate that explosive-type heavy-resistance training seems to be safe and well tolerated in healthy women even in the eighth decade of life and elicits adaptive neuromuscular changes in selected physiological variables that are commonly associated with the risk of falls and disability in aged individuals.

Muscle power, which is the product of contractile force and movement velocity, is a stronger predictor of functional motor performance, incidence of falling and self-reported functional status than maximal muscle strength in community-dwelling old adults (Foldvari et al., 2000; Skelton et al., 2002). Furthermore, lower limb muscle power declines at a faster related to the number of active sarcomeres in series (Edgerton et al., 1986; Kraemer & Newton, 2000). Thus, maximal muscle power depends on the muscle morphology (e.g. physiological muscle cross-sectional area, muscle fiber pennation angle, muscle fiber length, fiber-type composition) and neuromuscular activation properties (discussed below), and it

Explosive-type strength/power training in the old (60 yrs) and the very old (80 yrs)

Subjects
Mean age 62.7 (SD 2.2) and 81.8 (SD 2.7) yrs
n = 20 + 20 con n = 12 + 13 con

Caserotti,
Aagaard et al, 2008

Explosive-type strength/power training in the old (60 yrs) and the very old (80 yrs)

Subjects
Mean age 62.7 (SD 2.2) and 81.8 (SD 2.7) yrs

Duration, frequency of training
12 weeks, twice a week

Familiarisation period
2 wks with lower training loads (50% 1RM), and reduced movement velocity

Progressive load adjustment:
Every two weeks with a new estimated 1RM (5-RM test)

Exercises (bilateral)
Horizontal leg press, knee extension, calf rise, incline leg press, leg curl - slow ECC, rapid (max acc) CON actions

Exercise intensity and reps
75-80% 1RM loads, 8-10 reps, 4 sets each exercise

Caserotti,
Aagaard et al, 2008

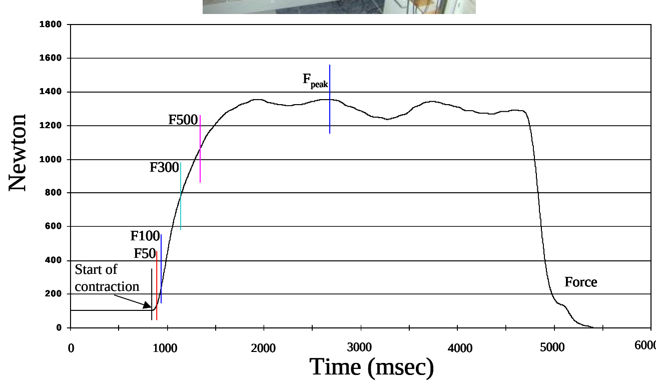
Explosive-type strength/power training in the old and the very old

Static leg extensor MVC and RFD

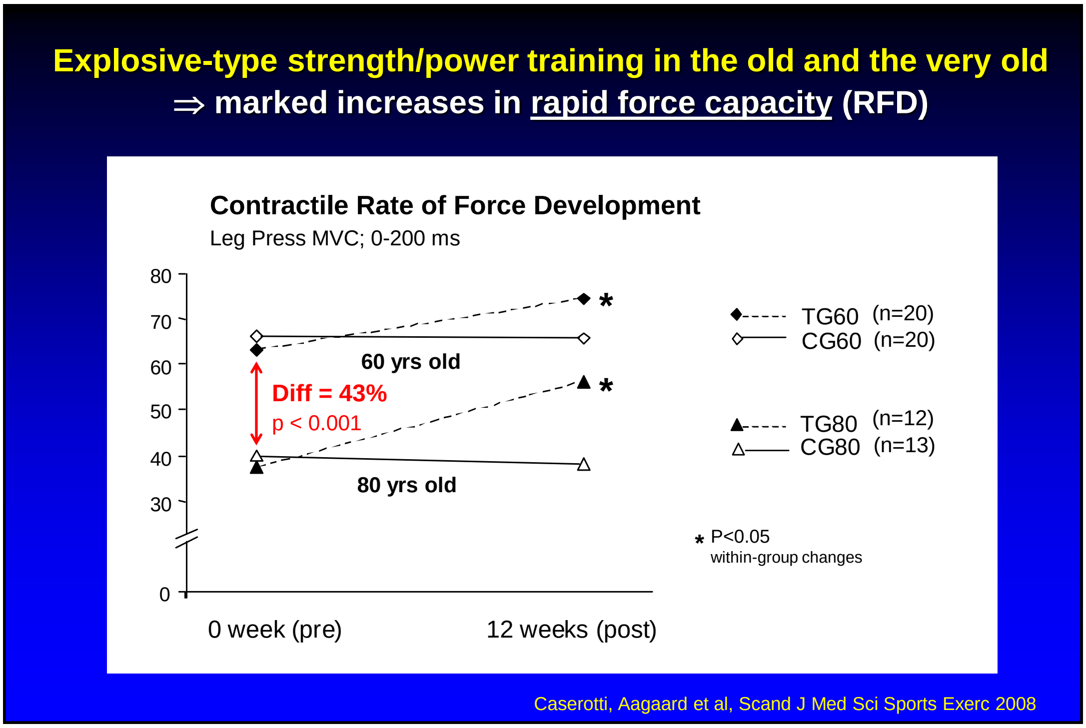
Unilateral isometric leg press test device

