The sixth age shifts
Into the tear and slipper'd pantaloons,
With spectacles on nose and pouch on side,
His youthful hose, well save'd, a world too wide
For his shrunk shanks; and his big manly voice,
Turning again toward childish treble, pipes
And whistles in his sound. Last scene of all,
That ends this strange eventful history,
Is second childishness and mere oblivion,
Sans teeth, sans eyes, sans taste, sans everything.
As You Like It, Act II, Scene VIII, lines 157-166

“Every day you get older. It’s the law”
Sundance Kid to Butch Cassidy

Exercise and Nutrition Workshop

Prefontaine
84 ml·kg⁻¹·min⁻¹

Male Marathoners
70
Female Marathoners
60
Sedentary College Age Men
50
Sedentary Middle Age Men
40
Sedentary College Age Women
30
Ice Hockey
20
Swimming
10

Exercise and Nutrition Workshop

1972 Silver Medal Olympic 8 Crew Team

$\text{VO}_{2}\text{max} = \text{Cardiac Output} \times \text{Arterio-Venous O}_2\text{ difference}$


Exercise and Nutrition Workshop
Longitudinal Changes in Aerobic Capacity According to Physical Activity

Prevalence of sarcopenia, Women

Prevalence of sarcopenia, Men

Sarcopenia

Age related loss of skeletal muscle mass


Sarcopenia

Loss of muscle by age

- 20 - 40: Decreased physical activity, decreased type II fiber size and amount. Maintenance of type I fibers
  - Maintenance of VO\textsubscript{2max} with training
  - Decreased sprinting capacity
- 40 - 60: Loss of motor units accelerates. Decreased sprinting capacity and VO\textsubscript{2max} even with training.
  - Concomitant increase in fat mass. Relative contribution of dietary fat to total energy intake increases. Visceral fat increases (decreased androgen levels), adipokine levels increase
  - Insulin resistance down regulates rate muscle protein synthesis (post prandial).
Sarcopenia

- 60 - 70:
  - Reduced physical activity
  - Reduced androgen production and menopause
  - Insulin resistance: Impaired glucose tolerance and type 2 diabetes.
  - Inflammation (increased total body and visceral fat)
  - Nutritional deficiencies (increased need for protein, micronutrients)
    - Impaired appetite regulation

- 70+:
  - Further reduction in physical activity
    - Weakness and accelerated loss of VO₂max
  - Bouts of enforced inactivity due to illness, hospitalization, depression
  - Fear of falling, Mild cognitive impairment
    - Macronutrient intake (%) constant - 35 - 40% of energy from fat
  - Reduce muscle protein synthesis
    - Decreased efficiency of synthesizing muscle protein
  - Increased muscle protein breakdown?
    - Inflammation, chronic diseases, poor regulation of ubiquitin expression (and ATP dependent protein degradation).

Sarcopenia: Healthcare Costs

- Prevalence > 20% of people over 65
- $18.5 Billion in 2000
  - 15% of total healthcare expenditures
  - $860 excess for each sarcopenic man and $933 for each sarcopenic woman
  - 10% reduction in sarcopenia prevalence would save $1.1 billion (in year 2000 $)

"Sarcopenia imposes a significant but modifiable economic burden on government-reimbursed healthcare services in the United States. Because the number of older Americans is increasing, the economic costs of sarcopenia will escalate unless effective public health campaigns aimed at reducing the occurrence of sarcopenia are implemented."

Age-related changes in thigh cross-sectional area

Sarcopenia: Healthcare Costs

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Relationship between muscle lipid and strength

- Muscle attenuation assessed by CT
- Lower attenuation = increased muscle lipid content
Fat mass rather than muscle strength is the major determinant of physical function and disability in postmenopausal women younger than 75 years of age. *Menopause* 13: 474, 2006

- X-sectional: 396 independent women 56-73 years
  - 43.7% overweight; 17.7% obese
  - "A 10-kg increase in total fat mass was associated with 0.5 point lower physical performance and 1.1 points lower physical activity and with 64% higher frequency of impaired activities of daily living, demonstrating a strong adverse effect of fat mass that does not seem to be compensated by the observed parallel increase in leg muscle mass."

