PHYSICS FOR

PHYSIOTHERAPHY

Angle of pulls of muscle

SABEENADEVI P

ASSISTANT PROFESSOR / PHYSICS/SNSCT

Angle of Pull of Muscle

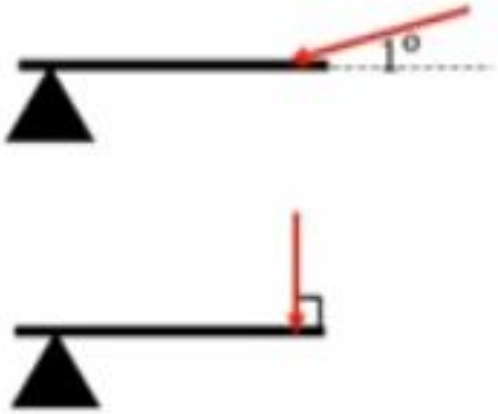
- The angle formed between the line of pull of a muscle and the longitudinal axis of the bone in which the muscle is acting.

- The line of pull is usually indicated by the joint angle. It affects the strength of muscle action; at only certain angles of pull can a muscle exert maximal tension.

Angle of Pull of Muscle

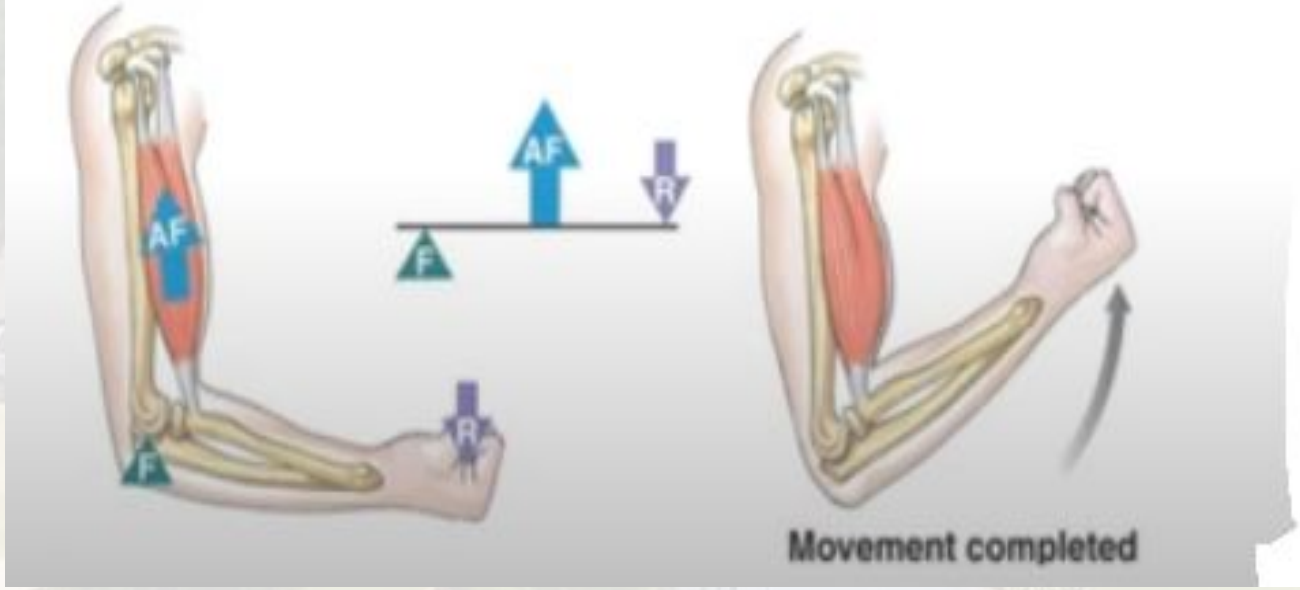
Definition

- A force is most effective when it is applied at **RIGHT ANGLE** to a lever.



