Effects of aging on neuromuscular function

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Outline

I. Sarcopenia and dynapenia

II. Motor unit loss

III. Muscle power vs. strength

IV. Fatigability with static vs. dynamic tasks

V. Summary
Neuromuscular changes with aging

“‘No decline with age is more dramatic or potentially more functionally significant than the decline in lean body mass… Why have we not given it more attention? Perhaps it needs a name derived from the Greek. I’ll suggest a couple: sarcomalacia or sarcopenia’”  (Rosenberg Am J Clin Nutrit 1989)

Sarcopenia – age-related loss of muscle mass
Neuromuscular changes with aging

• Sarcopenia is often used to refer to age-related losses of muscle mass and strength

• However, there is a growing body of evidence that age-related losses in strength are only weakly associated with losses in muscle mass

Dynapenia – age-related loss of strength and power


– impaired performance of daily activities
– reduced quality of life
Consequences of sarcopenia/dynapenia

Causes of sarcopenia/dynapenia

Fig. 1 Scheme summarizing the present concepts on the aetiology of sarcopenia.

Part II:
Motor unit loss
The motor unit (MU)

- A spinal motor neuron and the muscle fibres it innervates (Liddell & Sherrington Proc R Soc Lond Ser B 1925)

Adapted from:
Motor unit remodelling

- Motor neurons die in the course of healthy aging

- Reinnervation prevents/mitigates a reduction in muscle mass with each motoneuron lost
  - delays associated loss of strength and power

Adapted from:
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Number of motor units in a muscle

- Motor units cannot be counted, only estimated, in humans

- Decomposition-enhanced spike-triggered averaging (DE-STA)
  - motor unit number estimate (MUNE)
Subjects

- Examination of three age groups to provide insight into the time course of neuromuscular change:

  8-13 young men (22-33 years old; mean ≈ 26 y)
  8-13 old men (60-69 years old; mean ≈ 65 y)
  8-13 very old men (80-91 years old; mean ≈ 84 y)
**Subjects**

- All subjects were healthy and physically active
- These old and very old men represent more of a “best-case” scenario of aging than is typically seen in the elderly population
- MU loss occurs by 7th decade and accelerates with age

Other muscles

![Graph showing estimated number of motor units for different muscles with asterisks indicating statistical significance.]

- *Different from young

**Thenar**
Doherty et al. 1993

**Biceps/Brachialis**
Doherty et al. 1993

**Soleus**
Dalton et al. 2008
An influence of physical activity

• Might habitual physical activity play a role?

• Evidence in an animal model that long-term exercise slows age-related changes to motor neurons (Kanda & Hashizume Neurosci Res 1998)
Use it or lose it?

- Data were collected from the tibialis anterior of “old” (64±3 years) masters runners

### TABLE 2. Training profile of masters runners.

<table>
<thead>
<tr>
<th></th>
<th>Years of Training</th>
<th>Weekly Kilometers</th>
<th>Days Trained per Week</th>
<th>10-Mile (16 km) Finishing Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>38.2 ± 6.7</td>
<td>59.6 ± 10.1</td>
<td>6 ± 1</td>
<td>79.7 ± 6.8</td>
</tr>
<tr>
<td>Range</td>
<td>30–51</td>
<td>45–80</td>
<td>5–7</td>
<td>70–90</td>
</tr>
</tbody>
</table>

Values are presented as mean ± SD.

Masters of their domain

- MU loss is mitigated by chronic activity of the muscle

Systemic or specific?

• Does the prophylactic effect of habitual physical activity extend to other muscles?

• Data were collected from the biceps brachii of the masters runners as well as young adults and age-matched “old” adults
Even masters have their limits

- MU loss is not mitigated in an uninvolved muscle

Part III:
Muscle power vs. strength
Muscle power vs. strength

- Majority of research examining the impact of age on muscle function is focused on static strength rather than dynamic power

- Unfortunate because:
  - most daily tasks are dynamic
  - power is affected by age-related losses in both strength and velocity

\[
\text{Power} = \tau \times \omega
\]
Motor unit remodelling

- Reinnervation process may cause a shift toward a slower muscle
  - greater impact on muscle power than strength

Adapted from:
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Evoked contractile properties

- Intrinsic contractile properties can be assessed with external stimulation of the nervous system.
Intrinsic slowing of muscle

- 64 year old
- 86 year old

Scale: 2 Nm

Time: 100 ms
Dorsiflexor twitch contraction duration

- Contractile speed slows between 7th & 9th decades

Volitional angular velocity

- Measured “isotonically”
  - i.e., a fixed (ish) load is moved through a range of motion as fast as possible