---

**Frailty**

**Definition**

"I know it when I see it"

---

**Frailty**

Fried definition:

- "Shrinking" Weight loss, Sarcopenia
  - >10 lbs. lost (unintentionally in prior year)
- Exhaustion
  - Poor endurance, self report
- Low levels of physical activity
  - Lowest 20% (males < 383 kcal/wk, females < 270 kcal/wk)
- Low walking speed
  - Slowest 20%
- Muscle weakness
  - Lowest 20% (grip strength)


- 156 elderly men and women (>65 yrs)
- 96% of obese elderly were frail. Lower muscle quality (strength/mass) and lower quality of life compared to both frail and non-frail elderly

"These findings suggest that weight loss therapy may be particularly important in OE persons to improve physical function, in addition to improving the medical complications associated with obesity”

Physical Activity and Obesity

- 59% of owners of obese dogs are obese (Modern Veterinary Practice)
- Preschool children who watch more TV are fatter and are less active, and activity influences TEE. The results suggest that a relation between TV viewing and fatness is more likely to be due to an effect on food intake. (Am J Clin Nutr, 89, 2009)

Things you will never hear in the South

- We’re vegetarians.
- I’ll have grapefruit instead of biscuits and gravy.
- Give me a small bag of pork rinds.
- Trim the fat off that steak
- I’ll have the arugula and radicchio salad.
- Little Debbie snack cakes have too many fat grams.
- Be sure my salad dressing is on the side.

Aerobic Exercise and Aging: Does aging effect the adaptation to aerobic exercise training?

Recruited older (age 60-70 years) and young (20-30) men and women.

Frequency -- 3 d/wk
Intensity -- 70% VO2max
Duration -- 50 min/d

Older men and women experience a greater relative increase in aerobic capacity as a result of 12 weeks of aerobic exercise training

**Muscle Oxidative Capacity**

**Impaired Strength**
Inability to lift 4.5 kg

**Progressive Resistance Training**
- Exercise during which a muscle contracts just a few times against a heavy load or with high tension. The load is progressively increased with training.
- Distinct from endurance (aerobic exercise) training during which muscles contract against little or no resistance

**Resistance Exercise**
- Subjects
  - Previously sedentary men
  - Age 60-72
- Exercise
  - High intensity resistance training
  - Knee extensors and flexors
  - 80% of 1RM, 3 sets of 8 repetitions,
  - 1 RM measured weekly and 80% readjusted
  - 12 weeks in duration

---

Creatine Supplementation Enhances Isometric Strength and Body Composition Improvements Following Strength Exercise Training in Older Adults, J Gerontol. Med Sci 58: B11, 2003

- 28 men and women > 65 years old
- 14 weeks of resistance exercise, 5 g/d + 2 g/d glucose or 7 g/d glucose
- Cr: greater increase in lean body mass, weight, strength vs placebo

"In summary, 14 weeks of resistance training resulted in improvements in muscle strength and functional task performance. In addition, there was a greater increase in FFM, TBM, and isometric knee extension strength in those who supplemented with CrM. Although the mechanisms of these improvements remain to be elucidated, our results represent the first line of evidence suggesting that CrM supplementation may be beneficial to older adults who perform resistance exercise training."

Resistance Exercise:
High intensity - 80% of the 1RM.

*Three sets* - first two are 8 repetitions. Final set is to muscle failure.
If individual can perform more than 12 reps., intensity is increased in next training session.
Factors Affecting Bone Health

- Gender, Heredity Race
- Estrogen Status
- Body Type
- Nutrition
- Physical Activity
- Smoking
- Medications (cortisol, for example)

Osteoporosis

- One in two women and one in eight men aged 50 and over will have an osteoporosis-related fracture in their lifetime.
- The estimated national direct expenditures (hospitals and nursing homes) was $17 billion in 2001 -- $47 million per day.
  - The cost is rising

Study Design

- Random assignment to resistance exercise or sedentary control
- Control
  - Not engage in resistance exercise or other regular exercise program
  - Maintain body weight
- Exercise
  - 80% 1RM, 3 set of 8 reps, 2 d/wk
  - Upper and lower body exercise

