Kinesiology

Chapter 2
Neuromuscular Fundamentals

Skeletal Muscles

- Responsible for movement of body and all of its joints
- Muscle contraction produces force that causes joint movement
- Muscles also provide
  - protection
  - posture and support
  - produce a major portion of total body heat

Skeletal Muscles

- Over 600 skeletal muscles comprise approximately 40 to 50% of body weight
- 215 pairs of skeletal muscles usually work in cooperation with each other to perform opposite actions at the joints which they cross
- **Aggregate muscle action** - muscles work in groups rather than independently to achieve a given joint motion

Muscle Nomenclature

- Muscles are usually named due to
  - visual appearance
  - anatomical location
  - function
- Shape – deltoid, rhomboid
- Size – gluteus maximus, teres minor
- Number of divisions – triceps brachii
- Direction of its fibers – external oblique

Muscle Nomenclature

- Location - rectus femoris, palmaris longus
- Points of attachment - coracobrachialis, extensor hallucis longus, flexor digitorum longus
- Action - erector spinae, supinator, extensor digiti minimi
- Action & shape – pronator quadratus
Muscle Nomenclature

- Action & size – adductor magnus
- Shape & location – serratus anterior
- Location & attachment – brachioradialis
- Location & number of divisions – biceps femoris

Muscle Nomenclature

- Muscle grouping & naming
  - Shape – Hamstrings
  - Number of divisions – Quadriceps, Triceps Surae
  - Location – Peroneals, Abdominal, Shoulder Girdle
  - Action – Hip Flexors, Rotator Cuff

Shape of Muscles & Fiber Arrangement

- Muscles have different shapes & fiber arrangement
- Shape & fiber arrangement affects
  - muscle’s ability to exert force
  - range through which it can effectively exert force onto the bones

Shape of Muscles & Fiber Arrangement

- Cross section diameter
  - factor in muscle’s ability to exert force
  - greater cross section diameter = greater force exertion
- Muscle’s ability to shorten
  - longer muscles can shorten through a greater range
  - more effective in moving joints through large ranges of motion

Shape of Muscles & Fiber Arrangement

- 2 major types of fiber arrangements
  - parallel & pennate
  - each is further subdivided according to shape
- Parallel muscles
  - fibers arranged parallel to length of muscle
  - produce a greater range of movement than similar sized muscles with pennate arrangement

Fiber Arrangement - Parallel

- Categorized into following shapes
  - Flat
  - Fusiform
  - Strap
  - Radiate
  - Sphincter or circular
Fiber Arrangement - Parallel

• Flat muscles
  – usually thin & broad, originating from broad, fibrous, sheet-like aponeuroses
  – allows them to spread their forces over a broad area
  – Ex. rectus abdominus & external oblique

Fiber Arrangement - Parallel

• Fusiform muscles
  – spindle-shaped with a central belly that tapers to tendons on each end
  – allows them to focus their power onto small, bony targets
  – Ex. brachialis, biceps brachii

Fiber Arrangement - Parallel

• Strap muscles
  – more uniform in diameter with essentially all fibers arranged in a long parallel manner
  – enables a focusing of power onto small, bony targets
  – Ex. sartorius

Fiber Arrangement - Parallel

• Radiate muscles
  – also described sometimes as being triangular, fan-shaped or convergent
  – have combined arrangement of flat & fusiform
  – originate on broad aponeuroses & converge onto a tendon
  – Ex. pectoralis major, trapezius

Fiber Arrangement - Parallel

• Sphincter or circular muscles
  – technically endless strap muscles
  – surround openings & function to close them upon contraction
  – Ex. orbicularis oris surrounding the mouth

Fiber Arrangement - Pennate

• Pennate muscles
  – have shorter fibers
  – arranged obliquely to their tendons in a manner similar to a feather
  – arrangement increases the cross sectional area of the muscle, thereby increasing the power
Fiber Arrangement - Pennate

• Categorized based upon the exact arrangement between fibers & tendon
  – Unipennate
  – Bipennate
  – Multipennate


Fiber Arrangement - Pennate

– Unipennate muscles
  • fibers run obliquely from a tendon on one side only
  • Ex. biceps femoris, extensor digitorum longus, tibialis posterior

