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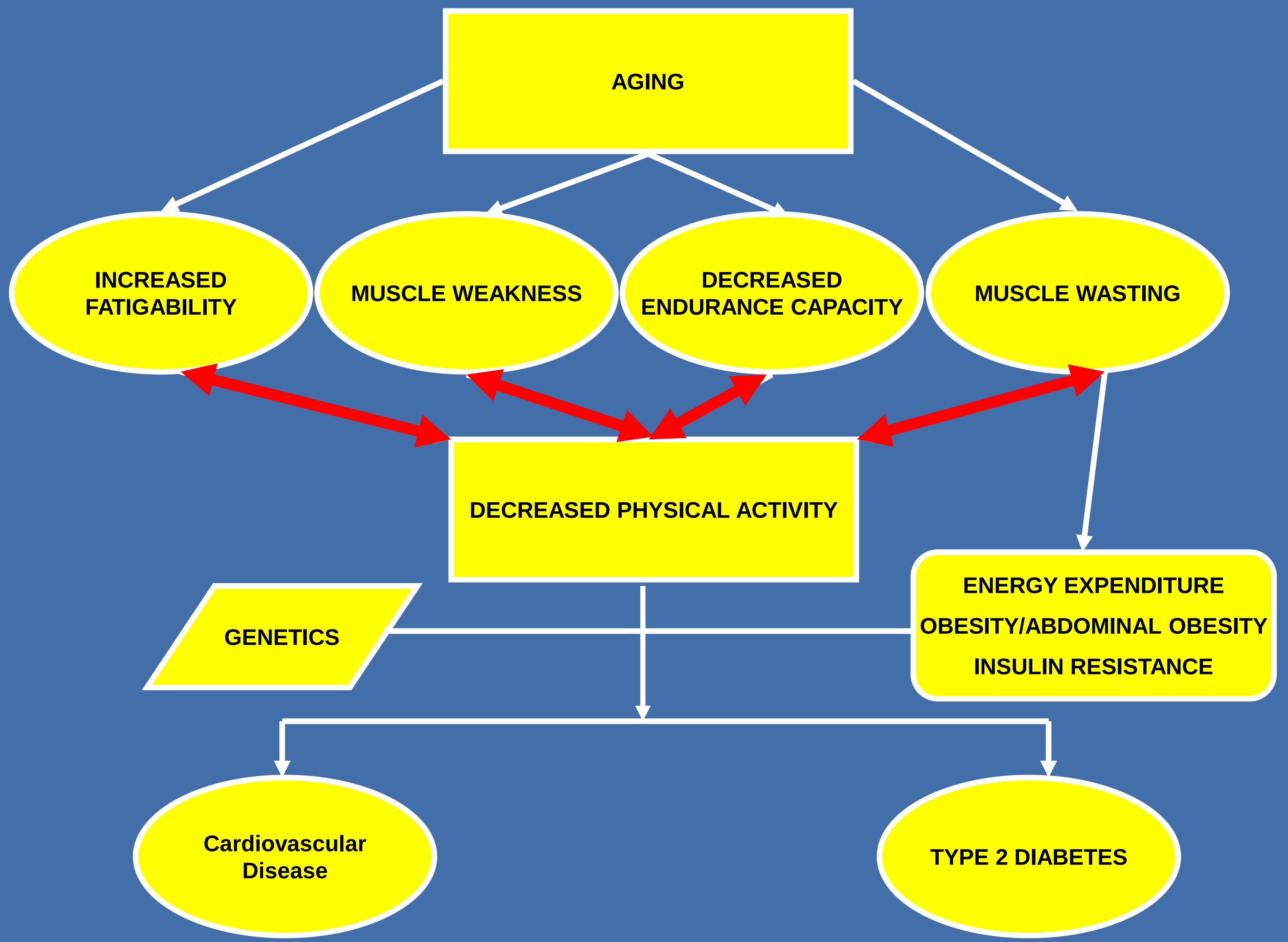
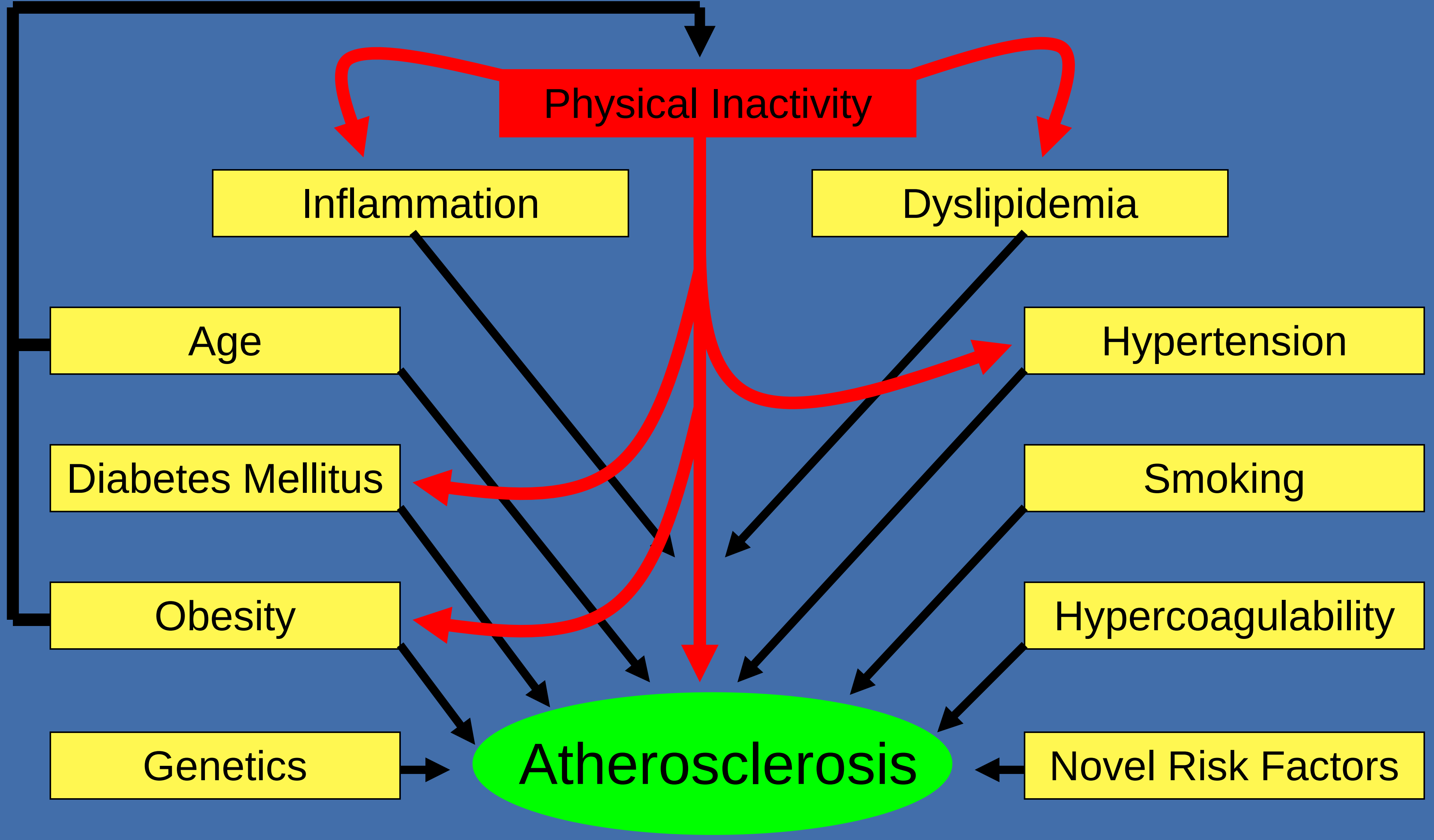
Exercise: Picking Up the Pace to Slow the Aging Process



AGING
INCREASED FATIGABILITY
MUSCLE WEAKNESS
DECREASED ENDURANCE CAPACITY
MUSCLE WASTING
DECREASED PHYSICAL ACTIVITY
GENETICS
ENERGY EXPENDITURE
OBESITY/ABDOMINAL OBESITY
INSULIN RESISTANCE
Cardiovascular Disease
TYPE 2 DIABETES

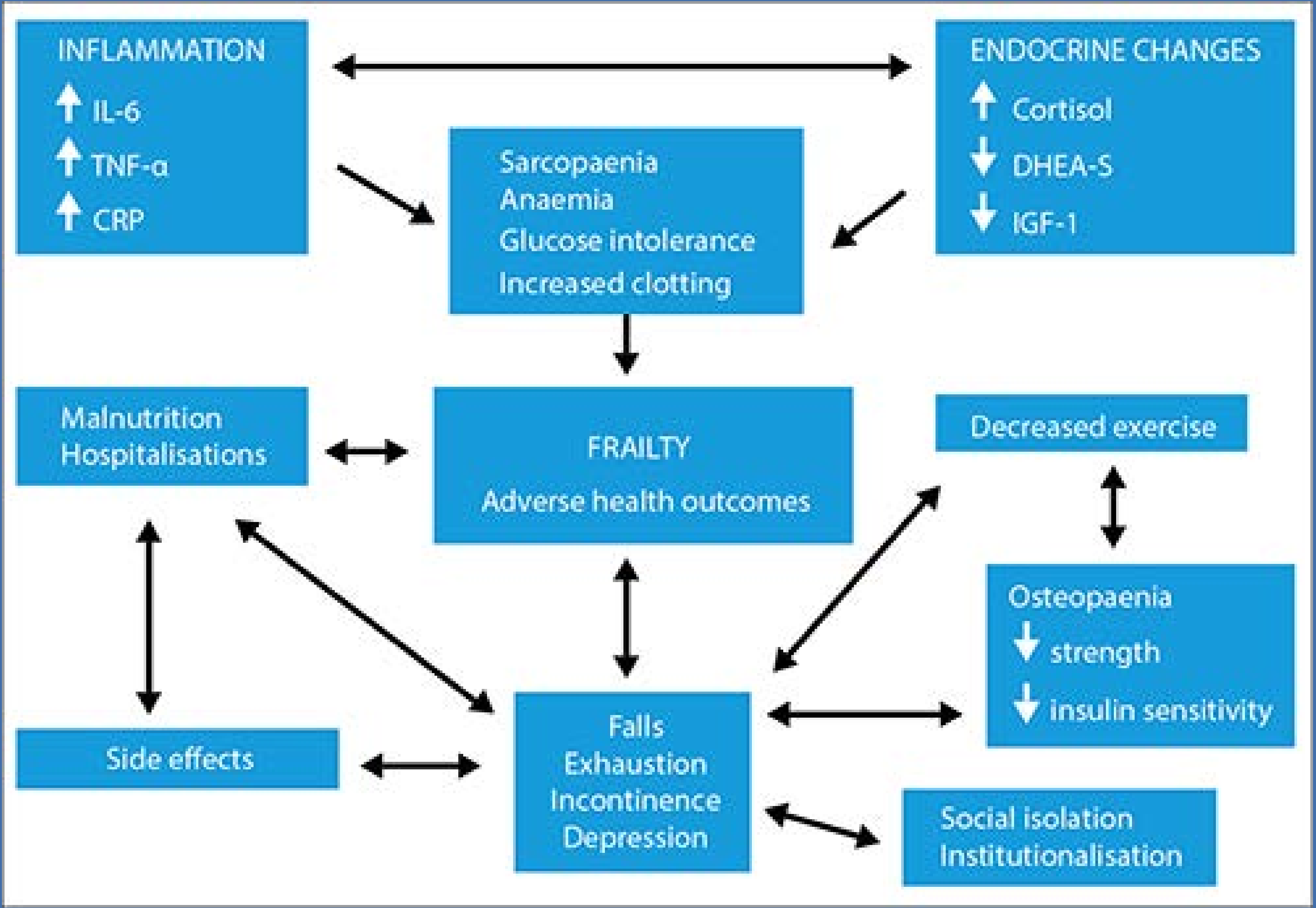
Risk Factors for Atherosclerosis



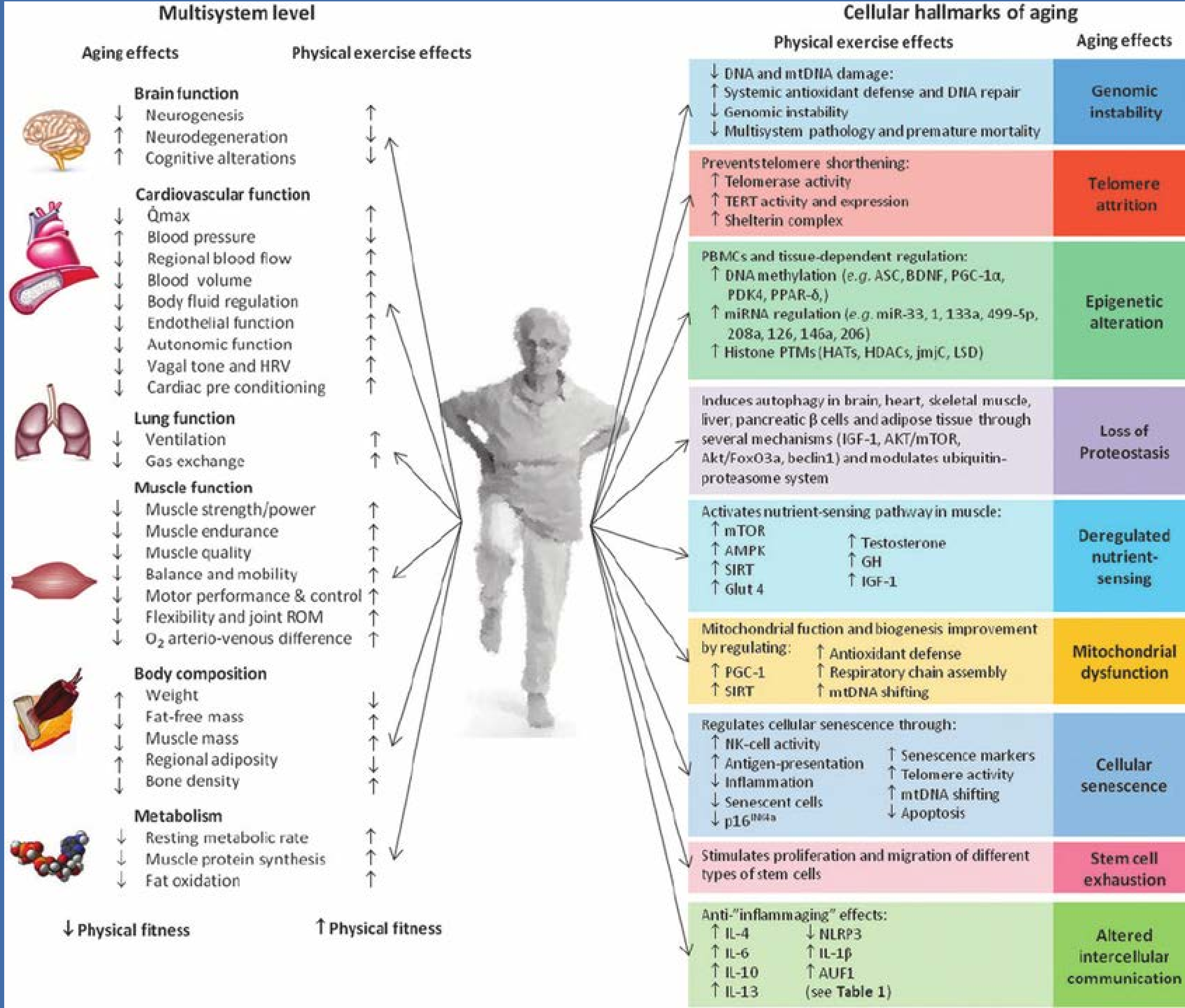
Frailty

- 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



de Villiers CME Vol 31, No 10 (2013)



