Exercise: Picking Up the Pace to Slow the Aging Process

Kerry J Stewart, EdD, Professor of Medicine
AGING

- DECREASED ENDURANCE CAPACITY
- MUSCLE WASTING
- MUSCLE WEAKNESS
- INCREASED FATIGABILITY

DECREASED PHYSICAL ACTIVITY

- GENETICS
- ENERGY EXPENDITURE
- OBESITY/ABDOMINAL OBESITY
- INSULIN RESISTANCE

Cardiovascular Disease

TYPE 2 DIABETES
Risk Factors for Atherosclerosis

- Age
- Diabetes Mellitus
- Obesity
- Genetics
- Inflammation
- Dyslipidemia
- Hypertension
- Smoking
- Hypercoagulability
- Novel Risk Factors

Physical Inactivity

Atherosclerosis
Frailty

- The condition of being weak and delicate
- It is a common geriatric syndrome that embodies an increased risk of significant declines in health and function in older adults
- A key characteristic is the degenerative loss of skeletal muscle mass, quality, and strength
- However, the rate of muscle loss is dependent on exercise level, co-morbidities, nutrition, and other factors
Age-associated changes in physiology and their consequences

INFLAMMATION
- IL-6
- TNF-α
- CRP

ENDOCRINE CHANGES
- Cortisol
- DHEA-S
- IGF-1

Sarcopaenia
Anaemia
Glucose intolerance
Increased clotting

FRAILTY
Adverse health outcomes

Malnutrition
Hospitalisations

Decreased exercise

Falls
Exhaustion
Incontinence
Depression

Side effects

Osteopaenia
- strength
- insulin sensitivity

Social isolation
Institutionalisation
FIGURE 3. World Health Organization health-fitness gradient. Most older adults fall along this continuum, with good health at one end, and physical frailty at the other. Exercise can improve health and fitness status, whereas a lack of exercise will accelerate its decline.

Physical Activity and Aging

- The typical aging curve suggest that most physiological functions improve from birth through the early teens.
- Most functions commonly level off in the mid-20’s and then it’s generally downhill from there for most physical and cognitive functions.
- However, the rate of change is not equal among individuals.
- There are several modifiable factors on the aging curve.
- These include:
  - Physical activity
  - Nutrition
  - Body fat
  - Muscle mass
  - Smoking
Dialogue Between Franklin and the Gout
Benjamin Franklin (1706–1790)
Midnight, 22 October, 1780.

FRANKLIN. What have I done to merit these cruel sufferings?
GOUT. Many things; you have ate and drank too freely, and
too much indulged those legs of yours in their indolence.
FRANKLIN. Who is it that accuses me?
GOUT. It is I, even I, the Gout
FRANKLIN. What! my enemy in person? For you would not
only torment my body to death, but ruin my good name; you
reproach me as a glutton and a tippler; now all the world, that
knows me, will allow that I am neither the one nor the other.
GOUT. The world may think as it pleases but I very well know
that the quantity of meat and drink proper for a man, who
takes a reasonable degree of exercise, would be too much for
another, who never takes any.
Normal changes in exercise capacity with aging

Aerobic capacity, muscle mass, and strength

- Aerobic capacity declines at about 1 percent per year from mid-life forward and at about 0.5 percent among habitually active persons.

- Loss of muscle mass and strength are also thought to accelerate after mid-life. Lean-mass loss is about 1 percent per year.
Magnetic resonance image of a thigh cross section from a 25-year-old man (left) and a 65-year-old man (right). The thighs are of similar size but the older man's shows a buildup of fat around and through the muscle, indicating substantial muscle loss.
Mechanisms that contribute to sarcopenia include physical activity.

- Nutritional
- Hormonal
- Metabolic
- Immunologic Factors

↓ Motor Units
↓ Muscle Fibers
Muscle Fiber Atrophy

↓ Muscle Mass
↓ Muscle Strength

Physical Activity

Sarcopenia

- Weakness
- Decreased Mobility

Disability and Loss of Independence
Change in Bone Mass with Age

Changes in bone mass with age

- peak bone mass
- menopause
- old age
- puberty

Bone mass

Age (years)
Prevalence of self-reported physical inactivity among adults aged ≥50 years, by chronic disease status* and age group — Behavioral Risk Factor Surveillance System, 2014
Physical activity can change the slope of aging
The physiology of exercise
Bone Mineral Density Changes Over Time in Sedentary Versus Active Women

