

# Osteology/Arthrology

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## Functions of the skeleton:

- Supporting framework for the body
- Red/white blood cell and platelet formation in the marrow
- Mineral storage (calcium, phosphorous)
- Protects vital organs

## Building blocks of bone:

- Calcium carbonate
- Calcium phosphate
- Collagen
- Water

## Bone tissue composed of:

- Osteocytes (widely separated cells)
- Matrix (25% water, 25% protein, 50% mineral salts)

## Bones:

- Long (femur, tibia etc) - compact bone filled with yellow marrow. Ends have spongy (cancellous) bone filled containing red marrow
- Short (wrist/ankle) - spongy bone with compact bone shell
- Flat (skull, scapula, ribs, ilium etc) - spongy bone between plates of compact bone. Broad surface for muscle attachment
- Irregular (vertebrae, ear bones etc)

## Vertebrae:

- 7 cervical
- 12 thoracic
- 5 lumbar
- 5 sacral
- 4 coccygeal
- Gets bigger towards the bottom to support increasing weight.
- Supports trunk and protects spinal cord
- Articulates on neural arches via intervertebral discs
- Discs absorb shock and allow the column to be strong and flexible
- **Scoliosis** - Abnormal lateral curvature
- **Kyphosis** - exaggerated posterior thoracic curve (humpback)
- **Lordosis** - exaggerated anterior lumbar curve (sway back)

## Joints :

- **Fibrous** (skull joints etc) - two bones joined by fibrous tissue, immovable
- **Cartilaginous** (vertebral joints, joint between ribs and sternum) - slightly moveable
- **Synovial** (elbow, knee, wrist etc) fully moveable. Most joints in the body.
  - **Synovial fluid** lubricates joint and supplies nutrients/removes waste from cartilage cells
  - **Ligaments** - fibrous connective tissue connecting bones together
  - **Tendon** - fibrous connective tissue joining muscle to bone
  - **Bursa** - sac/cavity at friction points filled with synovial fluid

## Joint disorders:

- **Sprain**: twisting/overstretching causes ligament to be overstretched or separated from bony attachment

- **dislocation:** articular surfaces of bones displaced. Blood vessels may rupture and nerves may be compressed
- **Subluxation:** partial dislocation
- **Bursitis:** inflamed bursa resulting from injury or infection
- **Arthritis:** joint inflammation from trauma, infection, etc.

**Structural limits to flexibility:**

- Bony structure of joint - can't be changed
- Ligaments
- Joint capsules
- Muscle-tendon unit - stretching involves this.

**Directions:**

- Frontal plane (front/back)
- Sagittal plane (left/right)
- Transverse plane (top/bottom)
- Medial (towards middle)
- Lateral (towards outside)
- Superior (towards head)
- Inferior (towards feet)
- Anterior (towards front)
- Posterior (towards back)
- Proximal (towards trunk)
- Distal (away from trunk)
- Internal/External

**Movements:**

- Flexion/extension
- Abduction/adduction
- Medial (inward rotation)/lateral (outward) rotation
- Supination (rotate upwards)/ pronation (rotate downwards)
- Elevation/depression
- Plantar flexion (foot towards ground) /dorsiflexion (foot towards body)

# Somatotype

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Primary determinants of body appearance is:

- Skeleton
- Muscle
- Fat

**Sheldon's somatotypes:**

- **Endomorphy** - softness/roundness
- **Mesomorphy** - muscle/bone/connective tissue
- **Ectomorphy** - linearity/fragility
- These three components ranked from 0-7. combined to form a somatotype.
- Most somatotypes dominated by two components (ex: mesomorphic endomorph)

**Heath-carter somatotype method:**

- 12 point scale instead of 7.
- **Sexual dimorphism** - distribution of female physique types vary from male distribution (i.e. females are more endomorphic and less mesomorphic than males)
- Ethnicity, genetics, and environment also affect somatotypes
- Somatotypes doesn't indicate height or body proportionality

# Anthropometry

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**Anthropometry** - measurement of body size/proportions (skinfold thickness, bone width + length, height, body weight)

- Two component model:
  - fat
  - fat free mass (organs, bone, muscle etc)
- Four component model -
  - Fat
  - Protein
  - Minerals
  - Water

## Why?

- Suitable body comp important for health
- Establish reasonable ranges for athletes in diff sports
- Used to develop weight reduction programs
- Knowledge of bone mineral content in women/children
- Monitor changes in body comp associated with disease

## Essential fat

- Fat required for normal functioning (components of cell membranes, synthesis of hormones, transport of vitamins etc)

## Storage fat

- Stored in adipose tissue as energy supply
- Located under skin and around some organs

## Male vs female body comp

- Males with apple shape have higher health risks
- Pear shape for females - switches to apple after menopause
- Women have more fat due to childbearing (breasts, pelvis and thigh)

## Adipose tissue

- Endocrine organ secreting peptide/non peptide compounds that trigger change throughout body
- Fat storage
- When fat cells expand, more of some compounds are released

## Causes of modern obesity

- Energy intake > energy expenditure. Our bodies were originally set up to deal with starvation, not excess
- Decreased physical activity (cars, tv, automation)
- Increased calorie consumption (large portion sizes, high sugar/fat diet)
- Social environment - advertising, peer pressure etc
- Biology - genetics
- Viruses?