Multisystem level
Aging effects
Physical exercise effects
Brain function
↓ Neurogenesis ↑
↑ Neurodegeneration ↓
↑ Cognitive alterations ↓
Cardiovascular function
↓ Q̇max ↑
↑ Blood pressure ↓
↓ Regional blood flow ↑
↓ Blood volume ↑
↓ Body fluid regulation ↑
↓ Endothelial function ↑
↓ Autonomic function ↑
↓ Vagal tone and HRV ↑
↓ Cardiac pre conditioning ↑
Lung function
↓ Ventilation ↑
↓ Gas exchange ↑
Muscle function
↓ Muscle strength/power ↑
↓ Muscle endurance ↑
↓ Muscle quality ↑
↓ Balance and mobility ↑
↓ Motor performance & control ↑
↓ Flexibility and joint ROM ↑
↓ O_2 arterio-venous difference ↑
Body composition
↑ Weight ↓
↓ Fat-free mass ↑
↓ Muscle mass ↑
↑ Regional adiposity ↓
↓ Bone density ↑
Metabolism
↓ Resting metabolic rate ↑
↓ Muscle protein synthesis ↑
↓ Fat oxidation ↑
↓ Physical fitness
↑ Physical fitness
Cellular hallmarks of aging
Physical exercise effects
Aging effects
↓ DNA and mtDNA damage:
↑ Systemic antioxidant defense and DNA repair
↓ Genomic instability
↓ Multisystem pathology and premature mortality
Genomic instability
Prevents telomere shorthening:
↑ Telomerase activity
↑ TERT activity and expression
↑ Shelterin complex
Telomere attrition
PBMCs and tissue-dependent regulation:
↑ DNA methylation (e.g. ASC, BDNF, PGC-1α, PDK4, PPAR-δ,)
↑ miRNA regulation (e.g. miR-33, 1, 133a, 499-5p, 208a, 126, 146a, 206)
↑ Histone PTMs (HATs, HDACs, jmjC, LSD)
Epigenetic alteration
Induces autophagy in brain, heart, skeletal muscle, liver, pancreatic β cells and adipose tissue through several mechanisms (IGF-1, AKT/mTOR, Akt/FoxO3a, beclin1) and modulates ubiquitin-proteasome system
Loss of Proteostasis
Activates nutrient-sensing pathway in muscle:
↑ mTOR
↑ AMPK
↑ SIRT
↑ Glut 4
↑ Testosterone
↑ GH
↑ IGF-1
Deregulated nutrient-sensing
Mitochondrial fuction and biogenesis improvement by regulating:
↑ PGC-1
↑ SIRT
↑ Antioxidant defense
↑ Respiratory chain assembly
↑ mtDNA shifting
Mitochondrial dysfunction
Regulates cellular senescence through:
↑ NK-cell activity
↑ Antigen-presentation
↓ Inflammation
↓ Senescent cells
↓ $p16^{INK4a}$
↑ Senescence markers
↑ Telomere activity
↑ mtDNA shifting
↓ Apoptosis
Cellular senescence
Stimulates proliferation and migration of different types of stem cells
Stem cell exhaustion
Anti-"inflammaging" effects:
↑ IL-4
↑ IL-6
↑ IL-10
↑ IL-13
↓ NLRP3
↑ IL-1β
↑ AUF1
(see Table 1)
Altered intercellular communication

WHO Health Fitness Gradient

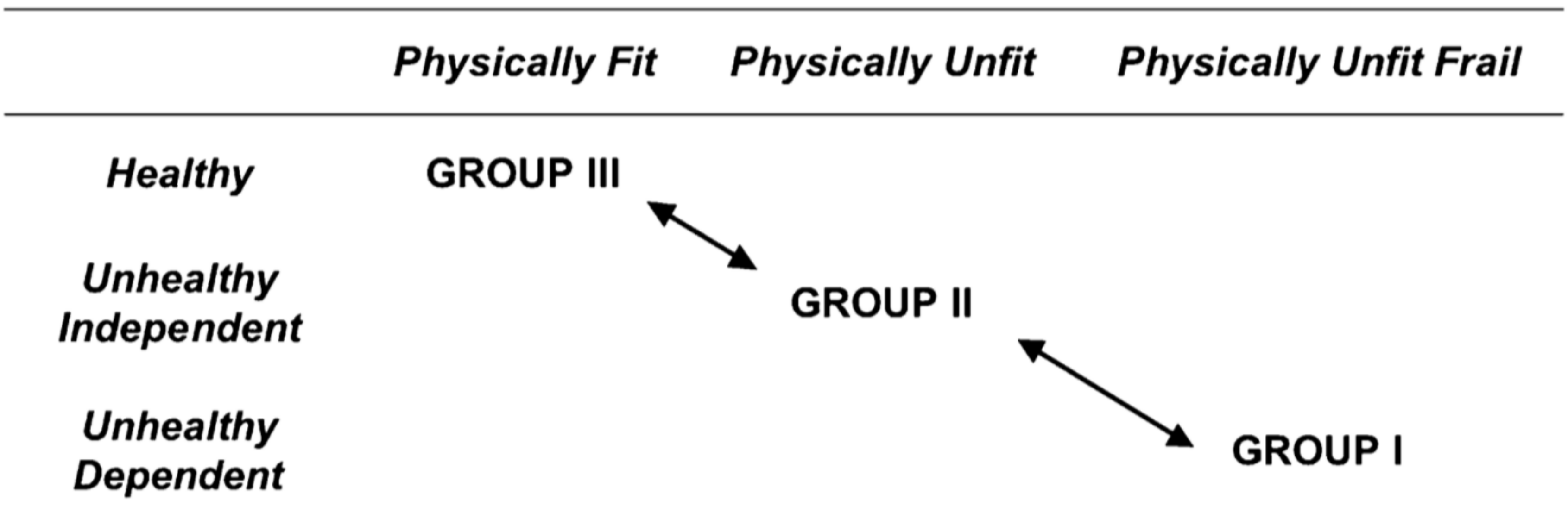


FIGURE 3. World Health Organization health-fitness gradient. Most older adults fall along this continuum, with good health at one end, and physical frailty at the other. Exercise can improve health and fitness status, whereas a lack of exercise will accelerate its decline.

Stewart Ann. N.Y. Acad. Sci. 1055:193-206. (2005)

Physical Activity and Aging

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- 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.

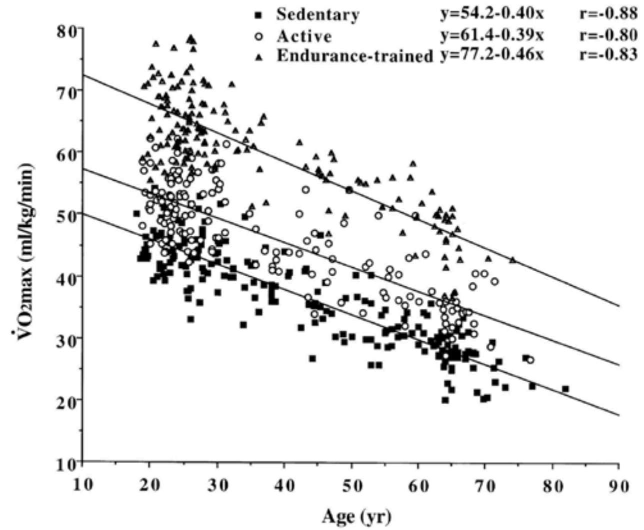
FRANKLIN. What have I done to merit these cruel sufferings?
GOUT. Many things; you have ate and drank too freely, and too much indulged those legs of yours in their indolence.
FRANKLIN. Who is it that accuses me?
GOUT. It is I, even I, the Gout
FRANKLIN. What! my enemy in person? For you would not only 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

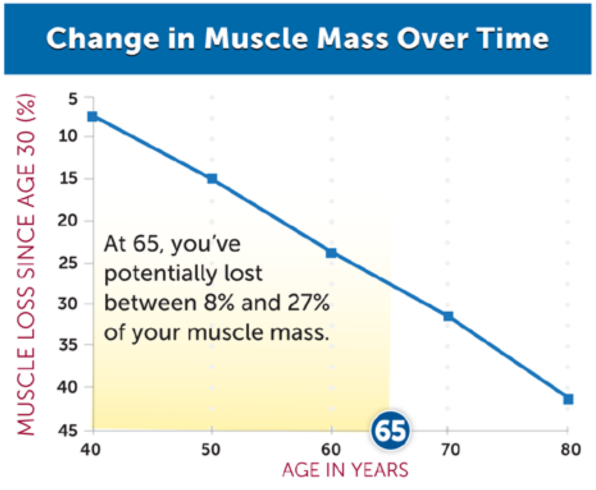
Aerobic capacity, muscle mass, and strength

- 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.



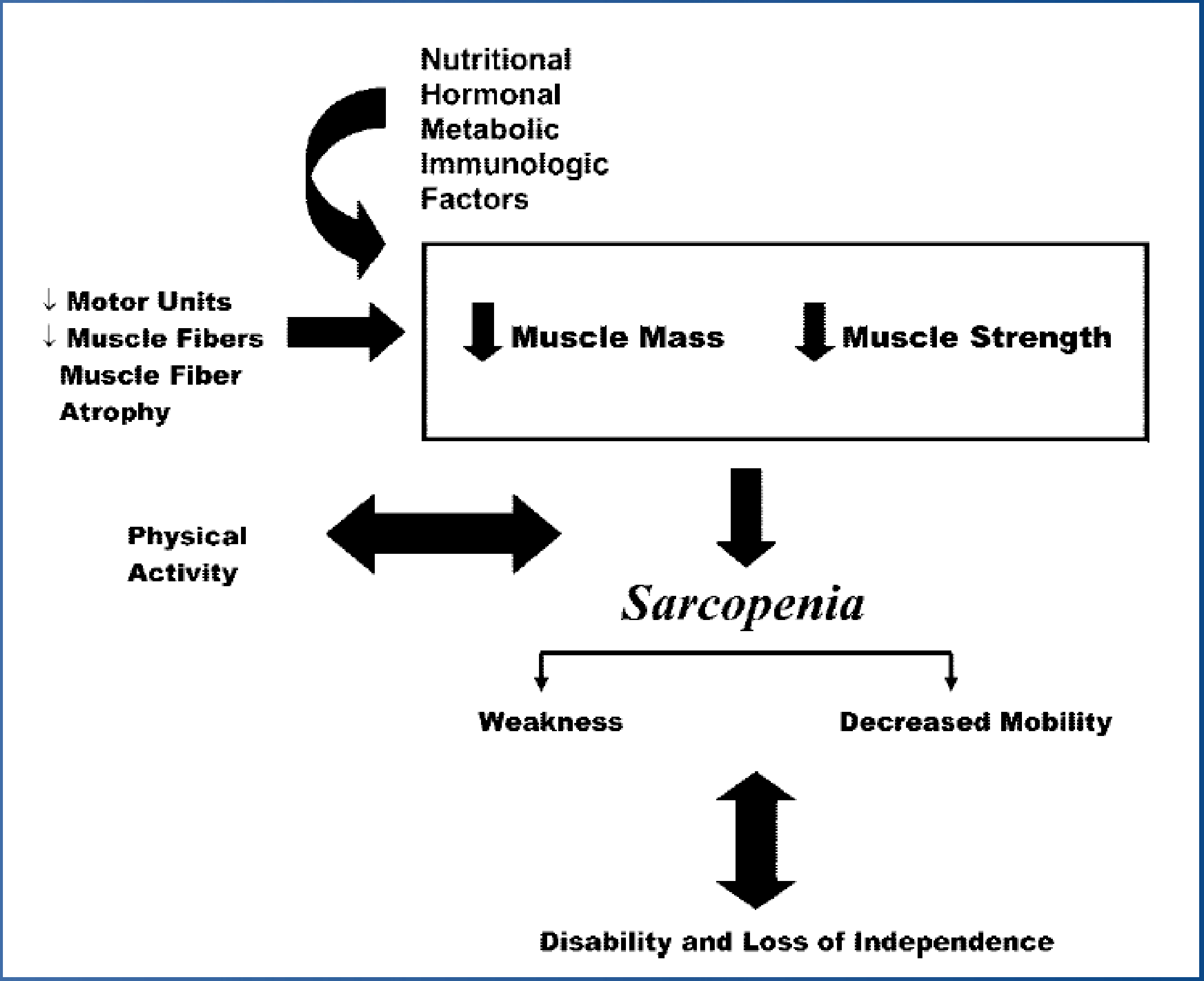
Age-related decline in V02 max in endurance-trained, active, and sedentary men. Source: Wilson, 2000



