Promoting Healthful Interventions: Exercise and Aging

MCB 135K

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Integrative Biology, UCB
I. Does Exercise Prevent Aging?

II. Does Exercise Slow Aging or Compensate for Aging Effects?

III. Why Exercise?

IV. How to Exercise?
Does Exercise Prevent Aging?

- Yes?!
- No?!
- Exercise Slows Aging and Compensates for Aging Effects.
Why Exercise?

- Cardiovascular Fitness & Health
- Metabolic Fitness & Health
- Muscular-Skeletal Strength, Flexibility & Health
- Freedom From Injury
- Antioxidant Defenses
- Sense of Well Being
Cardiovascular Fitness & Health

- Maximal Oxygen Consumption (VO$_2^{\text{max}}$) is the standard for cardiovascular fitness
- VO$_2^{\text{max}}$ is increased by regular, prolonged exercise
- VO$_2^{\text{max}}$ declines with aging, but can be maintained at high levels despite advancing years.
Leg Cycler Ergometer Evaluation of Maximal $O_2$ Consumption ($VO_2\text{max}$)
Treadmill Evaluation of Maximal O$_2$ Consumption (VO$_2$max)
Treadmill Evaluation of a Cardiac Patient- Exercise Stress Test
Figure 1-7  Relationship between oxygen consumption ($\dot{V}_{O_2}$) and external work rate (power output). In response to increments in power output, both trained and untrained individuals respond with an increase in $\dot{V}_{O_2}$. The greater ability of trained individuals to sustain a high power output is largely due to a greater maximal $O_2$ consumption ($\dot{V}_{O_2\text{max}}$).
Figure 32-1 (b) $y = V_{O2\text{max}}$ (ml • kg$^{-1}$ • min$^{-1}$). Although training will improve $V_{O2\text{max}}$ and the quality of life in the elderly, it will not prevent indefinitely the decline in functional capacity. $x = \text{age (hr)}$. Adapted from Suominen et al., 1980.
Cardiovascular Fitness & Health

- Regular prolonged exercise offers protection against having cardiovascular disease (Decreases Morbidity)
- Regular prolonged exercise offers protection against dying from cardiovascular disease (Decreases Mortality)
Figure 24-6  Deaths from CHD in longshoremen according to physical activity of work (range in kcal • min-1) and age at death. Shaded bars = heavy activity (5.2 - 7.5 kcal • min-1); unshaded bars = moderate and light activity (1.5 - 5.0 kcal • min-1). The relative risk of developing CHD for moderate and light exercise groups compared to heavy exercise groups given above bars. Adapted from Paffenbarger and Hale, 1975.
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Metabolic Fitness & Health

- Regular Physical Exercise Helps to Control Age-Related Increases in Body Fatness
- Regular Physical Exercise Reduces the Incidence and Severity of Type II Diabetes (NIDDM).
U.S. Obesity Trends in Adults


Prevalence of Obesity* Among U.S. Adults

BRFSS, 1991

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)

<10%  10% to 15%  >15%  N/A
Prevalence of Obesity* Among U.S. Adults
BRFSS, 1992

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)
Prevalence of Obesity* Among U.S. Adults
BRFSS, 1993

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)
Prevalence of Obesity* Among U.S. Adults
BRFSS, 1994

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)
Prevalence of Obesity* Among U.S. Adults
BRFSS, 1995

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)
Prevalence of Obesity* Among U.S. Adults
BRFSS, 1996

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)
Prevalence of Obesity* Among U.S. Adults

BRFSS, 1997

(“BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)

No Data <10% 10%-14% 15-19% ≥20%

Source: BRFSS, CDC.
Prevalence of Obesity* Among U.S. Adults

BRFSS, 1998

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)

No Data  <10%  10%-14%  15-19%  ≥20%

Source: BRFSS, CDC
Prevalence of Obesity* Among U.S. Adults

BRFSS, 1999

(“BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)

No Data <10% 10%-14% 15-19% ≥20%

Source: BRFSS, CDC.
Prevalence of Obesity* Among U.S. Adults

BRFSS, 2000

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)

Obesity* Trends Among U.S. Adults
(*BMI ≥ 30, or ~ 30 lbs. overweight for 5’4” person)

Prevalence of Obesity* Among U.S. Adults
BRFSS, 20??
(*Approximately 30 pounds overweight)
A darkening scene. The percentage of adults with diabetes increased throughout the United States between 1990 (top) and 2000 (bottom).

