Author: Brent C. Williams, M.D., M.P.H., 2009

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Physiology of Aging

Brent C. Williams, MD, MPH
Associate Professor of Medicine
University of Michigan
Intended Learning Outcomes

- Distinguish usual from successful aging.
- Describe the major age-associated changes in human physiology.
- Understand the “anti-aging” effects of exercise.
- Be able to assess nutritional status of older adults, including risks from medications.
- Appreciate the importance of functional assessment of older individuals.
What is Aging?
Aging

- is not a disease
- occurs at different rates
  - among individuals
  - within individuals
- does not generally cause symptoms
Characteristics of Mammalian Aging

- cellular and physiologic deterioration
- increased mortality with age following maturation
- increased vulnerability to disease
- decreased ability to adapt to stress
  - impaired homeostasis
“Normal” Aging as:

- Optimal – Best example or idealized
- Usual - most common
- Universal – seen in all humans

All are influenced by:
- Genetics
- Physiology
- Lifestyle
- Socioeconomics
Problems with Normal Aging

- heterogeniety
- normal does not imply without risk
- normal does not imply natural
Aging

Disease

Non-disease

Usual

Successful

Rowe & Kahn, Science 237:143, 1987
From Usual to Successful Aging – Clinical Approach

- Normalizing - Helps patients understand what to expect
  - Adjust to likely changes (e.g., sleep/wake, bowels, balance, benign forgetfulness)
  - Identify potential symptoms of disease (sleep apnea, depression; hypothyroidism; gait disorder; cognitive impairment)
Usual to Successful Aging for Clinicians (cont’d)

Maintain or improve modifiable causes of age-related change

- Exposures (UV radiation, noise)
- Psychological well-being (social isolation)
- Cognition (mental inactivity)
- Nutrition (cholesterol, sodium, calcium)
- Exercise (fitness, strength, balance)
Most people live nowhere near their limits. They settle for an accelerated aging, and early and precipitous fall. They give aging a bad name.

George Sheehan, M.D.
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What is normal (clinically expected) aging physiology?
Aging Physiology

[Graph showing the percent remaining of various physiological parameters (e.g., conduction velocity, basal metabolic rate, standard cell water, cardiac index, standard glomerular filtration rate (inulin), vital capacity, standard renal plasma flow (dirodast), standard renal plasma flow (PAH), and maximal breathing capacity) as a function of age (years).]
Overview of Aging Physiology

- Skin
- Body Composition
- Vision
- Special Senses
- Nervous System
- Musculoskeletal System
- Renal
- GI
- Cardiovascular
### Aging Skin

**TABLE 40-7**
Physiologic Changes in the Dermis with Aging

<table>
<thead>
<tr>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin more easily damaged</td>
</tr>
<tr>
<td>Delayed wound healing</td>
</tr>
<tr>
<td>Decreased inflammatory response</td>
</tr>
<tr>
<td>Decreased protection from ultraviolet light</td>
</tr>
<tr>
<td>Decreased urticarial reaction</td>
</tr>
<tr>
<td>Wrinkling, sagging skin</td>
</tr>
<tr>
<td>Skin easily stretched under low loads</td>
</tr>
<tr>
<td>Loss of resiliency</td>
</tr>
<tr>
<td>Diminished absorption</td>
</tr>
<tr>
<td>Altered thermal regulation</td>
</tr>
<tr>
<td>Decreased sensitivity to pain and pressure</td>
</tr>
</tbody>
</table>
Aging and Central Adiposity
Age-Associated Factors - Vision

- visual acuity (cataracts, macular degeneration)
- dark adaptation
- peripheral vision (glaucoma)
- contrast sensitivity
- accommodation
Age-Associated Factors - Special Senses

- **Auditory and Vestibular**
  - Presbycusis: high frequency hearing loss
  - Vestibular dysfunction

- **Smell**

- **Oral/Dental**
  - Teeth: 40% of elderly are edentulous
  - Taste
  - Salivary function
Age-Associated Factors - Nervous System

- CNS: decrease in nerve cell number
- basal ganglia atrophy
- ↓ dopamine and ↑ muscular rigidity
- ↓ step height
- ↑ reaction time
- PNS: decreased vibratory sensation
Age-associated Factors: Musculoskeletal system

- 30% loss in muscle mass 3rd to 8th decade - sarcopenia.