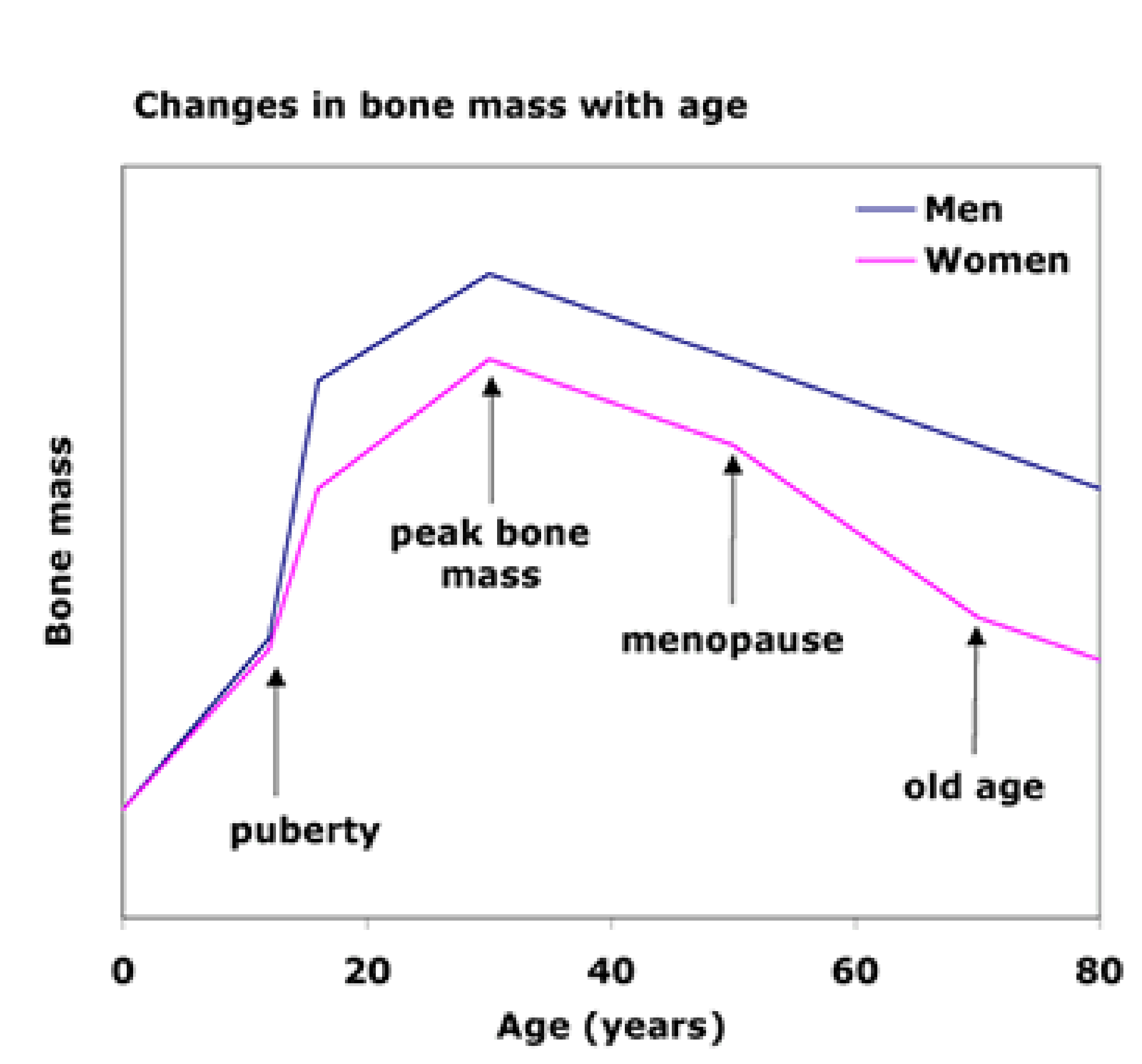
Sarcopenia: Loss of flesh

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



Change in Bone Mass with Age



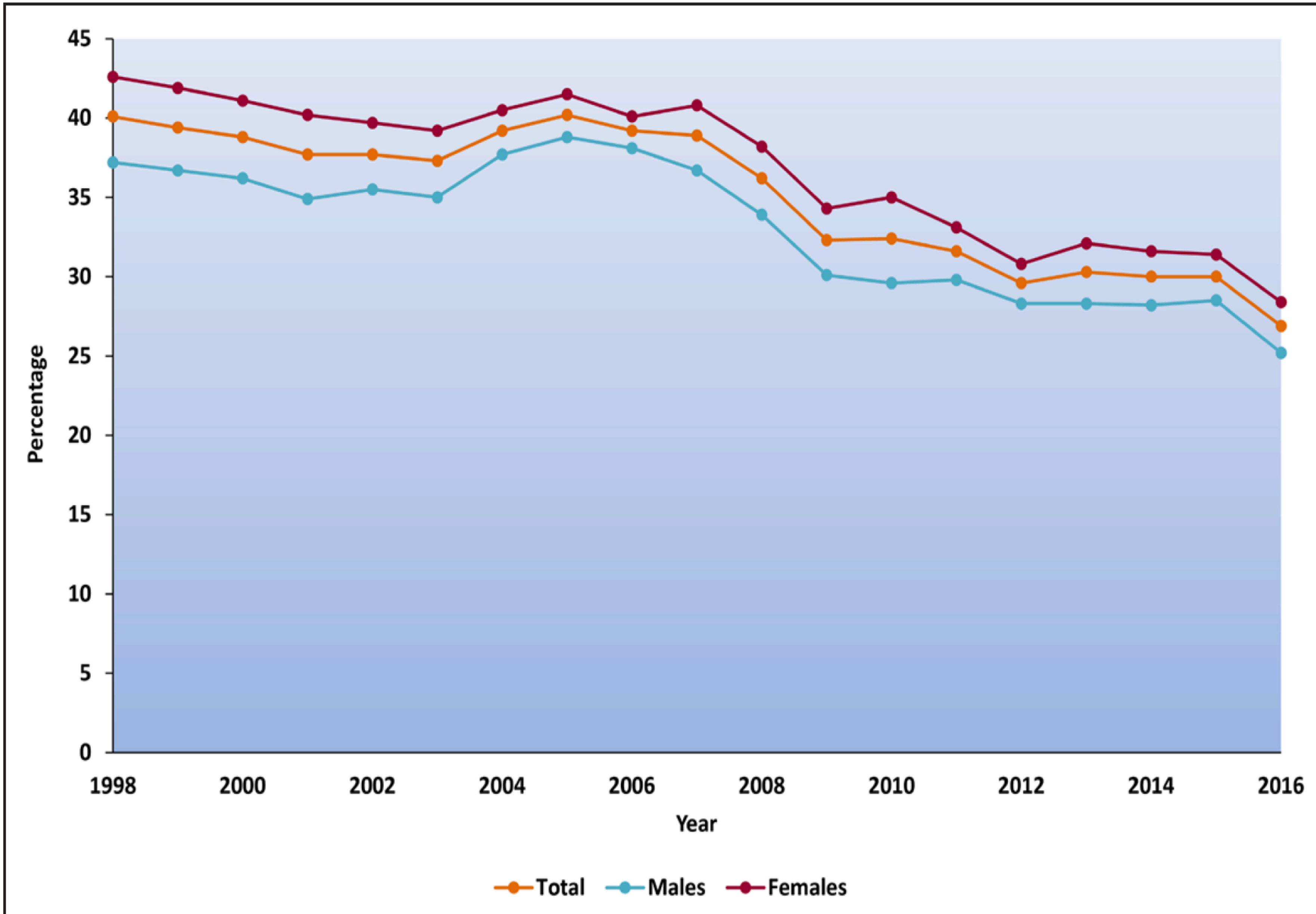
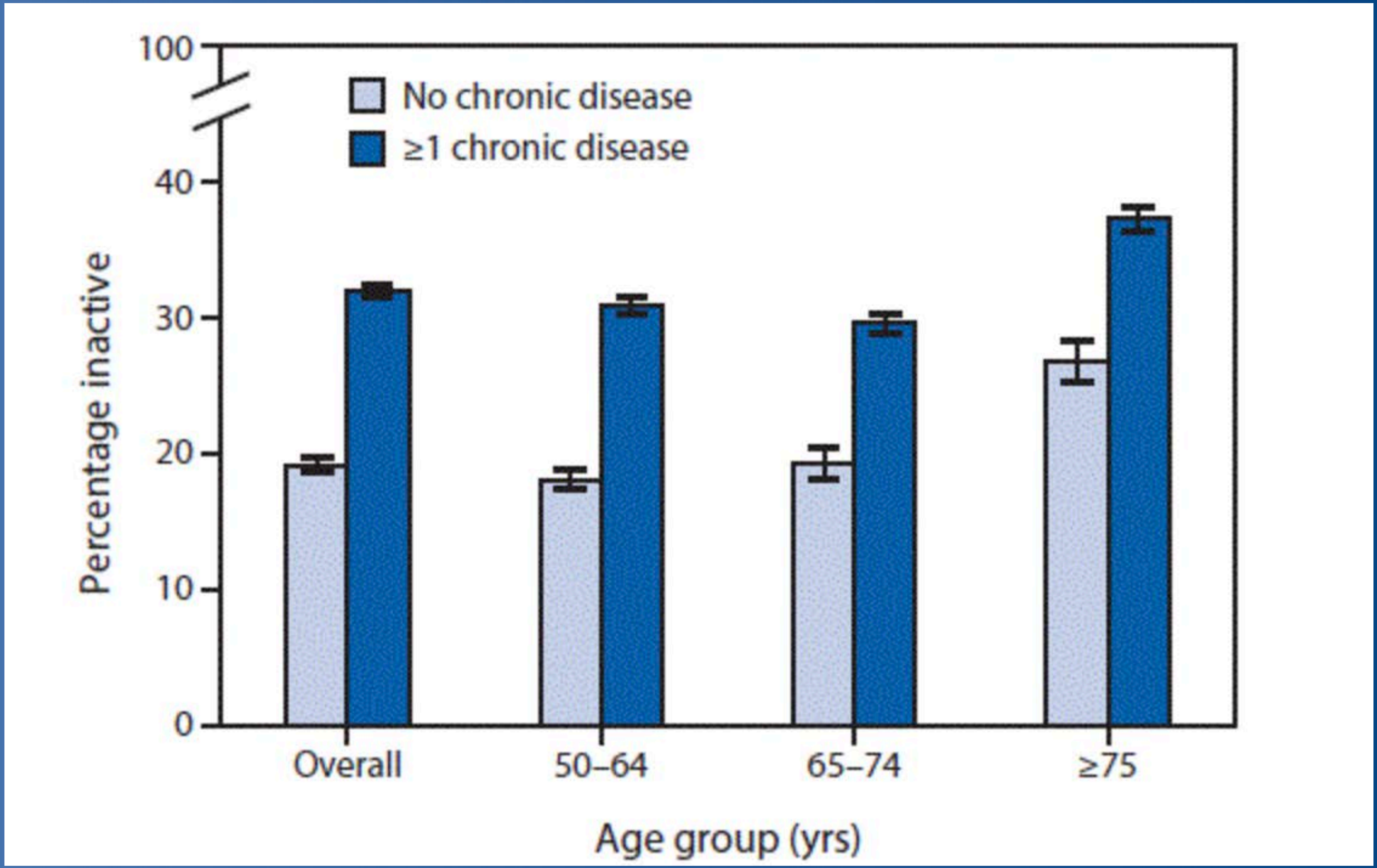


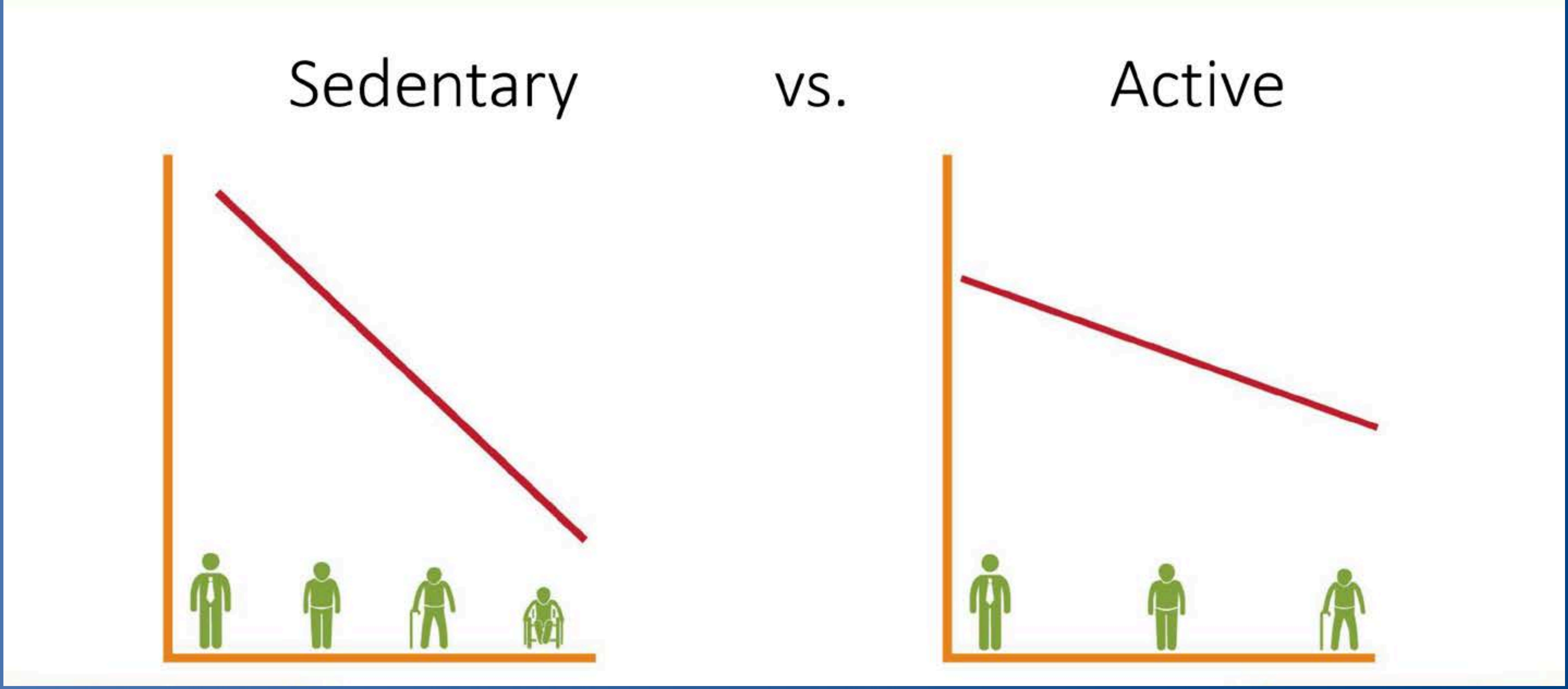
Chart 4-11. Trends in the prevalence of physical inactivity among adults ≥18 years of age, overall and by sex (NHIS, 1998–2016).
Percentages are age adjusted. Physical inactivity is defined as reporting no engagement in leisure-time physical activity in bouts lasting ≥10 minutes. NHIS indicates National Health Interview Survey.
Source: NHIS, 1998 to 2016 (National Center for Health Statistics).[7]