Fiber Arrangement - Pennate

– Bipennate muscle
  • fibers run obliquely on both sides from a central tendon
  • Ex. rectus femoris, flexor hallucis longus

Fiber Arrangement - Pennate

– Multipennate muscles
  • have several tendons with fibers running diagonally between them
  • Ex. deltoid
  – Bipennate & unipennate produce strongest contraction

Muscle Tissue Properties

• Skeletal muscle tissue has 4 properties related to its ability to produce force & movement about joints
  – Irritability or excitability
  – Contractility
  – Extensibility
  – Elasticity

Muscle Tissue Properties

• Irritability or Excitability - property of muscle being sensitive or responsive to chemical, electrical, or mechanical stimuli
• Contractility - ability of muscle to contract & develop tension or internal force against resistance when stimulated
Muscle Tissue Properties

- **Extensibility** - ability of muscle to be passively stretched beyond its normal resting length
- **Elasticity** - ability of muscle to return to its original length following stretching

Muscle Terminology

- **Intrinsic** - pertaining usually to muscles within or belonging solely to body part upon which they act
  - Ex. small intrinsic muscles found entirely within the hand or feet

Muscle Terminology

- **Extrinsic** - pertaining usually to muscles that arise or originate outside of (proximal to) body part upon which they act
  - Ex. forearm muscles that attach proximally on distal humerus and insert on fingers

Muscle Terminology

- **Action** - specific movement of joint resulting from a concentric contraction of a muscle which crosses joint
  - Ex. biceps brachii has the action of flexion at elbow
- Actions are usually caused by a group of muscles working together

Muscle Terminology

- **Innervation** - segment of nervous system defined as being responsible for providing a stimulus to muscle fibers within a specific muscle or portion of a muscle
  - A muscle may be innervated by more than one nerve & a particular nerve may innervate more than one muscle or portion of a muscle
Muscle Terminology

• **Amplitude** - range of muscle fiber length between maximal & minimal lengthening

• **Gaster (belly or body)**
  - central, fleshy portion of the muscle that generally increases in diameter as the muscle contracts
  - the contractile portion of muscle

Muscle Terminology

• **Tendon** - Fibrous connective tissue, often cordlike in appearance, that connects muscles to bones and other structures
  - Two muscles may share a common tendon
    - Ex. Achilles tendon of gastrocnemius & soleus muscles
  - A muscle may have multiple tendons connecting it to one or more bones
    - Ex. three proximal attachments of triceps brachii

Muscle Terminology

• **Origin**
  - Structurally, the proximal attachment of a muscle or the part that attaches closest to the midline or center of the body
  - Functionally & historically, the least movable part or attachment of the muscle

Muscle Terminology

• **Insertion**
  - Structurally, the distal attachment or the part that attaches farthest from the midline or center of the body
  - Functionally & historically, the most movable part is generally considered the insertion

Muscle Terminology

• When a particular muscle contracts
  - it tends to pull both ends toward the **gaster**
  - if neither of the bones to which a muscle is attached are stabilized then both bones move toward each other upon contraction
  - more commonly one bone is more stabilized by a variety of factors and the less stabilized bone usually moves toward the more stabilized bone upon contraction

Muscle Terminology

• **Ex. biceps curl exercise**
  - biceps brachii muscle in arm has its origin (least movable bone) on scapula and its insertion (most movable bone) on radius
  - In some movements this process can be reversed, Ex. pull-up
    - radius is relatively stable & scapula moves up
    - biceps brachii is an extrinsic muscle of elbow
    - brachialis is intrinsic to the elbow
Types of muscle contraction

• Contraction - when tension is developed in a muscle as a result of a stimulus
• Muscle “contraction” term may be confusing, because in some contractions the muscle does not shorten in length
• As a result, it has become increasingly common to refer to the various types of muscle contractions as muscle actions instead

• Muscle contractions can be used to cause, control, or prevent joint movement or
  – to initiate or accelerate movement of a body segment
  – to slow down or decelerate movement of a body segment
  – to prevent movement of a body segment by external forces
• All muscle contractions are either isometric or isotonic

Types of muscle contraction

• Isometric contraction
  – tension is developed within muscle but joint angles remain constant
  – static contractions
  – significant amount of tension may be developed in muscle to maintain joint angle in relatively static or stable position
  – may be used to prevent a body segment from being moved by external forces