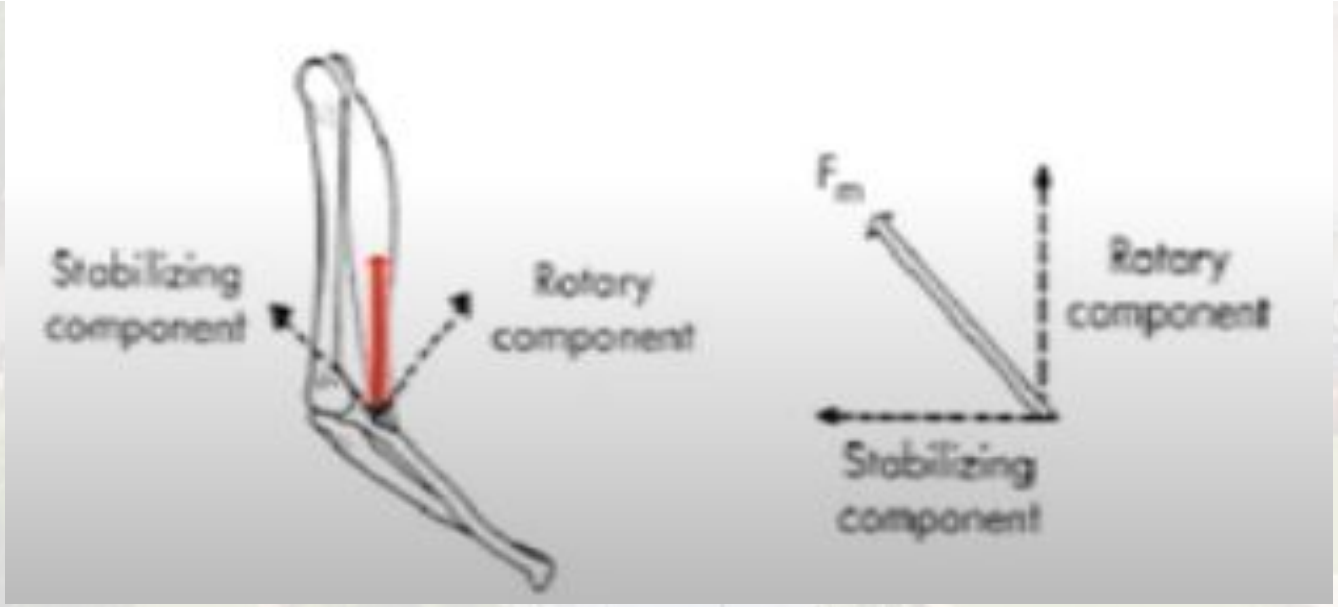
MECHANICAL EFFICIENCY OF A MUSCLE

- The pull is Most effective when the muscle is inserted at right angle to the bone.



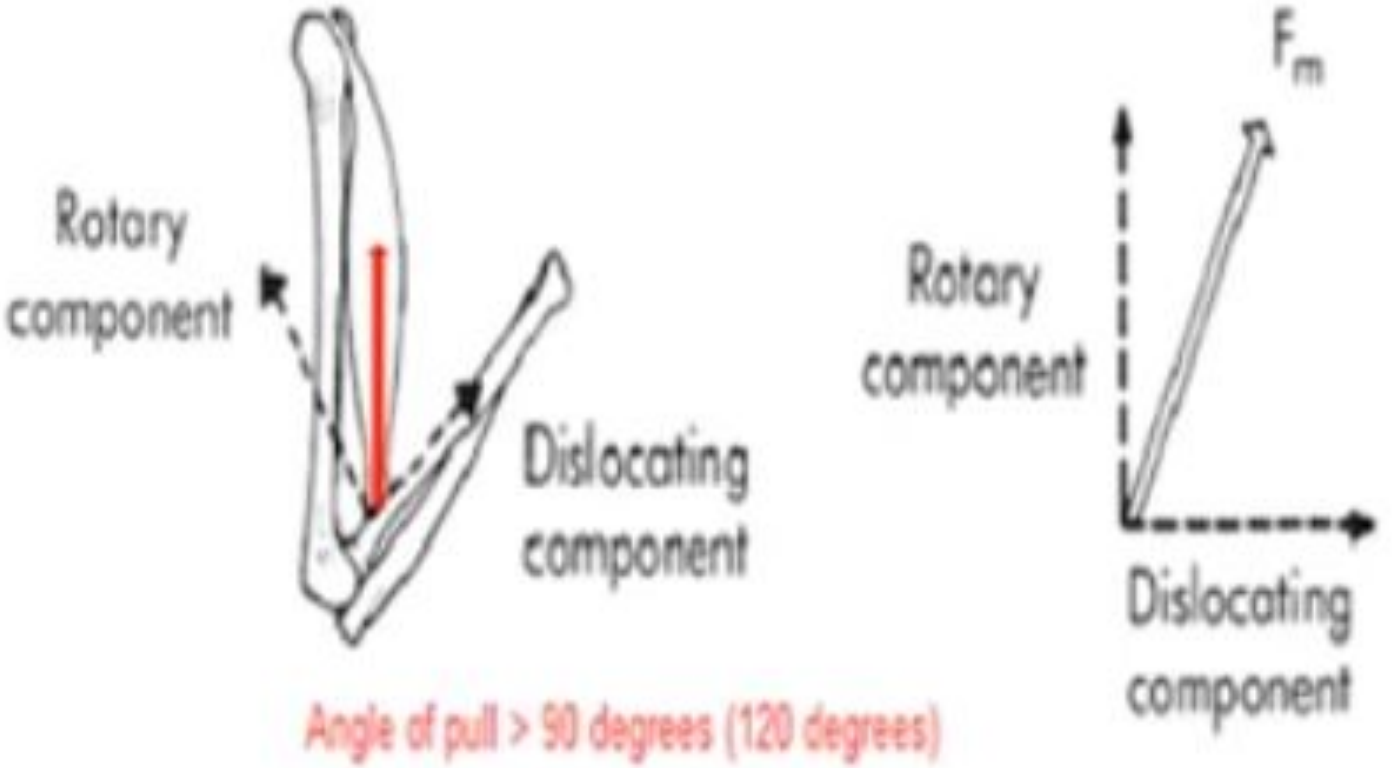
Angle of Pull of Muscle

- The efficiency **DECREASES** as the **angle of pull is reduced** – some force is used in pulling the bone of insertion towards the joint.
- This approximation has stabilizing effect on the joint which is greatest when direction of pull of muscle is longitudinal (i.e. in the long axis of bone of attachment).