Prevalence of self-reported physical inactivity among adults aged ≥50 years, by chronic disease status* and age group — Behavioral Risk Factor Surveillance System, 2014

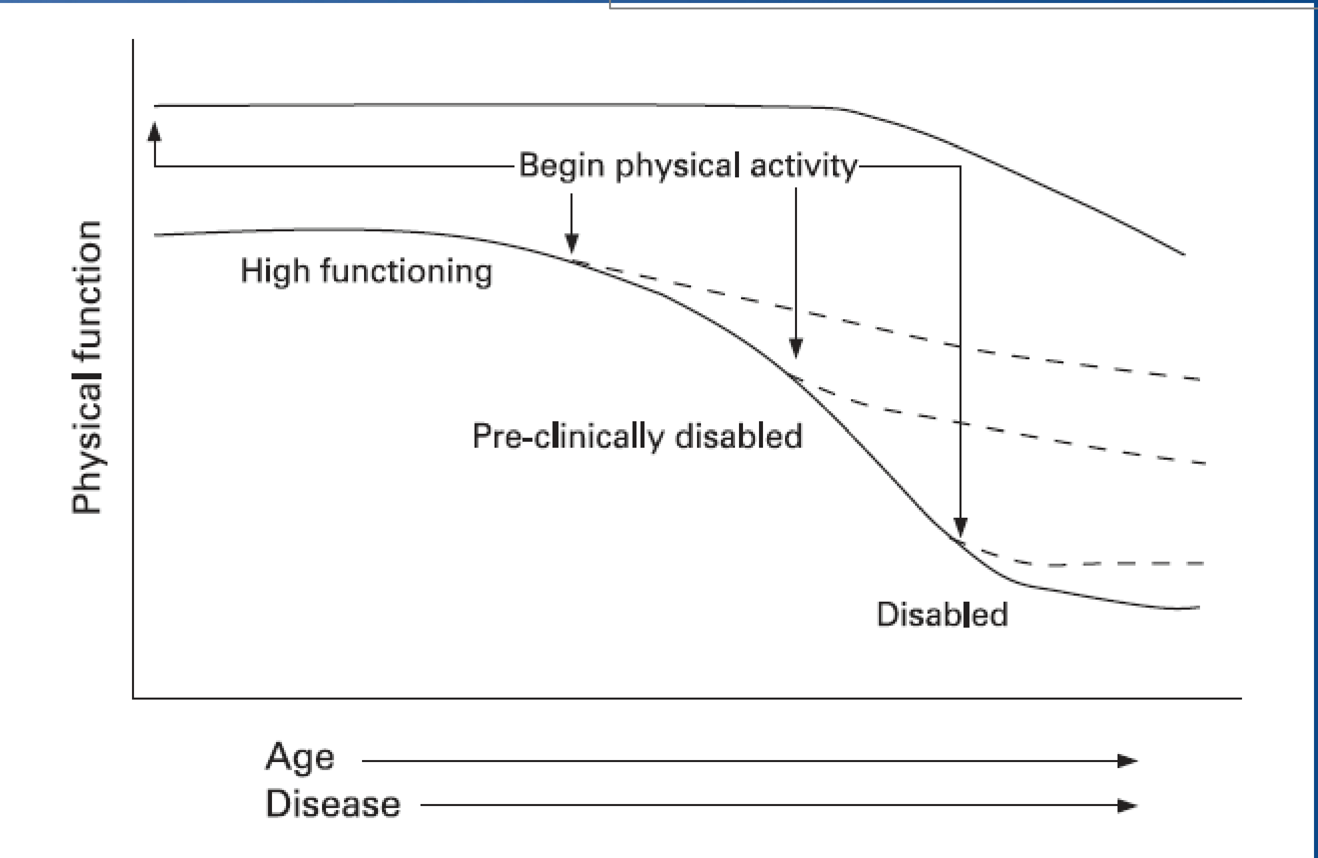


CDC September 2016

Physical activity can change the slope of aging

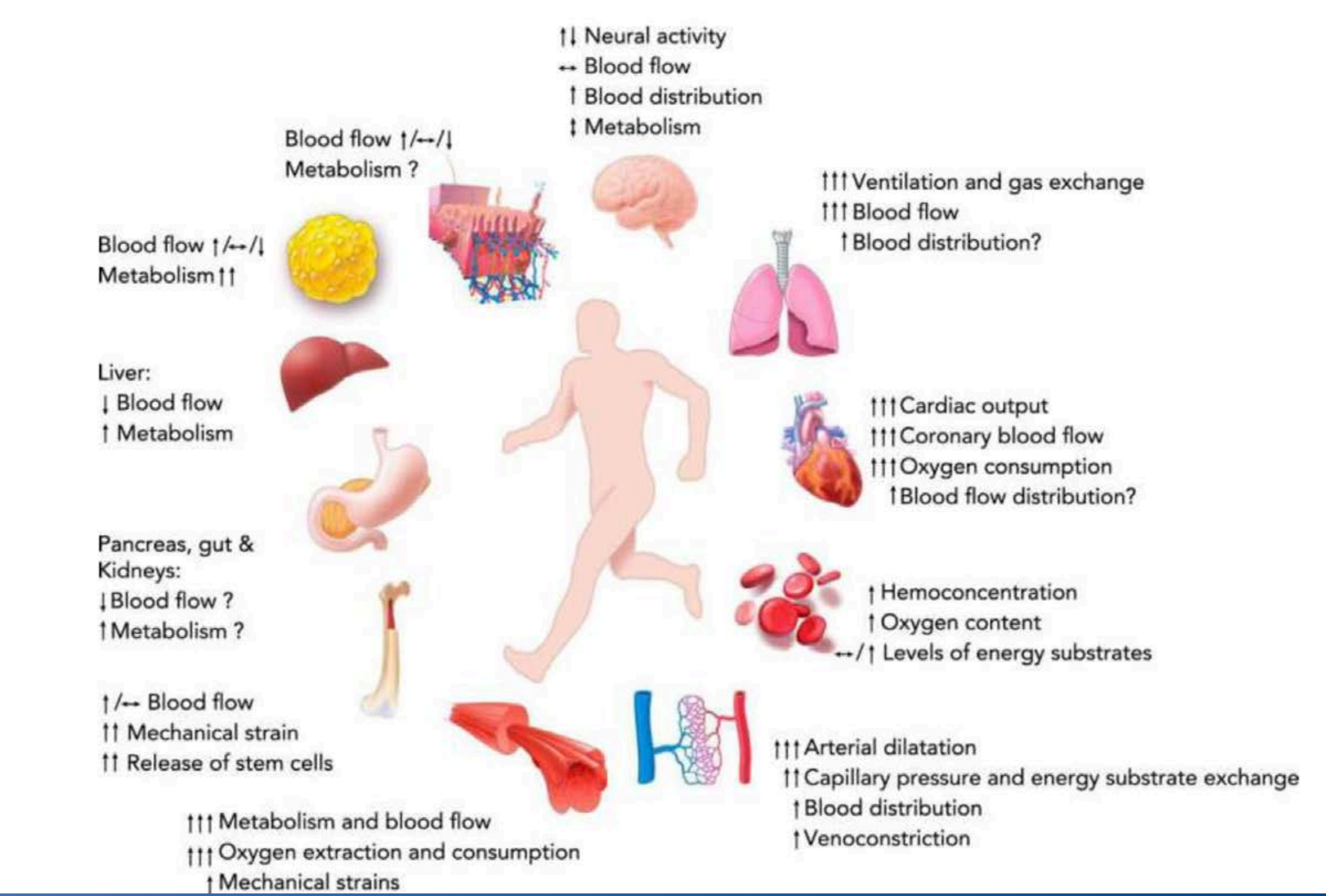


Physical function as it relates to age, disease, and physical activity

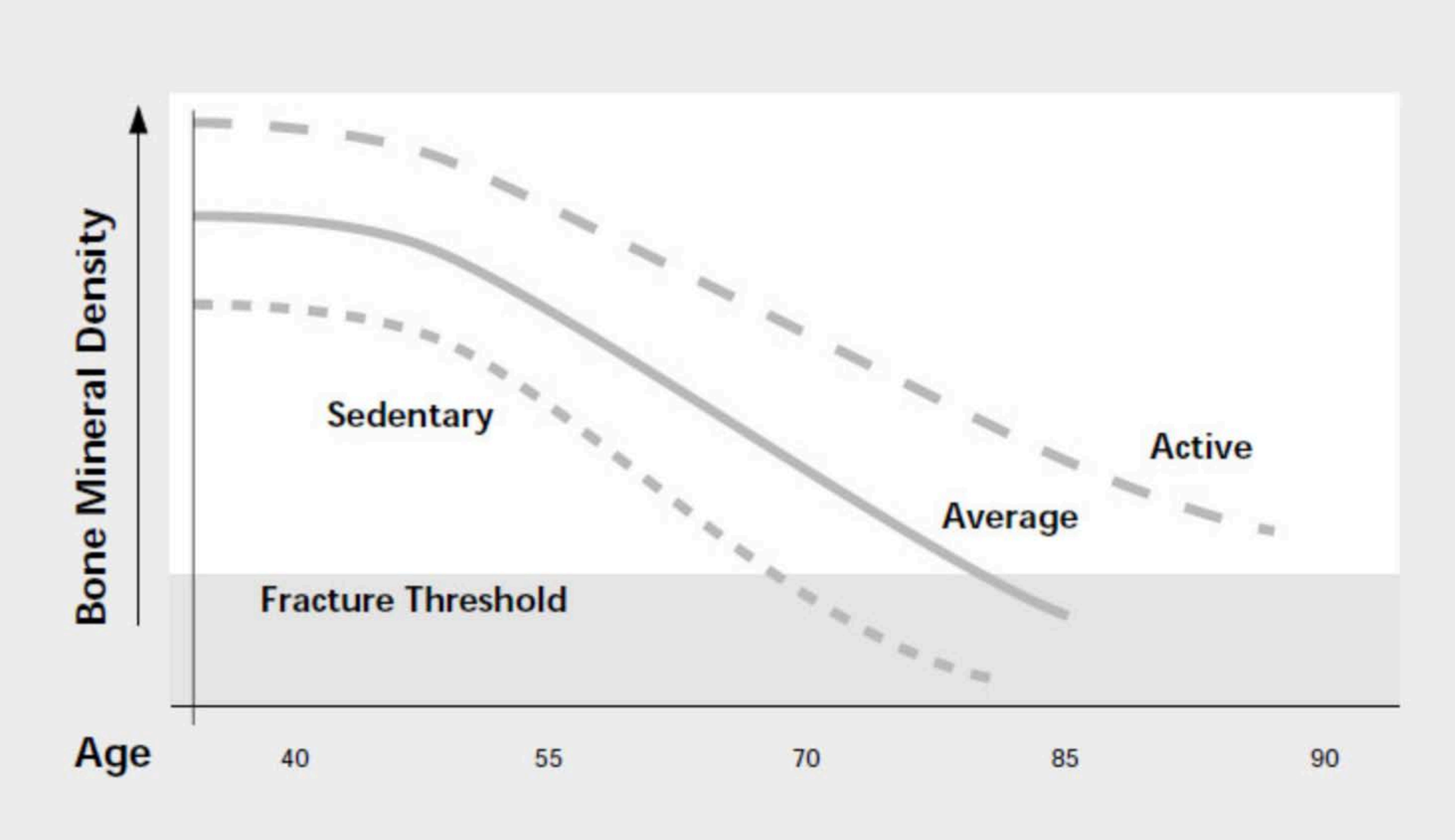


Physical activity impacts function at many stages in life to change the trajectory of decline. Being active when younger increases reserve capacity and delays decline later in life. Manini and Pahor. Br J Sports Med 2009:43; 28-31