Risk of death for 50-year-old white postmenopausal women

<table>
<thead>
<tr>
<th>Condition</th>
<th>Lifetime Risk (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip fracture</td>
<td>2.8</td>
</tr>
<tr>
<td>Breast cancer</td>
<td>2.8</td>
</tr>
<tr>
<td>Endometrial cancer</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Control (n=19) | Exercise (n=20) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>57.3</td>
</tr>
<tr>
<td>Yrs Menopause</td>
<td>9.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>62.2</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.1</td>
</tr>
</tbody>
</table>

Muscle Mass Change

-1 -0.5 0 0.5 1 1.5
LP KE LFD BE AF

Control Exercise
% change in strength

Relative gains in strength during one year


Stress and Bone Density

-3 -2 -1 0 1 2
Wt. Gain Wt. Stable Wt. Loss

-1 -0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0
Wt. Gain Wt. Stable Wt. Loss

• 3 - 4% increase in bone density in 6 months
• 50 heel drops per day

Bassey, E. J., Increase in femoral bone density in young women following high-impact exercise, Osteoporosis International 1994 4:72-75


-6,785 women > 65 yrs examined over an average of 5.7 yrs
- Wt. Loss > 5% from baseline
  - Asked about intention to lose weight
  - Wt. Loss: 78.3±5.3
  - Wt. Stable: 76.4±4.7
  - Wt. Gain: 75.4±4.2
• “Older women who experience weight loss in later years have increased rates of hip-bone loss and a two-fold greater risk of subsequent hip fracture, irrespective of current weight or intention to lose weight.”

“These findings indicate that even voluntary weight loss in overweight elderly women increases hip fracture risk.”

Death Rates According to Individual Performance Tests—Age and Sex Adjusted

Walking Speed Predicts Mortality

Energetics of Walking in Elderly People: Factors Related to Gait Speed
J Gerotol Med Sci 2010 Aug 1 (Epub)
• Determine metabolic and physiological factors associated with walking speed.
• 50 subjects: 25 men, 25 women
  – Average age: 72.7±1.2 y (60 – 88)
  – BMI: 26.0±0.53 (17 – 34)
• VO₂peak (ml • kg⁻¹ • min⁻¹)
  • 19.9±0.76 (11.3 – 36.5)

Measurements
• Short Physical Performance Battery
  – Habitual gait speed, chair stand, balance
• Body Composition (DEXA)
• Muscle Strength (1 RM)
• VO₂peak
  – Treadmill walking at comfortable speed, increase in incline until volitional fatigue
Measurements (continued)

- \( \text{VO}_2 \) at habitual walking speed (from SPPB)
  - 10 minutes
  - Rated perceived exertion
- \( \text{VO}_2 \) at standard walking speed (2 mph)
  - 10 minutes
  - RPE
- \( \text{VO}_2 \) while standing
  - Determination of “reserve” \( \text{VO}_2 \)
  - \( \text{VO}_2\text{peak} - \text{VO}_2 \) while standing

Slow vs. Fast Walkers

<table>
<thead>
<tr>
<th>Measure</th>
<th>Slowest 25%</th>
<th>Fast 25%</th>
<th>( \Delta )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitual Gait Speed (mph)</td>
<td>1.95 ± 0.05</td>
<td>3.31 ± 0.09</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>( \text{VO}_2\text{peak} ) (ml/kg/min)</td>
<td>15.6 ± 0.96</td>
<td>25.83 ± 1.64</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>( \text{VO}_2\text{peak} ) (L/min)</td>
<td>1.00 ± 0.08</td>
<td>2.08 ± 0.19</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>RPE at 2 mph</td>
<td>12.3 ± 0.6</td>
<td>11.2 ± 0.4</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>( \text{VO}_2 ) at 2 mph</td>
<td>0.66 ± 0.06</td>
<td>0.89 ± 0.04</td>
<td>0.656 (NIS)</td>
<td></td>
</tr>
<tr>
<td>Relative ( \text{VO}_2 ) of habitual gait speed ( %\text{VO}_2\text{peak} )</td>
<td>88.3 ± 6.4</td>
<td>58 ± 2.2</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Reserve ( \text{VO}_2 )</td>
<td>12.0 ± 0.90</td>
<td>22.4 ± 1.4</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>1 Repetition Maximum (lbs)</td>
<td>165 ± 57</td>
<td>315 ± 109</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
</tbody>
</table>

