

# FUNCTIONAL ANATOMY AND BIOMECHANICS OF MOVEMENT

Joanna Abbatt

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## INTRODUCTION:

### Terminology:

**Anatomical position** – movement described in relation to this, stance with feet and palms facing front

### Planes of body, related to joint movement

1. median/midsagittal, **sagittal plane** (medial/lateral, flexion/extension), movement front to back, back to front
2. **Frontal/coronal plane** (anterior/posterior, abduction/adduction) – sometimes called vertical plane, divides body front/back, movement side to side
3. **Transverse/horizontal plane** (rotation) – divides body into upper and lower, movement is parallel with horizon

Complex movements involve all 3 planes

### Directional orientation

*Medial /lateral*  
*Superficial/deep*  
*Superior(cephalic)*  
*Inferior(caudal)*  
*Anterior/posterior*  
*Proximal/distal*  
*Ventral/dorsal*  
*Intrinsic/extrinsic*  
*Ipsilateral/contralateral*

### Description of Joint Motion

**osteokinematics** – description of joint motion in relationship to the three planes

- sagittal plane
- coronal plane
- transverse plane

**arthrokinematics** – movement that takes place between joint surfaces, articular surfaces of bones, combination of roll, slide, glide, spin, approximation, separation, distraction dependent on joint

### Movements of the body

Flexion/extension – embryological front surfaces come together in flexion/ embryological front surfaces move apart in extension, dorsiflexion

Abduction/adduction

Medial rotation/lateral rotation

Rotation (axial skeleton)  
Circumduction  
Lateral flexion  
Supination/pronation  
Opposition  
Inversion/eversion  
Plantarflexion/dorsiflexion  
Elevation/depression  
Deviation  
Protraction/retraction

### **Types of joints**

Joint = point of contact between bones (articulation)

- all articulations have a fibrous, cartilaginous or synovial structure
- fibrous, cartilaginous joints have little if no movement capability whereas synovial joints contain a joint cavity which allows for space for movement = diarthroses or synovial joints

Synovial joints or freely moveable joints often have one convex, one concave surface, covered in hyaline cartilage which can withstand stresses, the entire joint is in the joint capsule, blood vessels bring nourishment, nerves bring sensory information.

*6 different types:*

- ball and socket
- hinge
- gliding
- ellipsoid
- pivot
- saddle joint

### **Cartilage**

- white connective tissue which covers articulating surface of bones
- cartilage absorbs shock, doesn't contain blood vessels, avascular – nutrients from synovial fluid and bone
- fibrocartilage – specially adapted for absorbing shock, high in collagen – menisci

### **Joint capsule**

- encloses joint, prevents liquid loss, binds articulating bones together

### **Ligaments**

- connect bones together at joint, bone to bone
- dense bundles of collagenous fibers
- cannot actively contract or stretch except for a few with high yellow elastic fibers
- contain sensory nerve cells
- excessive movements or trauma can sprain or rupture ligaments

### **Muscle tissue**

- skeletal muscle – composed of muscle cells (fibers), connective tissue (fascia), and numerous nerves and blood vessels, -- voluntary and striated muscles which attach to bones

- smooth muscle (intestines, blood vessels)
- cardiac muscle

### **Fascia/connective tissue**

- continuous sheath of fibrous membrane beneath skin and around muscles and organs, forms compartment of muscles, connects everything together
- woven tissue, organized through movement, hydration through movement
- Superficial fascia: immediately deep to skin, covers whole body
- Deep fascia: more complex design – surrounds muscle bellies, holding them and separating them into a functional group

### **Bursa**

- fluid filled bag, prevents friction between 2 structures, over 600
- between muscles, tendons, tendon/ligament, muscle/ligament

### **Nerves**

- provide each cell with ability to communicate with every other cell in body
  - nervous system – brain, spinal cord and nerves that pass throughout whole body
  - sensori-motor nerves – nerves create movement goals via connections with the brain
  - sensory nerve signals from muscles, joints, skin, etc. giving us our 'body sense' is called *proprioception*
- Plexus: network of intersecting blood vessels, intersecting nerves or intersecting lymph vessels

### **Blood vessels**

- bring nourishment and immunological protection to cells, remove waste products from cells
- arteries, veins, lymphatics

### **Organs/glands**

- help with cellular regeneration, maintain, replace and reproduce cells, these form the contents of our torso or trunk

### **Skeleton**

Bones – approximately 200, 206

- 1: Axial skeleton
  - cranium
  - Vertebral column
  - Ribs
  - Sternum
  - Hyoid bone
  
- 2: Appendicular skeleton
  - arms and legs
  - Pectoral girdle (scapula and clavicle)
  - Pelvic girdle (hips)

3 basic shapes of bones 1. long

- 2. short
- 3. flat

- bones have rigid yet elastic qualities
- skeleton, 15% of body's weight, 1/2 water, 1/2 solid matter

- bones act as levers for actions of muscles, attachments for muscles and provide architectural support for body