International Osteoporosis Foundation 2005 Invest in Your Bones Report
Cardioprotective Effects of Regular Physical Activity

**Figure 1.** Cardioprotective effects of regular physical activity. There are multiple mechanisms by which moderate to vigorous exercise training can decrease the risk of cardiovascular events. ↑ indicates increase; ↓, decrease; BP, blood pressure; CCACs, cultured/circulating angiogenic cells; EPCs, endothelial progenitor cells; HDL, high-density lipoprotein; HR, heart rate; and LDL, low-density lipoprotein.
Figure. The Greatest Potential Blood Pressure Reductions Following Aerobic, Resistance, & Concurrent Exercise Training among Adults with Hypertension (adapted from 11-13*)

- Systolic Blood Pressure:
  - Aerobic: -14.3
  - Resistance: -8.3
  - Concurrent: -9.2

- Diastolic Blood Pressure:
  - Aerobic: -10.3
  - Resistance: -5.2
  - Concurrent: -7.7

*The BP reductions after resistance (12) and concurrent (13) exercise were generated from additive statistical models that capture the combination of study-level moderators that elicit the optimal BP benefits.
Combined Aerobic and Resistive Training and Mild Hypertension

Subjects 18-59 yrs, mean 45, mean baseline BP 145/97, mean 7 week BP 131/84

Kelemen, Effron, Valenti, Stewart: JAMA 1990:263:2766-2771
Effect of Exercise on Blood Pressure in Older Persons
A Randomized Controlled Trial

• Subjects, aged 55-75 years had untreated SBP of 130 to 159 or DBP of 85 to 99 mm Hg
• 51 exercisers and 53 controls completed the 6-month trial
• Mean age was 63.6 ± 5.7 years, mean baseline BP was 140/77 in exercisers and 142/76 in controls
• Exercise consisted of supervised aerobic and resistance exercise 3 days/week