• Isotonic contractions involve muscle developing tension to either cause or control joint movement
  – dynamic contractions
  – the varying degrees of tension in muscles result in joint angles changing
• Isotonic contractions are either concentric or eccentric on basis of whether shortening or lengthening occurs

• Movement may occur at any given joint without any muscle contraction whatsoever
  – referred to as passive
  – solely due to external forces such as those applied by another person, object, or resistance or the force of gravity in the presence of muscle relaxation
Types of muscle contraction

- Concentric contractions involve muscle developing tension as it shortens

- Eccentric contractions involve the muscle lengthening under tension

Types of muscle contraction

- **Concentric contraction**
  - muscle develops tension as it shortens
  - occurs when muscle develops enough force to overcome applied resistance
  - causes movement against gravity or resistance
  - described as being a positive contraction

Types of muscle contraction

- **Eccentric contraction** (muscle action)
  - muscle lengthens under tension
  - occurs when muscle gradually lessens in tension to control the descent of resistance
  - weight or resistance overcomes muscle contraction but not to the point that muscle cannot control descending movement

Types of muscle contraction

- **Eccentric contraction** (muscle action)
  - controls movement with gravity or resistance
  - described as a negative contraction
  - force developed by the muscle is less than that of the resistance

Types of muscle contraction

- **Eccentric contraction** (muscle action)
  - results in the joint angle changing in the direction of the resistance or external force
  - causes body part to move against gravity or external forces
  - used to decelerate body segment movement
Types of muscle contraction

• **Eccentric contraction (muscle action)**
  – Some refer to this as a muscle action instead of a contraction since the muscle is lengthening as opposed to shortening
  – Various exercises may use any one or all of these contraction types for muscle development

Types of muscle contraction

• **Isokinetics** - a type of dynamic exercise using concentric and/or eccentric muscle contractions
  – speed (or velocity) of movement is constant
  – muscular contraction (ideally maximum contraction) occurs throughout movement
  – not another type of contraction, as some have described
  – Ex. Biodex, Cybex, Lido

Role of Muscles

• **Agonist muscles**
  – cause joint motion through a specified plane of motion when contracting concentrically
  – known as primary or prime movers, or muscles most involved

Role of Muscles

• **Antagonist muscles**
  – located on opposite side of joint from agonist
  – have the opposite concentric action
  – known as contralateral muscles
  – work in cooperation with agonist muscles by relaxing & allowing movement
  – when contracting concentrically perform the opposite joint motion of agonist

Role of Muscles

• **Stabilizers**
  – surround joint or body part
  – contract to fixate or stabilize the area to enable another limb or body segment to exert force & move
  – known as fixators
  – essential in establishing a relatively firm base for the more distal joints to work from when carrying out movements

Role of Muscles

• **Synergist**
  – assist in action of agonists
  – not necessarily prime movers for the action
  – known as guiding muscles
  – assist in refined movement & rule out undesired motions
Role of Muscles

- **Neutralizers**
  - Counteract or neutralize the action of another muscle to prevent undesirable movements such as inappropriate muscle substitutions
  - referred to as neutralizing
  - contract to resist specific actions of other muscles

Tying Roles of Muscles All Together

- Muscles with multiple agonist actions
  - attempt to perform all of their actions when contracting
  - cannot determine which actions are appropriate for the task at hand
- Actions actually performed depend upon several factors
  - the motor units activated
  - joint position
  - muscle length
  - relative contraction or relaxation of other muscles acting on the joint

Tying Roles of Muscles All Together

- Two muscles may work in synergy by counteracting their opposing actions to accomplish a common action

Tying Roles of Muscles All Together

- Example of muscle roles in kicking a ball
  - Muscles primarily responsible for hip flexion & knee extension are agonists
  - Hamstrings are antagonistic & relax to allow the kick to occur
  - Preciseness of the kick depends upon the involvement of many other muscles

Tying Roles of Muscles All Together

- Example of muscle roles in kicking a ball
  - The lower extremity route & subsequent angle at the point of contact (during the forward swing) depend upon a certain amount of relative contraction or relaxation in the hip abductors, adductors, internal rotators & external rotators (acting in a synergistic fashion to guide lower extremity precisely)