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

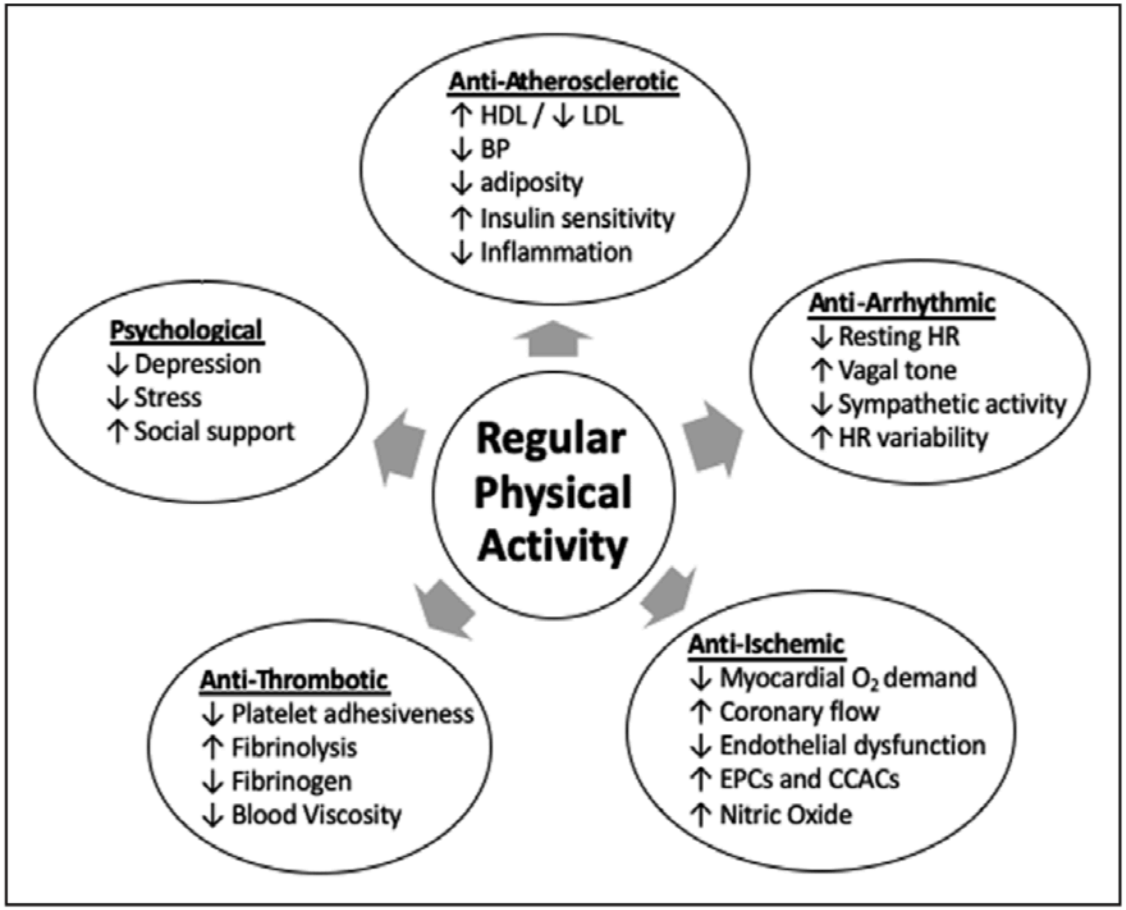
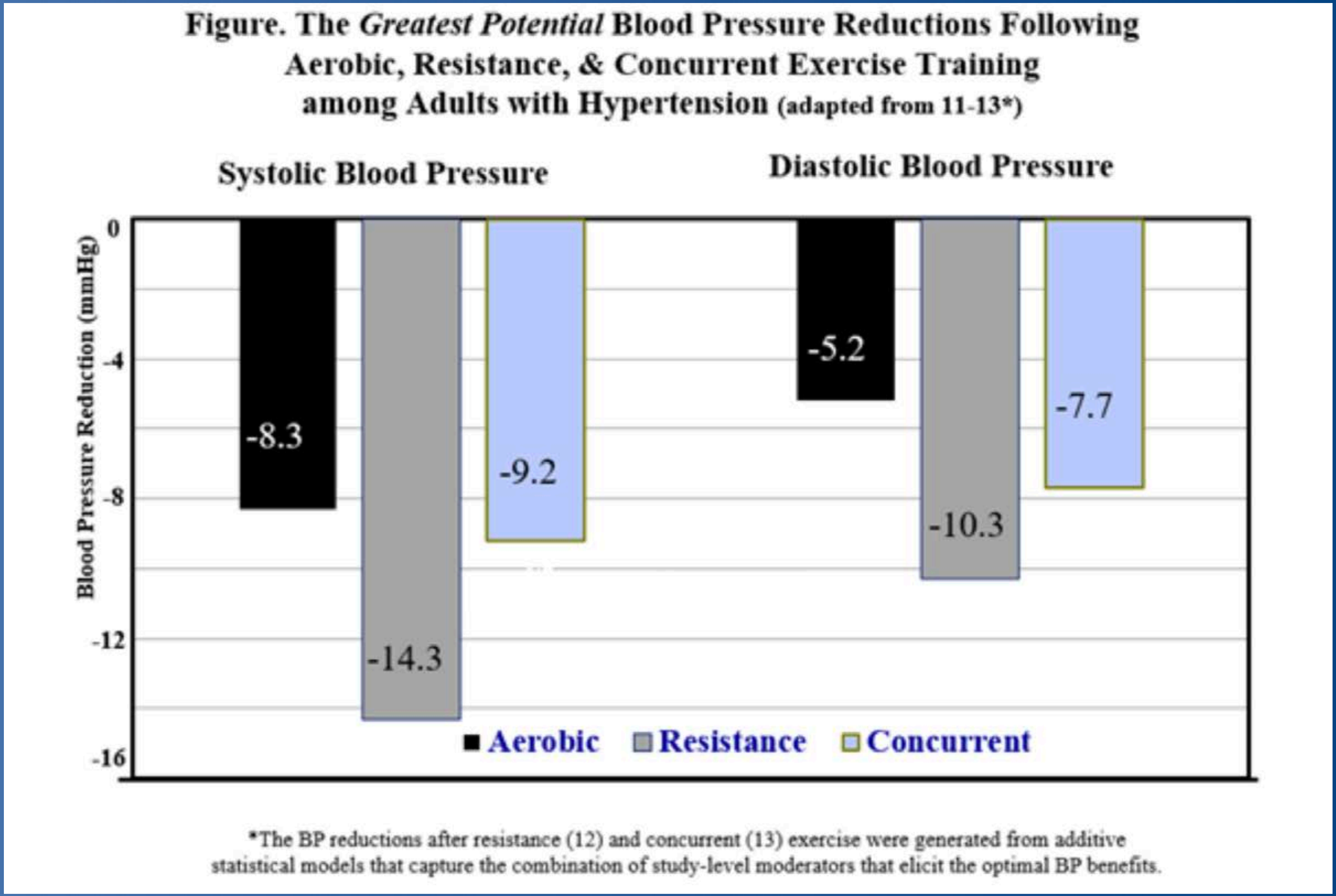


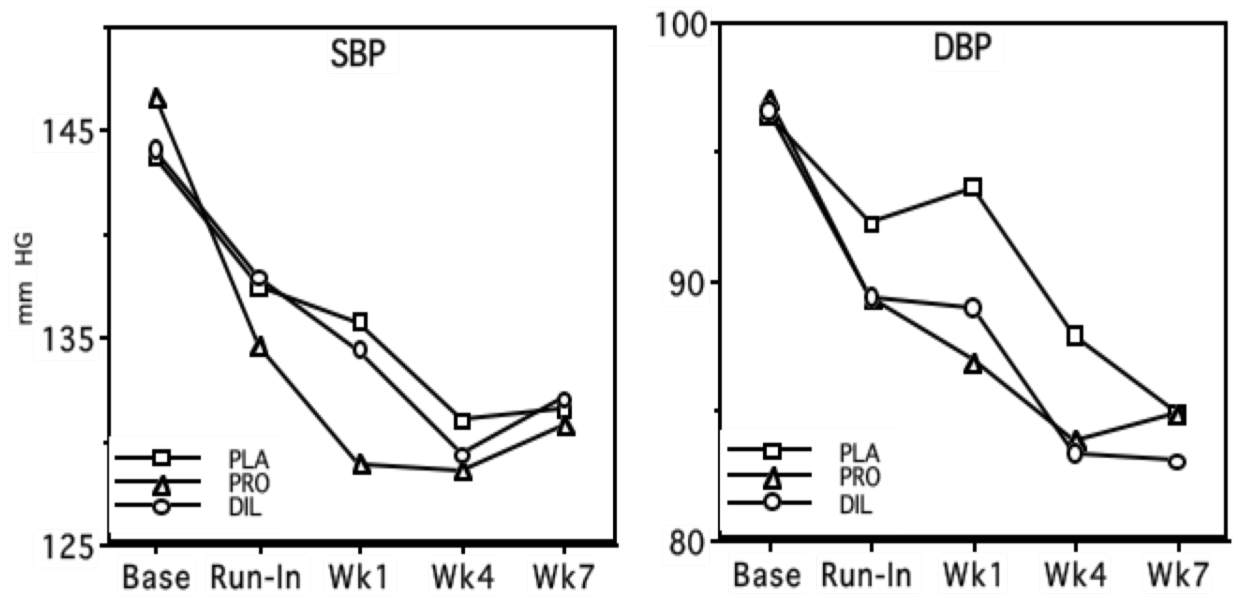
Figure 1. Cardioprotective effects of regular physical activity.
There are multiple mechanisms by which moderate to vigorous exercise training can decrease the risk of cardiovascular events. ↑ indicates increase; ↓, decrease; BP, blood pressure; CCACs, cultured/circulating angiogenic cells; EPCs, endothelial progenitor cells; HDL, high-density lipoprotein; HR, heart rate; and LDL, low-density lipoprotein.

Circulation: 2020: 141

American College of Sports Medicine Pronouncement on Exercise and Hypertension June 2019



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

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- 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 2. Changes in Blood Pressure, Fitness, Body Composition, and Aortic Stiffness From Baseline in 104 Randomized Participants

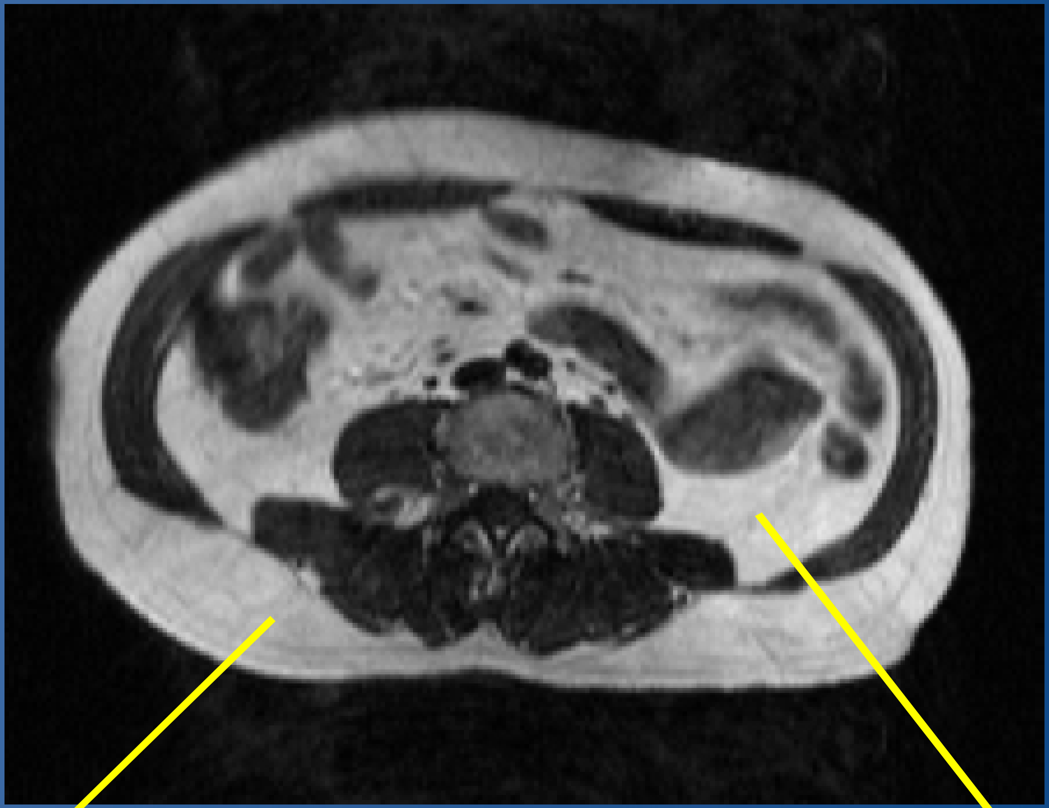
Variable	Exercise Group (n = 51)	Control Group (n = 53)	Difference (Exercise – Control)	*P* Value*
Resting hemodynamics, mean (95% CI)				
Systolic blood pressure, mm Hg	−5.3 (−8.1 to −2.5)	−4.5 (−6.7 to −2.2)	−0.8 (−4.4 to 2.8)	.67
Diastolic blood pressure, mm Hg	−3.7 (−5.1 to −2.4)	−1.5 (−2.9 to −0.2)	−2.2 (−4.1 to −0.3)	.02
Heart rate, beats/min	−3.9 (−5.4 to −2.4)	−2.2 (−3.8 to 0.5)	−1.8 (−4.1 to 0.5)	.12
Aerobic and strength fitness, mean (95% CI)				
Peak oxygen uptake, mL/kg per minute	4.0 (3.2 to 4.8)	−0.1 (−0.8 to 0.5)	4.1 (3.1 to 5.2)	<.001
Upper body muscle strength, kg	28.0 (23.9 to 32.1)	0.8 (−2.7 to 4.3)	27.3 (21.8 to 32.5)	<.001
Lower body muscle strength, kg	29.3 (25.0 to 33.7)	2.8 (−1.7 to 7.4)	26.5 (20.3 to 32.7)	<.001
Total muscle strength, kg	57.3 (49.6 to 64.7)	3.6 (−2.6 to 9.9)	53.7 (44.0 to 63.3)	<.001
Body composition, mean (95% CI)				
Body mass index, kg/m^2	−0.8 (−1.1 to −0.5)	−0.2 (−0.4 to 0.1)	−0.7 (−1.1 to −0.3)	<.001
Weight, kg	−2.3 (−3.1 to −1.4)	−0.5 (−1.2 to 0.1)	−1.7 (−2.8 to −0.7)	.002
Waist circumference, cm	−2.9 (−4.1 to −1.7)	−0.8 (−1.8 to 0.1)	−2.0 (−3.6 to −0.5)	.01
Abdominal total fat (MRI), cm^2	−52.5 (−66.6 to −38.7)	−6.5 (−20.3 to 7.3)	−46.0 (−65.4 to −26.5)	<.001
Abdominal visceral fat (MRI), cm^2	−26.7 (−35.6 to −17.9)	−3.8 (−10.8 to 3.3)	−23.0 (−34.2 to −11.8)	<.001
Abdominal subcutaneous fat (MRI), cm^2	−25.8 (−35.1 to −16.5)	−2.9 (−11.7 to 6.0)	−23.0 (−35.7 to −10.3)	<.001
Total body fat (DXA), %	−3.5 (−0.04 to −2.8)	−0.2 (−0.7 to 0.3)	−3.3 (−4.1 to −2.4)	<.001
Lean body mass (DXA), %	3.5 (2.8 to 4.2)	0.2 (−0.3 to 0.7)	3.3 (2.4 to 4.1)	<.001
Aortic stiffness, mean (95% CI)				
Pulse-wave velocity, cm/s†	111.2 (−35 to 257.5)	16.9 (−96 to 130)	94.4 (−276.5 to 87.8)	.35