Stewart et al: Arch Intern Med: 165, April 11, 2005
<table>
<thead>
<tr>
<th>Variable</th>
<th>Exercise Group (n = 51)</th>
<th>Control Group (n = 53)</th>
<th>Difference (Exercise – Control)</th>
<th>P Value*</th>
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</thead>
<tbody>
<tr>
<td>Resting hemodynamics, mean (95% CI)</td>
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<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>−5.3 (−8.1 to −2.5)</td>
<td>−4.5 (−6.7 to −2.2)</td>
<td>−0.8 (−4.4 to 2.8)</td>
<td>.67</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>−3.7 (−5.1 to −2.4)</td>
<td>−1.5 (−2.9 to −0.2)</td>
<td>−2.2 (−4.1 to −0.3)</td>
<td>.02</td>
</tr>
<tr>
<td>Heart rate, beats/min</td>
<td>−3.9 (−5.4 to −2.4)</td>
<td>−2.2 (−3.8 to 0.5)</td>
<td>−1.8 (−4.1 to 0.5)</td>
<td>.12</td>
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<tr>
<td>Aerobic and strength fitness, mean (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak oxygen uptake, mL/kg per minute</td>
<td>4.0 (3.2 to 4.8)</td>
<td>−0.1 (−0.8 to 0.5)</td>
<td>4.1 (3.1 to 5.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Upper body muscle strength, kg</td>
<td>28.0 (23.9 to 32.1)</td>
<td>0.8 (−2.7 to 4.3)</td>
<td>27.3 (21.8 to 32.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Lower body muscle strength, kg</td>
<td>29.3 (25.0 to 33.7)</td>
<td>2.8 (−1.7 to 7.4)</td>
<td>26.5 (20.3 to 32.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Total muscle strength, kg</td>
<td>57.3 (49.6 to 64.7)</td>
<td>3.6 (−2.6 to 9.9)</td>
<td>53.7 (44.0 to 63.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Body composition, mean (95% CI)</td>
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<tr>
<td>Body mass index, kg/m²</td>
<td>−0.8 (−1.1 to −0.5)</td>
<td>−0.2 (−0.4 to 0.1)</td>
<td>−0.7 (−1.1 to −0.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>−2.3 (−3.1 to −1.4)</td>
<td>−0.5 (−1.2 to 0.1)</td>
<td>−1.7 (−2.8 to −0.7)</td>
<td>.002</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>−2.9 (−4.1 to −1.7)</td>
<td>−0.8 (−1.8 to 0.1)</td>
<td>−2.0 (−3.6 to −0.5)</td>
<td>.01</td>
</tr>
<tr>
<td>Abdominal total fat (MRI), cm²</td>
<td>−52.5 (−66.6 to −38.7)</td>
<td>−6.5 (−20.3 to 7.3)</td>
<td>−46.0 (−65.4 to −26.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Abdominal visceral fat (MRI), cm²</td>
<td>−26.7 (−35.6 to −17.9)</td>
<td>−3.8 (−10.8 to 3.3)</td>
<td>−23.0 (−34.2 to −11.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Abdominal subcutaneous fat (MRI), cm²</td>
<td>−25.8 (−35.1 to −16.5)</td>
<td>−2.9 (−11.7 to 6.0)</td>
<td>−23.0 (−35.7 to −10.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Total body fat (DXA), %</td>
<td>−3.5 (−0.04 to −2.8)</td>
<td>−0.2 (−0.7 to 0.3)</td>
<td>−3.3 (−4.1 to −2.4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Lean body mass (DXA), %</td>
<td>3.5 (2.8 to 4.2)</td>
<td>0.2 (−0.3 to 0.7)</td>
<td>3.3 (2.4 to 4.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Aortic stiffness, mean (95% CI)</td>
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<td></td>
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<tr>
<td>Pulse-wave velocity, cm/s†</td>
<td>111.2 (−35 to 257.5)</td>
<td>16.9 (−96 to 130)</td>
<td>94.4 (−276.5 to 87.8)</td>
<td>.35</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; DXA, dual-energy x-ray absorptiometry; MRI, magnetic resonance imaging.
*Test for between-group difference on the change from baseline.
†Performed in a subset of 82 participants (40 exercisers [21 men and 19 women] and 42 controls [21 men and 21 women]).
<table>
<thead>
<tr>
<th>Variable</th>
<th>Systolic Blood Pressure</th>
<th>P Value</th>
<th>Diastolic Blood Pressure</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak oxygen uptake</td>
<td>-0.04</td>
<td>.68</td>
<td>-0.24</td>
<td>.02</td>
</tr>
<tr>
<td>Total muscle strength</td>
<td>-0.03</td>
<td>.76</td>
<td>-0.23</td>
<td>.02</td>
</tr>
<tr>
<td>Weight</td>
<td>0.17</td>
<td>.09</td>
<td>0.20</td>
<td>.05</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>0.12</td>
<td>.23</td>
<td>0.14</td>
<td>.15</td>
</tr>
<tr>
<td>Waist</td>
<td>0.12</td>
<td>.23</td>
<td>0.18</td>
<td>.07</td>
</tr>
<tr>
<td>Percentage of total body fat</td>
<td>0.17</td>
<td>.08</td>
<td>0.31</td>
<td>.001</td>
</tr>
<tr>
<td>Percentage of total lean mass</td>
<td>-0.16</td>
<td>.09</td>
<td>-0.30</td>
<td>.002</td>
</tr>
<tr>
<td>Abdominal total fat</td>
<td>0.18</td>
<td>.07</td>
<td>0.24</td>
<td>.02</td>
</tr>
<tr>
<td>Abdominal visceral fat</td>
<td>0.27</td>
<td>.006</td>
<td>0.30</td>
<td>.003</td>
</tr>
<tr>
<td>Abdominal subcutaneous fat</td>
<td>0.27</td>
<td>.006</td>
<td>0.27</td>
<td>.006</td>
</tr>
<tr>
<td>Pulse-wave velocity</td>
<td>-0.17</td>
<td>.14</td>
<td>-0.11</td>
<td>.35</td>
</tr>
<tr>
<td>Total daily energy expenditure</td>
<td>-0.13</td>
<td>.18</td>
<td>-0.20</td>
<td>.04</td>
</tr>
<tr>
<td>Total daily energy intake</td>
<td>0.16</td>
<td>.11</td>
<td>0.15</td>
<td>.12</td>
</tr>
<tr>
<td>Sodium intake</td>
<td>0.10</td>
<td>.37</td>
<td>0.10</td>
<td>.34</td>
</tr>
</tbody>
</table>
Abdominal Visceral Fat and Exercise Training in Older Men and Women

P<0.01, † P <0.01 exercise versus control group differences for the change from baseline. Solid bars, men; open bars, women.