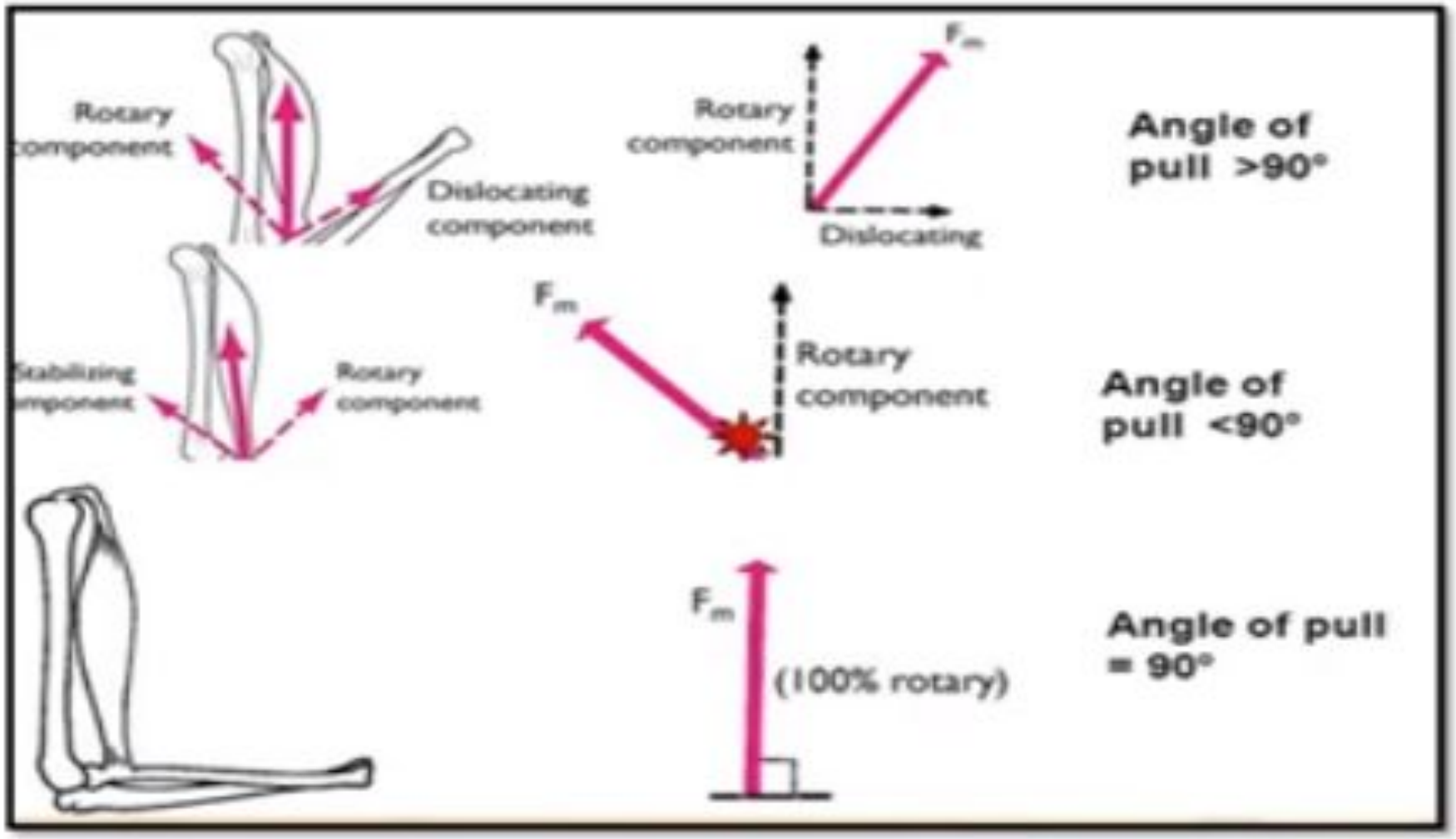


Angle of Pull of Muscle

- Mechanical efficiency is also reduced when angle of insertion is increased from right angle – joint becomes less stable.



Angle of Muscle pull



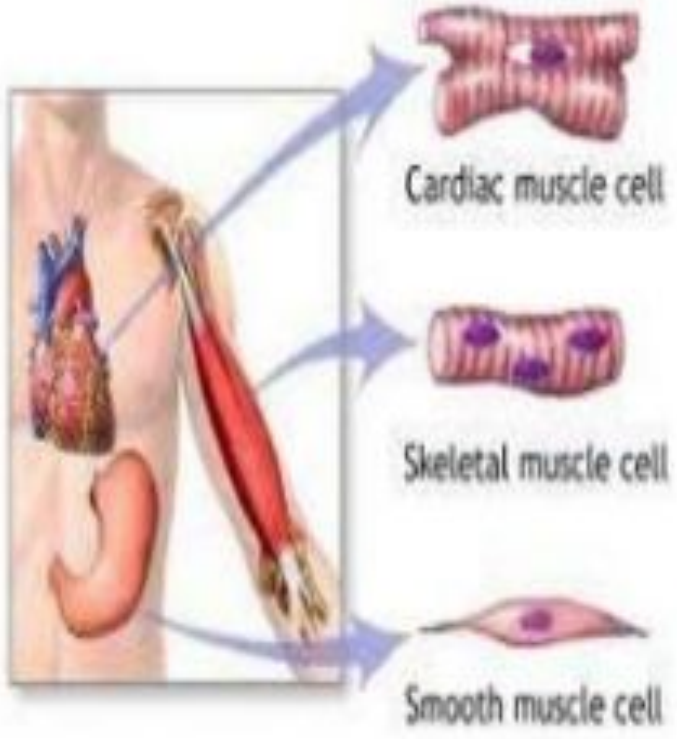
Types of muscles

There are three types of muscles:

1- Cardiac (in the heart).