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 4. Pearson Correlation Coefficients for Changes in Blood Pressure vs Changes in Selected Variables*

Variable	Systolic Blood Pressure	*P* Value	Diastolic Blood Pressure	*P* Value
Peak oxygen uptake	−0.04	.68	−0.24	.02
Total muscle strength	−0.03	.76	−0.23	.02
Weight	0.17	.09	0.20	.05
Body mass index, kg/m^2	0.12	.23	0.14	.15
Waist	0.12	.23	0.18	.07
Percentage of total body fat	0.17	.08	0.31	.001
Percentage of total lean mass	−0.16	.09	−0.30	.002
Abdominal total fat	0.18	.07	0.24	.02
Abdominal visceral fat	0.27	.006	0.30	.003
Abdominal subcutaneous fat	0.27	.006	0.27	.006
Pulse-wave velocity	−0.17	.14	−0.11	.35
Total daily energy expenditure	−0.13	.18	−0.20	.04
Total daily energy intake	0.16	.11	0.15	.12
Sodium intake	0.10	.37	0.10	.34

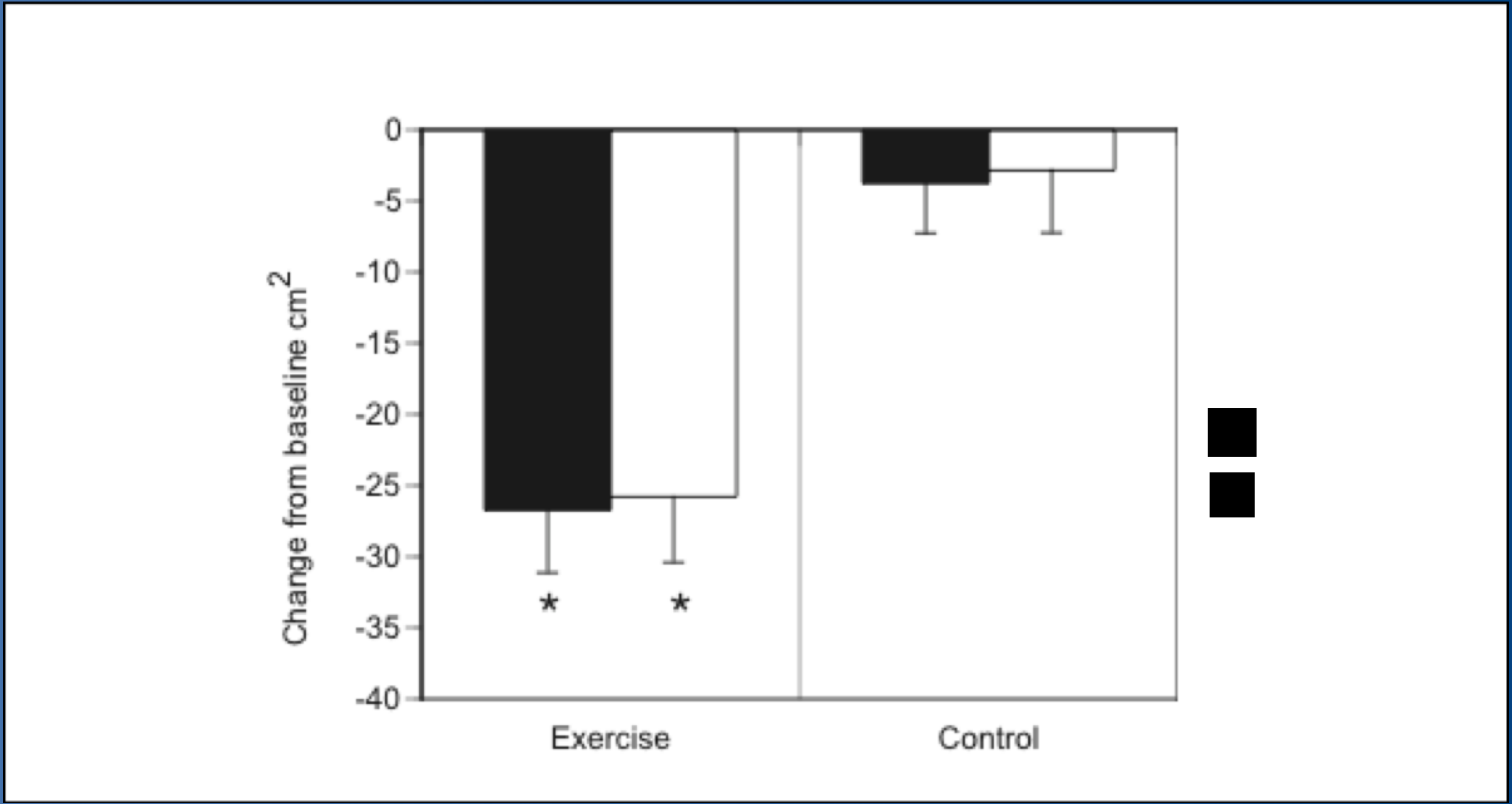
Abdominal Fat



Subcutaneous fat

Visceral fat

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.

Stewart et al. Archives Intern Med. 2005 Apr 11;165(7):756-62**.**

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

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- **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

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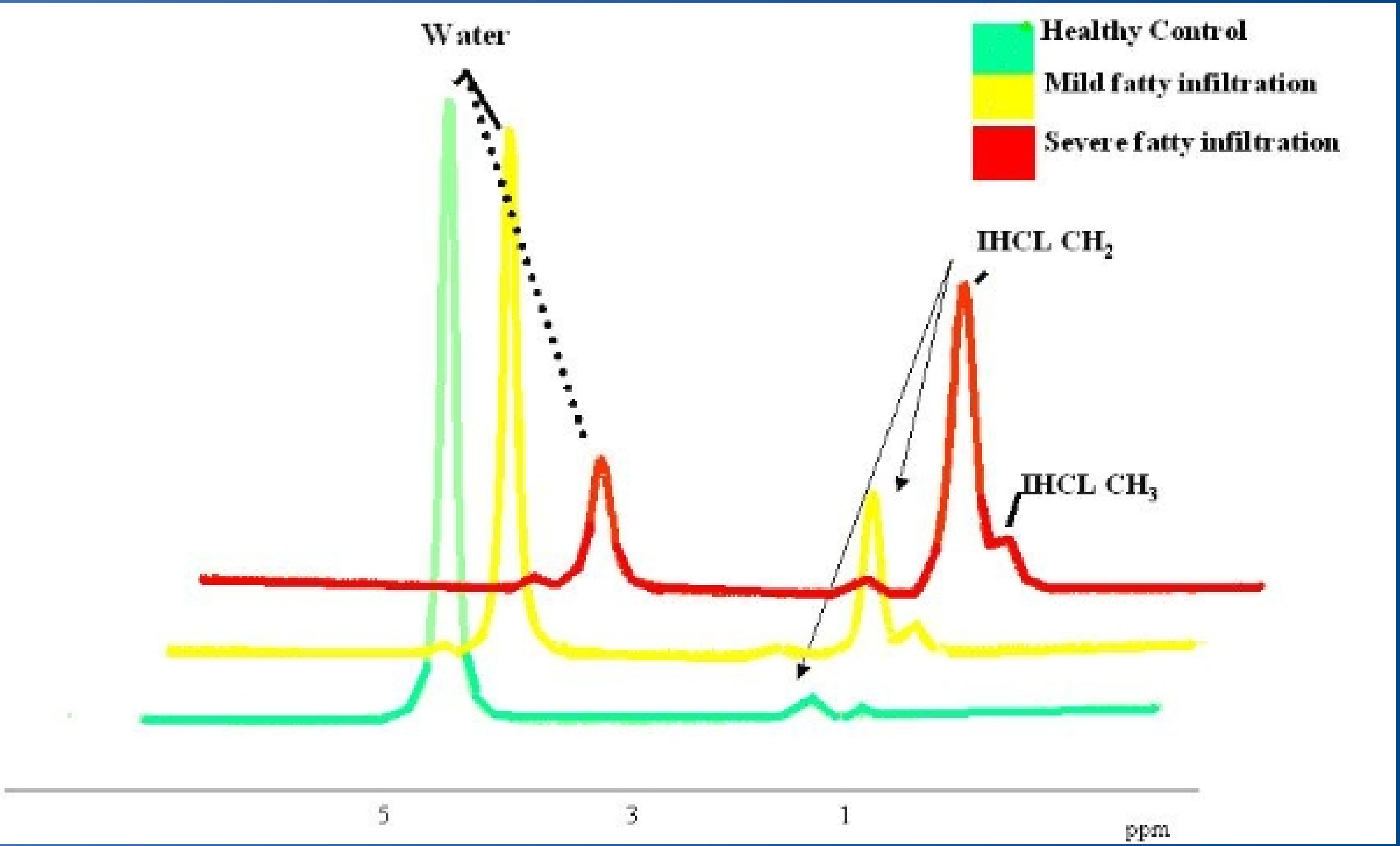
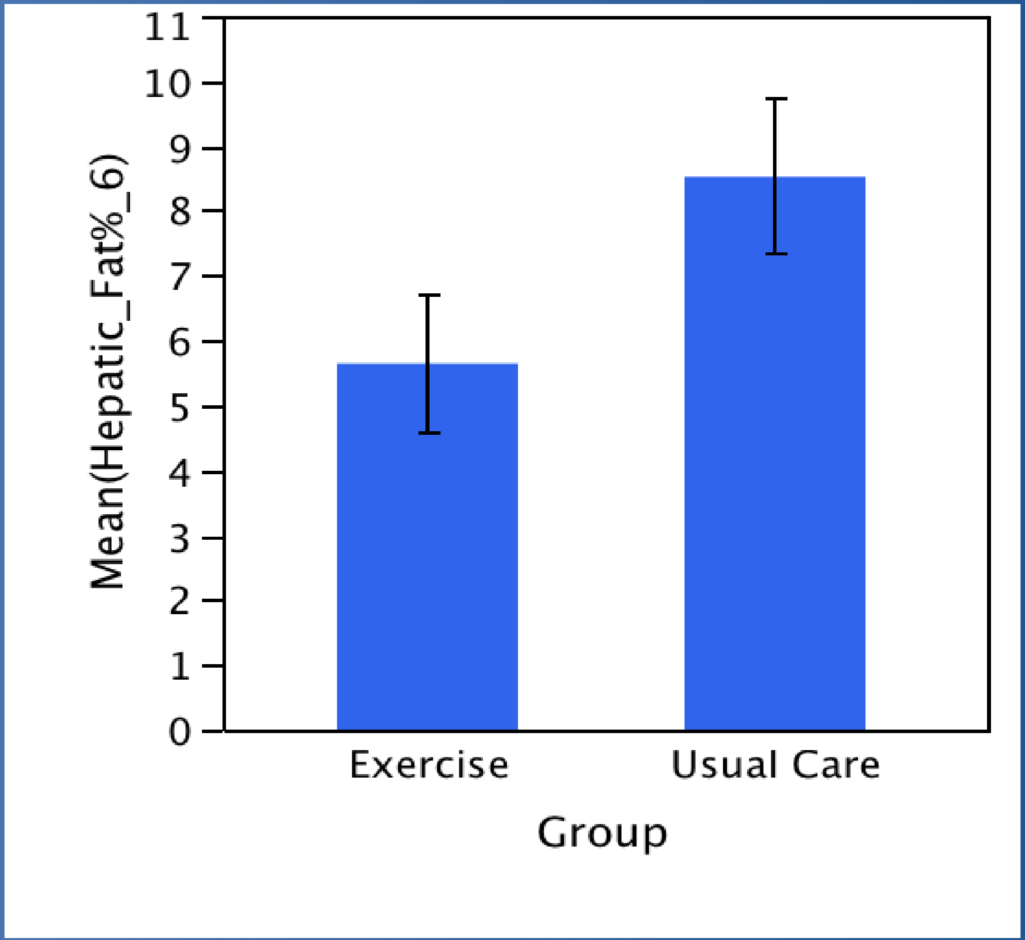
- Hepatic steatosis is leading cause of liver cirrhosis, failure, and cancer.
- Increased hepatic fat is also associated with increased cardiovascular disease risk factors such as blood pressure, cholesterol levels, insulin resistance.