Effect of Exercise on Blood Pressure in Older Persons
A Randomized Controlled Trial

• Conclusion
  – A 6-month program of aerobic and resistance training lowered DBP but not SBP in older adults with mild hypertension more than in controls.
  – The concomitant lack of improvement in aortic stiffness in exercisers suggests that older persons may be resistant to exercise-induced reductions in SBP.
  – Body composition improvements were associated with BP reductions and may be a pathway by which exercise training improves cardiovascular health in older men and women.
  – Though the reductions in BP were significant, they were less than what is typically seen in younger person with hypertension

Stewart et al: Arch Intern Med: 165, April 11, 2005
Liver Fat

- Hepatic steatosis is leading cause of liver cirrhosis, failure, and cancer.
- Increased hepatic fat is also associated with increased cardiovascular disease risk factors such as blood pressure, cholesterol levels, insulin resistance.
MR Spectra showing relative fat concentrations in the liver. The normal control (green) has 3% fat relative to the water resonance, whereas the severe NASH (red) has 238% fat relative to the water resonance.
Changes in Hepatic Fat With Exercise

- Subjects, n=102 with T2DM, mean age 57±6 years
- Hepatic fat decreased by 1.2% in exercisers vs 0.7 in controls, p=0.03
- Exerciser were less likely to progress to NAFLD vs controls, n=1 vs n=5, p=0.04

Hepatic fat in an exerciser before and after

Baseline: 19.7% Fat

6 months: 12.1% Fat
Exercise Effects on Bone Mineral Density: Sub Study Exercise and BP in Older Persons

• Weight loss typically reduces bone mineral density (BMD)
• Exercise may preserve or increase BMD even while reducing fatness
• We examined the relationships among exercise-induced changes in fitness and fatness with BMD

<table>
<thead>
<tr>
<th>Variable (mean ± SD)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Exercise (n = 26)</th>
<th>p value for change from baseline</th>
<th>Control (n = 27)</th>
<th>p value for change from baseline</th>
<th>p value for exercisers versus controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Total skeleton</td>
<td>−0.011 ± 0.022</td>
<td>0.02*</td>
<td>0.009 ± 0.032</td>
<td>0.17</td>
<td>&lt;0.01**</td>
</tr>
<tr>
<td>Lumbar spine (L1–L4)</td>
<td>−0.01 ± 0.038</td>
<td>0.19</td>
<td>−0.017 ± 0.064</td>
<td>0.17</td>
<td>0.62</td>
</tr>
<tr>
<td>Total hip</td>
<td>−0.002 ± 0.015</td>
<td>0.39</td>
<td>−0.004 ± 0.017</td>
<td>0.22</td>
<td>0.73</td>
</tr>
<tr>
<td>Femoral neck</td>
<td>0.005 ± 0.033</td>
<td>0.43</td>
<td>−0.008 ± 0.017</td>
<td>0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>Greater trochanter</td>
<td>−0.008 ± 0.017</td>
<td>0.02*</td>
<td>−0.004 ± 0.016</td>
<td>0.27</td>
<td>0.03*</td>
</tr>
<tr>
<td>Femoral shaft</td>
<td>−0.002 ± 0.018</td>
<td>0.56</td>
<td>−0.004 ± 0.026</td>
<td>0.41</td>
<td>0.75</td>
</tr>
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</table>

**Table 4.** Change in bone mineral density from baseline in exercise and control groups by gender

<table>
<thead>
<tr>
<th>Variable (mean ± SD)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Exercise (n = 25)</th>
<th>p value for change from baseline</th>
<th>Control (n = 26)</th>
<th>p value for change from baseline</th>
<th>p value for exercisers versus controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total skeleton</td>
<td>0.021 ± 0.057</td>
<td>0.43</td>
<td>0.003 ± 0.031</td>
<td>0.64</td>
<td>0.17</td>
</tr>
<tr>
<td>Lumbar spine (L1–L4)</td>
<td>0.000 ± 0.038</td>
<td>0.98</td>
<td>0.015 ± 0.064</td>
<td>0.27</td>
<td>0.34</td>
</tr>
<tr>
<td>Total hip</td>
<td>0.001 ± 0.012</td>
<td>0.67</td>
<td>−0.002 ± 0.010</td>
<td>0.30</td>
<td>0.31</td>
</tr>
<tr>
<td>Femoral neck</td>
<td>−0.004 ± 0.021</td>
<td>0.40</td>
<td>−0.005 ± 0.019</td>
<td>0.18</td>
<td>0.76</td>
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<tr>
<td>Greater trochanter</td>
<td>0.002 ± 0.014</td>
<td>0.53</td>
<td>0.002 ± 0.013</td>
<td>0.50</td>
<td>0.99</td>
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<tr>
<td>Femoral shaft</td>
<td>0.002 ± 0.015</td>
<td>0.48</td>
<td>−0.005 ± 0.014</td>
<td>0.09</td>
<td>0.10</td>
</tr>
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</table>

SD, standard deviation.