Reserve \( \text{VO}_2 \) vs habitual gait speed (\( \text{VO}_2\text{peak} - \text{VO}_2 \) while standing)

Kaplan-Meier survival estimates of dementia-free probability by performance-based physician function (PPF) scores

Kaplan-Meier survival estimates for the probabilities of being dementia-free


Fiatarone, M, E Marks, N Ryan, C Meredith, L Lipsitz, and W Evans, High intensity strength training in nonagenarians, JAMA, 265: 3029-3034, 1991
**SUBJECT CHARACTERISTICS**

6 Women
4 Men
Age = 90.2 ± 1.1 (86-96 Years)
Pattern of Care:
Level 1 = 4 Subjects
Level 2 = 8 Subjects
86% had a history of falls
7 Subjects used an ambulatory assistive device
4.5 ± 0.6 chronic diseases/subject

(Ann Al., 263 3029-3034, 1996)

---

**Strength Changes in Nonagenarians**

Eight weeks of progressive resistance exercise training resulted in a 200% increase in strength and a 10% increase in muscle size in 90-year-old nursing home residents

---

**Exercise training and nutritional supplementation for physical frailty in very elderly people**


Age = 87.0 ± 0.6 (range 72-98)
69% were over the age of 85

83% required an ambulatory assistive device
66% had fallen at least once in previous year
50% arthritis; 44% pulmonary disease; 44% osteoporotic fracture; 35% hypertension; 24% cancer; 18% diabetes; 13% myocardial infarction

---

**Kcals**

<table>
<thead>
<tr>
<th>Kcals</th>
<th>EX</th>
<th>EX+SUPP</th>
<th>SUPP</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Knee Extensor Strength 1 RM (% change)**

<table>
<thead>
<tr>
<th></th>
<th>EX</th>
<th>EX+SUPP</th>
<th>SUPP</th>
<th>Cont</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
In very old nursing home residents, 10 weeks of progressive resistance exercise training:

- Increased walking speed
- Increased stair climbing ability
- Increased spontaneous activity
- Decrease in depressive symptoms

Results and Conclusions:

- Significant Type II fiber atrophy and Z band and myofibril damage were present at baseline
- Combined weight lifting and nutritional supplementation increased strength by 257% and Type II fiber area by 10.1%
- Exercise was associated with a 2.5-fold increase in muscle neonatal myosin and a 491% increase in muscle IGF-1

Strength gains were greatest in the group that strength trained and received a protein-calorie supplement.

Muscle fiber and strength increases were significantly related to increased energy intake.

Helen Zechmeister, Age 81, Weight Lifter
Resistance Exercise:

- Increases Strength and Functional Capacity
- Increases Muscle Mass
- Enhances Nitrogen Balance (Retention of Protein)
- Increases Levels of Physical Activity
- Improves Bone Health, Decreasing Risk of Osteoporosis
- Increases Insulin Action, Decreasing Risk of Diabetes

A New Paradigm for Post-Cardiac Event Resistance Exercise Guidelines

"...changing the approach to resistance exercise in cardiac rehabilitation will accelerate patients’ return to their desired levels of daily activity, improving patient satisfaction and decreasing cardiac rehabilitation program attrition."

Physician recommendations after surgery involving sternotomy reported by patients in CR program at Baylor Med Ctr

- Lift >5 lbs for 6 wk
- Lift anything for 1 month
- Lift anything heavy for 8 wk
- Lift >2 lbs
- Lift or push anything
- Lift more than a gallon of milk for 4 wk
- Lift anything heavier than Dallas phone book
- Pull anything for 8 wks
- Mow anymore
- Vacuum
- Do anything but light cleaning for 7 wk
- Play tennis until after 6 wk
- Push a grocery cart
- Do anything strenuous
- Do yard work for 8 wk
- Do anything that would hurt you