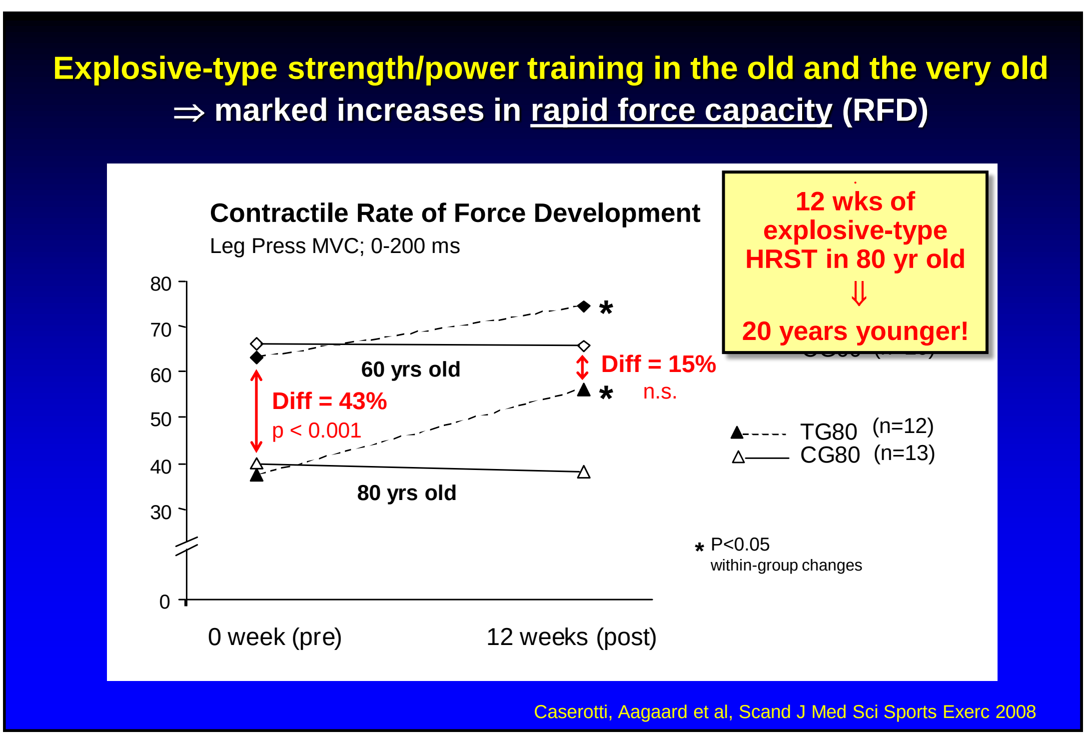
Paolo Caserotti

Explosive-type strength/power training in the old and the very old



Paolo Caserotti


Explosive-type strength/power training in the old and the very old
⇒ marked increases in rapid force capacity (RFD)
Contractile Rate of Force Development
Leg Press MVC; 0-200 ms
80
70
60
50
40
30
0
60 yrs old
Diff = 43%
p < 0.001
80 yrs old
0 week (pre)
12 weeks (post)
TG60 (n=20)
CG60 (n=20)
TG80 (n=12)
CG80 (n=13)
* P<0.05
within-group changes
Caserotti, Aagaard et al, Scand J Med Sci Sports Exerc 2008


Explosive-type strength/power training in the old and the very old
⇒ marked increases in rapid force capacity (RFD)
Contractile Rate of Force Development
Leg Press MVC; 0-200 ms
12 wks of
explosive-type
HRST in 80 yr old
⇓
20 years younger!
80
70
60
50
40
30
0
60 yrs old
Diff = 43%
p < 0.001
Diff = 15%
n.s.
80 yrs old
0 week (pre)
12 weeks (post)
TG80 (n=12)
CG80 (n=13)
* P<0.05
within-group changes
Caserotti, Aagaard et al, Scand J Med Sci Sports Exerc 2008

Explosive-type strength/power training in the old and the very old

⇒ marked increases in MVC, RFD and power

	TG 60	TG80
MVC (maximal strength)	+22%*	+28%*
RFD (rapid force capacity)	+18%*	+51%*
SSC muscle power (CMJ force plate)	+5%*	+6%*
1-leg muscle power (Power rig)	+12%*	+28%*

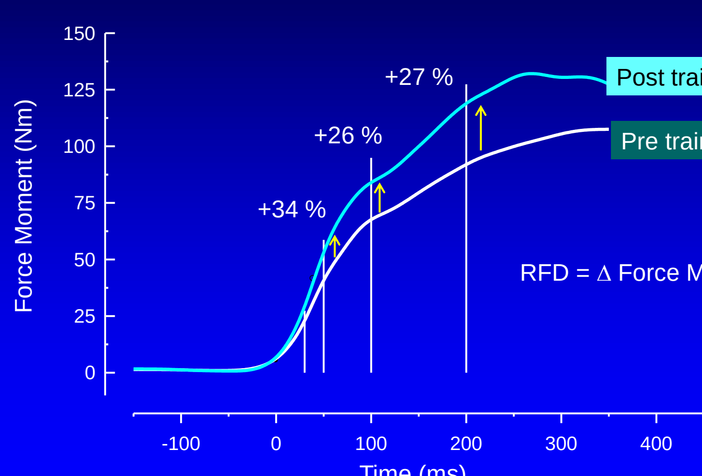
* pre vs post ($p<0.05$)

Caserotti, Aagaard et al, Scand J Med Sci Sports Exerc 2008

RFD Contractile Rate of Force Development

Elderly subjects (60-86 years) - hip replacement patients (n=11)

Pre and Post 12 wks unilateral resistance training - Affected Limb



Suetta, Aagaard, Kjær et al.
J Appl Physiol 2004

Training induced changes in explosive muscle strength (RFD)

Adaptive responses in aged individuals

Heavy-resistance strength training

↓

Concurrent increases in
maximal RFD and neuromuscular activity (iEMG)
in elderly individuals

Häkkinen & Häkkinen 1995 (age 50, 70 yrs, gender F, M)
Häkkinen et al. 1998 (age 40, 60 yrs, gender F, M)
Häkkinen et al. 2001 (age 63 yrs, gender F)
Suetta et al. 2004 (post hip replacement surgery, 60-86 yrs)
Barry et al. 2005 (age 60-79 yrs, gender F, M)

Training induced changes in explosive muscle strength (RFD)