Councilmember Miriam Hawley (right) tests out the Segway Human Transporter in front of the Civic Center Tuesday with the help of Stacy Ferguson (left), Segway's director of public affairs. "It's a wonderful thing (the Segway)," Hawley said. "I think it's a great mobility device."
IN THE BEGINNING…

And Now…
Figure 25-2  Relationship of body mass index and the risk of death from all causes.
Actual Causes of Death in the United States, 1990*

*Numbers approximated from various studies that used different approaches to derive estimates.

Contribution of Overweight and Obesity to Mortality from Cancer in the United States.
Data are from the Cancer Prevention Study II, 1982 through 1998.

Figure 1. Summary of Mortality from Cancer According to Body-Mass Index for U.S. Men in the Cancer Prevention Study II, 1982 through 1998.

For each relative risk, the comparison was between men in the highest body-mass-index (BMI) category (indicated in parentheses) and men in the reference category (body-mass index, 18.5 to 24.9). Asterisks indicate relative risks for men who never smoked. Results of the linear test for trend were significant (P<0.05) for all cancer sites.
Crossover Concept

- Exercise prescriptions to oxidize body fat need consider the Crossover Concept
- At exercise intensities eliciting greater than 45-50% VO_{2}\text{max}, the body fuel selection switches, crossover from, preponderance of lipid to mainly carbohydrate (glycogen, glucose, lactate).
Crossover Concept

Exercise Easier & Longer

% CHO or Fat vs. % VO₂ max

% Fat
% CHO
Figure 2. Cumulative Incidence of Diabetes According to Study Group.

The diagnosis of diabetes was based on the criteria of the American Diabetes Association. The incidence of diabetes differed significantly among the three groups (P<0.001 for each comparison).
Exercise Recommendation

- If you like the lecture,

- Take a Hike.
Mild - Moderate Exercise

Bear Valley Trail - Pt Reyes
Bear Valley Trail to Arch Rock-Pt Reyes
Exercise Recommendation

- If you don’t like the lecture
Exercise Recommendation

- If you don’t like the lecture,

  Take a Hike.
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Figure 18-5 A motor unit, consisting of a cell body, the outgrowing α motoneuron, and all of the muscle fibers it innervates. In this drawing, only two fibers are shown; in reality the number of muscle cells in a single motor unit ranges from several hundred to several thousand.
Figure 17-1  Muscle tissue is composed of muscle bundles (fascicles), muscle fibers (cells), myofibrils, and myofilaments (actin and myosin). From Edington and Edgerton
Figure 19-8 Relationship between number of motor units (MUs) and age in young and older men and women. There was a significant reduction in numbers of MUs with age ($P < 0.001$). Adapted from Doherty et al., 1993.
Figure 19-11 Weekly measurements of dynamic muscle strength (1-repetition maximum) of left knee extensors and flexors. Results are means ± SE. From Frontera et al., 1988. Used with permission.
Figure 19-2  Serial sections of quadriceps muscle from two different athletes, stained with two different stains: (a) and (b) from an outstanding sprinter, (c) and (d) from an outstanding distance runner. Sections (a) and (c) are stained for succinic dehydrogenase (SDHase); (b) and (d) stained for alkaline myofibrillar-ATPase stain (M-ATPase). Note that fast fibers, which stain dark with M-ATPase, often are pale and stain weakly with SDHase. FT = fast-twitch fibers; ST = slow-twitch fibers. Note the two dark FT fibers in (d), which also stain dark for SDHase in (c). These are FOG fibers (see Figure 18-15). SOURCE: Gollnick, et al., 1972. Used with permission.
Figure 19-13  Effects of strength training on the area of type I and type II fibers of vastus lateralis muscle of the left leg. Results are means ± SE. * Different from pretraining measurements ($P < 0.05$). SOURCE: Frontera et al., 1988. Used with permission.
John Turner: Age 67
Helen Zechmeister, Age 81

