MUSCLE SENSORY CONTROL AND STRETCH REFLEX

I. OVERVIEW – Muscle receptors are sense organs inside muscles and tendon that function in the control of posture and movement.

A. FUNCTIONS OF MUSCLE SENSORY RECEPTORS - Problem: Muscle receptors have both conscious and unconscious functions.

1) **KINESTHESIA = CONSCIOUS SENSE OF BODY POSITION AND MOVEMENT**; Signals from muscle sensory receptors reach thalamus and cortex; convey signals about body and limb position; as a result, movements can be performed and controlled without visual inputs.

Demonstration of Kinesthetic sense: Put your hands under the table (or tilt your head back so you can't see your hands). Without looking at them, touch the tips of the fingers of one hand to the tips of the fingers of another hand. You know where your hands are without seeing them. This is done using information from sense organs in muscle, tendons (and joints); these receptors are called proprioceptors (proprioception = sense of yourself).

2) **REFLEX AND COMPENSATORY REACTIONS** - **UNCONSCIOUS** - Many adjustments of posture and movement are made automatically and very rapidly and do not require conscious awareness or attention: Control of posture when standing: body tilt causes stretch (changes in length) of leg muscles and elicits reflexes (stretch reflexes) that restore body position when .

Stretch Reflex – When a muscle is stretched rapidly, a stretch reflex (automatic reaction) is evoked that causes the <u>stretched muscle to contract</u>.

Clinical - Stretch reflexes are clinically used to evaluate nervous system function. Stretch reflexes (also erroneously termed Deep Tendon Reflexes) are tested by tapping on a muscle tendon (see below).

Clinical Correlate: **Peripheral neuropathies** can produce loss of axons in peripheral nerves; in rare cases (of **Guillain-Barre syndrome**, loss of neurons with large axons), patients have no motor deficits but lose all proprioception and have no sense of body position; **patients train themselves to use vision (exteroception) to compensate for proprioceptive loss**

B. Definitions and Terminology: **Proprioception and Kinesthesia**

1. Types of sensation –

<u>Proprioception</u> = detection of position and movement of body itself; derivation from proprius (Latin for 'one's own') and perception;
<u>Exteroception</u> = detection of outside world (ex. vision, touch)
<u>**Kinesthesia**</u> - **is a person's conscious awareness of position and movement of their body and limbs; dependent upon signals from muscle sensory receptors that are transmitted in pathways that reach the brain (thalamus and cortex)**.

C. OVERVIEW - Muscle receptors = Muscle spindles and Golgi tendon organs; contribute to Kinesthesia but have other functions that do not require conscious awareness. Two major types of receptors associated with muscles:

1. **Muscle spindles** - **monitor position and movement velocity.** Spindles are specialized skeletal muscle cells that have both motor and sensory innervation; complex structure and function; sensory neurons are **sensitive to stretch** and signal **changes in muscle length**. Some neurons also indicate **velocity** of movement (velocity = change in length/time). Sensitivities of sense organs are **adjusted by gamma motor neurons** that innervate the spindle muscle cells (Note: a spindle is a shape like a rod with tapered ends)

2. **Golgi tendon organs** - **monitor force**; located in muscle tendons or connective tissue attachments; anatomy simple; muscle contractions produce tension in muscle tendon causing Golgi tendon organs to fire; Golgi tendon organs **signal the force produced by muscle**.

II. MUSCLE PROPERTIES - overview of terms used to describe muscle contractions.

A. **Determining body position from muscle length** - Using simple geometry, you can calculate **limb position** (joint angles) if you know the lengths of muscles. If you know how fast lengths of muscles are changing (**velocity** = change in length/time), you can calculate the **rate of limb movement**. The nervous system apparently does these calculations in providing sense of body position and movement.

B. **Muscle tonus = amount of tension in muscle at rest.** Normal muscle has a certain amount of tension at rest and resistance to being stretched. This is due, in part, to activity in alpha (α) motor neurons at rest, which is influenced by muscle receptors.

Clinical Test of Muscle Tonus/muscle strength: Evaluating tonus is a standard neurological test. **Tonus can be tested by slowly stretching a muscle**; first tell patient to relax (see below).

Clinical Correlate: Changes in muscle tonus can be an important clinical sign: ex. **increased tonus occurs in Upper motor neuron disorders** (Upper Motor Neurons = descending pathways (ex. from brain) that synapse on alpha motor neurons; Lower Motor Neurons = alpha motor whose axons innervate skeletal muscles).

III. **MUSCLE SPINDLES -** specialized muscle cells with sensory and motor nerve endings; found inside muscle among regular muscle cells.

A. Orientation - in a muscle, orientation of muscle spindles is parallel to regular muscle cells (termed **IN PARALLEL**). **(Note: When a muscle is stretched, the muscle spindles located in the muscle are stretched)**. .

