Chapter 2
Neuromuscular Fundamentals

Manual of Structural Kinesiology
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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

Shape of Muscles & Fiber Arrangement

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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

- **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

- **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

- **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

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

- **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

- **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

- **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

- **Aponeurosis**
  - A tendinous expansion of dense fibrous connective tissue that is sheet- or ribbonlike in appearance and resembles a flattened tendon
  - Aponeuroses serve as a fascia to bind muscles together or as a means of connecting muscle to bone

- **Fascia**
  - A sheet or band of fibrous connective tissue that envelopes, separates, or binds together parts of the body such as muscles, organs, and other soft tissue structures of the body
  - In certain places throughout the body, such as around joints like the wrist & ankle, fascial tissue forms a retinaculum to retain tendons close to the body

- **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

- **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

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

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

Types of muscle contraction

- 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

- 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

Types of muscle contraction

- 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
  - force developed by the muscle is greater than that of the resistance
  - results in joint angle changing in the direction of the applied muscle force
  - causes body part to move against gravity or external forces

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

- **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

Types of muscle contraction

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

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

• **Agonist muscles**
  - Primary or prime movers, or muscles most involved
  - Some agonist muscles, because of their relative location, size, length, or force generation capacity, are able to contribute significantly more to the joint movement than other agonists
  - Assistors or assistant movers
  - Agonist muscles that contribute significantly less to the joint motion
  - Consensus among all authorities regarding which muscles are primary movers and which are weak assistants does not exist in every case

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
  - Ex. quadriceps muscles are antagonists to hamstrings in knee flexion

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
  - Ex. biceps curl
    - Muscles of scapula & glenohumeral joint must contract in order to maintain shoulder complex & humerus in a relatively static position so that the biceps brachii can more effectively perform curls

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
  - Helping synergists & true synergists

Role of Muscles

• **Helping synergists**
  - Have an action in common but also have actions antagonistic to each other
  - Help another muscle move the joint in the desired manner and simultaneously prevent undesired actions
  - Ex. Anterior & posterior deltoid
    - Anterior deltoid acts as an agonist in glenohumeral flexion, while posterior deltoid acts as an extensor
    - Helping each other, they work in synergy with middle deltoid to accomplish abduction

Role of Muscles

• **True synergists**
  - Contract to prevent an undesired joint action of agonist and have no direct effect on agonist action
  - Ex. Finger flexors are provided true synergy by wrist extensors when grasping an object
    - Finger flexors originating on forearm and humerus are agonists in both wrist flexion & finger flexion
    - Wrist extensors contract to prevent wrist flexion by finger flexors
    - This allows finger flexors to utilize more of their force flexing the fingers
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
  – Ex. when only supination action of biceps brachii is desired, the triceps brachii contracts to neutralize the flexion action of the biceps brachii

Role of Muscles

• **Force Couples**
  – Force couples occur when two or more forces are pulling in different directions on an object, causing the object to rotate about its axis
  – Coupling of muscular forces together in the body can result in a more efficient movement

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)
Tying Roles of Muscles All Together

- Example of muscle roles in kicking a ball
  - 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

- 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

Tying Roles of Muscles All Together

- Example of muscle roles in kicking a ball
  - 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

• 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

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

• Electrical muscle stimulation
  – reverse approach of electromyography
  – use electricity to cause muscle activity
  – surface electrodes are placed over muscle & the stimulator causes muscle to contract
  – joint actions may then be observed to see the effect of the muscle’s contraction

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
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
Consider the following

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
  - interpretes sensory stimuli from body to a degree for determine 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

• PNS - 2 groups of nerves of primary importance
  – Cranial nerves
  – Spinal nerves

• Cranial nerves
  – 12 pair originating from undersurface of brain & exiting from the cranial cavity through skull openings
  – numbered for the order in which they emerge from anterior to posterior
  – named in relation to their function or distribution
Neural control of voluntary movement

• Cranial nerves
  – I, II, & VIII are sensory
  – III, IV, VI, XI, & XII, except for some proprioceptive function, are primarily motor
  – V, VII, IX, & X have mixed functions - both motor & sensory

I. Olfactory
  – smell
  – identifying familiar odors

II. Optic
  – sight or Vision
  – visual acuity

III. Oculomotor
  – levator of eyelid; superior, medial, and inferior recti; inferior oblique muscles of eyeball
  – upward, downward, & medial gaze, reaction to light