Adaptive responses in aged individuals

Heavy-resistance strength training

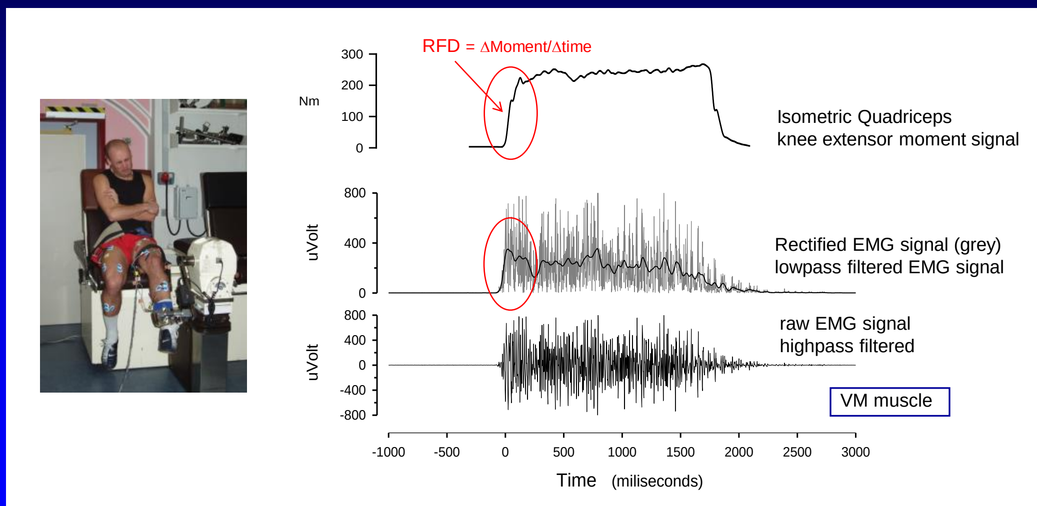
↓

Concurrent increases in
maximal RFD and neuromuscular activity (iEMG)
in elderly individuals

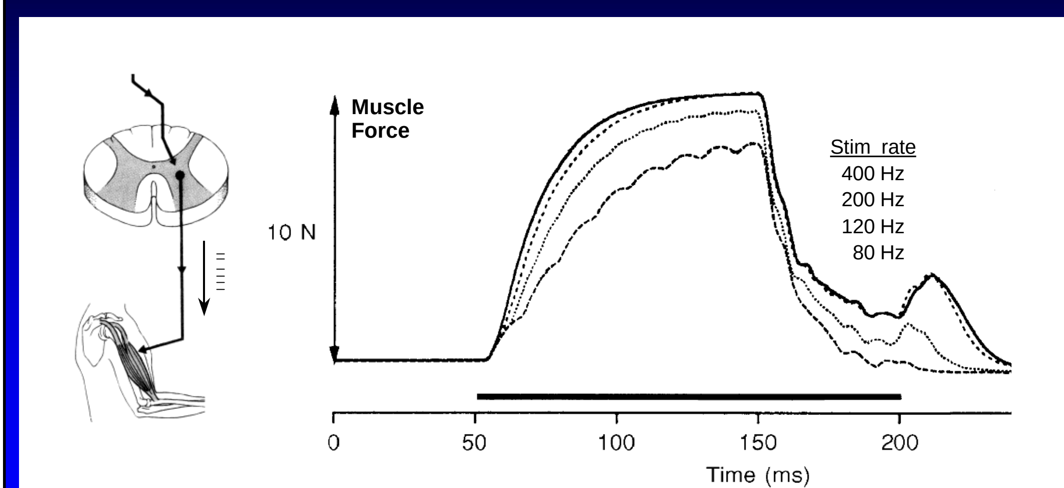
Functional consequences
- enhanced acceleration
- elevated maximal movement velocity
- elevated muscle force & power during rapid movements
- reduced risk of falls

Influence of neuromuscular activity on RFD

Rapid force capacity (RFD) is strongly influenced by the magnitude of neuromuscular activity at onset of contraction

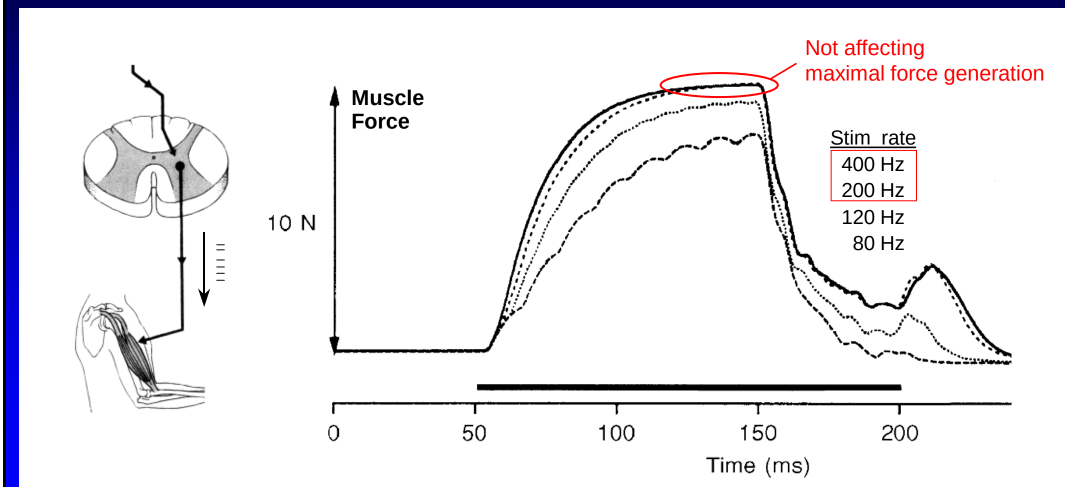


Very high firing rates of spinal motorneurons increases the maximal Rate of Force Development



