Effects of Aging on the Musculoskeletal System

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Effects of Aging

General Theories

Cellular Basis of Aging

1. Wear and tear damage from internal and external sources.

- External- toxic damage of chromosomes or genes that results in cell death
  - irradiation
  - chemicals
  - infection

- Internal- repeat usage produces change in mechanical structure
Effects of Aging
General Theories
Cellular Basis of Aging

2. Damage from accumulation of internal by-products of normal metabolism, by-products which escape total degradative processes.

3. Genetic predetermination of life-span of cell that exists within the cell nucleus, determining:
   - age we will reach
   - way in which aging process will be manifested

Current Recommendations for Long Life

- Nutritious and low calorie diet
- Exercise
- Red wine in moderation
- Avoid stress
- Life partner
- Optimistic attitude
- Continued lifelong education
- No smoking
- Pick parents who live to be very, very old

Aging
General Effects
- ↓ in blood supply to tissues
- ↓ in number of reparative cells
- less extensible tissue 2° ↑ collagen fiber cross-links
- ↓ in metabolic activity of the reparative cells
  1. ↓ capacity for healing response
  2. ↓ inflammatory response
  3. healing tissue is structurally weaker
  4. NEED TO BE PATIENT!!!!!!

Effects of Aging
Bone
- tensile strength and density ↑ to 3rd decade
- then ↑ rate of bone loss 2° ↑ rate of bone resorption without ↑ rate of bone deposition
- results in ↓ bone density, cortical and trabecular thickness, trabeculae #
- osteoporosis- ↓ mass of bone/volume, or ↑ porosity
- ↓ strength and ↑ in brittleness
Effects of Aging
Bone

- osteocytes- ↓ cellular metabolic activity
  ↓ #
  ↓ matrix production
- ↑ in mineral content but also ↑ porosity which add up to bone that is more brittle
- ↓ estrogen levels in women result in less inhibition of bone resorption compared with men

Effects of Aging
Bone

Both men and women have ↑ bone loss with aging, but degree to which loss for women exceeds loss for men depends on anatomic site:

- loss rate men 2/3 for women in femoral neck
  - 2:1 ratio, therefore, for hip fractures
- loss rate men 1/4 for women in lumbar spine
  - 8:1 ratio, therefore, for lumbar vertebral body fractures
Effects of Aging Bone

- Senile Osteoporosis - ↓ BMD with age in cortical and trabecular bone, primarily in women and to lesser degree in men
- Postmenopausal Osteoporosis - excessive trabecular bone loss in women associated with ↓ in estrogen levels and vertebral body fractures

Exercise and Older Bone

- Older runners are able to maintain BMD of the spine and lower extremities (Wiswell et al, 2002)
- Tai Chi improves BMD in elderly and decreases fall risk (Qin et al, 2005)
- Strength training will produce increased bone density in older men and women (Fatouros et al, 2005; and Maddalozzo et al, 2000)
Bone and Steroid

- 25% of patients receiving long-term steroid treatment (e.g., prednisone for RA or respiratory problems with an inflammatory component) will develop an osteoporosis-related fracture
- These individuals need counseling regarding prevention of osteoporosis


Effects of Aging

Bone - Implications for Intervention

- Attend to issues related to magnitude, duration, and frequency
- Sufficient calcium, Vitamin D, and estrogen blood levels
- Effect of original bone density
- Deleterious effects of excessive loading- e.g., abdominal flexion exercises and posture
- Strength training as well as running and weight bearing exercise such as Tai Chi will produce increases in bone density
Effects of Aging
Bone - Implications for Intervention

- Hormone Replacement Therapy (HRT)- HRT following menopause can significantly increase BMD and reduce fracture risk

Effects of Aging
Articular Cartilage

- ↑ H₂O with DJD cartilage perhaps due to damage of ultrastructure that resists swelling less
- ↑ displacement with loading 2° ↑ permeability attributable to lower resistance to fluid flow with ↓ ground substance and ↓ collagen density
- time of deformation preserved to some degree?
Effects of Aging
Articular Cartilage

Wear of Articular Cartilage

- ↑ stiffness of subchondral bone that results in ↑ in compressive stress imposed on the articular cartilage.
- proteoglycan loss which ↓’s cross-links between collagen fibers, contributing to mechanical wear

Implications for Intervention

- Attenuate contact force
- Improve contact area
- exercises that may involve fluid film lubrication
- bracing to deal with instabilities
- repair of ligamentous insufficiencies
- modification/redirection of activities
- Positive effects of moderate exercise on glycosaminoglycan content in knee cartilage: a four-month, randomized, controlled trial in patients at risk of osteoarthritis.
**Intervertebral Disc Structure**

Nucleus pulposus (NP) is surrounded by an anulus fibrosus (AF) and bordered superiorly and inferiorly by the cartilaginous vertebral end-plates (VEP).

**Anulus Fibrosus Structure**

Arranged in 10-12 sheets, or lamellae (Latin *lamella*, for sheets): thick anteriorly and laterally, but thin and packed tighter posteriorly, an area of structural weakness.
**Anulus Fibrosus**  
Structural Organization

Orientation of collagen fibers relative to fibers in adjacent lamellae promotes strength for the anulus.