- These synergistic muscles are not primarily responsible for knee extension & hip flexion but contribute to accuracy of the total movement
- They assist in refining the kick & preventing extraneous motions
Tying Roles of Muscles All Together

- Example of muscle roles in kicking a ball
  - These synergistic muscles in contralateral hip & pelvic area must be under relative tension to help fixate or stabilize the pelvis on that side to provide a relatively stable base for the hip flexors on the involved side to contract against
  - Pectineus & tensor fascia latae are adductors and abductors, respectively, in addition to flexors

- Abduction & adduction actions are neutralized by each other
  - Common action of the two muscles results in hip flexion

- Antagonistic muscles produce actions opposite those of the agonist
  - Ex. elbow extensors are antagonistic to elbow flexors
  - Elbow movement in returning to hanging position after chinning is extension, but triceps & anconeus are not being strengthened
  - Elbow joint flexors contract concentrically followed by eccentric contraction of same muscles

Reversal of Muscle Function

- A muscle group described to perform a given function can contract to control the exact opposite motion

Determination of Muscle Action

- Variety of methods
  - consideration of anatomical lines of pull
  - anatomical dissection
  - palpation
  - models
  - electromyography
  - electrical stimulation
Determination of Muscle Action

• Palpation
  – using to sense of touch to feel or examine a muscle as it is contracted
  – limited to superficial muscles
  – helpful in furthering one’s understanding of joint mechanics
• Long rubber bands may be used as models to simulate muscle lengthening or shortening as joints move through ranges of motion

Determination of Muscle Action

• Electromyography (EMG)
  – utilizes either surface electrodes which are placed over muscle or fine wire/needle electrodes placed into muscle
  – as subject moves joint & contracts muscles, EMG unit detects action potentials of muscles and provides an electronic readout of contraction intensity & duration
  – most accurate way of detecting presence & extent of muscle activity

Lines of Pull

Consider the following
1. Exact locations of bony landmarks to which muscles attach proximally & distally and their relationship to joints
2. Planes of motion through which a joint is capable of moving
3. Muscle’s relationship or line of pull relative to the joint’s axes of rotation

Lines of Pull

Consider the following
4. As a joint moves the line of pull may change & result in muscle having a different or opposite action than in the original position
5. Potential effect of other muscles’ relative contraction or relaxation on a particular muscle’s ability to cause motion
6. Effect of a muscle’s relative length on its ability to generate force
7. Effect of the position of other joints on the ability of a biarticular or multiarticular muscle to generate force or allow lengthening
Neural control of voluntary movement

• Muscle contraction result from stimulation by the nervous system
• Every muscle fiber is innervated by a somatic motor neuron which, when an appropriate stimulus is provided, results in a muscle contraction

Neural control of voluntary movement

• The stimulus may be processed in varying degrees at different levels of the central nervous system (CNS) which may be divided into five levels of control
  – cerebral cortex
  – basal ganglia
  – cerebellum
  – brain stem
  – spinal cord

Neural control of voluntary movement

• Cerebral cortex
  – highest level of control
  – provides for the creation of voluntary movement as aggregate muscle action, but not as specific muscle activity
  – interprets sensory stimuli from body to a degree for determination of needed responses

Neural control of voluntary movement

• Basal ganglia
  – the next lower level
  – controls maintenance of postures & equilibrium
  – controls learned movements such as driving a car
  – controls sensory integration for balance & rhythmic activities

Neural control of voluntary movement

• Cerebellum
  – a major integrator of sensory impulses
  – provides feedback relative to motion
  – controls timing & intensity of muscle activity to assist in the refinement of movements

Neural control of voluntary movement

• Brain stem
  – integrates all central nervous system activity through excitation & inhibition of desired neuromuscular functions
  – functions in arousal or maintaining a wakeful state
Neural control of voluntary movement

- Spinal cord
  - common pathway between CNS & PNS
  - has the most specific control
  - integrates various simple & complex spinal reflexes
  - integrates cortical & basal ganglia activity with various classifications of spinal reflexes

Neural control of voluntary movement

- Functionally, PNS is divided into sensory & motor divisions
  - Sensory or afferent nerves bring impulses from receptors in skin, joints, muscles, & other peripheral aspects of body to CNS
  - Motor or efferent nerves carry impulses to outlying regions of body from the CNS