<sup>a</sup>Values are absolute mean change from baseline. *p < 0.05 (bolded); **p < 0.01 (bolded).
Table 5. Pearson correlations of changes in bone mass density with changes in body composition and fitness by gender

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women ($n = 53$)</th>
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<tbody>
<tr>
<td></td>
<td>Total skeleton</td>
<td>Lumbar spine</td>
<td>Total hip</td>
<td>Femoral neck</td>
<td>Greater trochanter</td>
<td>Femoral shaft</td>
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<tr>
<td>Body weight</td>
<td>0.10</td>
<td>0.17</td>
<td>-0.07</td>
<td>-0.32*</td>
<td>0.18</td>
<td>-0.09</td>
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<tr>
<td>Body mass index</td>
<td>0.10</td>
<td>0.15</td>
<td>-0.05</td>
<td>-0.33*</td>
<td>0.20</td>
<td>-0.06</td>
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<tr>
<td>Body fat (%)</td>
<td>0.11</td>
<td>0.14</td>
<td>-0.07</td>
<td>-0.18</td>
<td>0.16</td>
<td>-0.14</td>
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<tr>
<td>Lean mass (%)</td>
<td>-0.12</td>
<td>-0.14</td>
<td>0.06</td>
<td>0.16</td>
<td>-0.16</td>
<td>0.13</td>
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<tr>
<td>Fat mass</td>
<td>0.05</td>
<td>0.12</td>
<td>-0.09</td>
<td>-0.25</td>
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<tr>
<td>Lean mass</td>
<td>0.04</td>
<td>-0.05</td>
<td>-0.01</td>
<td>-0.24</td>
<td>0.06</td>
<td>0.06</td>
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<tr>
<td>Abdominal total fat</td>
<td>0.19</td>
<td>0.08</td>
<td>0.02</td>
<td>-0.05</td>
<td>0.20</td>
<td>0.04</td>
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<tr>
<td>Abdominal subcutaneous fat</td>
<td>0.23</td>
<td>0.02</td>
<td>-0.01</td>
<td>-0.04</td>
<td>0.17</td>
<td>0.02</td>
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<tr>
<td>Abdominal visceral fat</td>
<td>0.04</td>
<td>0.17</td>
<td>0.05</td>
<td>-0.08</td>
<td>0.19</td>
<td>0.05</td>
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<tr>
<td>Peak oxygen uptake</td>
<td>-0.22</td>
<td>0.01</td>
<td>0.20</td>
<td>0.36*</td>
<td>-0.07</td>
<td>0.16</td>
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<tr>
<td>Upper-body strength</td>
<td>-0.17</td>
<td>0.07</td>
<td>0.06</td>
<td>0.01</td>
<td>-0.01</td>
<td>0.08</td>
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<tr>
<td>Lower-body strength</td>
<td>-0.16</td>
<td>-0.04</td>
<td>0.05</td>
<td>0.00</td>
<td>0.05</td>
<td>0.05</td>
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<tr>
<td>Total strength</td>
<td>-0.18</td>
<td>0.01</td>
<td>0.06</td>
<td>0.01</td>
<td>0.02</td>
<td>0.07</td>
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<table>
<thead>
<tr>
<th>Variable</th>
<th>Men ($n = 51$)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Total skeleton</td>
<td>Lumbar spine</td>
<td>Total hip</td>
<td>Femoral neck</td>
<td>Greater trochanter</td>
<td>Femoral shaft</td>
</tr>
<tr>
<td>Body weight</td>
<td>-0.06</td>
<td>-0.23</td>
<td>0.01</td>
<td>0.07</td>
<td>0.02</td>
<td>0.02</td>
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<tr>
<td>Body mass index</td>
<td>-0.02</td>
<td>-0.18</td>
<td>-0.05</td>
<td>0.03</td>
<td>-0.04</td>
<td>-0.01</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>-0.16</td>
<td>0.01</td>
<td>-0.11</td>
<td>-0.06</td>
<td>0.10</td>
<td>-0.22</td>
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<tr>
<td>Lean mass (%)</td>
<td>0.15</td>
<td>-0.02</td>
<td>0.12</td>
<td>0.07</td>
<td>-0.10</td>
<td>0.24</td>
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<tr>
<td>Fat mass</td>
<td>-0.20</td>
<td>-0.10</td>
<td>-0.09</td>
<td>-0.05</td>
<td>0.10</td>
<td>-0.18</td>
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<tr>
<td>Lean mass</td>
<td>0.25</td>
<td>-0.20</td>
<td>0.29*</td>
<td>0.21</td>
<td>0.01</td>
<td>0.43**</td>
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<tr>
<td>Abdominal total fat</td>
<td>-0.04</td>
<td>-0.09</td>
<td>0.01</td>
<td>-0.04</td>
<td>0.01</td>
<td>0.10</td>
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<tr>
<td>Abdominal subcutaneous fat</td>
<td>-0.14</td>
<td>-0.23</td>
<td>-0.12</td>
<td>-0.05</td>
<td>-0.04</td>
<td>-0.08</td>
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<tr>
<td>Abdominal visceral fat</td>
<td>0.05</td>
<td>0.04</td>
<td>0.11</td>
<td>-0.03</td>
<td>0.04</td>
<td>0.21</td>
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<tr>
<td>Peak oxygen uptake</td>
<td>-0.19</td>
<td>-0.13</td>
<td>0.07</td>
<td>-0.08</td>
<td>0.01</td>
<td>0.15</td>
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<tr>
<td>Upper-body strength</td>
<td>0.21</td>
<td>-0.08</td>
<td>0.02</td>
<td>0.02</td>
<td>-0.18</td>
<td>0.17</td>
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<tr>
<td>Lower-body strength</td>
<td>0.25</td>
<td>0.10</td>
<td>0.28*</td>
<td>-0.04</td>
<td>0.11</td>
<td>0.40**</td>
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<tr>
<td>Total strength</td>
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<td>0.01</td>
<td>0.17</td>
<td>-0.01</td>
<td>-0.03</td>
<td>0.32*</td>
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</tbody>
</table>