- Osteoarthritis
  - weight bearing (spine/knees/1st metatarsophalangeals)
  - repeated strain (distal interphalanges/1st carpometacarpals)

- Osteopenia/-porosis (80% women >65 y/o osteopenia)
  - decreased activity, dietary calcium, estrogen withdrawal
Aging Renal Physiology

- GFR ➖ 30-46%
- Tubular function
- Renal plasma flow ➖ ~50%

CrCl = [(140 - age) x (BW)]/[72 x SrCr ]

- Multiply x 0.85 for females
- BW in kg (LBW or IBW with edema or obesity)
Absorption: GI Physiology

- GI absorptive cells ↓
- GI motility ↓ or normal
- Sphincter activity ↓
- GI blood flow ↓
- Gastric acid secretion ↓
- Active transport ↓
Afterload: Vascular Changes

- Vascular Smooth Muscle
  - Increased thickness of intima and media
  - Matrix
    » Collagen deposition, increased fibronectin, crosslinking (AGEs)
    » Fragmentation of elastin, calcium deposition

Net result is increased vascular stiffness.
Summary: Age-associated changes in cardiovascular physiology

- Maintenance of resting left ventricular function.
- Decreased ability to compensate for stress or impaired LV function.
  - Blunted heart rate response to exercise requires a compensatory increase in stroke volume to increase cardiac output.
Effect of Aging & CAD on Exercise LV Ejection Fraction

Fleg et al., J App Physiol, 1993
Aging and Aerobic Capacity
"I don't know if I'll do it next year. ... But wait until I hit that magic 95-year-old age group."

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Aging, Health Risks and Cumulative Disability

- Longitudinal study of 1741 U Penn alumni
- Health Risk in 1962 (age mean 43 yrs.) determined from BMI, smoking, and exercise; low, moderate, high
- Disability index determined in 1986: 100% greater in high than low risk group (1.02 vs, 0.49; P<0.001)
- Progression in disability postponed by 7 years.

Source: Vita et al., NEJM 338:1035, 1998
Disability Index According to Age at the Time of the Last Survey and Health Risk in 1986.

Vita et al., NEJM 338:1035, 1998
True or False?

Older people should stop exercising and rest.
Rather than seeking permission to exercise, you should have to get permission to be sedentary.

Maria Fiatarone, M.D.
Aging: A state of chronic exercise deficiency?

Only 29% of elderly report any regular exercise.

<table>
<thead>
<tr>
<th>Physiologic Characteristic</th>
<th>Aging</th>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat mass</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Bone mineral density</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>VO₂ max</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Muscle strength</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Glucose tolerance</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Insulin sensitivity</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>
Benefits of Exercise

- **Weight loss**
  - Decrease central adiposity
  - Increase lean body mass
- **Blood pressure decline**
- **Aerobic capacity increase**
- **Insulin sensitivity increase**
- **Increase bone mass**
- **Increase muscle strength**
- **Increase perceived well being**
FIGURE 13-1
Relationship between risk of usual aging and pathology.
Herb Kirk, 101
Beaverton, Oregon

Background: Kirk dropped out of college in 1915 to attend naval pilot training school in Pensacola, Florida. He resumed his college education at age 95 and graduated from the University of Montana at 96. He’s the oldest living navy pilot from World War I.

Recent accomplishments: At the Portland Marathon’s Marafun Kids’ Run in late September, Kirk finished the 2-mile course in about 36 minutes. As far as we know, that makes him the first centenarian to complete an organized running event. Kirk was accompanied by a son, a grandson and several great grandchildren—to make a total of four generations. He said he would have run the Portland 5-Mile, but he wasn’t sure the kids could cover the distance.