2- Skeletal (around the skeleton).

3- Smooth (in the viscera).



Functions of skeletal muscles

1. They produce tension.
2. They are responsible for body movement.
3. They provide power either to mobilize bones or to stabilize them so, skeletal muscle can be considered as *"force generator system "*.
4. They maintain posture.

Muscle Tension

- Most important characteristic of muscle is it's ability to develop tension & to exert force on bony lever.
- Tension can be either active or passive; total tension is the sum of both active & passive tension.

Passive Tension

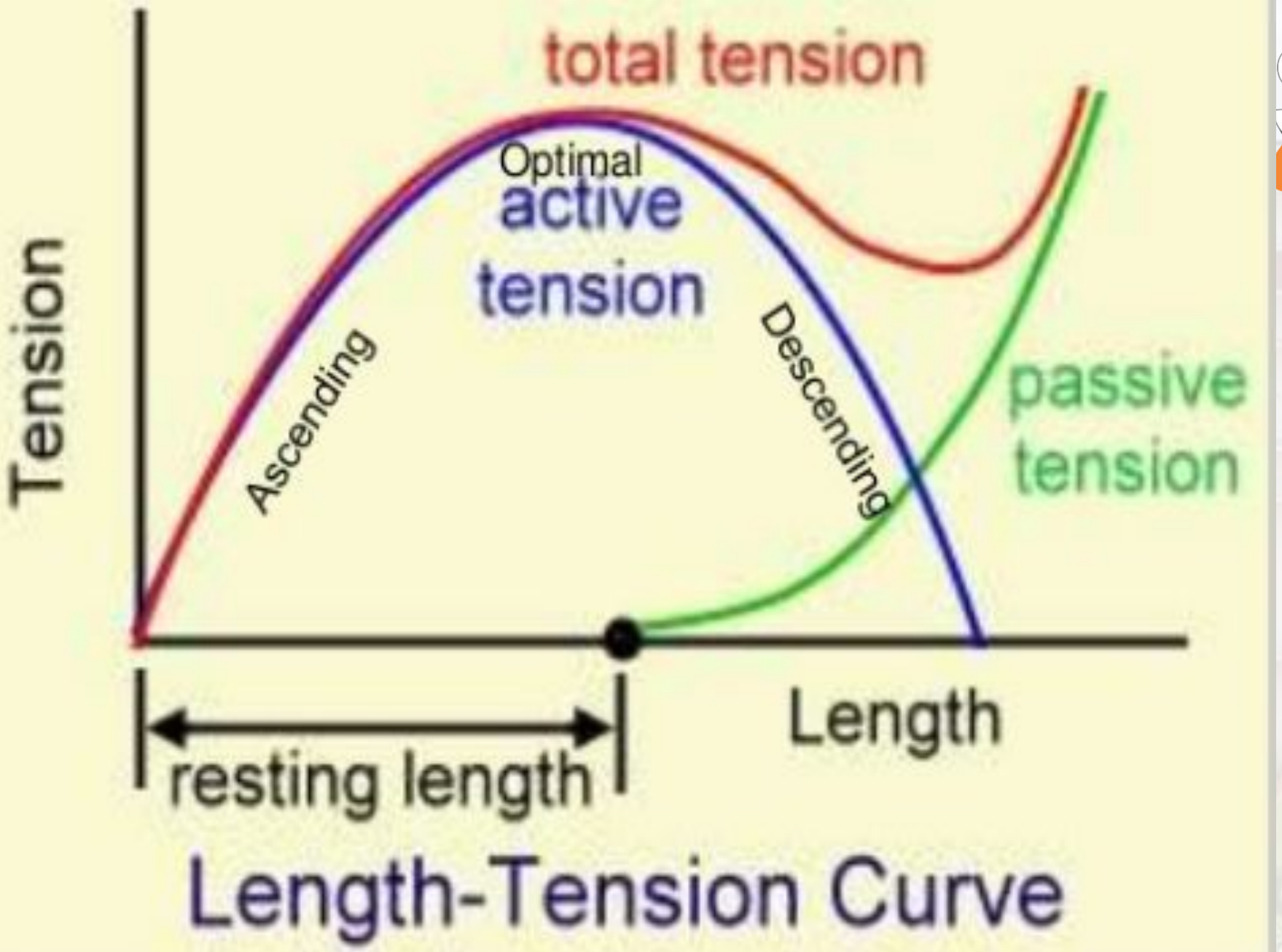
- Refers to tension developed in parallel elastic component.
- Also known as non-contractile tension.
- Created by lengthening the muscle beyond the slack length of the tissues.
- Parallel muscle component may add to active tension by muscle when lengthened; or it may become slack & doesn't contribute to total muscle tension

Active Tension

- Refers to tension developed by contractile element of muscle. So called as contractile tension.
- It is initiated by cross bridge formation & movement of thin & thick filaments.
- The amount of tension generated depends on neural factors (frequency, number & size of motor unit) & mechanical properties (isometric length tension relationship & force velocity relationship) of muscle.