B. Number of muscle spindles per muscle - The number of spindles in a muscle varies from around 20 to several hundred. **Muscle spindles are found most densely in muscles that are used for fine control** (ex. interosseus muscles of hand or extraocular muscles of eye).

Terminology: **Muscle cells inside the muscle spindle are called intrafusal cells; all the remaining regular skeletal muscle cells in the muscle are called extrafusal cells.** (Note about terminology in texts: a muscle fiber is a muscle cell).

C. **Structure of Muscle Spindle and Contractile Properties of Spindle Muscle Cells – Muscle cells inside spindle (intrafusal muscle cells) are specialized; there are fast and slow contracting muscle cells in each spindle.**

D. **Motor Innervation of muscle spindle** - Spindle muscle cells receive their own motor innervation by **Gamma (γ) motor neurons**; Gamma motor neurons only innervate muscles spindles not regular muscle cells; there are fast and slow motor neurons (matching the spindle muscle cells); Gamma motor neurons cannot be selectively activate (no selective, voluntary control).

E. **Sensory innervation of muscle spindle** – **All sensory neurons detect stretch of muscle cell (and, therefore, muscle as a whole)**. There are two types of sensory neurons that differ in their distribution and responses.

1. **Primary (Group Ia) sensory neurons** - 1 neuron per spindle; innervate all muscle cells in spindle; very fast conducting. Primary sensory neurons **detect length of muscle and rate of change of length**.

2. **Secondary (Group II) sensory neurons -** 1-5 neurons per spindle; innervate only slow contracting spindle muscle cells (not fast); Secondary sensory neurons **detect only length of muscle (NOT rate of change of length)**.

Important Clinical Note: Testing Stretch (Deep Tendon) Reflex – <u>**All muscle spindle sensory are activated by a tap on the tendon of a muscle**</u> **when it is relaxed**; this produces a **very fast, very small lengthening of the muscle** and can activate all the muscle spindles in a muscle simultaneously; **Tapping on a tendon activates muscles spindles but does NOT activate Golgi tendon organs**.

Note: Why have sensitivity to velocity? **Velocity sensitivity makes reactions to perturbations faster.** ex. Suddenly tilting forward when standing in a moving bus<u>**: small rapid change in length produces large discharge from Group Ia**</u>, very little firing in Group II.

F. **Alpha-Gamma Co-activation** – In voluntary movements, Gamma motor neurons are activated at the same time as alpha motor neurons. **Gamma motor neurons adjust length of muscle spindle**. **Sensory neurons then can discharge when the muscle is stretched from any position.**

Note: Gamma motor neurons set sensitivity of muscle spindles so they will readily signal stretch from any starting length i.e. from any joint position; perturbations that produce stretch can be detected from any position (or during joint movements).

G. **Why patients must be told to relax before a Neurological test** - **Gamma motor neurons set the sensitivity of muscle spindles; if spindle muscle cells are tense, the sensory endings will fire to a very small stretch.** Gamma dynamic motor neurons are activated in behaviors in which rapid compensation may be necessary (ex. walking on a thin rail or tightrope).

Main Clinical Note: Gamma motor neurons receive inputs via descending motor pathways. These inputs may contribute to apparently increased reflexes if patients are nervous in a neurologic exam. **Get patients to relax before testing.**

IV. GOLGI TENDON ORGANS - sensory neurons sensitive to force of contraction; there are 1-2 sensory neurons per Golgi Tendon Organ

A. **Structure and Force Detection** - Golgi tendon organs are innervated by large sensory neurons (Type 1b) that end in muscle tendons or connective tissue attachments (near where muscle cells attach, called myotendinous junction). Branches intertwine with collagen fibers. Large forces applied to the tendon cause it to become taut. The collagen fibers squeeze together (like a rubber band becoming thinner) causing endings to depolarize and neuron to discharge. This occurs when muscle contracts against a large load or when strong forces are applied to a contracted muscle. **Firing is maintained as long as force is developed.** Golgi tendon organs are **IN SERIES** with muscle cells.

B. **Responses of tendon organs** - when muscle contracts against a large load **(isometric contraction)**, **tendon organs fire intensely**; when contract against a moderate load **(isotonic contraction)**, **tendon organ firing** reflects amount of force needed to move load. **Muscle stretch or tendon tap does NOT excite tendon organs.**

SUMMARY OF PROPERTIES OF MUSCLE SENSORY RECEPTORS

Sense Organ	**Number of sensory neurons per sense organ**	**Innervates**	**Signal**	**Activated by tendon tap in Clinical Test of Stretch reflex**
Muscle Spindle Primary Ia	1	All spindle muscle cells (fast and slow contracting)	Movement Velocity and Length	Yes – Fire intensely
Muscle Spindle Secondary II	1-5	Only slow contracting spindle muscle cells	Length NOT velocity	Yes – Fire intensely
Golgi Tendon Organ Ib	1-2	Muscle tendon at junction with muscle cells	Muscle Force	No – do not fire in clinical test