Source: W. Evans
Professor Paola Timiras, 21+
Figure 17-3  An electron micrograph of a mature skeletal muscle from a ten-year-old boy. A satellite cell (Sat) is visible between the muscle (M) fiber’s plasma membrane (Pm) and the basement membrane (Bm). Fibroblasts (Fib) are visible in the extracellular space. Bar = 7 µm. SOURCE: H. Ishikawa, 1966.
Detection of nuclei in the active phase of growth. Nuclei in the active phase of growth were identified on day 4 (A) and day 8 (B) in the exercised leg only using a Ki-67 antibody. Areas positive for Ki-67 stained brown while the nuclei were counterstained blue using haematoxylin.
Does Exercise Result in Satellite Cell Activation and Muscle Cell Hyperplasia?

Can Satellite Cell Activation be used to Manage Sarcopenia in Aging?
How to Exercise
New Technology-Plyometrics

Dr. Stan Lindstedt, NAU

Pronghorn Antelope
Muscles as springs: Absorbed energy is stored and recovered e.g., during running

- Elastic recoil potential energy is used in running locomotion to enhance force production in the subsequent stride.
- This property of muscle is both time-dependent and adaptable.
- Despite their prevalence in movement, lengthening (eccentric) contractions are poorly understood.

Lindstedt et al., NIPS, 2001
If the force applied to a muscle exceeds the force generated by it, muscle absorbs mechanical work.

The absorbed work can be dissipated as heat (muscle acts like a shock) e.g., when hiking downhill.
Lengthening contractions - clinical applications

- **Unique Properties**
  - Maximum force production is MUCH (2-3x) greater (stimulus for muscle hypertrophy)
  - Energy cost to produce force is MUCH (1/5) lower

- **Unique Application**
  - Chronic eccentric training may be ideal for improving locomotor muscle size, strength and performance in individuals for whom exercise is limited by oxygen uptake or delivery (e.g., CHF, COPD).

*Lindstedt et al., J. exp. Biol., 2002*
Eccentric Ergometer

3 hp motor drives pedals in reverse direction, the subject resists this movement while attempting to match target on screen.

LaStayo et al., Am. J. Physiol., 2000
Adverse Responses?

- No significant leg pain
- No significant rise in serum creatine kinase
- No significant drop in isometric force production
Leg Strength

- Isomeric leg strength was measured weekly.
- To account for learning, we used week three values as “baseline”
- Concentric controls improved by 18%
- Plyometric subjects improved by 60%
Strength and Fall-Risk

Isometric Strength (N)

High Fall Risk
Low Fall Risk

Plyometric Training
Weeks of Training

Exercise Intensity (RPE)

- Very Very Hard
- Very Hard
- Hard
- Somewhat Hard
- Fairly Light
- Very Light
- Very Very Light

Weeks of Training

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
Exercise Intensity (RPE)

Weeks of Training

Very Very Light
Very Light
Fairly Light
Somewhat Hard
Hard
Very Hard
Very Very Hard

Total Negative Torque (Nm)

Exercise Intensity (RPE) Chart

- Exercise intensity levels range from Very Very Light to Very Very Hard.
- Total negative torque values range from -300 to -0 Nm.

Graph shows changes in exercise intensity and total negative torque over weeks of training.
Will plyometric (eccentric) exercises prove more effective than typical concentric exercises in promoting muscle hyperplasia by activating satellite cells?
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- Sense of Well Being
Muscular-Skeletal Strength, Flexibility & Health

- Muscle Strength Can Increase In the Aged
- Exercise Has a Role in Developing and Maintaining the “Bone Bank”
- Increased Strength and Coordination Can Help Prevent Falls and Consequent Injuries
### Osteoporosis