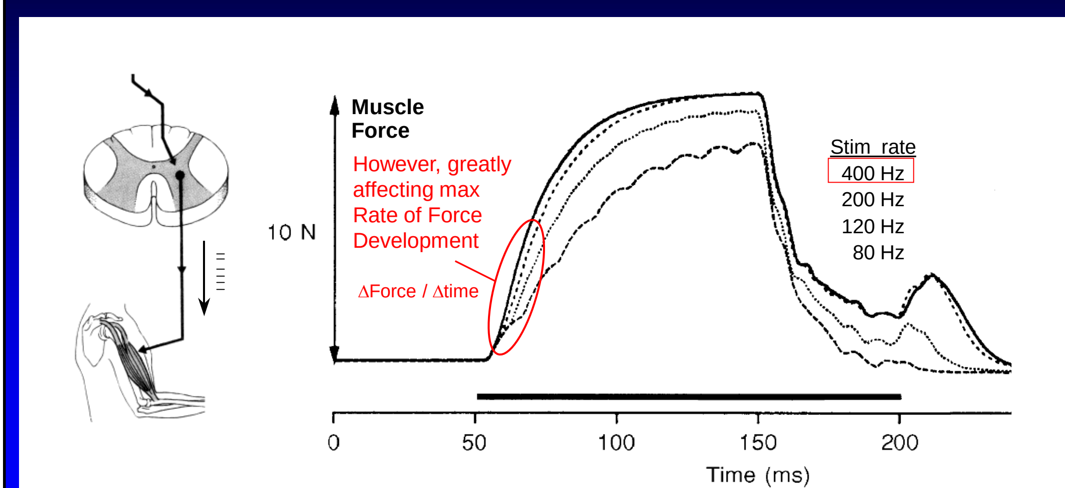
De Haan, Exp Physiol 1998 (rat GM, in situ)

Elevated motorneuron firing rates leads to increases in the maximal Rate of Force Development



De Haan, Exp Physiol 1998 (rat GM, in situ)

Elevated motorneuron firing rates leads to increases in the maximal Rate of Force Development

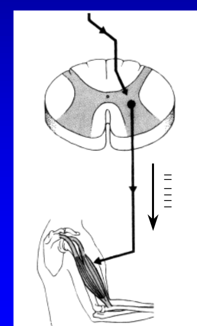


De Haan, Exp Physiol 1998 (rat GM, in situ)

Ageing and neuromuscular function

Motorneuron firing frequency

What is the effect of strength/power training on maximal MN firing frequency in old adults?



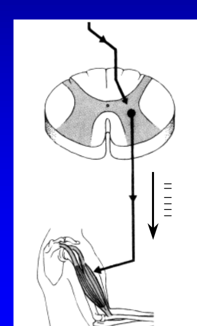
Ageing and neuromuscular function

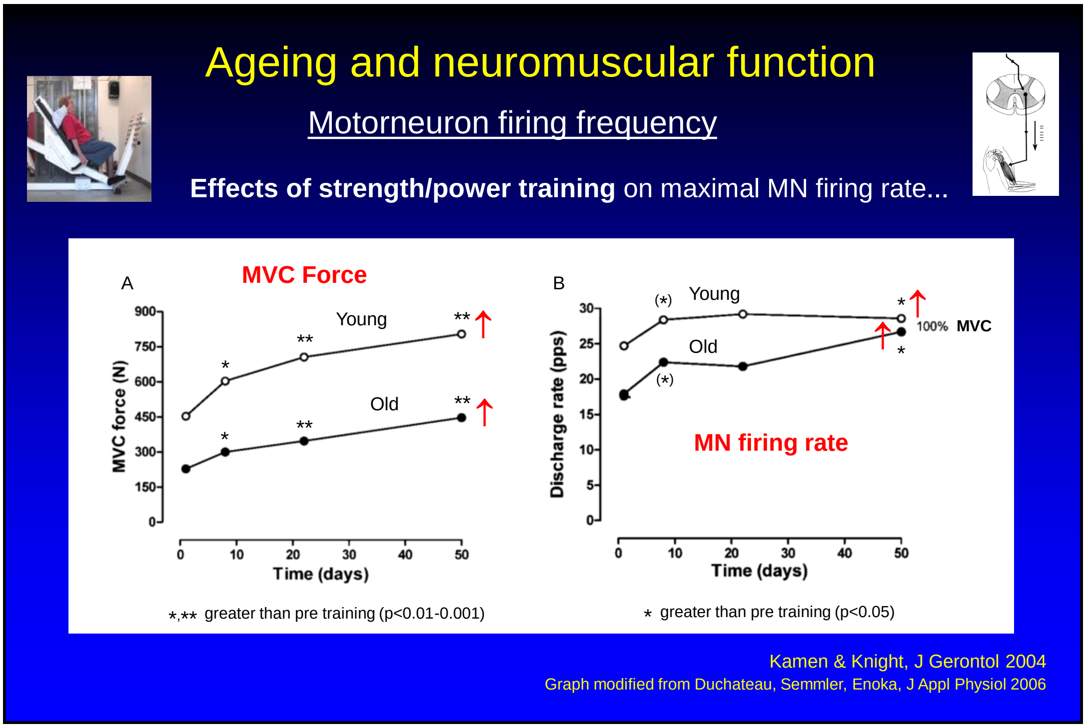
Motorneuron firing frequency

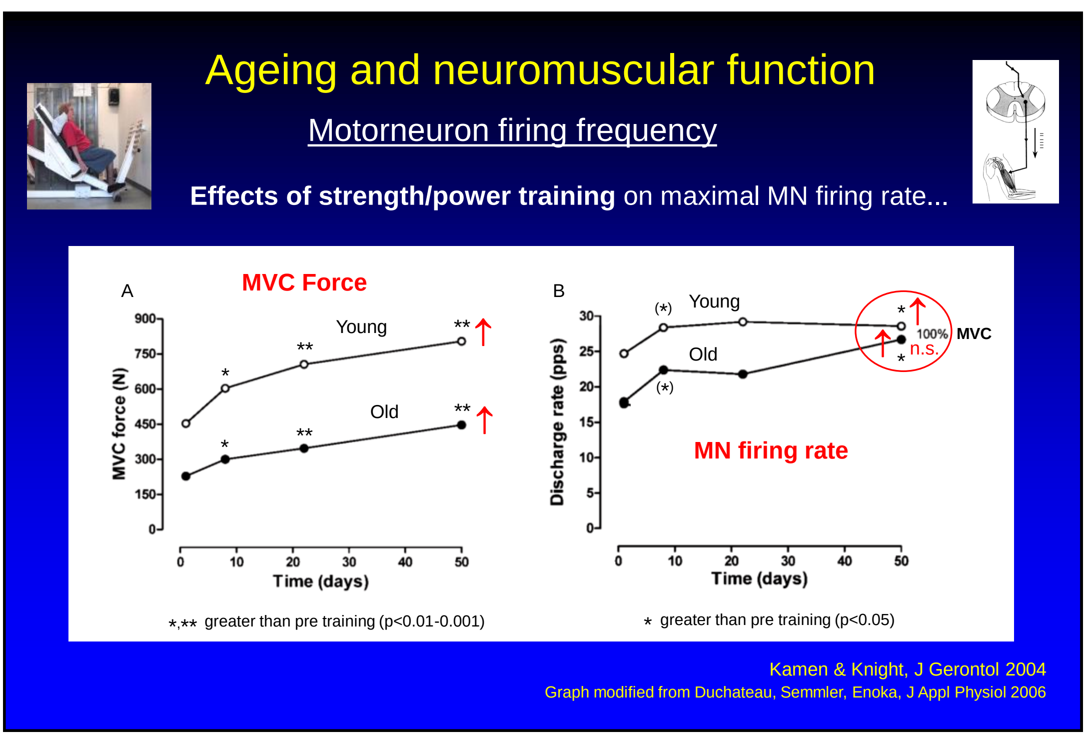
What is the effect of strength/power training on maximal MN firing frequency in old adults?

