Week 3: Electromyography (EMG) II

BIOE 320 Systems Physiology Laboratory

Objectives

1. To measure knee reflex time under different conditions using the reflex hammer
2. To compare and correlate magnitude of hammer strike to magnitude of response via EMG activity

Background

Skeletal muscle control is important for most of our daily activities, from maintaining body posture to performing activities that require more precise movements. To appropriately perform muscle activities, your central nervous system needs to know the initial position of your body and the progression of movements so that adjustments can be made as needed. This information, known as proprioceptive input, can be acquired from your brain through different receptors in your eyes, joints, vestibular apparatus, skin, and muscles themselves. There are two types of muscle receptors tasked with monitoring changes in muscle length (**muscle spindles**) or muscle tension (**Golgi tendon organs**). In this lab, we will focus on the function of muscle spindles and their importance in spinal cord reflexes.

Muscle spindles, which are distributed throughout the fleshy part of skeletal muscles, send information to the nervous system about length or rate of change of length of a muscle. Each muscle spindle has its own afferent nerve supply and efferent nerve supply. The former carries signals from the sensory receptor to the spinal cord, while the latter carries outgoing signals from the spinal cord to the effector organ.

Efferent or motor nerves can be divided into alpha motor neurons, which innervate extrafusal muscle fibers, and gamma motor neurons, which innervate intrafusal muscle fibers. Afferent or sensory nerves consist of primary endings that can detect changes in muscle length and the speed at which that change occurs, and secondary endings that detect only changes in muscle length.

When the muscle is passively stretched, the muscle spindles are also stretched, causing an increase in the rate of firing of the afferent nerve fibers. The afferent neuron directly synapses on the alpha motor neuron that innervates the extrafusal fibers of the same muscle, and therefore causes the muscle to contract (Fig. 1). This mechanism serves as a local negative feedback system that resists passive changes in muscle length so that the optimal resting length can be maintained.

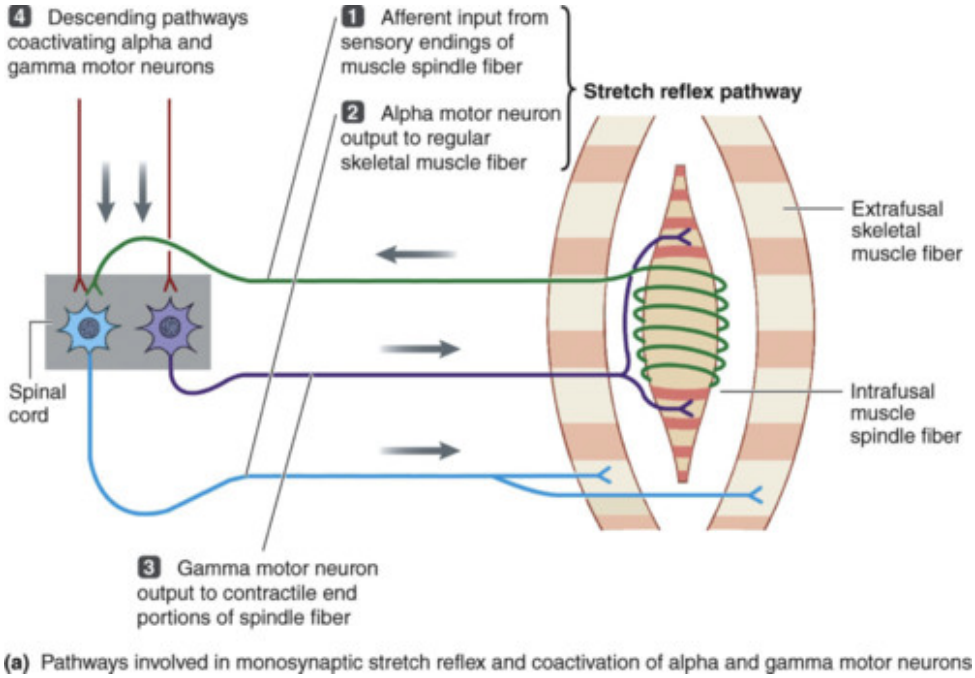

Figure 1: Function of muscle spindle during a monosynaptic stretch reflex.

Spinal cord reflexes represent the most basic of motor responses. These reflexes are carried out entirely within the spinal cord and are modified by inputs from higher brain centers to generate complex movements. The myotatic, or muscle stretch reflex, is an example of a spinal reflex. When the tendon is hit, the muscle and associated spindle are stretched, causing an increase in the firing rate (action potential spike frequency) of the sensory afferent neuron. This signal is relayed through the spinal cord back to the alpha motor neuron that causes the outlying muscle to contract (reflex response). A monosynaptic stretch reflex depends on three factors:

1. **Reflex arc length**: distance that the signal travels from the muscle spindle to the spinal cord region where it synapses with the motor nerve and back (i.e. sensory nerve plus motor nerve path)
2. **Nerve conduction velocity**
3. **Synaptic transmission time**

The **knee jerk reflex** is a spinal reflex activated by tapping the patellar tendon below the kneecap. This tendon then stretches the muscle spindles, generating sensory impulse to the spinal cord. Alpha motor neurons in the spinal cord cause a brief, rapid contraction of the quadriceps femoris, which causes the leg to extend.