Isometric length tension relationship :-

- There is direct relationship between isometric tension development & length of sarcomeres in muscle fiber.
- At optimal length – maximal isometric tension (due to position of thin & thick filaments forming maximum number of cross bridges in sarcomere)
- Lengthening or shortening beyond optimal length cause reduced amount of active tension. (fewer cross bridges formation)


total tension
Optimal
active
tension
Tension
Ascending
Descending
passive
tension
Length
resting length
Length-Tension Curve

- As muscle elongates, passive elastic tension increases.
- This passive tension is added to active tension resulting in total tension.
- When the muscle is shortened – sarcomere s at shorter length – reduces distance between Z discs – inter-digitation of thin & thick filaments – interferes with formation of cross bridges.
- This is applicable only in isometric contraction.
- During dynamic contraction length tension relationship must be combined with force velocity relationship to determine the effect that both length & velocity have on muscle tension.

Application of length tension relationship :-

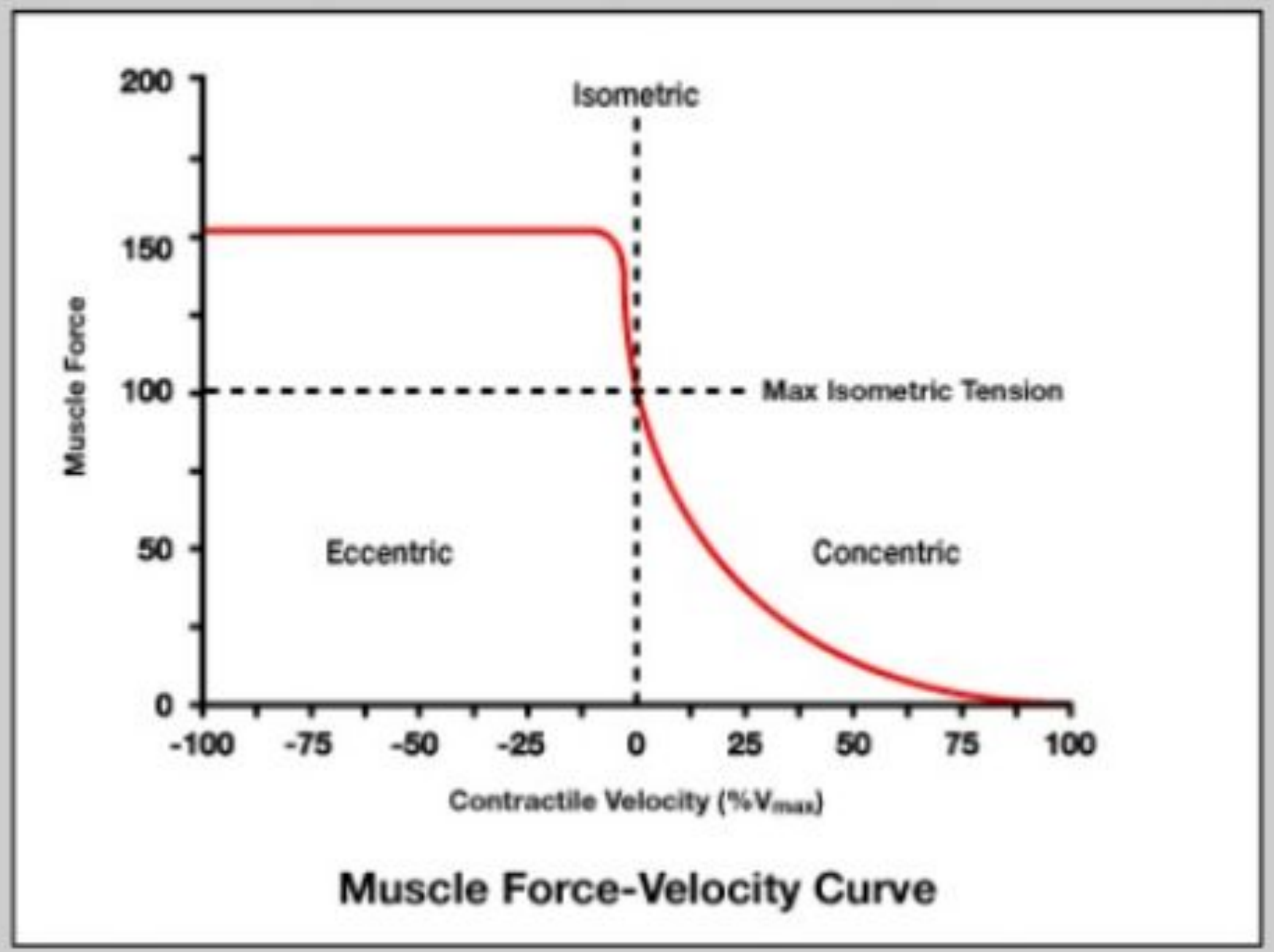
- When applying to muscle joint system – sarcomere length is not same throughout.
- So at a particular joint position- there are sarcomeres at many different lengths corresponding to different point of length tension relationship.
- During movement torque produced at joint is not only due to muscle force but also function of moment arm (MA) of muscle.
- So at particular joint position, muscle length may be short but has long MA, maintaining higher torque.

