ARTICLE
Student Friendly Technique to Demonstrate Coordination between Postural (Involuntary) and Voluntary Muscle Contractions

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Electromyography is a very useful technique for a number of clinical and research applications in physiology and other life science applications. We have adapted this technique as a student exercise to explore important aspects of postural control. With minimal effort and some mathematical calculations this student friendly technique efficiently demonstrates the interaction of anticipatory, or feedforward, mechanisms and feedback correction from sensory input.

   Key words: postural control, feedforward, electromyography, physiology, RMS, second derivative

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Postural control
Postural control is a complex interaction of anticipatory, or feedforward, mechanisms and feedback correction from sensory input. This phenomenon has been reviewed in some depth by Massion (1992).

   As a component of the motor plan for moving a body part, the effect of the planned movement on the stability of the rest of the body is "evaluated" to produce anticipatory changes in other muscle groups. These changes may precede the movement of the primary muscle groups involved in the intended task. The example in Figure 1, illustrates an experimental procedure to observe the involuntary changes in leg muscle activity that provide preparatory postural support for the voluntary movement of the arm.
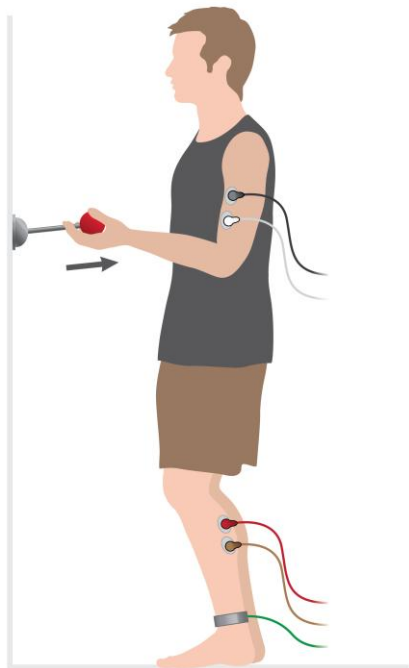

Figure 1. Proper electrode placement to record EMG from biceps brachii and gastrocnemius muscles. Volunteer will react to an auditory (or other) cue and pull him or herself forward, voluntarily activating the biceps.

   This set of interactions is covered in chapter 17 of Purves et al. (2012). The voluntary action of the biceps brachii tends to pull the subject forward. To compensate for the anticipated instability, a contraction of the gastrocnemius muscle precedes the onset of bicep activity. This feedforward mechanism anticipates a change in body stability, and thus creates a steadying reaction in what would appear to be unrelated muscle groups. This phenomenon provides a wide array of opportunities for inquiry-based and student-designed projects.

Technique can be added to an existing laboratory
Computer-based data acquisition systems have become quite common in undergraduate physiology laboratories. These powerful systems can be used to record and measure any number of physiological parameters of interest to neurobiologists.

   Electromyography is a technique used to detect the electrical potential generated by active muscle cells. The signals can be analyzed to detect activation level or to analyze the biomechanics of human or animal movement. For this exercise, we are most interested in the activation order of the muscle groups of interest. We use an AC coupled human-safe bio amplifier to measure the electrical activity of the muscle underneath electrodes placed on the skin. Virtually any human-safe bio amplifier used for electrocardiography or electroencephalography will work for electromyography.

MATERIALS AND METHODS
We have chosen the classical biceps and gastrocnemius combination to illustrate the phenomena. However, this technique can be adapted to virtually any set of muscle groups.

EMG recording
A human-safe dual-channel bio amplifier capable of recording signals in the 5 mV range and a computer-based data recording system are used to record EMG signals from the relevant muscle groups. Suggested recording parameters for acquiring the EMG signal are: Sampling rate of 2000 samples/second, low-pass filter (hardware or

digital) at 2kHz. A high-pass filter at 10 Hz will remove DC artifacts from the signal. Appropriate cables and disposable Ag/AgCl electrodes to connect to the amplifier are also necessary. Electrode paste, abrasive gel and alcohol swabs may improve signal quality, but are often not needed.

The students will need to work in groups of at least two; three per group would be ideal, with a volunteer, one to run the software, and one to apply the stimuli.