This entire system can be generalized as a control system in which a regulated variable (e.g. the spike frequency of the stretch receptor) is continuously adjusted by negative feedback. Fig. 2 shows a generalized diagram of a negative feedback control system. The set point is the desired value of the regulated variable. The forward and feedback gain represent places where the signal is multiplied by some value. The output is measured by a detector and fed back to an integrating center (the summation sign in the diagram), which takes the difference between the set point and feedback. This difference is used

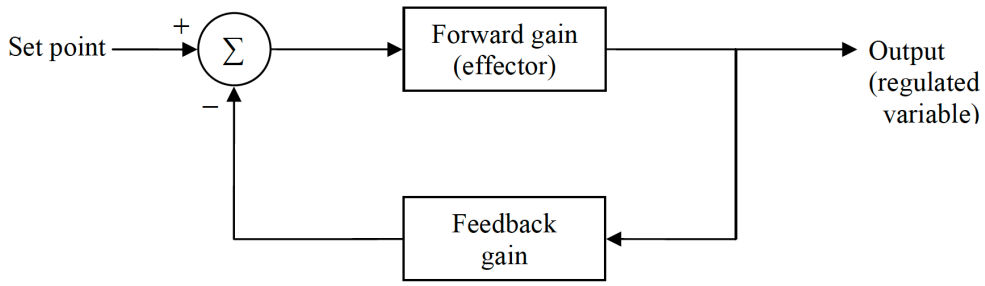

Figure 2: Function of muscle spindle during a monosynaptic stretch reflex.

to control the effector responsible for the output variable. We can use this type of generalization to explore properties of the stretch reflex and how it changes.

1. Write the physiological analog of the spinal reflex arc to each component of the negative feedback system diagram:
   (a) Set point:
   (b) Forward gain (effector):
   (c) Output (regulated variable):
   (d) Feedback gain:
2. What happens to the regulated output variable if it is higher than the set point? What if it is lower?

Experimental Methods

Setting Up the Software

1. Open BIOPAC student lab lessons software and select *L20 - Spinal Cord Reflexes*.
2. Plug the output line from the reflex hammer into channel 1 of the MP3X unit. The signal from the reflex hammer record the impact of the hammer with a surface.
3. Plug the electrode lead set (SS2L) into channel 2. The signal from the electrodes records the EMG of the muscle activity.
4. Follow the instructions on-screen for subject preparation for knee electrodes.
   - Red (+): lower quadriceps, closer to knee
   - White (-): upper quadriceps, closer to waist
   - Black (ground): knee cap
5. Follow the instructions on-screen to calibrate.

Regular Procedure

1. Have the subject sit with their legs hanging freely over the edge of the chair.
2. Select *Record* when you are ready to start recording.
3. Strike the patellar ligament on the knee and observe the resulting reflex contraction.
4. Continue recording and repeat the strike on the patellar ligament 15-20 times, as necessary, to get consistent data.
5. Click on the *Suspend* button to pause or stop recording.
6. Determine the reaction times for each strike and record them on your handout. Additionally, determine the magnitude of the hammer strike and the EMG pulse for each strike. For all three measurements, calculate the mean and standard deviation.
7. Is there a relationship between hammer strike force and reaction time? Explain.
8. Is there are relationship between hammer strike force and the magnitude of the muscle response? Explain.
9. Measure the length of this reflex arc, realizing that it involves the L2, L3, and L4 segments of the spinal cord. Calculate an estimate of the nerve conduction velocity. Do you expect this to be an overestimate or an underestimate? Why? **Record the conduction velocity as you will need this information for your post-lab assignment**.
10. Do not remove the electrodes. After checking your results (and before you exit this screen and begin data analysis), continue to the following section.

Jendrassik Maneuver

1. Maintain the electrodes and leads as described in the previous section.
2. Have the subject remain seated with their legs hanging freely over the edge of the chair.
3. Have the subject perform the Jendrassik Maneuver. To perform this maneuver, the subject must grip both hands together across their chest and attempt to pull them apart with maximum force while the knee jerk reflex is obtained (Fig. 3).
4. Follow the instructions on-screen to collect the necessary data.
5. When you are done, select *Suspend*.
6. Determine the reaction times for each strike and record them on your handout. Additionally, determine the magnitude of the hammer strike and the EMG pulse for each strike. For all three measurements, calculate the mean and standard deviation.
7. How do the reaction times during the Jendrassik maneuver compare to the regular procedure? Explain the change or lack of change.
8. How do the muscle response magnitudes during the Jendrassik maneuver compare to the regular procedure? Recall the negative feedback diagram (Fig. 2). Which variable do you think has changed?

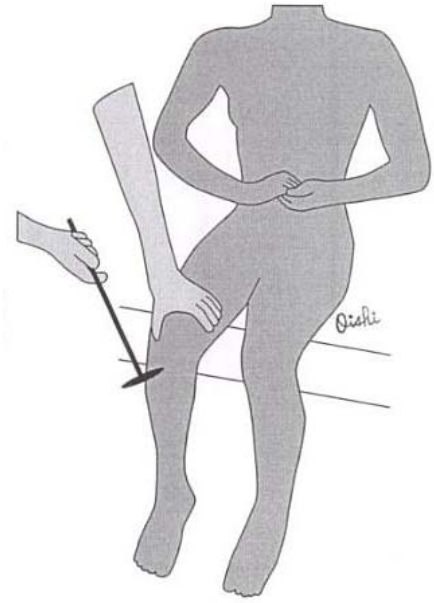

Figure 3: Jendrassik maneuver

9. One feature of negative feedback systems with high gain is *ringing*, the presence of transient oscillations in the regulated variable before it settles to a steady-state value. Did you observe ringing in any of your experiments? If so, in what test(s)? Briefly describe how this occurs in terms of the feedback diagram. Why does high gain make ringing more likely?