Neural control of voluntary movement

- Efferent nerves further subdivided into
  - voluntary or somatic nerves which are under conscious control & carry impulses to skeletal muscles
  - involuntary or visceral nerves, referred to as the autonomic nervous system (ANS) which carry impulses to the heart, smooth muscles, and glands

Neural control of voluntary movement

- Neurons (nerve cells) - basic functional units of nervous system responsible for generating & transmitting impulses and consist of
  - a neuron cell body
  - one or more branching projections known as dendrites which transmit impulses to neuron & cell body
  - axon - an elongated projection that transmits impulses away from neuron cell bodies

Neural control of voluntary movement

- Neurons are classified as one of three types according to the direction in which they transmit impulses
  - Sensory neurons
  - Motor neurons
  - Interneurons

Neural control of voluntary movement

- Sensory neurons transmit impulses to spinal cord & brain from all parts of body
- Motor neurons transmit impulses away from the brain & spinal cord to muscle & glandular tissue
- Interneurons are central or connecting neurons that conduct impulses from sensory neurons to motor neurons
Proprioception & Kinesthesia

• Activity performance is significantly dependent upon neurological feedback from the body
• We use various senses to determine a response to our environment
  – Seeing when to lift our hand to catch a fly ball

Proprioception & Kinesthesia

• Taken for granted are sensations associated with neuromuscular activity through proprioception
• Proprioceptors - internal receptors located in skin, joints, muscles, & tendons which provide feedback relative to tension, length, & contraction state of muscle, position of body & limbs, and movements of joints

Proprioception & Kinesthesia

• Proprioceptors work in combination with other sense organs to accomplish kinesthesia
• Kinesthesia – conscious awareness of position & movement of the body in space
• Proprioceptors specific to muscles
  – Muscles spindles
  – Golgi tendon organs (GTO)

Proprioception & Kinesthesia

• Proprioception
  – Subconscious mechanism by which body is able posture & movement by responding to stimuli originating in proprioceptors of the joints, tendons, muscles, & inner ear

Proprioception & Kinesthesia

• Muscle spindles
  – concentrated primarily in muscle belly between the fibers
  – sensitive to stretch & rate of stretch
  – Insert into connective tissue within muscle & run parallel with muscle fibers
  – Spindle number varies depending upon level of control needed
    • Ex. Greater concentration in hands than thigh

Proprioception & Kinesthesia

• Muscle spindles & myotatic or stretch reflex
  1. Rapid muscle stretch occurs
  2. Impulse is sent to the CNS
  3. CNS activates motor neurons of muscle and causes it to contract

Proprioception & Kinesthesia

- Ex. Knee jerk or patella tendon reflex
  - Reflex hammer strikes patella tendon
  - Causes a quick stretch to musculotendinous unit of quadriceps
  - In response quadriceps fires & the knee extends
- More sudden the tap, the more significant the reflexive contraction

Proprioception & Kinesthesia

- Stretch reflex may be utilized to facilitate a greater response
  - Ex. Quick short squat before attempting a jump
  - Quick stretch placed on muscles in the squat enables the same muscles to generate more force in subsequently jumping off the floor

Proprioception & Kinesthesia

- Golgi tendon organ
  - found serially in the tendon close to muscle tendon junction
  - sensitive to both muscle tension & active contraction
  - much less sensitive to stretch than muscles spindles
  - require a greater stretch to be activated

Proprioception & Kinesthesia

- Quality of movement & reaction to position change is dependent upon proprioceptive feedback from muscles & joints
- Proprioception may be enhanced through specific training
All or None Principle

- When muscle contracts, contraction occurs at the muscle fiber level within a particular motor unit
- Motor unit
  - Single motor neuron & all muscle fibers it innervates
  - Function as a single unit

Typical muscle contraction
- The number of motor units responding (and number of muscle fibers contracting) within the muscle may vary significantly from relatively few to virtually all
- Depending on the number of muscle fibers within each activated motor unit & the number of motor units activated

All or None Principle

- Regardless of number, individual muscle fibers within a given motor unit will either fire & contract maximally or not at all

Factors affecting muscle tension development

- Difference between lifting a minimal vs. maximal resistance is the number of muscle fibers recruited
- The number of muscle fibers recruited may be increased by
  - Activating those motor units containing a greater number of muscle fibers
  - Activating more motor units
  - Increasing the frequency of motor unit activation