### **Muscles/Tendons**

- muscles produce or prevent movement of joints
- tendon is part of muscle which crosses over joints, connecting to bone, some muscles have tendinous tissue through whole length
- muscles often cross joints on diagonal, therefore muscle produces spiral motion pathway of limb through space and can be monoarticular/polyarticular
- muscle made up of bundles of fibers held together by deep fascia, epimysium (encases muscle belly), perimysium, and endomysium which are all connective tissue
- lots of muscle fibers make a fascicle, blood vessels within muscle, fascicle sheath around fibers
- food = O<sub>2</sub> in blood – more blood in area = more cellular regeneration, tissue regeneration
- strength and flexibility, stability necessary

- **origin** – bone fixed

- **insertion** – bone that moves due to contraction

- all muscles have normal resting length, elastic properties so will try to maintain normal resting length - muscles attach differently to bones

- length/force relationship in skeletal muscle

- different shapes of muscles – long, fan, flat, short

agonist = prime mover, muscle that produces movement

antagonist = opposing movement, muscle that resists agonist

synergist = muscles that support agonist

contraction of muscle – usually origin and insertion move together

1. isotonic contraction
2. isometric contraction
3. eccentric contraction – most strength, easier to injure

stability produced if mutually opposing muscles are working

Inversion of muscle actions

\*muscles can contract to 50% of their length, after this other muscles take over

Considerations:

May need to strengthen or stretch dependent upon individual

It takes 2 months to increase muscle size so that it's thicker and stronger, strength gains seen before are motor control and skill

### **TRUNK AND SPINE**

Consists of bones (pelvis, thorax, spine/skull), muscles (pelvis floor, spinal and abdominal wall, chest wall, etc.), contents of these structures (organs, glands of digestion, circulation, reproduction, respiration, etc.)

- flexible spine

- upper trunk/lower trunk, diaphragm separates it

### ***Bony landmarks/ pelvis, lumbar spine L1-L5***

- top of pelvis = iliac crest, anterior superior iliac spine, posterior superior iliac spine
- bottom of pelvis = ischial tuberosities
- back pelvis = sacrum, lumbo-sacral juncture at top, coccyx at bottom
- front pelvis = pubic symphysis, superior pubic ramus, inferior pubic ramus to acetabulum
- pelvic inlet (front sacrum, superior aspect pubic symphysis), pelvic outlet (pelvic floor)

### ***Landmarks, thoracic T1-T12***

- top = sternum, manubrium, 1<sup>st</sup> rib circle
- bottom = xiphoid process of sternum, lowest ribs, diaphragm on inside
- back = thoracic vertebrae and costovertebral joints of T1-12
- front = entire sternum, each rib to sternal cartilage (not floating ribs)

### ***Landmarks, skull/top of spine C1-C7***

- top = midpoint between ears on sagittal suture
- bottom = atlanto-occipital joint, midpoint between indentations just below ears between mastoid process and jaw, level of hard palate
- C7

### **sacrum**

5 fused S1-S5, S1= base of sacrum

S5= inferior surface articulates with coccyx called apex of sacrum

### **Coccyx**

Remnant of tail, 3-4 fused

### **Sacro-iliac joint/SI joint**

Slight movement, part fibrous, part synovial

Hypomobile, hypermobile

Reinforced by capsule and strong ligaments and muscles

- Interosseus sacroiliac ligament
- Anterior sacroiliac ligament
- Sacrospinous ligament
- Sacrotuberous ligament
- Posterior sacroiliac ligaments

### **Lumbosacral joint**

Sacral base tilted front

Discs L4, L5 & L5, S1 thicker anterior and concave posterior

L5 tendency to slide front due to forces moving down

### **Function of vertebral column**

1. Provides base of support
2. link between upper and lower extremities
3. mobility for trunk, shock absorption against gravity
4. stable base for attachment for ligaments, bones and muscles of extremities, rib cage and pelvis
5. protects the spinal column

- stability and mobility
- central tunnel = spinal cord, spinal nerves
- 33 short bones called vertebrae, 23 intervertebral discs
- cervical = 7, thoracic = 12, lumbar = 5, sacral = 5 fused, coccygeal = 4 small bones fused, -vertebrae increase in size from cervical to lumbar spine and decrease in size from sacral to coccygeal

### **sagittal curvatures – observe standing**

- primary, secondary curves
- lordosis, kyphosis, concave, convex
- scoliosis – structural/functional

### **Neutral spine**

- ASIS, pubic symphysis, L5, lumbar spine lordosis
- thoracic kyphosis
- cervical lordosis

### **Movements**

flexion/extension (anterior/posterior)

lateral flexion/sidebending

rotation

translation

Range of movement depends on vertebral level

Combination of movements

### **Vertebral structure**

1. body (anterior – near to central axis, supports weight)
2. vertebral arch (posterior)
  - spinous process
  - facets - zygapophyseal joints, provide stability
  - transverse process – attachments
  - spinal cord passes through vertebral column, spinal nerves branch off

### **Articulations**

1. cartilaginous joints – between vertebral bodies and discs
2. synovial joints – between superior facets of one vertebrae and inferior facets of another
  - joints between articular processes = facet or zygapophyseal
  - all facet joints except between C1 C2 are synovial
  - where vertebral column articulates with ribs it is synovial and also for skull
  - SI joints – part fibrous, part synovial