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**Weight Transmission in the Intervertebral Disc**

Compression raises the pressure in the fluid-filled nucleus pulposus. Pressure is then directed radially into the anulus and raises tension in the anulus fibers.
Weight Transmission in the Intervertebral Disc

Tension within the anulus fibers provide a reaction force against the nucleus (B) that resists any further radial expansion of the nucleus. Nuclear pressure then is exerted on the vertebral end-plates (VEP). Weight, then, is borne by the stiffer anulus fibers and by pressure within the nucleus pulposus (C). Contact pressures are then distributed from the VEP to the next vertebral body.

Effects of Aging Intervertebral Discs

Nucleus Pulposis

- ↓ proteoglycans from 65% dry weight to 30% dry weight by age 60
- 6% ↓ in H₂O during adulthood
- ↓ in chondroitin sulfate- binds H₂O in nucleus
- ↑ in collagen content
- ↑ collagen-proteoglycan binding
- Type II collagen of the nucleus takes on appearance of Type I collagen of annulus
Effects of Aging
Intervertebral Discs
Nucleus Pulposus

- Previously detailed changes in composition and structure result in stiffer material that is less able to recover from creep deformation
- less distinction between annulus and nucleus
- nucleus less able to exert fluid pressure and transmit loads and direct radial hydraulic pressures on the annulus
  \[\therefore\text{ concentrates focal loads on the annulus}\]

Effects of Aging
Intervertebral Discs - Annulus Fibrosus

- \(\downarrow\) in diameter of the collagen fibrils
- \(\uparrow\) in overall collagen content - loss proteoglycans
- \(\downarrow\) in elastin fiber content from 13% at age 26 to 8% at age 62
- fibrillations with age that may enlarge to fissures that allow protrusion of nucleus material
- discs enlarge in A-P diameter as well as height (10%) from 2nd to the 7th decade as the vertebral body endplates become concave and allow the disc material to sink into the vertebral body (Ferguson and Steffen, 2003)
Intervertebral Disc and Smoking

- Smoking during the one year prior to presentation with LBP - increased risk for prolapsed disc
- Smoking greater than 15 years - decreased success following discectomy
- Nicotine reduces # viable cells, GAG & collagen synthesis, and Type I rather than Type II collagen synthesis in IVD - disc degeneration in rats


Effects of Aging
Intervertebral Discs
Implications for Intervention

- Attend to issues related to magnitude, duration, and frequency of spinal loading
- “good posture” may help avoid focal concentration of loads in discs that are less able to distribute loads throughout the disc and less capable of withstanding focal loading of weaker annulus material
- Avoid smoking
Effects of Aging
Meniscus
• Normal amount of fraying of the meniscal edges
• ↑ in proteoglycan content
• ↑ in calcium pyrophosphate dihydrate (CPPD) crystals within the substance of meniscal material
• ↑ in hydroxyapatite crystals in the vessels of the outer third of the meniscus
∴ stiffer material that is less able to act as a shock absorber and distribute pressures over a larger area of articular cartilage

Effects of Aging
Tendon and Ligament
• no great change in ultimate strength of tendon with aging until the 7th decade
• similar changes in ligament- ↑ avulsion fracture?
• increase in stiffness with aging secondary to an increase in cross-linkage binding between adjacent collagen fibers
∴ slightly weaker material that reaches greater levels of stress with accessory motions secondary to increased stiffness- more avulsion fx’s?
Effects of Aging
Tendon and Ligament
Implications for Intervention

- Modulation of magnitude, duration, and frequency of loads
- Progressive increase in these variables for someone who is increasing their physical activity levels to avoid avulsion fracture
- Older individuals generally are at greater risk for chronic rather than acute musculoskeletal conditions- patience for healing of chronic irritations of tendon and ligament
Effects of Aging
Muscle

- preferential atrophy of Type II fibers, atrophy of Type I fibers to lesser degree
- also preferential ↓ in number of Type II fibers
- replacement of muscle with fibrous connective tissue
- loss of overall ability to produce peak tension, torque, and angular work
- common operational definitions of endurance relatively unaffected—tied to peak variables

Effects of Aging
Muscle
Implications for Intervention

- Less intense inflammatory response secondary to ↓ blood supply—good! less scar tissue
- fewer and less metabolically active mast cells—patience with healing and rehabilitation efforts in general.
Effects of Aging
Muscle
Implications for Intervention

Ability to train muscle and achieve increases in muscle performance variables may occur with similar % increases initially compared with younger muscle, but will level off at lower absolute levels and earlier.

Effects of Aging
Proprioception

- general loss of proprioception with aging
  - ↓ ability to detect threshold of movement
  - ↓ ability to replicate joint position
- ↑ in simple reaction time
- ↑ in complex reaction time

∴ ↓ ability to respond to internally or externally imposed perturbations during rehab or functional activities- still may be a rehab goal, though
Effects of Aging
Cardiopulmonary

- ↓ sweat rates
- ↓ lung functional surface area for gas exchange
- ↑ airway resistance
- ↓ vital capacity
- ↑ mean arterial pressure
- ↑ atherosclerosis
- ↓ cardiac stroke volume

Effects of Aging
Cardiopulmonary
Implications for Intervention

- Older individuals less able to dissipate heat and deal with heat stress
- Reduced capacity for exercise in terms of
  - reduced capacity to oxygenate blood
  - reduced capacity to deliver blood to working muscles
  - possibility of reduced blood supply to cardiac muscle