Hepatic Fat MR Spectroscopy



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

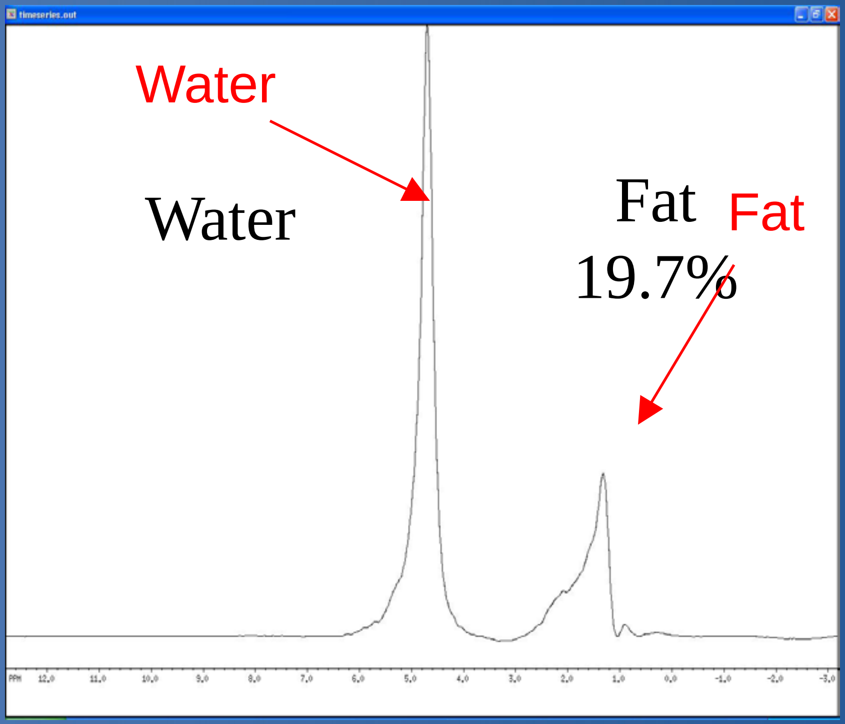


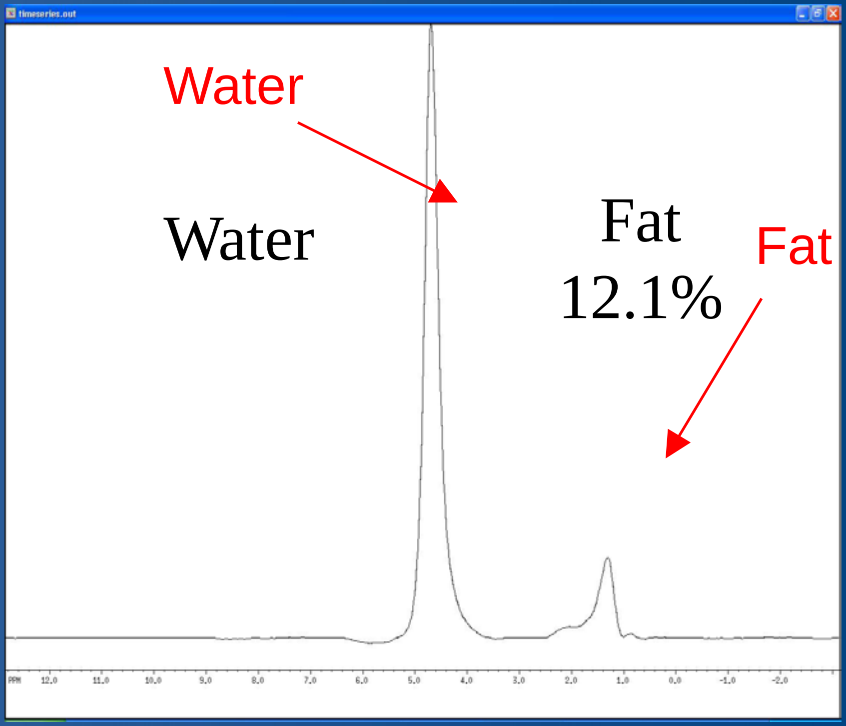
- Subjects, n=102 with T2DM, mean age 57±6 years
- Hepatic fat decreased by 1.2% in exercisers vs 0.7 in controls, p=0.03
- Exerciser were less likely to progress to NAFLD vs controls, n=1 vs n=5, p=0.04

P<0.03 for difference at 6-months adjusted for baseline values

Bonekamp, Susanne, Bethany B. Barone, Jeanne M. Clark, and Kerry J. Stewart. **Hepatology**. 48 (S1), 806A, 2008.

Hepatic fat in an exerciser before and after





Baseline

6 months

Exercise Effects on Bone Mineral Density: Sub Study Exercise and BP in Older Persons

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- 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

Stewart et al. (Am J Prev Med 2005;28(5):453–460

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

	Women				
Variable (mean ± SD)[a]	**Exercise (n = 26)**	**p value for change from baseline**	**Control (n = 27)**	**p value for change from baseline**	**p value for exercisers versus controls**
Total skeleton	−0.011 ± 0.022	**0.02***	0.009 ± 0.032	0.17	**<0.01****
Lumbar spine (L1–L4)	−0.01 ± 0.038	0.19	−0.017 ± 0.064	0.17	0.62
Total hip	−0.002 ± 0.015	0.39	−0.004 ± 0.017	0.22	0.73
Femoral neck	0.005 ± 0.033	0.43	−0.008 ± 0.017	0.02	0.07
Greater trochanter	−0.008 ± 0.017	**0.02***	−0.004 ± 0.016	0.27	**0.03***
Femoral shaft	−0.002 ± 0.018	0.56	−0.004 ± 0.026	0.41	0.75
	Men				
Variable (mean ± SD)[a]	**Exercise (n = 25)**	**p value for change from baseline**	**Control (n = 26)**	**p value for change from baseline**	**p value for exercisers versus controls**
Total skeleton	0.021 ± 0.057	0.43	0.003 ± 0.031	0.64	0.17
Lumbar spine (L1–L4)	0.000 ± 0.038	0.98	0.015 ± 0.064	0.27	0.34
Total hip	0.001 ± 0.012	0.67	−0.002 ± 0.010	0.30	0.31
Femoral neck	−0.004 ± 0.021	0.40	−0.005 ± 0.019	0.18	0.76
Greater trochanter	0.002 ± 0.014	0.53	0.002 ± 0.013	0.50	0.99
Femoral shaft	0.002 ± 0.015	0.48	−0.005 ± 0.014	0.09	0.10

SD, standard deviation.

[a]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

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

*$p < 0.05$ (bolded); **$p < 0.01$ (bolded).

Conclusion on bone from this study

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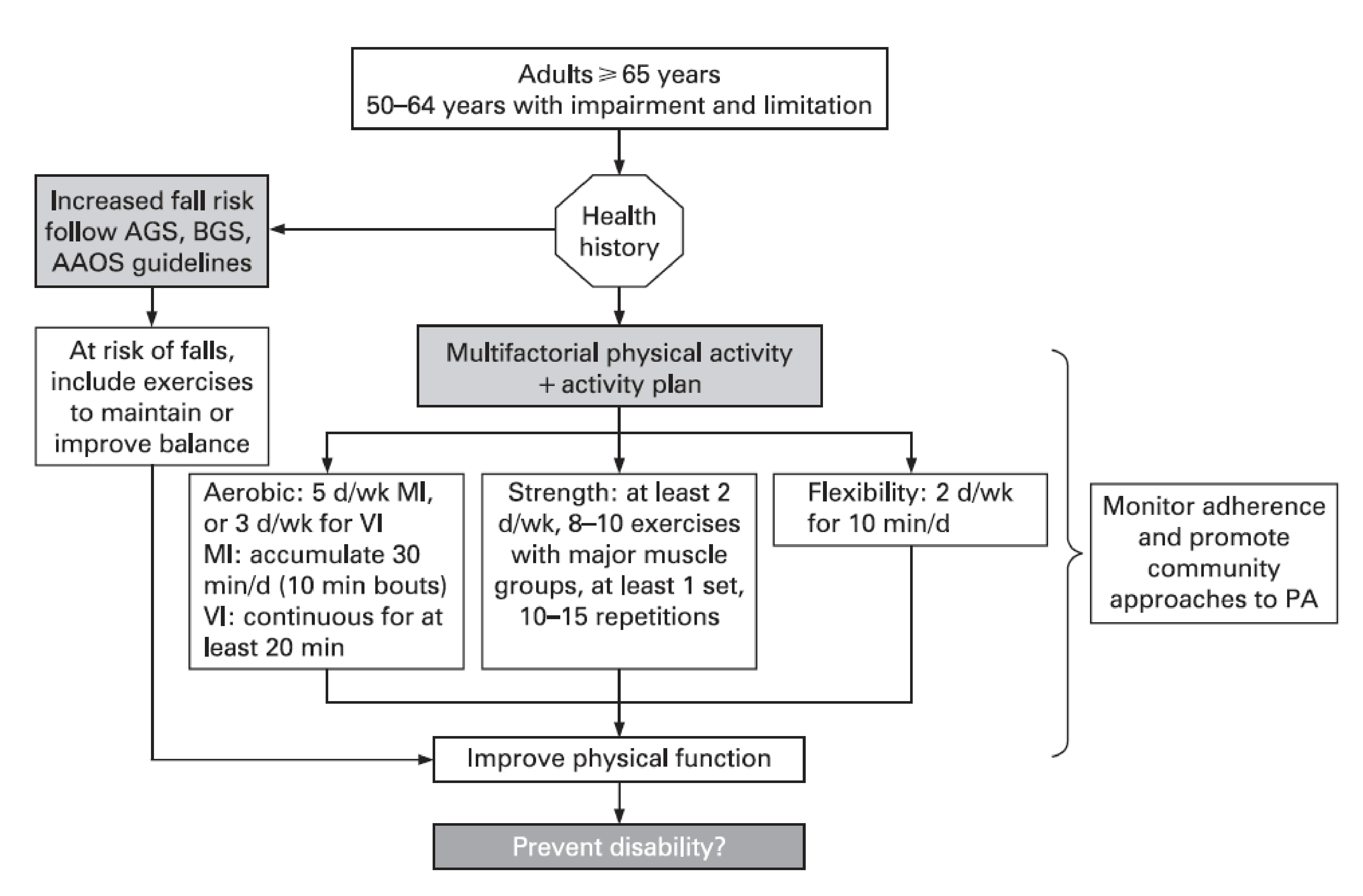
- The overall effect of exercise on BMD was minimal.
- However, there was considerable variation in response, and BMD was modestly increased in those participants with the greatest improvements in fitness and leanness.
- Reduced BMD that is typically associated with reduced fatness did not occur when 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

Stewart et al. (Am J Prev Med 2005;28(5):453–460

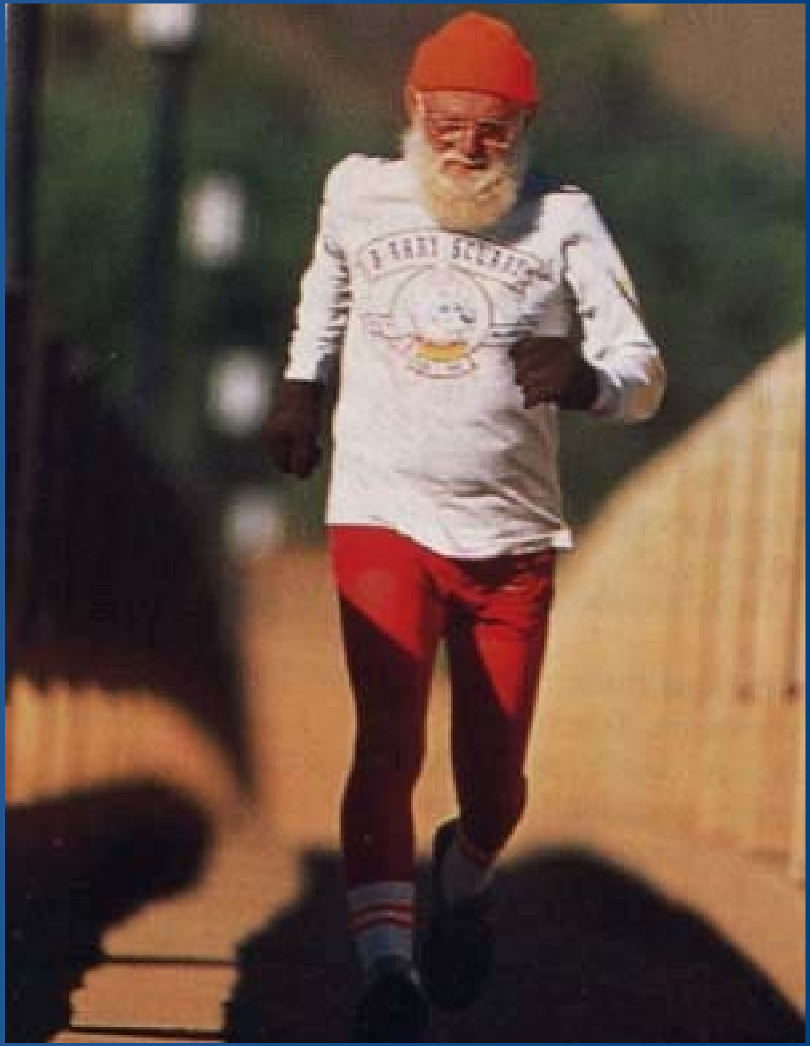
ACSM/AHA Guidelines for Physical Activity in Older Adults