### **Ligaments**

- along entire length of spine, extensive ligamentous system

  1. intrasegmental system, between individual or adjacent vertebrae
  2. intersegmental system, binds number of vertebrae

- total support of both systems needs muscles to help

## **Discs**

- all spinal movement within intervertebral discs
- with aging, wear and tear disc can lose role as shock absorber
- disc and nucleus get nutrients from surrounding blood vessels of nucleus and from within the vertebral bodies
- process of diffusion – slow process of fluid transport from the vertebral body and via the porous endplates throughout the disc and nucleus by the process of compression and decompression
- process strongly affected by posture and movement
- mechanical failure leads to structural changes to soft tissue such as discs, nucleus, vertebral capsule ligaments, etc.
- fluid escapes from nucleus, fluid compresses nerve roots

## **Vertebral movements and disc**

**Flexion:** top vertebra mobile so moves front, disc compressed anteriorly and expanded posterior, nucleus moves back, greater risk of disc injuries

**Extension:** opposite, top vertebrae tilts backwards disc compressed posterior and expanded anteriorly, nucleus moves forward

**Lateral flexion:** sides move together while further sides apart, disc expanded and nucleus moves to opposite side

**Rotation:** torsion effect on fibers which leads to reduction in height of disc and slight compression on nucleus, nucleus receives compression both horizontally and vertically

## **Lumbar spine**

L1-L5, articulates with sacrum, T12

Concave lordosis

Bodies of vertebrae large, transverse process, long for muscle attachment

Spinous process, short and massive

### *Bony landmarks*

ASIS, PSIS, top of sacrum

Iliac crest = L4, posterior spinous process

T12

L3 – belly button

Ilium, pubis, ischion

## **Thoracic spine**

Thoracic vertebrae, 12, thorax/rib cage – 12 paired ribs and sternum - ribs and rib cage capable of a lot of movement, each rib moves at its joint with 2 vertebrae

Kyphosis – variations

Spinous processes elongated and compressed laterally and directed inferiorly

Transverse process decrease in length from top to bottom.

Facets articulate with rib heads, facets round and flat, allow flexion, extension and side bending.

Ribs 1-7 limited mobility

Ribs 8, 9, 10 “false ribs” have longer costal cartilage

Ribs 11 and 12 “floating ribs” have no anterior attachment so greatest mobility at T11 and T12

In contrast to lumbar spine, thickness of disc much less

### *Landmarks:*

- sternum, xiphoid process, clavicle, scapula, sterno-clavicular joint, acromio-clavicular, superior angle of scapula, spine of scapula, inferior angle of scapula, acromion process – shoulder tip – outer tip of thorax, landmark for T2, T3
- medial border of scapula
- superior border of scapula
- lateral border of scapula
- glenoid fossa, shoulder joint

### **Cervical spine**

Atlas - C1, Axis, C2 - modified for support and movements of skull

C1 shorter spinous process allows good extension, flexion

C3-C7 more typical, good mobility

Due to the structure of the vertebrae, increased mobility and discs about 1/3 as thick as the bodies.

Transverse process shorter and broader than thoracic, tend to limit sidebending as they come in contact.

Correct alignment necessary for protection of soft tissues - spinal nerves, arteries and veins pass through – lordosis.

Arthritic changes of cervical spine occur 40% after 40 years, 80% after 60 years.

neutral alignment:

ideal = lordosis with slight extension in upper and lower cervical spine

- can be affected by hearing and vision, habits during talking, laughing, reading, computer, etc.

### **LAYERS OF MUSCLES IN BACK:**

1<sup>st</sup> layer: trapezius,

2<sup>nd</sup> layer: latissimus dorsi

3<sup>rd</sup> layer: beneath upper trapezius – levator scapulae, rhomboids

4<sup>th</sup> layer: underneath is posterior serratus

5<sup>th</sup> layer: splenius, upper spine to base of skull

6<sup>th</sup> layer: erector spinae, pelvis, rib cage, skull, and all vertebrae – iliocostalis, longissimus, spinalis

7<sup>th</sup> layer: deeper, transverso-spinalis, semi-spinalis, spinalis

8<sup>th</sup> layer: deeper fibers of transverso-spinalis, multifidus,

9<sup>th</sup> layer: beneath this between first 2 vertebrae and base of skull are sub occipitals, rotatores, interspinalis, intertransversarii

10<sup>th</sup> layer: deepest quadratus lumborum

Fascia covers all, integrates lower back muscles with abdominal wall.

Spinal muscles are extensors, they maintain the spine erect against gravity.

### **Range of Motion of Spine (ROM)**

(Please note these are generalized measures)

Lumbar Spine:

Rotation - 5 degrees

Flexion – 40-50 degrees

Extension – 15-20 degrees

Lateral Flexion – 20 degrees



Thoracic Spine:

Rotation – 30 degrees

Flexion – 30-40 degrees

Extension – 20-25 degrees

Lateral Flexion – 25 degrees

Cervical Spine:

Rotation – 90 degrees

Flexion – 45-50 degrees

Extension – 85 degrees

Lateral Flexion – 40 degrees