## Body composition assessment techniques

- **Direct methods** - chemical analysis of cadavers
- **Indirect methods** - noninvasive techniques on living subjects
  - **Height-weight tables**
    - doesn't account for body comp

- Most data is outdated and biased to middle-aged whites (not representative of modern population)
  - No accepted method for determining frame size
- **Body density/volume measurements**
  - Density = mass/volume
  - Use underwater weighing/volumetry to measure volume . Or air displacement.
  - Equation then used to determine % body fat
    - Assumes human body has fat and nonfat compartments
    - Each compartment has densities that are known constants
    - However density of nonfat compartment is now shown to vary due to age/sex/racial group
- **Weight-height indices (BMI)**
  - Body mass/height<sup>2</sup>
  - Doesn't account for body comp (overweight does not always mean over-fat)
- **Skinfold measurements** - relationship between subcutaneous fat and internal body fat/body density
  - Use sum of a number of fatfolds as an indication of relative fatness
  - Use fatfolds in conjunction with equations and tables to predict % body fat
  - Assumes:
    - Constant densities in 2-comp model
    - Proper measurement technique
    - Constant compressibility of skinfold
    - Fixed adipose tissue patterning
    - Fixed proportion of internal to external fat
  - Two types of body comp equations
    - Population-specific equations
    - Generalized equations
  - Still has 3-4% error
- **Canadian physical activity, fitness and lifestyle appraisal**
  - BMI
  - Sum of 5 skinfolds
  - Waist girth
- **O-scale**
  - Adiposity rating
  - Proportional weight rating
  - Stanine scale
- **Bioelectrical impedance analysis**
  - Measure electrical resistance of body
  - Impedence is greater in adipose tissue than in bone/muscle <- more water content
  - Not that accurate due to fluctuating water content levels throughout the day
  - 3-5% error
- Other methods such as x-ray absorptiometry, ultrasound, MRI, etc are expensive. Machinery/resources should be used for more urgent procedures

# Growth/development

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**Growth** - progressive development of a living being/part of organism from earliest stage to maturity

## Postnatal growth stages

- Neonatal: birth-4wks
- Infancy: 4wks-2yrs
- Childhood: infancy-puberty
- Adolescence: starts at ~9 for girls and ~11 for boys

## Growth curves

- Distance curve - measurement vs time
- Velocity curve - increments in growth
- Longitudinal data - growth curve derived from repeated measurements of group or individual over a period of years
- Cross sectional data - comparing measurements of several age groups

## Height growth

- Girls enter puberty earlier than boys, therefore finish growing faster.
- Boys have 2 more years of growth before growth spurt, during which the legs are growing faster than the trunk (therefore boys usually end up taller than females)

**Osteoporosis** - bones become thin and brittle due to decreased mineral content (easier fracture)

- Vitamin D important (sun + diet)
- Peak bone mineral density achieved around age 20.
- Minimal bone growth after growing years

## Changes in body proportion:

- Infant - large head compared to body. Lower body less developed than upper limbs
- Extremities develop faster than central parts (hands develop faster than arms etc)
- Facial bones grow faster than skull
- Reproductive organs develop rapidly during puberty -> also causes changes to body size and shape, muscle fat and bone proportions
- **Menarche** - menstruation

## Indices of maturity:

- **Radiological (skeletal) age** - usually examine the hand and wrist for maturity
- **Dental age** - first set of teeth 6mo-2yrs. Permanent teeth from 6-13 yrs
- **Growth curves**
- **Sexual age** - public hair, genital development.
- **Neural age** - Girls usually ahead of boys during motor and sensory development phase. Ahead in fine motor skills

5 types of skeletal development:

- Average
- Early maturers (tall during childhood, not as adults)
- Early maturers + genetically tall
- Late maturers (small during childhood, average as adults)
- Late maturers + genetically short

## Factors influencing growth and maturation

- Genetic control
- Nutrition - malnutrition delays growth

- Secular trends - children now growing faster and stop growing earlier. Probably due to better nutrition, less disease
- Season and climate - long limbs of africans = lose heat better. Thick body + short limbs of north asiatic = retain heat better
- Racial differences (ie. Asians are shorter, but have longer trunks and shorter legs. Africans have long legs and shorter trunk etc)