Quote: “I enjoyed myself thoroughly. I’ll keep coming back to this race for the next 25 years.”
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Protein-Calorie Malnutrition Among Older Persons

- 5-12% in community
- 30-61% hospitalized
- 40-85% in long-term care facilities.
Inadequate Nutrition Among Older Individuals

- Increases severity of disease
- Increases possibility of physical limitations due to decreased musculature
- Decreases functional status
- Can increase drug effects due to changed metabolism and/or weight loss
Importance of Nutrition for Older Adults

Older Adults are at increased risk of inadequate diet from:

- Diseases - acute/chronic
  - half of hospitalized older patients are malnourished.
- Physical limitations
- Inability to chew and poor oral health
- Social isolation/depression/low income
- Impaired functional status
- Alcohol use and abuse
- Drug - nutrient Interactions
### Causes of Malnutrition

<table>
<thead>
<tr>
<th>Medications</th>
<th>Oral factors</th>
<th>Wandering (dementia)</th>
<th>Hyperthyroidism etc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotional probs</td>
<td>Neoplasia</td>
<td>Enteric problems</td>
<td></td>
</tr>
<tr>
<td>Anorexia</td>
<td></td>
<td>Eating problems</td>
<td></td>
</tr>
<tr>
<td>Late-life paranoia</td>
<td></td>
<td>Low-salt / chol</td>
<td></td>
</tr>
<tr>
<td>Swallowing disorders</td>
<td></td>
<td>Social problems</td>
<td></td>
</tr>
</tbody>
</table>

Assessing Nutritional Status

- Screening tools (e.g. DETERMINE; Mini-Nutritional Assessment) to identify patients at risk.
- Anthropometric data
  - BMI, percent weight change
  - Changes in body composition
- Albumin, cholesterol
- Vitamin levels - 25-OH-D3, B₁₂
- Involuntary weight loss > 10% (high specificity)
Food Check List

Activities of Daily Living
- What are they able to do?

Food intake
- Food preparation capability or food provided
- What is being consumed?
  - Total amount of food
  - Types of food (fruits, veggies, protein foods, grains)
  - Fluids: Water especially
Medication Check List

- Number of medications
- Possible nutrient-drug interactions
- Vitamin B12 status (B12 is less absorbed with increasing age due to less intrinsic factor being produced in the stomach)
- Vitamin D status (low milk intake, no sunshine)
How Drugs Affect Nutritional Status

- Approximately 34 million Americans are 65 years or older yet they consume 30% of all medications.
  - Average patient taking 3 to 7 medications at one time.
- Medications alter food intake, absorption, metabolism and excretion of nutrients.
- Decreases in appetite, taste and smell.
- May cause GI disturbances such as nausea, constipation, and/or diarrhea.
Dietary Recommendations for Older Individuals

- Adequate protein (1.0 gm/kg rather than 0.8).
- Ample fruits and vegetables for nutrients and to avoid constipation.
- Optimal Calcium intake for men and women > age 65: 1500 mg daily
- Whole grain products (nutrient density and fiber).
- Ample fluids, especially water.
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True or False?

The majority of older people are self sufficient.
Katz Activities of Daily Living (ADL) Scale

**Definition:** Things you needed to be able to do to go to kindergarten.

**Components**
- Bathing
- Dressing
- Toileting
- Transfer
- Grooming
- Feeding

**Rated by level of assistance required**
Independent, needs some assistance, unable to perform task
**Instrumental Activities of Daily Living**

**Definition:** Things you needed to do for yourself when you went off to college.

- Grocery Shopping
- Meal preparation
- Driving or using public transportation
- Taking medications
- Laundry
- Using telephone
- Managing finances
- Housework
Instrumental Activities of Daily Living

**Definition**: Things you needed to do for yourself when you went off to college.

- Grocery Shopping
- Meal preparation
- **Driving** or using public transportation
- Taking medications
- Laundry
- Using telephone
- Managing finances
- Housework
ADL/ IADL Limitations

Percentage

> age 65
65-74 years
> age 75

ADL Limitation
IADL Limitation

National Health Interview Survey, 1999 data. CDC: NCHS.
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Slide 32: Fleg et al., J App Physiol, 1993
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Slide 44: Source Undetermined
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