Electrode attachment to the subject

Skin over the biceps brachii and gastrocnemius should be cleaned with alcohol wipes and lightly abraded if necessary. The differential leads from the amplifier should be placed over the largest part of the muscle groups of interest. Typical electrode placement over the biceps and gastrocnemius muscles are illustrated in Figure 1.

The volunteer is required to stand upright and pull themselves forward, voluntarily activating the biceps reacting to an audio tone. A doorjamb will work as the "lever" to pull against in Figure 1. Alternately a coat rack (supported by another volunteer) or rope may be secured to the wall for the subjects to pull themself against.

Polarity

The polarity of EMG signals is arbitrary. There are many ways to visualize EMG signals, these include rectifying and integrating the signal. In this exercise, I use a root mean square (RMS) calculation to visualize the "power" of the EMG signal. This will allow for easy detection of the onset of the muscle activation.

Detection of EMG onset in response to an audio tone

The volunteer should relax and wait for the audio tone (or other cue). Start the recording software and record baseline EMG. Play an audio tone and have the volunteer pull the lever. Be sure to annotate the record indicating exactly when audio tone occurs.

Once you have a satisfactory response (Figure 2), record a minimum of three responses, approximately 1 minute apart, so an average time difference between onsets of muscle activation may be calculated.
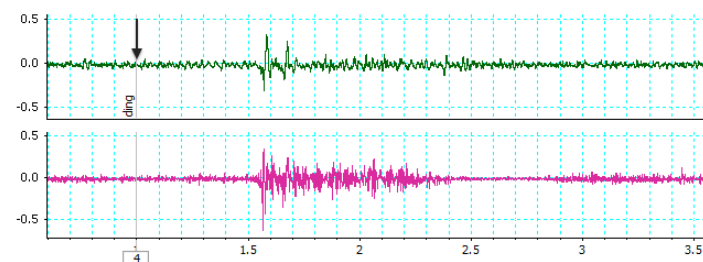
Figure 2. Typical EMG signal after response to audio cue (arrow). The green trace is raw bicep signal, pink trace is raw gastrocnemius. Horizontal axis is time in seconds, audio cue (ding) occurs one second after sampling starts, vertical axis is millivolts.

RESULTS

Time course

The key element in the signal we are interested in is the onset of the EMG signal relative to baseline, see Figure 3.
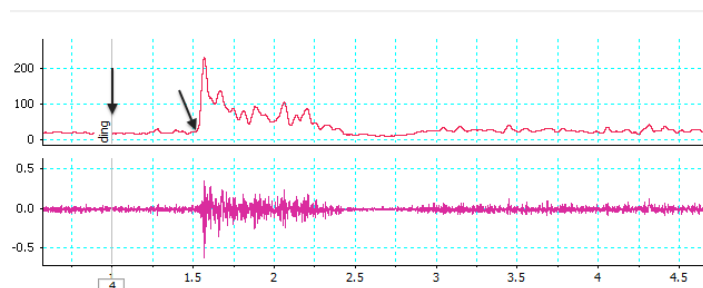
Figure 3. Onset of muscle contraction, the top (red) trace is the RMS of the bottom raw (pink) EMG signal. Left arrow indicates audio cue (ding) one second after sampling starts. Right arrow is the onset of EMG activity above baseline. Vertical axis is millivolts for EMG and arbitrary units for RMS; horizontal axis is time in seconds.