# Evaluation of physical fitness

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## Components of health related physical fitness

- Cardio-respiratory endurance-aerobic power
- Strength
- Muscular endurance
- Flexibility
- Body comp

## Objectives of physical testing

- Assess status of people entering program
- Prescribe correct amount of activity to individuals
- Evaluate progress
- Increase motivation
- Evaluate success in achieving objective

## Characteristics of a good physical test

- **Validity** - measures what it's supposed to measure
- **Reliability** - consistent. Test procedures should be standardized
- **Objectivity** - multiple tests should agree on scoring
- **Accuracy** - how close is the result to the 'true' value
  - Systematic errors - errors that systematically shift measurements in one direction away from true value
- **Norms** - relative rating to other people
  - Norms taken from wide distribution of population?
  - Large sample size?
  - Norms being used for specific groups they were prepared for?
- **Economy** - costs and time required
  - Lab tests require specialized equipment and usually only one person at a time
  - Field tests require inexpensive equipment and little specialized training. Usually can be done in a group, but is less precise than lab tests.

# Skeletal muscle

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## 3 types of muscle tissue:

- **Skeletal muscle** - attaches to and moves skeleton. Forms striated (ridged) pattern
  - 75% water, 20% protein, the rest is inorganic salts, pigments, fats, carbs
- **Smooth muscle** - walls of hollow organs (like stomach, lungs) and blood vessels. Involuntary control
- **Cardiac muscle** - contractile tissue of heart wall. Has characteristics of smooth and skeletal muscle (organized like skeletal, but is involuntary)

## Criteria used to name muscles:

- Shape - trapezius, rhomboid, deltoid (triangular)
- Action - flexor, extensor
- Location - anterior, major
- Divisions - triceps brachii, quadriceps femoris
- Size relationships - gluteus maximus/minimus
- Direction of fibers - transversus (across), rectus (straight)

## Skeletal muscle shapes:

- Unipennate
- Bipennate
- Multipennate
- Longitudinal
- Radiate

## Muscle actions:

- **Prime mover** - contraction primarily responsible for a movement
- **Antagonist** - muscles that oppose each other upon contraction (ex: biceps/triceps, quads/hamstring)
- **Fixators/stabilizers** - immobilize a bone or joint near origin of prime mover to allow prime mover to act more efficiently.

## Gross anatomy

- **Tendons** - extensions of connective tissue membranes beyond the end of the muscle. Much stronger than muscle
- **Origin** - less movable end of a muscle
- **Insertion** - more movable end of a muscle
- **Belly** - widest portion of a muscle between origin and insertion

## Connective tissue

- **Parimysium**
- **Endomysium**
- **Epimysium**

## Anatomy of skeletal muscle

- Each muscle cell contains many microfibrils (contractile proteins)
- Arrays of microfibrils = sarcomere
- Actin = thin filament
- Myosin = thick filament

## Blood supply

- Muscle tissue has 3-4 capillaries surrounding each fiber. Training can increase the amount of capillaries per fiber

- As muscle force increases, intramuscular pressure also increases and can start to restrict blood flow within the muscle (15-20% max muscle force)
- 50% max muscle force can completely stop blood flow

### Function of skeletal muscle

- **Motor unit** - motor neuron + muscle fibers involving that motor neuron.
  - Cell body of motor neuron located in spine
  - **All-or-none law**
  - Slow twitch oxidative (SO / type I)
  - Fast twitch oxidative glycolytic (FOG / type IIa)
  - Fast twitch glycolytic (FG / IIb)
- Controlling force production:
  - Multiple motor unit summation - activate more motor units
  - Frequency/wave summation - many action potentials generate more force
  - All motor units activated + high firing rate = max muscle activation
- Isolated muscle can exert maximal force/tension while in resting stretched position. As muscle shortens, less tension can be exerted
  - Hence stretching before exercises

3 factors affecting strength of muscle:

- Speed of shortening
- Initial length of muscle fibers
- Angle of pull on skeleton

# Muscular strength

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## Types of muscular contraction:

- **Dynamic (isotonic) contraction** - levers move through range of motion when appropriate muscles perform work
  - **Concentric contraction** - muscle shortens with varying tension as it lifts constant load
  - **Eccentric contraction** - external resistance exceeds muscle force, muscle lengthens while developing force (gravity resistance)
- **Isometric contraction** - static contraction. Tension developed, but no change in angle of joint or length of muscle
- **Isokinetic contraction** - muscle shortened at constant velocity determined by instrumentation. Allows exertion of maximal force throughout full range of motion