Factors affecting muscle tension development

- Number of muscle fibers per motor unit varies significantly
  - From less than 10 in muscles requiring precise and detailed such as muscles of the eye
  - To as many as a few thousand in large muscles that perform less complex activities such as the quadriceps

- Motor unit must first receive a stimulus via electrical signal known as an action potential for the muscle fibers in the unit to contract
- Subthreshold stimulus
  - Not strong enough to cause an action potential
  - Does not result in a contraction
Factors affecting muscle tension development

• **Threshold stimulus**
  – Stimulus becomes strong enough to produce an action potential in a single motor unit axon
  – All of the muscle fibers in the motor unit contract

• **Submaximal stimuli**
  – Stimuli that are strong enough to produce action potentials in additional motor units

• **Maximal stimuli**
  – Stimuli that are strong enough to produce action potentials in all motor units of a particular muscle

Factors affecting muscle tension development

• As stimulus strength increases from threshold up to maximal, more motor units are recruited and overall muscle contraction force increases in a graded fashion.

Factors affecting muscle tension development

• Greater contraction forces may also be achieved by increasing the frequency or motor unit activation.

• Phases of a single muscle fiber contraction or twitch:
  – Stimulus
  – Latent period
  – Contraction phase
  – Relaxation phase

Factors affecting muscle tension development

• **Summation**
  – When successive stimuli are provided before relaxation phase of first twitch has completed, subsequent twitches combine with the first to produce a sustained contraction
  – Generates a greater amount of tension than single contraction would produce individually
  – As frequency of stimuli increase, the resultant summation increases accordingly producing increasingly greater total muscle tension.
Factors affecting muscle tension development

- **Tetanus**
  - results if the stimuli are provided at a frequency high enough that no relaxation can occur between contractions

- **Treppe**
  - Occurs when multiple maximal stimuli are provided at a low enough frequency to allow complete relaxation between contractions to rested muscle
  - Slightly greater tension is produced by the 2nd stimulus than with 1st

Factors affecting muscle tension development

- **Treppe**
  - 3rd stimulus produces even greater tension than the 2nd
  - Staircase effect occurs only with the 1st few stimuli
  - Resultant contractions after the initial ones result in equal tension being produced

Muscle Length - Tension Relationship

- Generally, depending upon muscle involved
  - Greatest amount of tension can be developed when a muscle is stretched between 100% to 130% of its resting length
  - Stretch beyond 100% to 130% of resting length significantly decreases the amount of force muscle can exert

Muscle Length - Tension Relationship

- Generally, depending upon muscle involved
  - A proportional decrease in ability to develop tension occurs as a muscle is shortened
  - When shortened to around 50% to 60% of resting length ability to develop contractile tension is essentially reduced to zero
Muscle Length - Tension Relationship

- Ex. 1. Increasing ability to exert force
  - Squat slightly to stretch the calf, hamstrings, & quadriceps before contracting same muscles concentrically to jump
- Ex. 2. Reducing ability to exert force
  - Isolate the gluteus maximus by maximally shortening the hamstrings with knee flexion

Muscle Force – Velocity Relationship

- When muscle is contracting (concentrically or eccentrically) the rate of length change is significantly related to the amount of force potential
- When contracting concentrically against a light resistance muscle is able to contract at a high velocity

Muscle Force – Velocity Relationship

- As resistance increases, the maximal velocity at which muscle is able to contract decreases
- Eventually, as load increases, the velocity decreases to zero resulting in an isometric contraction
- As load increases beyond muscle’s ability to maintain an isometric contraction, the muscle begins to lengthen resulting in an eccentric contraction

Muscle Force – Velocity Relationship

- Slight increases in load result in relatively low velocity of lengthening
- As load increases further the velocity of lengthening will increase as well
- Eventually, load may increase to point where muscle can no longer resist, resulting in uncontrollable lengthening or dropping of load
- Inverse relationship between concentric velocity & force production

Muscle Force – Velocity Relationship

- Angle of pull
  - Angle between the line of pull of the muscle & the bone on which it inserts (angle toward the joint)
  - With every degree of joint motion, the angle of pull changes
  - Joint movements & insertion angles involve mostly small angles of pull
Angle of pull