UNTRAINED STATE:
Maximal motorneuron firing frequency recorded during MVC is reduced in elderly vs young subjects

Patten et al. 1999, 2001, Connelly et al. 1999, Kamen & Knight 2004, Klass Duchateau et al. 2008, Christie & Kamen 2010




Ageing and neuromuscular function
Motorneuron firing frequency
Effects of strength/power training on maximal MN firing rate...
A
MVC Force
MVC force (N)
Young
Old
Time (days)
*,** greater than pre training (p<0.01-0.001)
B
Discharge rate (pps)
Young
Old
100% MVC
MN firing rate
Time (days)
* greater than pre training (p<0.05)
Kamen & Knight, J Gerontol 2004
Graph modified from Duchateau, Semmler, Enoka, J Appl Physiol 2006


Ageing and neuromuscular function
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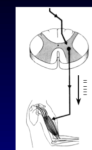
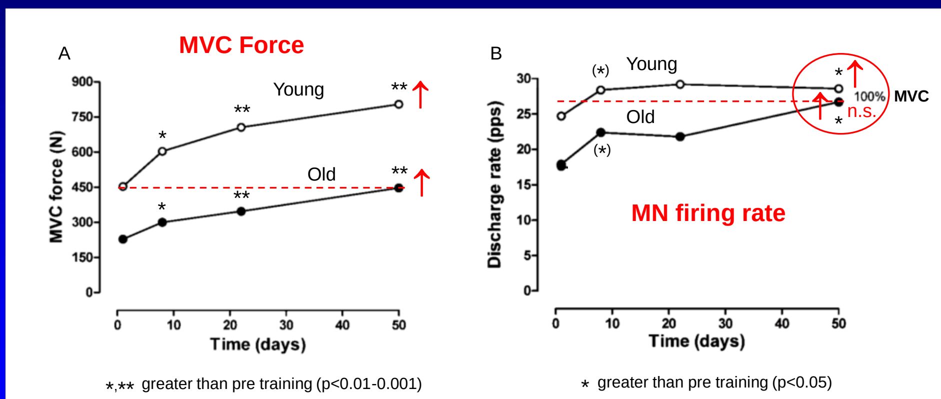
A
MVC Force
MVC force (N)
Young
Old
Time (days)
*,** greater than pre training (p<0.01-0.001)
B
Discharge rate (pps)
Young
Old
100% MVC
n.s.
MN firing rate
Time (days)
* greater than pre training (p<0.05)
Kamen & Knight, J Gerontol 2004
Graph modified from Duchateau, Semmler, Enoka, J Appl Physiol 2006

Ageing and neuromuscular function



Motorneuron firing frequency

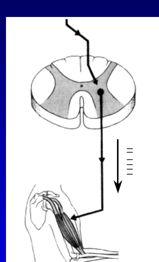
Effects of strength/power training on maximal MN firing rate...



Kamen & Knight, J Gerontol 2004

Graph modified from Duchateau, Semmler, Enoka, J Appl Physiol 2006

Strength training induce changes in maximal motorneuron firing frequency in young and old individuals



Strength/power training

⇓

↑ motorneuron firing rate (at 100% MVC) in both young and old subjects

Patten et al. 1999 (old, young), 2001 (young)
Van Cutsem et al. 1998 (young), Kamen & Knight 2004 (old, young)
Christie & Kamen 2010 (old, young)

Furthermore, after strength training maximal motorneuron firing rate did <u>not</u> differ between old and young subjects

Patten et al. 1999, Kamen & Knight 2004, Christie & Kamen 2010

Effects of strength training in frail elderly patients

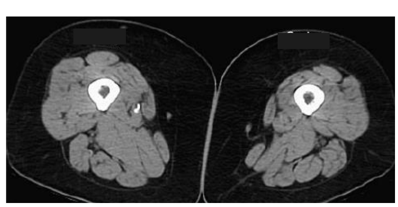
Well, does the need exist?

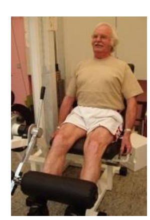
Effects of strength training in frail elderly patients

Well, does the need exist? **YES !**

Often, severe muscle atrophy is observed in elderly patients...

Strength training is the only exercise modality known to effectively increase muscle mass





Effects of strength training in frail elderly patients

Does it lead to improved functional capacity?

pre post training?

Effects of strength training in frail elderly patients

Does it lead to improved functional capacity?