Students will be tempted to measure the time difference from the first peak of the gastrocnemius RMS signal and peak of the bicep RMS signal to calculate the time difference between muscle contractions. Actually, we are interested in the time difference between the *onset* of each muscle groups contraction. Using the waveform cursor (or its equivalent in the software of choice) students should look for the point at which the signal shifts abruptly above the baseline. This is the point of maximum acceleration in the signal and can be visualized by using the second derivative of the RMS signal as shown in Figure 4. Students can then very easily compare the time between the first peaks shown on the second derivative channels as shown in Figure 5.
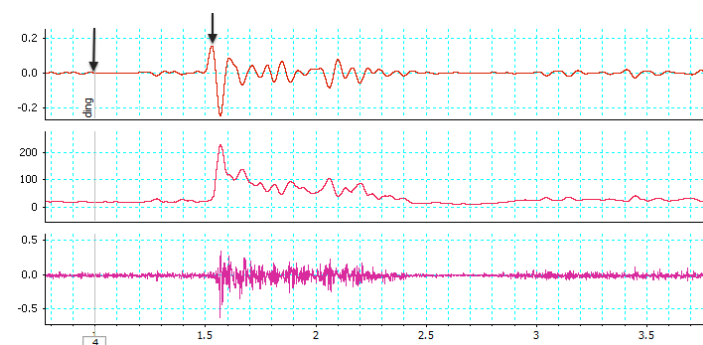
Figure 4. The second derivative provides an excellent visual cue for measuring the onset of EMG signal. The top (light red) trace is the second derivative of the dark red RMS signal on the middle channel. The indicated peak represents the point of maximum change (onset of the contraction). The bottom channel (pink) is raw EMG signal. Left arrow indicates audio cue (ding) one second after sampling starts. Vertical axis is millivolts for EMG and arbitrary units for RMS and derivative; horizontal axis is time in seconds.
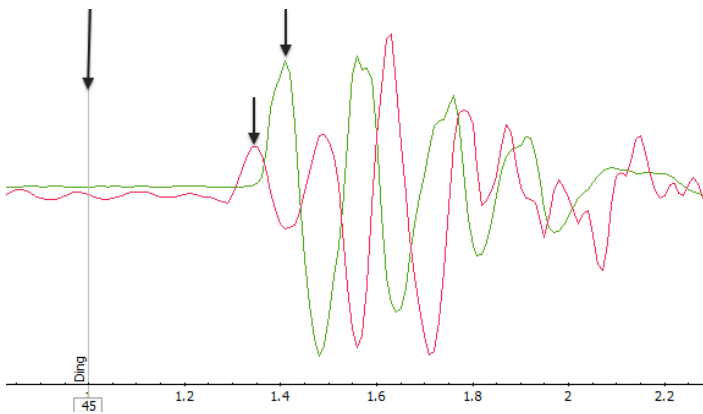
Figure 5. Measuring the time between gastrocnemius onset (light red) to biceps onset (light green) is very intuitive using the second derivative peaks with the data traces overlaid. Left arrow indicates audio cue (ding) one second after sampling starts. Vertical axis is arbitrary units for derivative; horizontal axis is time in seconds.

Measuring additional components of postural position

Adding a force plate to this exercise allows students to also visualize the time course of the change in center of gravity as the subject pulls himself or herself forward. Depending upon your recording system, you will likely need 3 additional channels to record from typical force plates. In this exercise LabChart® with the Wii balance board extension and additional channel calculations were used to show the change in center of gravity of the volunteer as they pull themselves forward after an audio cue. Figure 6 shows the sequence of events from the audio cue to gastrocnemius contraction, and bicep onset, through to the shift in center of gravity.
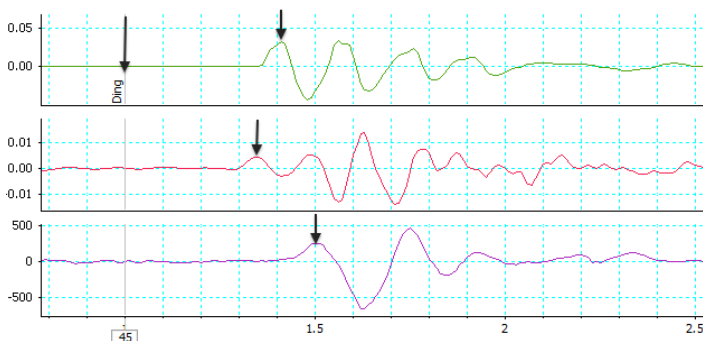

Figure 6. The second derivative of the RMS signals from biceps (light green) gastrocnemius (light red) and center of gravity (purple). Arrows indicate onset of each event. Vertical axis is arbitrary units for RMS and center of gravity; horizontal axis is time in seconds.

DISCUSSION

Student-designed and inquiry-based exercises are possible as any number of different muscle groups and changes in stimuli presentation can be tested using this basic protocol. In addition to audio cues, visual cues (a blinking LED, for example) could be used.

Since measuring reaction times is a built in component of this exercise, any of the perturbations normally used in reaction time testing may be combined with this protocol. Facors such as age, gender, stimulants, distraction, etc. may be combined and tested by students.

Instructors who are already recording biopotentials from human subjects can add this technique to their laboratory with no additional equipment. This exercise can be combined with other exercises to enhance the student experience in your course.

REFERENCES

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