- Muscles has diminished ability to produce isometric contraction at extremes of joint motion.
- Common in muscles that cross more than one joint, in which muscle length excursion is greater than in single joint muscles.
- Torque of muscle reduces when full ROM is attempted at all joints crossed by multijoint muscle.
- This decrease in torque is called as active insufficiency.

Force – velocity relationship :-

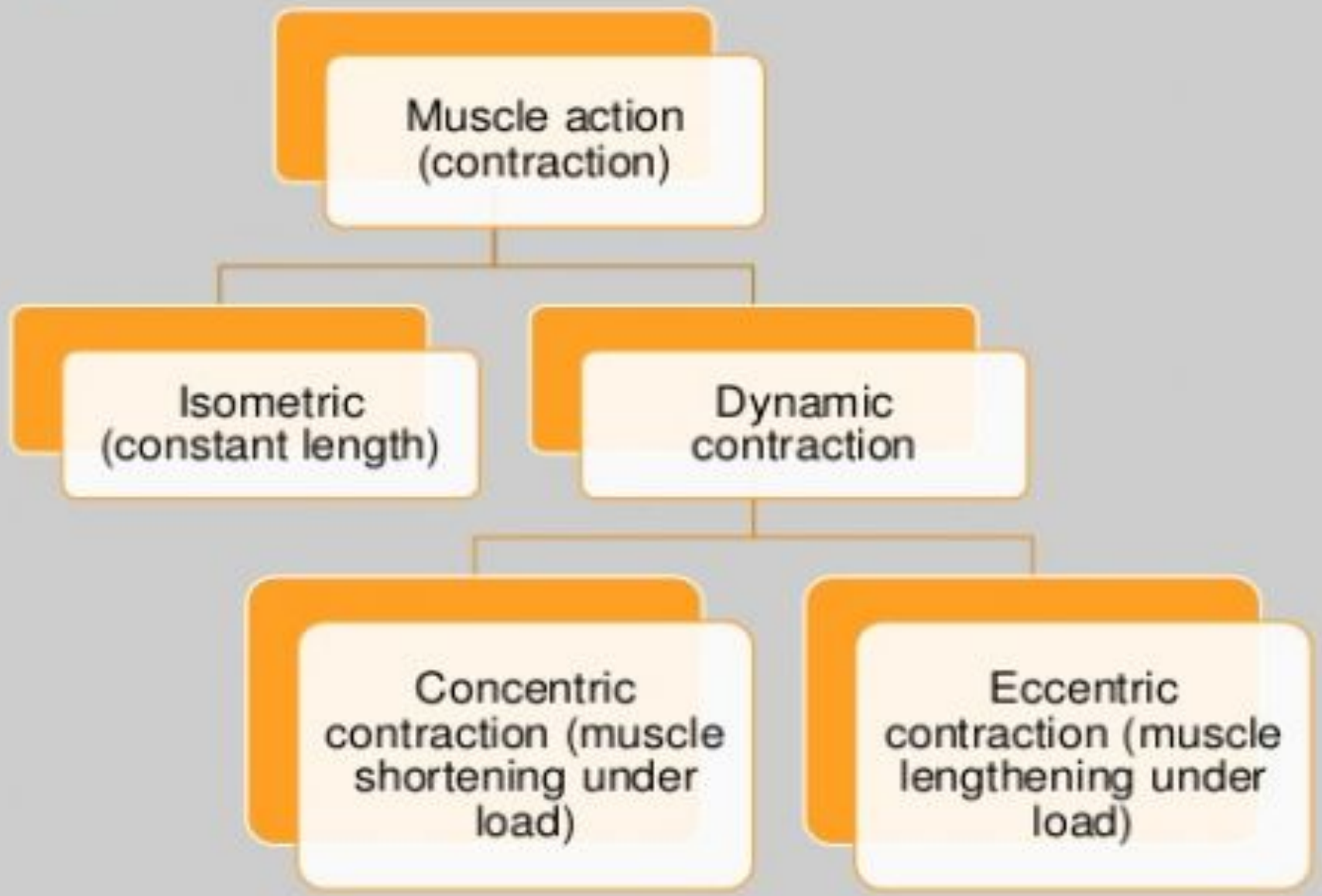
- Another factor affecting tension development is speed of shortening of myofilaments. (Rate at which myofilaments slide & form & re-form cross bridges)
- Speed of shortening depends on type & length of muscle fiber.
- Force velocity relationship describes the relation between velocity of muscle contraction & the force produced. (concentric & eccentric muscle contraction)

- The force generated is the function of velocity of muscle contraction.
- Eg.
  - Concentric contraction- as speed decreases tension increases.
  - Isometric contraction- speed of shortening is 0, but tension reduced is more than concentric.
  - Eccentric contraction – as speed of lengthening increases, tension increases & then plateaus.