YES !

pre post training

Rehabilitation from elective Hip replacement Surgery by use of Strength Training

Strength Training protocol

Strength exercises - heavy loads

unilateral heavy-resistance strength training - Affected Limb

Knee-extension

Leg-press

wks 1: 3 sets x10 reps (50% 1RM ~20RM load), wks 2-4: 3x12 (65%1RM ~15RM),

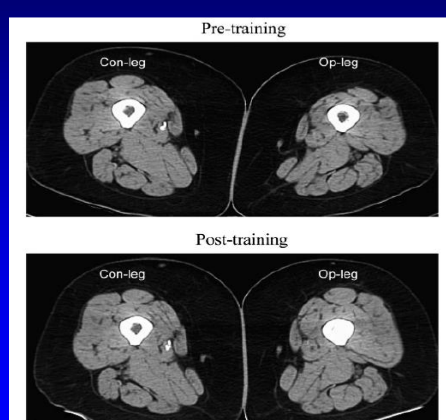
wks 5-6: 4x10 (70%1RM ~12RM), wks 7-8: 5x8 (80%1RM ~8RM),

wks 9-10: 4x8 (80%1RM ~8RM), wks 11-12: 3x8 (80%1RM ~8RM)

Suetta, Aagaard et al, JAGS 2004, J Appl Physiol 2004

Rehabilitation from elective Hip replacement Surgery by use of Strength Training

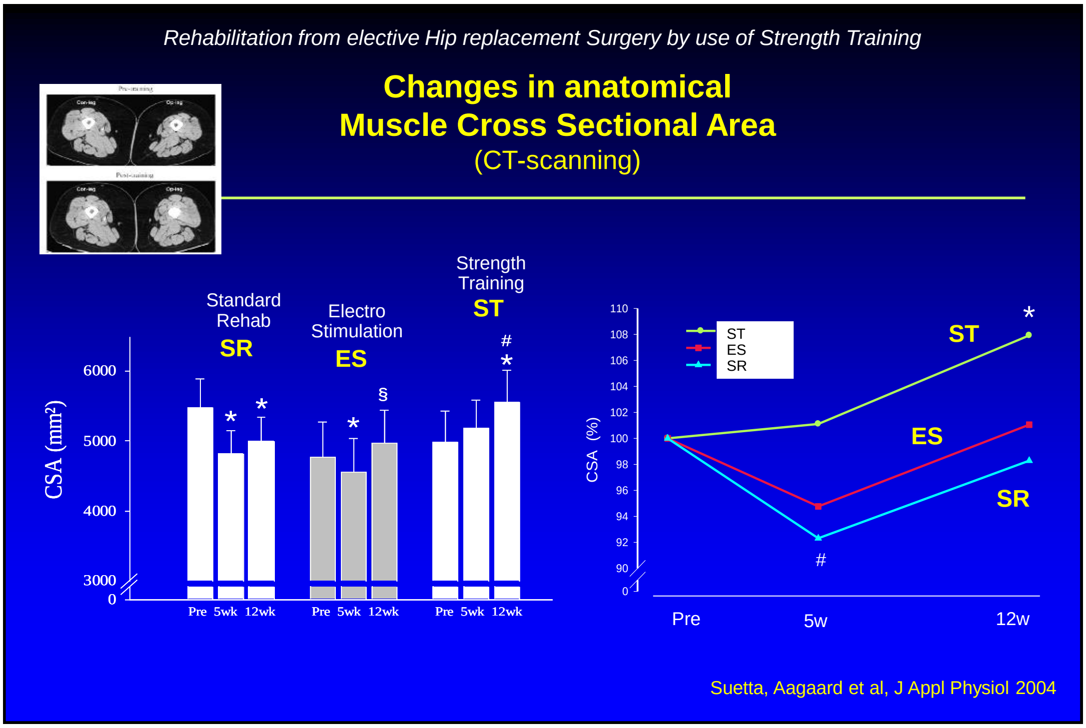
Changes in anatomical Muscle Cross Sectional Area
(CT-scanning)