* loads normalized to peak isometric torque during a maximal voluntary contraction (MVC)
Dorsiflexor angular velocity

- velocity decreases between 3rd & 7th decades

Dorsiflexor strength

- strength decreases between 7th and 9th decades

Dorsiflexor power

- power decreases between 3^{rd} & 7^{th} decades

Loss of strength vs. power

- power deficits > strength deficits at both ages

Functional relevance of power

http://www.youtube.com/watch?v=T7efWmFSroo
Part IV:
Fatigability with static vs. dynamic tasks
Muscle fatigue

• Fatigue is highly dependent on task performed
  – e.g., reports that fatigue ↑, ↓, or ↔ with age

• Majority of studies involve isometric contractions
  and report enhanced muscle endurance with age
  – greater metabolic efficiency (ATP production via
    aerobic metabolism) (Lanza et al. 2004)

• Greater endurance in the elderly does not fit with
  what we observe in real life
What happens with dynamic tasks?

- Results are **equivocal** when velocity is constrained (isokinetic contractions)


The importance of velocity

slow (60°/s) isokinetic task
– similar fatigue

moderate (180°/s) isokinetic task
– greater fatigue in old

unconstrained velocity task
– greater fatigue in old

Dorsiflexor fatigue

- fatigue is increased in the 9th decade

Part V: Summary
Summary

• Motor units are lost with healthy aging but habitual activity can have a protective effect.
Summary

- Contractile slowing contributes to power losses in excess of any strength losses

![Graph showing MVC and power at 50% MVC as a percentage of young value for Old and Very Old groups. Symbols indicate significance differences: * different from young, † different from young & old.]
Summary

- Fatigability increases with age during tasks most similar to activities of daily living.
A final (sobering) thought

- These data represent the best-case scenario of aging and so the age-related losses in power and endurance in the general population are certain to be underestimated.
Thank you
Extra slides
Simple analogy of the technique

- Suppose you wanted to estimate the number of potatoes in a basket
Simple analogy of the technique

STEP 1
• Get the mass of the basket of potatoes (less the mass of the empty basket)
  20kg

STEP 2:
• Take a sample of individual potatoes (e.g., 20) and find the mean mass
  80g
Simple analogy of the technique

STEP 3

• Divide total mass by mean mass of a single potato to an estimate of the number in the basket

\[ \text{estimate} = \frac{20\, kg}{0.08\, kg} \]

\[ \text{estimate} = 250 \text{ potatoes} \]
The M-potential / M-wave / CMAP

- **Electrical (EMG) response** of a muscle to external stimulation

- When size does not increase despite an increase in current, all functional motor units of a muscle have been activated
Signal decomposition

Raw surface EMG signal split into single surface motor unit potentials (S-MUPs)

(the individual potatoes)
Motor unit number estimate

\[ MUNE = \frac{\text{maximal } M\text{-potential}}{\text{mean } S\text{-MUP}} \]

6.4mV

21\(\mu\)V
Motor unit number estimate

\[ MUNE = \frac{6400 \mu V}{21 \mu V} = 304 \]
Muscle mass

Imaged subjects in a 3 Tesla magnet

24 year old  
65 year old  
80 year old
Anterior compartment muscle mass

- muscle mass is preserved with age

Strength & power normalized to muscle mass

Strength & power normalized to muscle mass

- decrease in muscle quality not quantity is most responsible

Summary

• Contractile slowing contributes to power losses in excess of any strength losses

• Deficits of strength and power without a loss of muscle mass indicate that muscle quality is more influential than muscle quantity
Contradictory evidence

- However, when matched for strength, young adults are still more fatigable than old adults.

![Graph showing time to failure for old and young adults](image)

20% MVC of elbow flexors

©2005 the American Physiological Society
Contradictory evidence

- When blood flow is occluded, young adults are still more fatigable than old adults

Intermittent MVCs (5s on, 5s off) of dorsiflexors

©2007 the American Physiological Society
Neuromuscular changes with aging

- Sarcopenia is often used to refer to age-related losses of muscle mass and strength

- However, there is a growing body of evidence that age-related losses in strength are only weakly associated with losses in muscle mass

Dynapenia – age-related loss of strength and power


- impaired performance of daily activities
- reduced quality of life
- financial burden
The cost of sarcopenia/dynapenia

• In the US in 2000, an estimated $18.5 billion was spent on the direct healthcare costs attributable to the age-related loss of muscle mass, strength and power (Janssen et al. J Am Geriatr Soc 2004)

• In contrast, osteoporotic fractures – an event synonymous with debilitation and a drain on healthcare resources – had an estimated cost of $13.8 billion in 1995 (Ray et al. J Bone Miner Res 1997)