IV. Trochlear
  – superior oblique muscle of eyeball
  – downward and lateral gaze

V. Trigeminal
  – touch, pain
  – skin of face, scalp behind the ears, mucous membranes of nose, sinuses, mouth, anterior tongue
  – muscles of mastication
  – corneal reflex, facial sensation, teeth clenching; chewing

VI. Abducens
  – lateral rectus muscle of eyeball
  – lateral gaze

VII. Facial
  – taste
  – touch, pain
  – facial muscles
  – lateral gaze, facial expressions, identifying familiar tastes with front of tongue

VIII. Vestibulocochlear (Acoustic Nerve)
  – hearing, balance/equilibrium
  – detecting presence of sounds, balance & coordination

IX. Glossopharyngeal
  – touch, pain
  – taste
  – muscles of pharynx
  – gag reflex, swallowing
### Neural control of voluntary movement

**X. Vagus**
- touch, pain
- muscles of palate, pharynx, & larynx
- gag reflex, swallowing, speech

**XI. Accessory**
- sternocleidomastoid & trapezius muscle
- shoulder shrugging, head movement

**XII. Hypoglossal**
- muscles of tongue
- tongue movements

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**Neural control of voluntary movement**

**Spinal nerves**
- 31 pairs originate from the spinal cord
- pass through openings between the vertebrae on each side
- from here certain spinal nerves form different plexuses
- eventually become peripheral nerve branches supplying specific anatomical locations while others run directly to specific anatomical locations

- 8 cervical nerves
- 12 thoracic nerves
- 5 lumbar nerves
- 5 sacral
- 1 coccygeal nerve

**Cervical nerves 1 through 4**
- form the cervical plexus
- generally responsible for sensation from upper part of shoulders to back of head and front of neck
- supplies motor innervation to several muscles of the neck

**Cervical nerves 5 - 8 & thoracic nerve 1**
- form the brachial plexus
- supplies motor & sensory function to the upper extremity and most of the scapula
Neural control of voluntary movement

• Thoracic nerves 2-12 run directly to specific anatomical locations in thorax
• All lumbar, sacral, & coccygeal nerves form the lumbosacral plexus which supplies sensation & motor function to lower trunk, entire lower extremity & perineum

Neural control of voluntary movement

• Sensory function of spinal nerves is to provide feedback to CNS regarding skin sensation
• Dermatome - defined area of skin supplied by a specific spinal nerve
• Myotome - muscle or group of muscles supplied by a specific spinal nerve
• Certain spinal nerves are also responsible for reflexes

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
  – Motor neurons
  – Sensory 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 & Kinesthesis

• 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 & Kinesthesis

• 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 & Kinesthesis

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

Proprioception & Kinesthesis

• Proprioceptors specific to joints & skin
  – Meissner’s corpuscles
  – Ruffini’s corpuscles
  – Pacinian corpuscles
  – Krause’s end-bulbs

Proprioception & Kinesthesis

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

Proprioception & Kinesthesis

• 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 & Kinesthesis

• 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

- Tension in tendons & GTO increases as muscle contract, which activates GTO
  1. GTO stretch threshold is reached
  2. Impulse is sent to CNS
  3. CNS causes muscle to relax
  4. Facilitates activation of antagonists as a protective mechanism
- GTO protects us from an excessive contraction by causing its muscle to relax

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 muscle spindles
  - Require a greater stretch to be activated

Proprioception & Kinesthesia

- Pacinian corpuscles
  - Concentrated around joint capsules, ligaments, tendon sheaths & beneath skin
  - Activated by rapid changes in joint angle & by pressure changes affecting the capsule
  - Activation only last briefly & is not effective in detecting constant pressure
  - Helpful in providing feedback regarding the location of a body part in space following quick movements such as running or jumping
Proprioception & Kinesthesis

• Ruffini’s corpuscles
  – located in deep layers of the skin and the joint capsule
  – activated by strong & sudden joint movements as well as pressure changes
  – reaction to pressure changes are slower to develop

• Ruffini’s corpuscles
  – activation is continued as long as pressure is maintained
  – essential in detecting even minute joint position changes & providing information as to exact joint angle

• Meissner’s corpuscles & Krause’s end-bulbs
  – located in the skin & other subcutaneous tissues
  – important in receiving stimuli from touch
  – not as relevant to kinesthesis