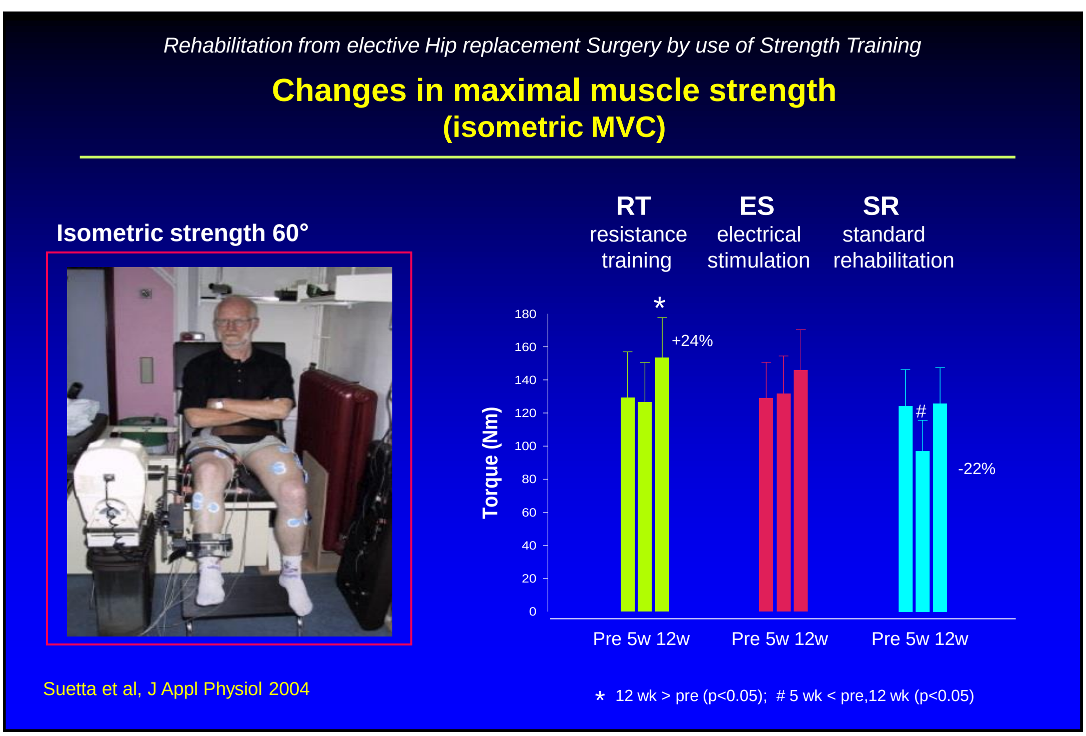


PRE training

POST training

Suetta, Aagaard et al, J Appl Physiol 2004

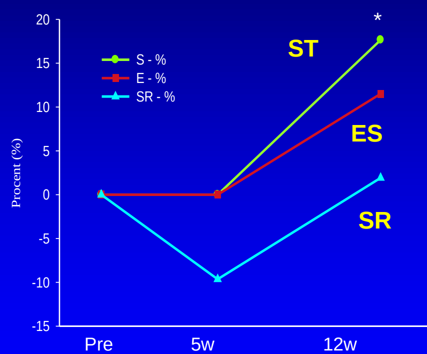

Rehabilitation from elective Hip replacement Surgery by use of Strength Training
Changes in anatomical
Muscle Cross Sectional Area
(CT-scanning)
Standard Rehab
SR
Electro Stimulation
ES
Strength Training
ST
CSA (mm²)
6000
5000
4000
3000
0
Pre 5wk 12wk
Pre 5wk 12wk
Pre 5wk 12wk
CSA (%)
110
108
106
104
102
100
98
96
94
92
90
0
ST
ES
SR
Pre
5w
12w
#
Suetta, Aagaard et al, J Appl Physiol 2004


Rehabilitation from elective Hip replacement Surgery by use of Strength Training
Changes in maximal muscle strength
(isometric MVC)
Isometric strength 60°
RT
resistance training
ES
electrical stimulation
SR
standard rehabilitation
Torque (Nm)
180
160
140
120
100
80
60
40
20
0
+24%
-22%
#
Pre 5w 12w
Pre 5w 12w
Pre 5w 12w
Suetta et al, J Appl Physiol 2004
* 12 wk > pre (p<0.05); # 5 wk < pre,12 wk (p<0.05)

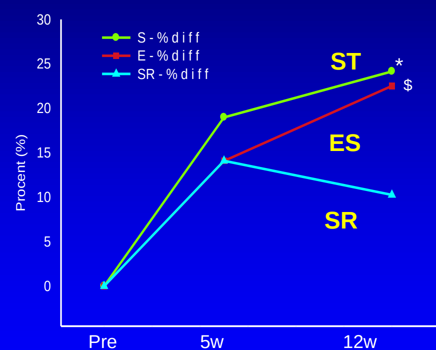
Rehabilitation from elective Hip replacement Surgery by use of Strength Training

Changes in Functional Capacity

Max 10m walk speed



Speed of Chair-rising x 5



Suetta, Aagaard, Kjaer et al, JAGS 2004

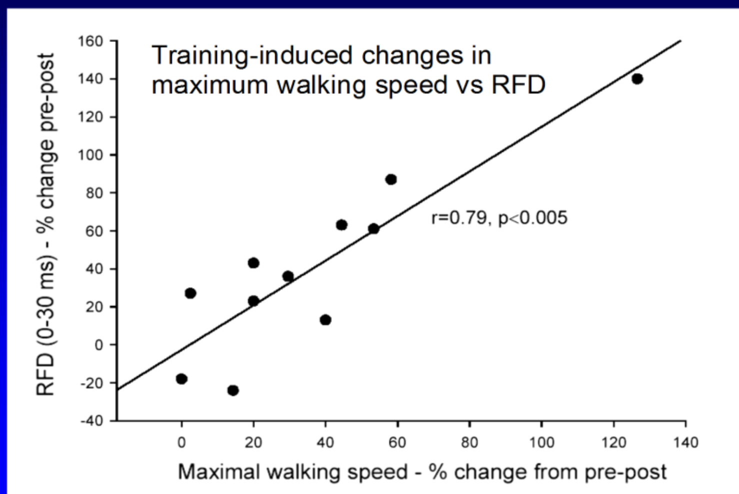
Rehabilitation from elective Hip replacement Surgery by use of Strength Training

Does training-induced gains in rapid force capacity RFD result in improved functional performance?

? →

Rehabilitation from elective Hip replacement Surgery by use of Strength Training

Does training-induced gains in rapid force capacity RFD result in improved functional performance? **YES!**



Suetta, Aagaard, Kjaer et al, J Appl Physiol 2004

Impaired fine motor control with aging

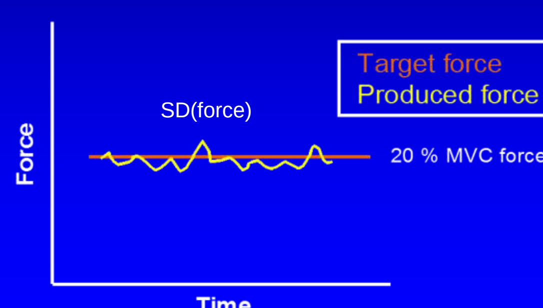
Effects of resistance training

Force steadiness

Submaximal force steadiness

A measurement of the fluctuations in force during isometric or dynamic muscle contraction

courtesy P Caserotti

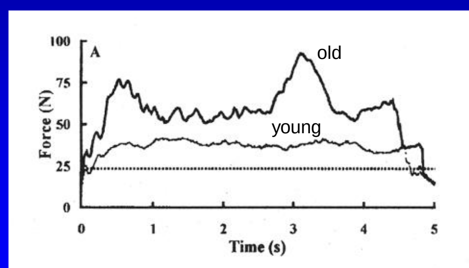


Impaired fine motor control with aging
Effects of resistance training

Force steadiness

Greater force error, less steady muscle forces (↑SD) during submaximal constant-force motor tasks in elderly compared to young subjects

Tracy & Enoka 2002, Hortobagyi et al. 2001



tracking of 25-N target force during 5-sec slow-speed eccentric quadriceps contraction (15°/s)
post 10 familarization trials