Muscle Force-Velocity Curve

Types of muscle action :-



Characteristic	Isometric contraction	Concentric contraction	Eccentric contraction
Sarcomere length	Constant	Shorten	Lengthen
Bone movement	No	Closer together	Move away
Work done by muscle	0 or no work	Positive work	Negative work
Tension development	Great	Low	Greatest
Example	Maintaining elbow at 90 with dumbbell	Elbow flexion full ROM with dumbbell	Elbow extension full ROM with dumbbell

Production of torque :-

- Assessing muscle strength is actually determining the amount of joint torque that muscle produces.
- In muscle experiments, it is isolated from the body & activated but in the body muscle is attached to the bones to produce force, but it acts over MA at joint to produce torque.
- MA of muscle changes with joint position & also muscle length changes according to the joint movement.
- So at different joint position, muscle affects the amount of torque produced.
- During dynamic movement, velocity of shortening & lengthening changes force production & thus torque.

Interaction of muscles & tendon :-

- Interaction of muscle & tendons including aponeurosis during muscle contraction & movement has important functional implication.
- During isometric contraction, muscle actually shortens & tendon lengthens slightly.
- So the compliance of tendon is important to in torque production of muscle.

- This is the basic of plyometric exercises, where muscle tendon complex is stretched before concentric contraction of muscle
- A stretch immediately before concentric contraction produces much greater torque.
- Exact mechanism is still unknown but considered as muscle fibers tends to have same length while tendon lengthens, storing energy to be used during concentric contraction.

Isokinetic exercises & testing :-

- In isokinetic contraction, the angular velocity of bony component is preset & kept constant by a mechanical device throughout the joint ROM.
- It's a description of joint motion because the muscle fascicles do not shorten at constant velocity during the movement.
- As speed of movement is controlled by device, resistance is directly proportional to the torque produced at all points in ROM.
- So as the torque produced by muscle increases, magnitude of torque of resistance increases proportionately.
- Excellent means of testing muscle strength. (biodex, cybex, kin com)

- Benefit of isokinetic exs over free weight lifting is it accommodates for the changing torques created by muscles throughout the ROM.
- As preset speed is achieved, isokinetic device produces resistance that matches torque of muscle.
- Can be used for strength training & to compare relative strength of one muscle group to another.
- Limitation – functional movements rarely needs the speed & complete ROM provided by the isokinetic equipment.

CLASSIFICATION OF MUSCLES

- Muscle are classified in different ways –
  - According to shape (rhomboids, deltoid)
  - No of heads (biceps, triceps, quadriceps)
  - Location (biceps femoris, tibilis anterior)
  - Combination of location & function (EDL, FPB)
  - On the basis of action (flexors, extensors, abductors, adductors, rotators)
  - According to role (agonist, antagonist, synergists)

Based on role of muscle in movement :-

- Agonist/ prime movers – muscle producing desired movement.
- Antagonist – muscles producing exactly opposite of the desired movement. The desired motion is not opposed but the muscle has potential to oppose the movement.
- Co-contraction – simultaneous contraction of agonist & antagonist.
- Synergist – muscle helping agonist to perform desired movement.

Based on muscle architecture :-

- Muscle can change its role.
- Antagonist in one action can be synergist for other.
- Eg. Extensors & flexors on ulnar side of wrist are antagonist during radial deviation but synergist during ulnar deviation.

Based on length of moment arm :-

- The orientation of muscle to the joint has also been used to classify muscle into groups.
- The length of muscle MA is important to determine joint torque & ROM.

FACTORS AFFECTING MUSCLE FUNCTION

- In addition to the factors seen till now, other factors affecting muscle function are :-
  - Types of joint & location of muscle attachment
  - Number of joints crossed by the muscle
  - Passive insufficiency
  - Sensory receptors

Types of joint & location of muscle attachment :-

- The structure of joint determines the type & range of motion to occur.
- The muscle location or line of action relative to the joint determines the motion of muscle.
- Eg. Anterior muscles (flexors), posterior (extensors), lateral (abductors), medial (adductors).
- Distal attachment close to joint – wide ROM (mobility); at distance from joint axis – stability function (majority of force is directed towards the joint that compresses the joint surfaces).

- The stability function changes throughout the motion as rotatory or compressive component of muscle force vary indirectly with each other.
- Maximum joint stability is at the point of greatest compressive force.
- Usually each group of muscle acting on joint produces different torque at same joint.
- Disturbances in normal ratio of agonist & antagonists pair may create imbalance of joint – risk of injury.

Number of joints crossed by the muscle :-

- Many functional movements require coordinated movements of several joints controlled by combination of muscles.
- To produce a purposeful movement pattern, the control is designed to minimize necessary muscle force to accomplish the task & minimize muscle fatigue.
- This motor control strategy ensures that movement is done efficiently.
- It needs coordinated efforts of single joint & multi joint muscles.

- Single joint muscle produce force & work primarily in concentric & isometric contraction whereas multijoint muscles are recruited to control fine regulation of torque during dynamic movements (eccentric more than concentric action).
- Multi joint muscles are recruited during complex motions requiring movement around multiple axes.