Forces required to perform ADLs

<table>
<thead>
<tr>
<th>Activity</th>
<th>Force in lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pushing open door to cardiac rehab</td>
<td>15.5</td>
</tr>
<tr>
<td>Pulling open door to leave CR</td>
<td>22</td>
</tr>
<tr>
<td>Pushing open door to leave building</td>
<td>15</td>
</tr>
<tr>
<td>Pulling door to Dr. office</td>
<td>14.5</td>
</tr>
<tr>
<td>Pushing door to leave Dr. office</td>
<td>15.5</td>
</tr>
<tr>
<td>Pushing IV pole with bag across carpet</td>
<td>6.5</td>
</tr>
<tr>
<td>Opening freezer door</td>
<td>15</td>
</tr>
<tr>
<td>Pulling 1 gallon of milk from refrigerator</td>
<td>10.5</td>
</tr>
<tr>
<td>Lifting full laundry hamper</td>
<td>21.5</td>
</tr>
<tr>
<td>Fishing industrial toilet</td>
<td>15.5</td>
</tr>
<tr>
<td>Pushing with aid of arm to rise off bench</td>
<td>27.5</td>
</tr>
<tr>
<td>Opening car door</td>
<td>12.5</td>
</tr>
<tr>
<td>Lifting a Dallas phone book</td>
<td>4.5</td>
</tr>
</tbody>
</table>

The effect of different intensity modalities of resistance training on beat-to-beat blood pressure in cardiac patients

- Fourteen patients (age 46-72 yr)
  - 1-3 months post CABG, coronary angioplasty, or valvular surgery
- Continuous monitoring of BP and HR during low and high intensity resistance ex.
  - Low: 4 sets of 17 reps at 40% 1RM (34 sec.)
  - High: 4 sets of 10 reps at 70% 1RM (20 sec)

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Systolic BP</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>120</td>
<td>95</td>
</tr>
<tr>
<td>High</td>
<td>140</td>
<td>115</td>
</tr>
</tbody>
</table>

- Significantly greater increase in systolic BP with low vs. high intensity
- Significantly greater rise in HR with low vs high intensity
Conclusions

- "Sets of < 10 repetitions of high intensity should be preferred to longer sets with low intensity"
- Pauses between sets should exceed 1 min.

Bedrest and Aging

- 10 days complete bedrest
- 12 subjects, 67 ± 5 years
- Eucaloric diet, 0.8g protein/kg/d
- Body composition (DEXA)
- Fractional Synthetic Rate of muscle protein
  – 24-h infusion of $^{13}$C$_6$-phenylalanine, vastus lateralis biopsy pre-post infusion

Loss of Leg Muscle Mass: DEXA
Effect of 10 days of bed rest on skeletal muscle in Healthy older adults, JAMA 297: 2007

N Balance: 0.8 g protein kg$^{-1}$ d$^{-1}$

10 days of bedrest
Fractional Synthetic Rate of Skeletal Muscle

44% reduction
**VO\textsubscript{2max}**

-15.1±4.3% change
-1% reduction/year with normal aging
10 d bedrest = 15 years of aging

*P < 0.01*

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**Massachusetts: Keep Moving Walking Clubs**
Peer driven program administered through MA Executive Office of Elder Affairs

---

**Peer Exercise Program Promotes Independence**

**PEPPI**
- Joint program between Penn State University and PA Department of Aging
- Training of community-based peer leaders
- Peer leaders establish exercise program in community

---

**PEPPI Community-Based Exercise**
- 82% can walk better
- 95% are better able to get up from a seated position
- 78% can climb stairs more easily
- 84% have improved balance

---

**PEPPI Participants**
- 99% state that their health has improved
- 87% state that they are more independent
Biomarkers

- Muscle Mass
- Strength
- Basal Metabolic Rate
- Body Fat
- Aerobic Capacity

- Blood Pressure
- Insulin Sensitivity
- Cholesterol/HDL
- Bone Density
- Body Temperature Regulation

Woody Brown
Age 83
Surfer

John Turner:
Age 67
Weight Lifter

The Future of Nursing Homes

Though I look old, yet I am strong and lusty;
For in my youth I never did apply
Hot and rebellious liquors in my blood
Nor did I with unbashful forehead woo
The means of weakness and debility;
Therefore my age is as a lusty winter,
Frosty, but kindly. Let me go with you;
I'll do the service of a younger man
In all your business and necessities

William Shakespeare, As you like it, Act II, Scene III, lines 46-55

Nobody really lives long enough to die of old age.
We die from accidents, and most of all, disuse

Walter Bortz, M.D.