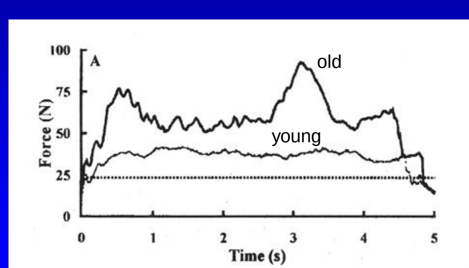
Hortobagyi et al. 2001

Impaired fine motor control with aging
Effects of resistance training

Force steadiness

Potential mechanisms: age related changes in

- MU size and firing rate variability Tracy & Enoka 2002, Barry & Enoka 2007
- MU synchronization Patten & Kamen 1996
- Antagonist coactivation Enoka 1997



tracking of 25-N target force during 5-sec slow-speed eccentric quadriceps contraction (15°/s)
post 10 familarization trials

Hortobagyi et al. 2001

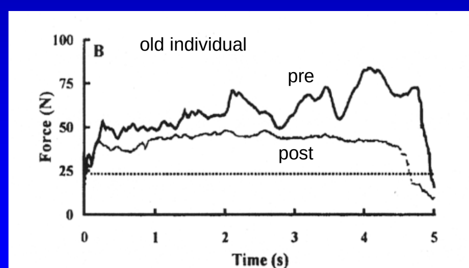
Impaired fine motor control with aging

Effects of resistance training

Effects of strength training in elderly

improved force accuracy
force error 30-60% reduced

improved force steadiness
SD 20-40% reduced



Hortobagyi et al. 2001

Impaired fine motor control with aging

Effects of resistance training

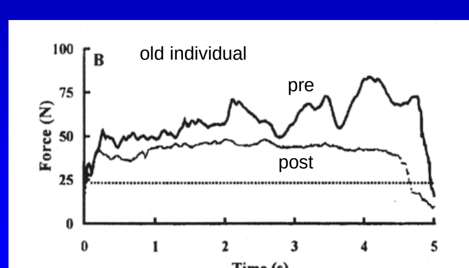
Effects of strength training in elderly

improved force accuracy
force error 30-60% reduced

improved force steadiness
SD 20-40% reduced

↑ maximal muscle strength
+26% isometric
+34% concentric
+24% eccentric

↑ explosive muscle strength
+46% RFD 0-200 ms



Hortobagyi et al. 2001

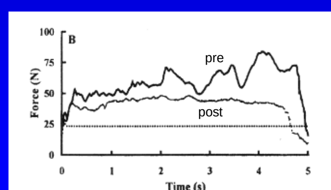
Impaired fine motor control with aging

Effects of resistance training

Effects of resistance training in elderly

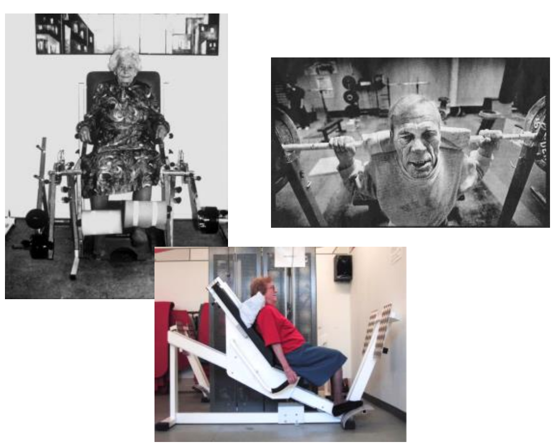
- ▼ Improved force steadiness
  - reduced SD(force)
- ▼ Improved force accuracy

= Improved fine motor control



Hortobagyi et al, J Gerontol 56A 2001
Tracy, Enoka et al, JAP 96, 2004
Tracy & Enoka, MSSE 38, 2006

SUMMARY Effects of strength/power training on neuromuscular function and muscle size in the elderly



SUMMARY Effects of strength/power training on neuromuscular function and muscle size in the elderly

Strength and Power properties

- ↑ dynamic muscle strength, ↑ isometric muscle strength
  Frontera 1988, Fiatarone 1990, Häkkinen 1998, Harridge 1999, Suetta 2004, Beyer 2007
- ↑ muscle power
  Beyer 2007, De Vos 2005, Caserotti 2008
- ↑ rapid force capacity (rate of force development: RFD)
  Häkkinen 1995 1998 2001, Hortobagyi 2001, Suetta 2004, Barry 2005, Caserotti 2008

Neural factors

- ↑ EMG amplitude and rate of EMG rise
  Häkkinen 1995 1998 2001, Suetta 2004, Barry 2005
- ↑ maximal motor neuron firing frequency
  Patten 1999, Kamen & Knight 2004, Christie & Kamen 2010
- improved force steadiness, enhanced fine motor control
  Hortobagyi 2001, Tracy 2004, Tracy & Enoka 2006

Muscular factors

- ↑ single muscle fiber CSA, ↑ whole muscle CSA
  Frontera 1988, Häkkinen 1998, Harridge 1999, Esmarck 2003, Kryger & Andersen 2007, Suetta 2004 2008
- ↑ myogenic satellite cell activation
  MacKey 2007, Petrella 2008
- ↑ muscle fiber pennation angle, ↑ tendon stiffness
  Reeves 2003, Reeves 2006, Suetta 2008

Effects of aging on muscle and neural function - influence of training

OVERALL CONLUSION

The age-related loss in muscle mass and the concurrent decrease in maximal muscle strength, rapid force capacity (RFD) and power can be slowed or reversed by training (strength training!)

Likewise, the age-related impairment in neural function can be effectively compensated by training (strength training)

!! ALSO the case in frail elderly patients !!

OVERALL EFFECT OF STRENGTH/POWER TRAINING IN THE ELDERLY?

Strength/Power TRAINING

⇓

Adaptive changes in muscle size and neuromuscular function

⇓

improved function in ADL

(activities of daily living)

Aagaard, Suetta,Caserotti, et al, Scand J Med Sci Sports 2010

Acknowledgements

Charlotte Suetta	Michael Kjær
Paolo caserotti	Peter Magnusson
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Ulrik Frandsen	Peter Krustrup
Niels Ørtenblad	Lis Puggaard

Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark;

Institute of Sports Medicine Copenhagen, University of Copenhagen