• 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

- **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

Factors affecting muscle tension development

- 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

Factors affecting muscle tension development

- **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 & 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

- Latent period
  - Brief period of a few milliseconds following stimulus
- Contraction phase
  - Muscle fiber begins shortening
  - Lasts about 40 milliseconds
- Relaxation phase
  - Follows contraction phase
  - Last about 50 milliseconds

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
  - 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

- Maximal ability of a muscle to develop tension & exert force varies depending upon the length of the muscle during contraction

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 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 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

- 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 results 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

- As force needed to cause movement of an object increases the velocity of concentric contraction decreases
- Somewhat proportional relationship between eccentric velocity & force production
- As force needed to control an object’s movement increases, the velocity of eccentric lengthening increases, at least until when control is lost

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

- 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

- 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

- At all other degrees of the angle of pull, one of the other two components of force are operating in addition to rotary component
  - 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

Angle of pull

- Sometimes desirable to begin with the angle of pull is at 90 degrees
  - chin-up (pull-up)
  - angle makes the chin-up easier because of more advantageous angle of pull
  - compensate for lack of sufficient strength

Angle of pull

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

Angle of pull

- 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 uniarticular 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

Angle of pull

- Uniarticular, biarticular, and multiarticular muscles
  - Muscle does not actually shorten at one joint & lengthen at other
    - 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

Uniarticular, biarticular, and multiarticular muscles

• 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

Web Sites

Human Anatomy Online
  http://innerbody.com/image/musflow.html
  – An interactive site with details on the muscular and nervous systems.

BBC Science & Nature
  http://bbc.co.uk/science/humanbody/body/interactives/3dipsaw_02/index.shtml
  – An interactive site allowing you to select the innervation for the muscles.

Functions of the Muscular System
  http://training.seer.cancer.gov/module_anatomy/unit41_muscle_functions.html
  – Several pages with information on skeletal muscle structure, types, and groups, along with unit review and quizzes.

Web Sites

U.S. National Library of Medicine’s Visible Human Project
  AnatQuest Anatomic Images Online
  – A great resource using a cut-away viewer to see cadaver images throughout the body to identify the relevant anatomy.

The Physician and Sportsmedicine
  – Refining rehabilitation with proprioception training: expediting return to play.

Get Body Smart
  www.getbodysmart.com/index.htm
  – An online interactive tutorial on the muscular and nervous systems.

Web Sites

Neurologic Exam: An anatomical approach
  http://medlib.med.utah.edu/neurologicexam/home_exam.html
  – A very thorough site on neurological exams, including numerous movies with both normal and pathological results.

Cranial Nerves: Review info
  www.gwc.maricopa.edu/class/bio201/on/cranial.htm
  – A good resource on the cranial nerves.

University of Arkansas for Medical Sciences Nerve tables
  http://anatomy.uams.edu/anatomy/html/nerves.html
  – Numerous tables of all nerves throughout the body.

Dermatomes
  www.meddean.luc.edu/lumen/MedEd/GrossAnatomy/learnem/dermatomes_der.htm
  – An interactive review of the body’s dermatomes.

Web Sites

Loyola University Medical Education Network Master Muscle List
  www.meddean.luc.edu/lumen/MedEd/GrossAnatomy/dissectorpim.html
  – An interactive and graphical review of the muscles indexed alphabetically and by region.

Proprioception Exercises Can Improve Balance
  http://sportsmedicine.about.com/library/weekly/aa062200.htm
  – Proprioception.

Meds 1 Neurophysiology 2003
  www.med.uwo.ca/physiology/courses/medsweb
  – A site on neurophysiology with Flash animation.

Muscular System
  www.bip.psu.edu/faculty/strauss/anatomy/mus/muscular.htm
  – Cadaveric photos of the cat muscular system.
Web Sites

Functions of the Nervous System
http://training.seer.cancer.gov/module_anatomy/unit51_nerve_functi ons.html
- Several pages with information on the nervous system organization, nerve structure, unit review, and quizzes.

Training for Proprioception & Function
www.coachr.org/propero.htm
- Information on improving body awareness movement efficiency.

Fitter International
www.fitter1.com/article_proprioception.htm?mtcPromotion=Articles &%3E%3E%3EProperception
- Products and articles on proprioception.