- Angle of pull decreases as bone moves away from its anatomical position through local muscle group’s contraction
- Range of movement depends on type of joint & bony structure
- Most muscles work at angles of pull less than 50 degrees
- Amount of muscular force needed to cause joint movement is affected by angle of pull

Angle of pull

- Rotary component (vertical component) - component of muscular force that acts perpendicular to long axis of bone (lever)
  - When the line of muscular force is at 90 degrees to bone on which it attaches, all of the muscular force is rotary force (100% of force is contributing to movement)
  - All of force is being used to rotate the lever about its axis
  - The closer the angle of pull to 90 degrees, the greater the rotary component

Angle of pull

- Rotary component continues with less force, to rotate the lever about its axis
- Second force component is the horizontal, or nonrotary component and is either a stabilizing component or a dislocating component, depending on whether the angle of pull is less than or greater than 90 degrees

Angle of pull

- If angle is less than 90 degrees, the force is a stabilizing force because its pull directs the bone toward the joint axis
- If angle is greater than 90 degrees, the force is dislocating due to its pull directing the bone away from the joint axis

Uniarticular, biarticular, and multiarticular muscles

- Uniarticular muscles
  - Cross & act directly only on the joint that they cross
  - Ex. Brachialis
    - Can only pull humerus & ulna closer together
Uniarticular, biarticular, and multiarticular muscles

- Biarticular muscles – cross & act on two different joints
  - Depending, biarticular muscles may contract & cause motion at either one or both of its joints
  - Two advantages over uniaxial muscles
    • can cause and/or control motion at more than one joint
    • are able to maintain a relatively constant length due to "shortening" at one joint and "lengthening" at another joint

- Muscle does not actually shorten at one joint & lengthen at another
  - The concentric shortening of the muscle to move one joint is offset by motion of the other joint which moves its attachment of muscle farther away
  - This maintenance of a relatively constant length results in the muscle being able to continue its exertion of force

Uniarticular, biarticular, and multiarticular muscles

- Ex. 1 Hip & knee biarticular muscles
  - Concurrent movement pattern occurs when both the knee & hip extend at the same time
  - If only knee extension occurs, rectus femoris shortens & loses tension as do other quadriceps muscles, but its relative length & subsequent tension may be maintained due to its relative lengthening at the hip joint during extension

- Ex. 2 Hip & knee biarticular muscles
  - Countercurrent movement pattern occurs in kicking
  - During the lower extremity forward movement phase the rectus femoris concentrically contracts to flex the hip & extend the knee
  - These two movements, when combined, increase the tension or stretch on the hamstring muscles both at the knee & hip

Uniarticular, biarticular, and multiarticular muscles

- Multiarticular muscles act on three or more joints due to the line of pull between their origin & insertion crossing multiple joints
- Principles relative to biarticular muscles apply similarly to multiarticular muscles

Reciprocal Inhibition or Innervation

- Antagonist muscles groups must relax & lengthen when the agonist muscle group contracts
  - This reciprocal innervation effect occurs through reciprocal inhibition of the antagonists
  - Activation of the motor units of the agonists causes a reciprocal neural inhibition of the motor units of the antagonists
  - This reduction in neural activity of the antagonists allows them to subsequently lengthen under less tension
Reciprocal Inhibition or Innervation

• Ex. Compare the ease of
  – stretching hamstrings when simultaneously contracting the quadriceps vs.
  – stretching hamstrings without contracting quadriceps

Active & Passive Insufficiency

• As muscle shortens its ability to exert force diminishes
  – Active insufficiency is reached when the muscle becomes shortened to the point that it can not generate or maintain active tension
  – Passively insufficiency is reached when the opposing muscle becomes stretched to the point where it can no longer lengthen & allow movement

Active & Passive Insufficiency

• Easily observed in either biarticular or multiarticular muscles when full range of motion is attempted in all joints crossed by the muscle
  – Ex. Rectus femoris contracts concentrically to both flex the hip & extend the knee
  – Can completely perform either action one at a time but actively insufficient to obtain full range at both joints simultaneously

Active & Passive Insufficiency

– Similarly, hamstrings can not usually stretch enough to allow both maximal hip flexion & maximal knee extension due passive insufficiency
• As a result, it is virtually impossible to actively extend the knee fully when beginning with the hip fully flexed or vice versa