Passive insufficiency :-

- It's a term used for insufficient length.
- Single joint muscle rarely are of insufficient extensibility to allow full ROM at joint.
- Two joint or multi joint muscle, frequently are of insufficient extensibility to permit full ROM simultaneously at all joints crossed by the muscle.
- The passive tension developed in stretched muscle is sufficient to either cause motion or limit the motion.

Sensory receptors :-

- Normal motor control for voluntary movements depends on coordination of descending motor pathways from cortex, muscle action & a constant flow of sensory information.
- In muscle, feedback comes from 2 important sensory receptors : Golgi tendon organ (GTO) & muscle spindle.
- GTO – in tendons at myotendinous junction – sensitive to tension – activated by active muscle contraction or excessive passive stretch – when excited, sends message to CNS to adjust the muscle tension.

- Muscle spindle – consist of 2-10 specialised muscle fibers enclosed in connective tissue sheath – interspersed throughout the muscle – sensitive to length & velocity of lengthening – send message to brain (cerebellum) about state of stretch of muscle.
- Muscle spindle is responsible for sending the message to the muscle to contract when the tendon is tapped with hammer.
- Receptors in the joint capsule & ligaments also influences muscle activity.
- Feed forward control – important role in voluntary movement – allows for anticipatory control of muscle action.

IMMOBILIZATION

- Affects both the muscle structure & function.
- Effects depends on –
  - Immobilization position
    - Shortened
    - Lengthened
  - Percentage of fiber types within the muscle
  - Length of immobilization period

In shortened position :-

- Adapts to new position with following structural changes –
  - ↓no of sarcomere with compensatory ↑ in sarcomere length
  - ↑ amount of perimysium
  - Thickening of endomysium
  - Collagen fibril orients more circumferentially
  - ↑ connective tissue : muscle fiber tissue
  - Loss of weight & muscle atrophy
- Functional changes :-
  - Maximal tension is generated in shortened position
  - Resist passive lengthening – limits joint ROM
  - Overall ↓ in tension generating capacity
  - ↑stiffness to passive stretch

In lengthened position :-

- Fewer structural & functional changes.
- Structural changes :-
  - ↑ no of sarcomere - ↓sarcomere length
  - ↑endomyseal & perimyseal tissue
  - Muscle hypertrophy may be followed by atrophy
- Functional changes :-
  - Increased maximum tension generating capacity

INJURY

Overuse :-

- May cause injury to tendons, ligaments, bursae, nerves, cartilage & muscle.
- Common cause – repetitive trauma (doesn't allow time to complete tissue repair) – microtrauma – triggers inflammation – swelling.
- Commonly affected by overuse at musculotendinous junction.
- Muscles & tendons –fatigue
- Bursae – inflames – effusion & thickening
- Nerves – compression injury

Muscle strain :-

- Can occur from single high force contraction of muscle where lengthening is by external forces.
- Usually fails between junction of muscle & tendon.
- Localized bleeding
- Acute inflammatory response – swelling, redness & pain

Eccentric exercise induced muscle injury :-

- Injury can occur even after single bout of eccentric activity. (30-40min downhill walk)
- Significant & sustained reduction in maximum voluntary contraction.
- Can cause loss of coordination, DOMS, swelling, stiffness

AGING

Fiber number & type changes :-

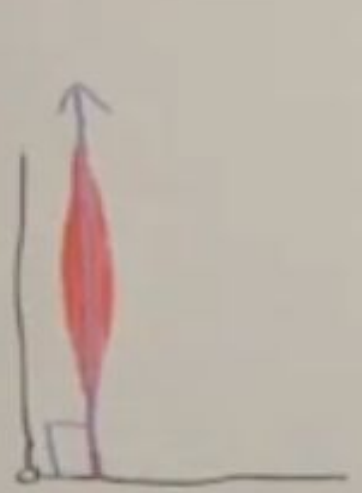
- Muscle strength reduces due to sarcopenia.
- Sarcopenia is a result of loss of muscle fiber & decrease in size of existing fibers.
- Gradual decrease in type II & increase type I fibers
- Decrease in no of motor units; remaining motor units has higher no of fibers per motor unit

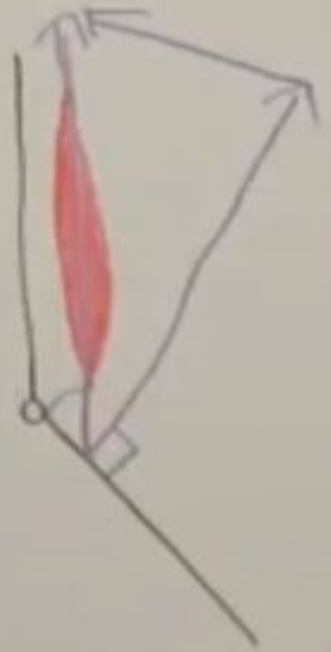
Connective tissue changes :-

- Increase amount of connective tissue within extracellular matrix of muscle – decreases ROM & increases muscle stiffness – reduces muscle strength – increases risk of fall.

ANGLE OF MUSCLE PULL

DEFINITION: ANGLE BETWEEN BONE MUSCLE INSERTS AND LINE OF MUSCLE PULL, ON JOINT SIDE





$\theta = 90$ = rotatory

$\theta < 90$ = stabilizing + rotatory

$\theta > 90$ = dislocating + rotatory

Thank you