**Annual Incidence of Common Diseases In Women**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoporotic Fractures</td>
<td>&gt; 1,000,000</td>
</tr>
<tr>
<td>Heart Attack</td>
<td>513,000</td>
</tr>
<tr>
<td>Stroke</td>
<td>228,000</td>
</tr>
<tr>
<td>Breast Cancer</td>
<td>182,000</td>
</tr>
<tr>
<td>Uterine Cancer</td>
<td>32,000</td>
</tr>
<tr>
<td>Ovarian Cancer</td>
<td>26,000</td>
</tr>
<tr>
<td>Cervical Cancer</td>
<td>15,800</td>
</tr>
</tbody>
</table>

*Source: CDC & W. Evans*
OSTEOPOROSIS

Associated with 1.3 Million Fractures Each Year

> 250,000 hip fractures
> 240,000 wrist fractures
> 500,000 spinal fractures

Source: CDC & W. Evans
Stress and Bone Density

- 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

Source: W. Evans
Effects of strength training on balance:

Backward Tandem Walk Time

Source: W. Evans
Freedom From Injury

Freedom From Injury = Freedom of Movement
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- Sense of Well Being
Antioxidant Defenses

- Regular Physical Exercise Helps to Increase or Maintain Control Age-Related Decreases in Muscle Mitochondrial Mass and Antioxidant Defenses

- Training can result in **100% Increments** in Mitochondrial Mass, Oxidative (Respiratory Enzymes) and Related Enzymes for Defense Against Oxygen-Free Radicals
Figure 17-1  Muscle tissue is composed of muscle bundles (fascicles), muscle fibers (cells), myofibrils, and myofilaments (actin and myosin). From Edington and Edgerton
Figure 6-3  Cross sections of human skeletal muscle tissue illustrating the sampling design used for analyzing muscle respiratory structures. The low-level magnification is used for assessing capillarity and fiber size. The intermediate magnification allows for estimating the volume density of mitochondria and other sarcoplasmic components. The highest magnification allows measurement of mitochondria compartmental spaces and membrane surface areas (arrows = capillaries; c= capillary; e = erythrocyte; mc = central mitochondria; mf = myofibrils; cr = cristae; g = glycogen; gm = mitochondrial granule; ma = matrix; im = intermembrane space; om = outer mitochondrial membrane. SOURCE: Hoppeler, 1986. Used with permission.
Figure 6-4  Cross section of a portion of a human muscle fiber exposing the A-and I-band and the Z-line regions. Lipid droplets (li) are seen in contact with mitochondria (m). It is evident that the mitochondria in this muscle fiber form an extensively branched tubular network, or reticulum. SOURCE: Hoppeler, 1986. Used with permission.
Metabolic Fitness & Health

- Regular Physical Exercise Helps to Control Age-Related Decreases in Lean Body (Muscle) Mass
- Regular Physical Exercise Helps to Increase or Maintain Control Age-Related Decreases in Muscle Mitochondrial Mass and Antioxidant Defenses
Why Exercise?

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Sense of Well Being

- Physical Exercise Improves Mood
- Physical Exercise May Promote Increases in Levels of Brain-Derived Neurotrophic Factor (BDNF) and other Growth Factors (IGF & FGF).
- BDNF Expression Appears to Increase In Activity- and Cognition-Related Areas such as the Hippocampus.
From: Carl W. Cotman & Nicole C. Bechtold, Institute for Brain Aging and Dementia and Department of Neurology, UC, Irvine
Alzheimer’s Foundation of America

- Participate in activities that stimulate your brain, such as reading, crossword puzzles.
- Play bridge, and other mental exercises.
- Be social. Maintaining a network of friends will lessen the likelihood of isolation and depression while increasing the overall level of brain stimulation.
- Exercise daily, such as walking 30 minutes per day. Physical activity significantly lessens the chance of cardiovascular complications that could cause dementia.
Control hypertension, diabetes and heart disease—risk factors for dementia—through physical exercise, quitting smoking, controlling blood pressure, lowering cholesterol, and avoiding obesity.

Follow a healthy diet and take vitamins, including vitamins C and E, and folic acid.

Limit alcohol consumption. Alcohol has a direct toxic effect on the brain that adds to the loss of nerve cells and synapses.
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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 not 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
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Exercise Recommendation

Take a Hike.