* $p < 0.05$ (bolded); ** $p < 0.01$ (bolded).
Conclusion on bone from this study

• The overall effect of exercise on BMD was minimal.
• However, there was considerable variation in response, and BMD was modestly increased in those participants with the greatest improvements in fitness and leanness.
• Reduced BMD that is typically associated with reduced fatness did not occur when fatness was reduced by exercise, suggesting that exercise may reduce the loss of bone with aging.
• A more intense program at specific bone sites and of longer duration may be required to enhance BMD in older persons.

ACSM/AHA Guidelines for Physical Activity in Older Adults

- Adults ≥ 65 years
- 50–64 years with impairment and limitation

Increased fall risk: follow AGS, BGS, AAOS guidelines

Health history

- At risk of falls: include exercises to maintain or improve balance

Multifactorial physical activity + activity plan

Aerobic: 5 d/wk MI, or 3 d/wk for V1
MI: accumulate 30 min/d (10 min bouts)
V1: continuous for at least 20 min

Strength: at least 2 d/wk, 8–10 exercises with major muscle groups, at least 1 set, 10–15 repetitions

Flexibility: 2 d/wk for 10 min/d

Improve physical function

Prevent disability?

Monitor adherence and promote community approaches to PA
Some key features of aerobic and resistance exercise
Aerobic Exercise

• Increases heart rate and breathing for extended periods of time
• Requires a steady supply of oxygen to promote sustained activity, e.g., walking, jogging, swimming, cycling
• Improves the health of the heart, lungs, and circulation
• Shown to help prevent or delay some diseases
Resistance Exercise

- Exercise is done against a force or resistance such as weightlifting
- Increases muscle strength and endurance
- Increases muscle mass which is the key to higher metabolism
Recommendations for resistance training:
Minimum of one exercise per major muscle group

- Chest
- Shoulders
- Arms
- Back
- Abdomen
- Thighs
- Lower legs
Aerobic and Resistance Training

• Both training modalities promote benefits in physical fitness and health-related factors

• The estimated weightings in terms of physiological benefits are often substantially different
Aerobic exercise has a greater beneficial impact on:

- Maximal oxygen uptake
- Heart rate and stroke volume
- Submaximal and maximal exercise time
- Blood pressure though some studies show greater benefits from resistance exercise
- Percent body fat
Resistance training has a greater beneficial impact on:

- Muscular strength and endurance
- Lean body mass
- Basal metabolic rate
- Preventing frailty and falls in the elderly
Aerobic and resistance training have similar beneficial effects on:

• Bone mineral density
• Glucose tolerance and insulin sensitivity
• Weight control
  – Aerobic exercise burns more calories
  – Resistance training assists in energy expenditure by increasing lean body mass and basal metabolism
<table>
<thead>
<tr>
<th>Variable</th>
<th>Aerobic Exercise</th>
<th>Resistance Exercise</th>
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</thead>
<tbody>
<tr>
<td>Body composition</td>
<td></td>
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<tr>
<td>Bone mineral density</td>
<td>††</td>
<td>††</td>
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<tr>
<td>Percent body fat</td>
<td>↓↓</td>
<td>↓</td>
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<tr>
<td>Lean body mass</td>
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<td>††</td>
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<tr>
<td>Muscle strength</td>
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<tr>
<td>Glucose metabolism</td>
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<tr>
<td>Insulin response to glucose challenge</td>
<td>↓↓</td>
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<tr>
<td>Basal insulin levels</td>
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<tr>
<td>Insulin sensitivity</td>
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<tr>
<td>Plasma lipids and lipoproteins</td>
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<tr>
<td>HDL cholesterol</td>
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<tr>
<td>LDL cholesterol</td>
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<tr>
<td>Triglycerides</td>
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<tr>
<td>Cardiovascular dynamics</td>
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<tr>
<td>Resting heart rate</td>
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<tr>
<td>Stroke volume, resting and maximal</td>
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<tr>
<td>Cardiac output, rest</td>
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<tr>
<td>Cardiac output, maximal</td>
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<tr>
<td>SBP at rest</td>
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<tr>
<td>DBP at rest</td>
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</tr>
<tr>
<td>$\dot{V}O_2_{\text{max}}$</td>
<td>†††</td>
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<tr>
<td>Submaximal and maximal endurance time</td>
<td>†††</td>
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<tr>
<td>Submaximal exercise rate-pressure product</td>
<td>†††</td>
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<tr>
<td>Basal metabolic rate</td>
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<tr>
<td>Health-related quality of life</td>
<td>†0</td>
<td>†0</td>
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</tbody>
</table>

† Indicates values increase; ↓, values decrease; 0, values remain unchanged; 1 arrow, small effect; 2 arrows, moderate effect; 3 arrows, large effect; HDL, high-density lipoprotein cholesterol; and LDL, low-density lipoprotein cholesterol. Adapted with permission from Pollock and Vincent.11
## Psychological Benefits of Physical Activity for Older Persons (WHO)

### Immediate Benefits
- Relaxation
- Stress and anxiety
- Enhanced mood state

### Long Term Effects
- General well-being
- Improved mental health
- Cognitive improvement
- Motor control and performance
- Skill acquisition
Social Benefits of Physical Activity for Older Persons (WHO)

**Immediate Benefits**
- Empowering older individuals
- Enhanced social and cultural integration

**Long Term Effects**
- New friendships
- Widened social and cultural networks
- Role maintenance/new role acquisition
- Enhanced intergenerational activity
Enhanced Intergenerational Activity

82

59

32

Not telling
Yet Another Generation
The Future: Gene Therapy?

The techniques currently available to do this are so inefficient that gene replacement is not yet practical for most of the chronic health conditions that emerge in older age.
Regular physical activity that is performed on most days of the week reduces the risk of developing or dying from some of the leading causes of illness and death in the United States. Millions of Americans suffer from illnesses that can be prevented or improved through regular physical activity.

Center for Disease Control: Physical Activity and Health.
From: Association of Daily Step Count and Step Intensity With Mortality Among US Adults


NHANES. Step measured by pedometer 2003-2006, mortality ascertained through 2015. n=4840. Mortality rates adjusted for age; diet; sex; race/ethnicity; BMI; education; alcohol consumption; smoking; 7 comorbid conditions; mobility limitations; and self-reported HRQOL.
“Le Sage et la Goutte”
Poem by Madame Brillon to Benjamin Franklin when he was bedridden by Gout in October 1780

“Moderation, dear Doctor,” said the Gout, “Is no virtue for which you stand out, You like food, you like ladies’ sweet talk, You play chess when you should walk.”