Some key features of aerobic and resistance exercise

Aerobic Exercise

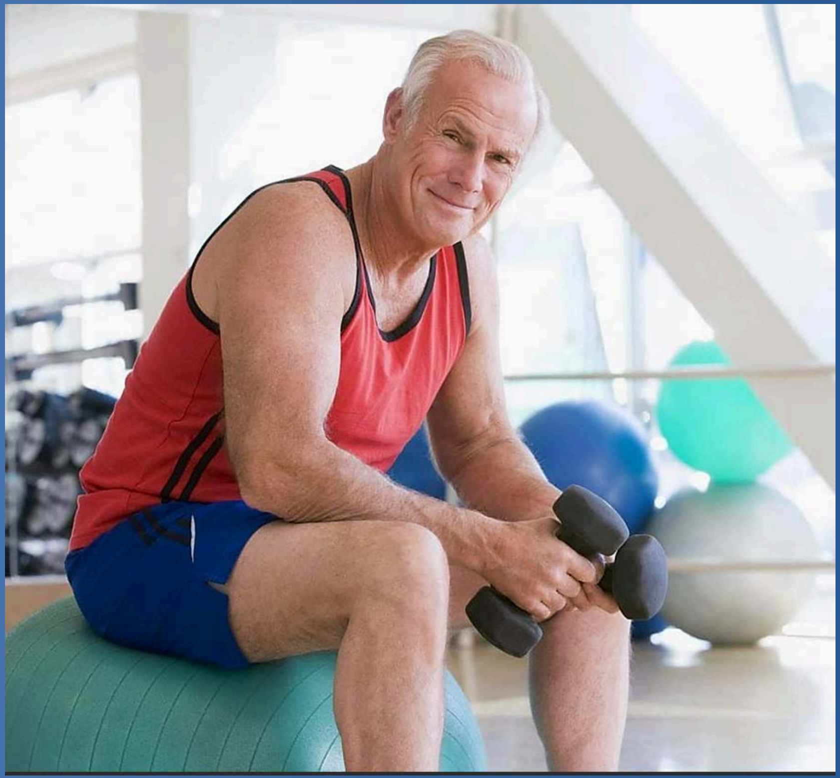
- Increases heart rate and breathing for extended periods of time
- Requires a steady supply of oxygen to promote sustained activity, e.g., walking, jogging, swimming, cycling
- Improves the health of the heart, lungs, and circulation
- Shown to help prevent or delay some diseases



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

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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:

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- 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 1. Comparison of Effects of Aerobic Endurance Training With Strength Training on Health and Fitness Variables

Variable	Aerobic Exercise	Resistance Exercise
Body composition		
Bone mineral density	↑↑	↑↑
Percent body fat	↓↓	↓
Lean body mass	0	↑↑
Muscle strength	0↑	↑↑↑
Glucose metabolism		
Insulin response to glucose challenge	↓↓	↓↓
Basal insulin levels	↓	↓
Insulin sensitivity	↑↑	↑↑
Plasma lipids and lipoproteins		
HDL cholesterol	↑0	↑0
LDL cholesterol	↓0	↓0
Triglycerides	↓↓	↓0
Cardiovascular dynamics		
Resting heart rate	↓↓	0
Stroke volume, resting and maximal	↑↑	0
Cardiac output, rest	0	0
Cardiac output, maximal	↑↑	0
SBP at rest	↓0	0
DBP at rest	↓0	0
$\dot{V}o_2$max	↑↑↑	↑0
Submaximal and maximal endurance time	↑↑↑	↑↑
Submaximal exercise rate-pressure product	↓↓↓	↓↓
Basal metabolic rate	↑0	↑
Health-related quality of life	↑0	↑0

↑ 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)

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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)

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Immediate Benefits

- Empowering older individuals
- Enhanced social and cultural integration

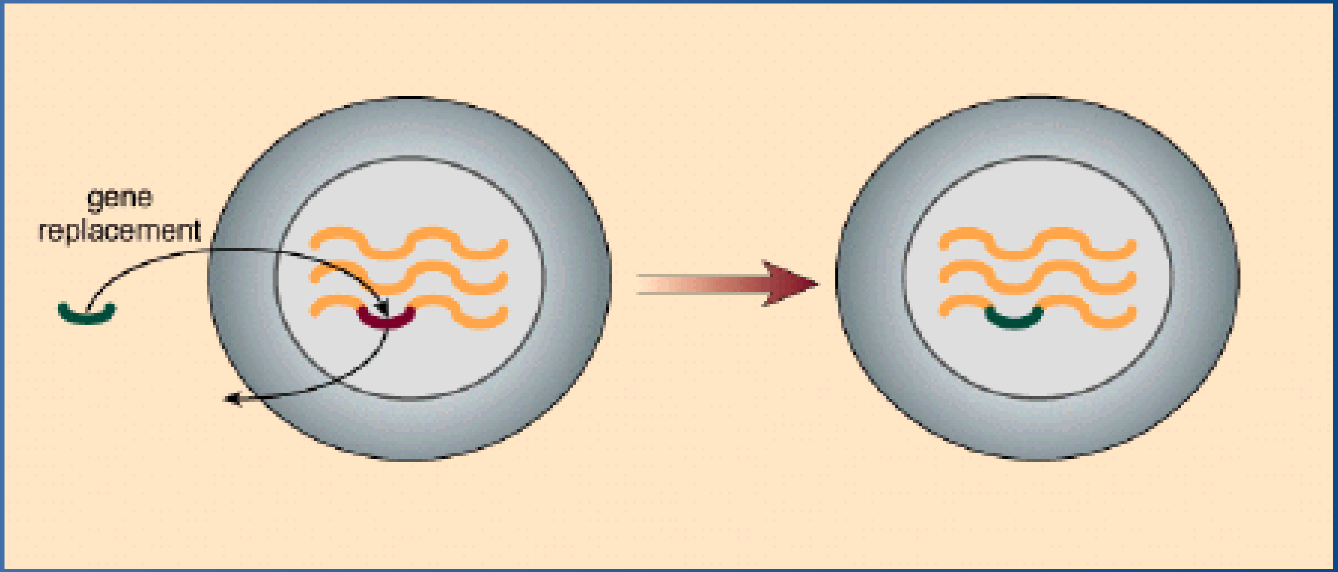
Long Term Effects

- New friendships
- Widened social and cultural networks
- Role maintenance /new role acquisition
- Enhanced intergenerational activity

Enhanced Intergenerational Activity

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

The Present and Future: Gym Therapy

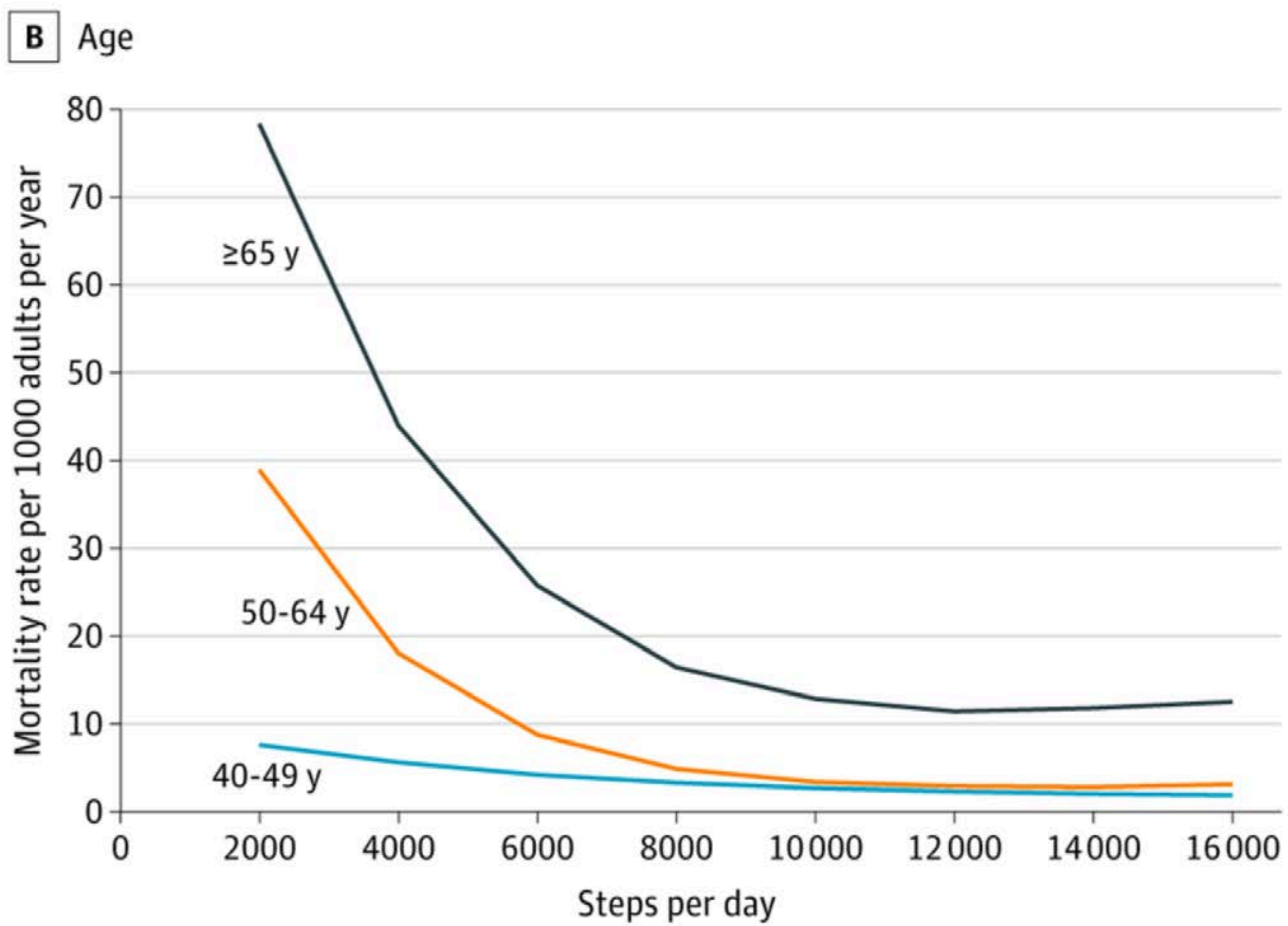
Regular physical activity that is performed on most days of the week reduces the risk of developing or dying from some of the leading causes of illness and death in the United States. Millions of Americans suffer from illnesses that can be prevented or improved through regular physical activity.

Center for Disease Control: Physical Activity and Health.

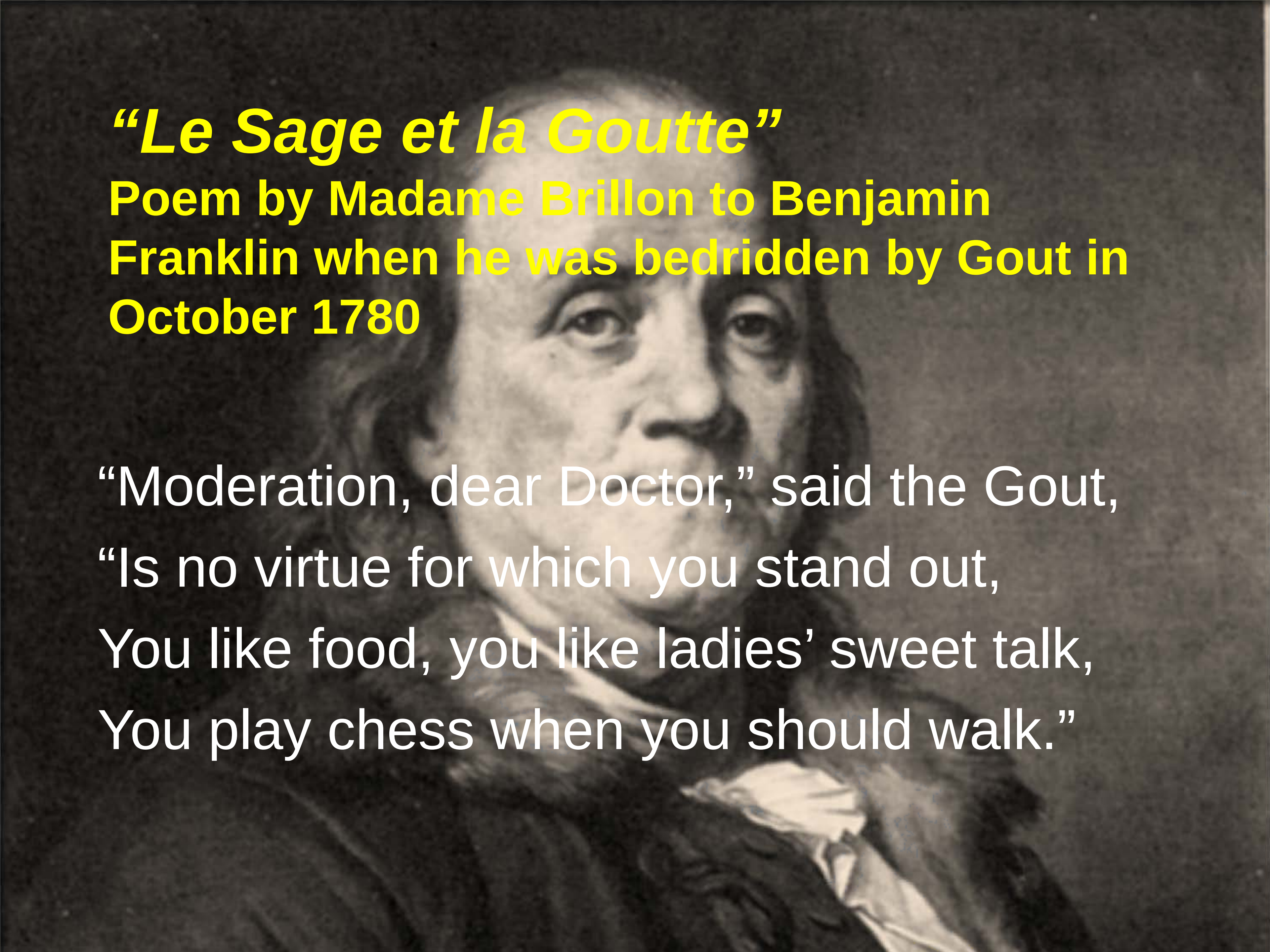
JAMA Network

From: **Association of Daily Step Count and Step Intensity With Mortality Among US Adults**

JAMA. 2020;323(12):1151-1160. doi:10.1001/jama.2020.1382



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.”