## Strength testing techniques:

- **One rep max** - max amount of weight lifted once.
  - Nautilus machine - leverage characteristics change as joint goes through range of muscle - muscle stressed more at optimal joint angles
- **Dynamometer techniques** - spring device that deforms a certain amount as force is applied to it (ex: hand grip dynamometer)
- **Computer assisted isokinetic methods**

## Strength test considerations

- Give standardized instructions before test
- Any warmups should be of uniform duration/intensity
- Angles of measurement should be consistent among subjects
- Consider differences in body size/proportion
- Test/training specificity
- Safety
- Test administrators should be properly trained + good understanding of procedures

## Factors affecting strength

- **Muscle cross sectional area** - strong positive correlation between muscle CSA and strength
  - Muscles increase in strength by increasing size + increasing firing rate of motor units
  - Hypertrophy - Increase in size of cell
  - Hyperplasia - increase in number of cells
    - No direct evidence hyperplasia occurs in humans
- **Body size** - + correlation between body size/mass and strength
  - Negative correlation between body mass and strength/mass ratio
    - Smaller athletes stronger than larger athletes
    - Large athletes for absolute strength
    - Small athletes for high strength/body mass ratio (Ex: gymnastics)
- **Muscle fiber composition** - + correlation between % fast twitch fibers and strength
- **Mechanical factors** - force exerted by muscle is affected by:
  - Initial length of muscle fibers
  - Angle of pull of muscle on bony skeleton
  - Speed of shortening
- **Sex/age**
  - After age 16, female is 2/3 as strong as boys
  - Before puberty boy strength is only a little greater than girl strength
  - Hormones are responsible for increase in muscle bulk in males (testosterone)
  - Muscle gain due to hypertrophy, not hyperplasia
  - Males generally stronger because:
    - Physically larger than average female

- Body comp differences
- Body proportion differences (males have broader shoulders = more muscle mass on frame, females have broader hips)
- Cultural factors (less emphasis on females to be strong)
- No difference between female and male muscles

### **Benefits of strength training**

- Provides foundation for other components of fitness (muscular endurance etc)
- Slow down muscle loss accompanied by aging, make daily activities easier
- Increase size and strength of muscle fibers
- Increase tendon, ligament, bone strength
- Strong muscles protect joints better
- Look hot.
- Helps prevent posture problems
- Strong muscle less likely to be injured
- Improve self esteem

# Biomechanics

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**Biomechanics** - application of mechanical laws to living structures (locomotor system of human body)

## Uses:

- Improvement of sports skill techniques
- Design of sports equipment
- Injury prevention
- Clinical analysis of movement pathology
- Design of prosthetics
- Design of rehab devices

**Qualitative analysis** - observation (teachers/coaches)

**Quantitative analysis** - numerical analysis from data collection during movement performance (researchers)

Force (N) = mass \* acceleration

Weight = mass \* 9.81 (gravity acc)

**Torque (N\*m)** - rotary force

**Moment arm** - perpendicular distance between force's line of action and axis of rotation

**Mechanical advantage** - ratio of force arm length to resistance arm length

**Pressure (N/cm<sup>2</sup>)** - force distributed over given area **P = F/A**

**Compression** - pressing/squeezing force axially through body

**Tension** - pulling/stretching force axially through body

**Shear** - force directed parallel to surface

## How to lift heavy stuff:

- Get help
- Stand facing object with feet flat, shoulder width apart. Stable base - avoid slippage
- Face object in direction of planned movement - avoid turning with object
- Keep object close to body
- Get good grip on object
- Bend at knees and hips, keep back straight
- Lift using knee and hip muscles, not arms and back
- Carry object close to center of gravity
- Avoid lifting heavy things after a long period of sitting. Stand/stretch a bit first
- Avoid lifting/spine bending right after waking up

**Center of gravity** - point of intersection of 3 cardinal planes of body

- Describe movement of body through space
- Important for stability
- Important factor in calculation of amount of work done
- **Reaction board method** - for static position of body. Assuming CG is at fulcrum, then apply principle of levers
- **Segmental method** - for locating CG of body in motion

**Stability** - Firmness of balance can be increased by:

- Increasing body mass

- Increasing size of base of support in direction of line of action of external force
- Vertically positioning CG low as possible
- Increase friction between body and surface contacted
- Horizontally positioning CG near edge of base of support towards oncoming external force

#### **Newton's laws of motion**

- **First law - law of inertia** - body maintain state of rest or constant velocity unless acted on by external force that changes state.
- **Second law - law of acceleration** -  $F = m \cdot a$
- **Third law - law of reaction** - when one body exerts a force on a second body, second body exerts reaction force equal in magnitude and opposite direction on the first body.
- **Momentum =  $m \cdot v$**