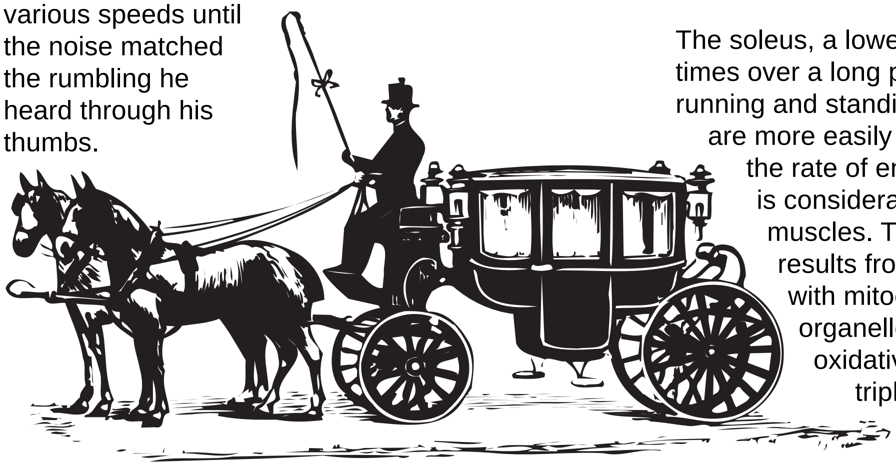
*A Live Demonstration*
*by* ®**GRASS**

# Acoustic Myography (AMG)

## Introduction

The muscles of the body are continually contracting and relaxing in the wake human being. During contraction, they generate sounds. Under ordinary conditions these sounds are not heard, but if you place both thumbs in your ears and make a fist, you will hear a low rumble. The tighter the fist, the louder the sound. You are hearing the sounds of the forearm muscles as they contract. The main frequency of the muscle sound is 25 Hertz, which is at the lower limit of human hearing.

In 1810, the British physicist, physician and chemist, William Hyde Wollaston, compared the muscle sounds to the distant rumble of carriages over the cobblestone streets of London. To check his work, he had his carriage driven through the streets at various speeds until the noise matched the rumbling he heard through his thumbs.



Knowing the size of the cobblestones, and the wheel diameter, he was able to calculate the muscle sounds to be about 25 Hertz.

The mechanical stethoscope, used to listen to sounds in the body, is not suitable to listen to muscle sounds. In fact, it filters out most sounds below 50 Hertz. Most audiologists consider 20 Hertz to be the lower limit of hearing. Below about 30 Hertz, sound loses its tonal quality and becomes a deep rumble. The power spectrum for the acoustic signal is fairly broad, ranging from about 10 to 50 Hertz with a peak at about 15 to 18 Hertz.

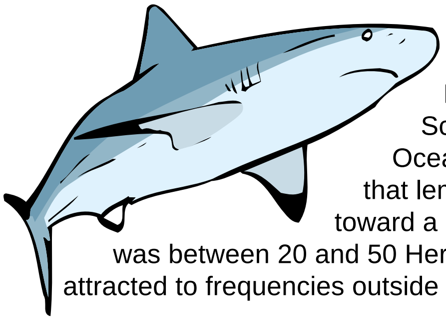
Oster has conducted experiments in which the subject supports a lead weight in the palm of his hand, while the muscle sounds are recorded from the biceps. When the weight is held steady to maintain constant contraction, the amplitude of the muscle sound is directly proportional to the weight. This fact implies that the measurement of muscle sounds can be used to determine how hard a muscle is working. With a weight held in the hand, the least sound comes from the biceps when the angle between the forearm and upper arm is 115 degrees.

The soleus, a lower leg muscle, contracts many times over a long period without fatigue in walking, running and standing. The other skeletal muscles are more easily fatigued and it is apparent that the rate of energy transformation in the soleus is considerably less than the rate in other muscles. The endurance of the soleus results from the fact that it is richly supplied with mitochondria, the energy transducing organelles of the cell. In the mitochondria, oxidative enzymes produce adenosine triphosphate (ATP), the universal cellular fuel.

Muscle fibers having many mitochondria are “slow twitch” fibers, those with fewer mitochondria that can contract rapidly are “fast twitch” fibers. Slow twitch fibers are important for endurance while fast twitch fibers are needed for speed. It may be possible to evaluate the training of marathon runners by monitoring and comparing sounds from soleus and gastronemius muscles.

## Use in Animal Behavior

Those studying animal behavior may find uses for muscle sounds. Several species of fish generate sounds by vibrating their swim bladders, the inflatable organ that maintains buoyancy. *Gouramis* emit sounds, apparently from muscular contraction, only when they are involved in mating. It has been shown that sharks are attracted to low frequency sounds.



In 1963, Donald R. Nelson and Samuel H. Gruber of Scripps Institution of Oceanography showed that lemon sharks moved toward a source of sound if it was between 20 and 50 Hertz, but were not attracted to frequencies outside this range.

Dr. Margaret A. Vince, of the Agricultural Research Council in Britain, has detected muscle sounds from the eggs of the Japanese quail using a special transducer.

## Origin of Muscle Sounds

It appears that the rumbling sounds come from resonant frequency vibrations of muscle fibers. Whole muscles from Frog (*Rana pipiens*) have been used for *in vitro* recording of muscle sounds. The muscle is isolated and placed in a temperature-controlled bath of frog Ringer. The muscle is electrically stimulated while acoustic signals are recorded with a hydrophone nearby. The typical waveforms from this preparation exhibit a series of oscillations that initially increase in amplitude and frequency and then decrease in amplitude and frequency.

When the muscle contracts, the continuous rumbling tone does not always start immediately. With slight contractions, clicks or sharp pulse tones are sometimes heard. With increasing contraction, the time between clicks shortens until the sound merges into the low rumble. The clicks come from the muscle motor units. Each motor unit is made up of a group of fibers activated by a single nerve. The size of the motor unit and its action can vary depending on the function of the muscle. In the gastrocnemius, a typical motor unit is made up of about 2000 fibers. In the orbicularis oculi, the eyelid muscle, each motor unit consists of only about 20 fibers. In blinking, the eyelid responds in about 50 milliseconds with the response being an all-or-nothing one. All motor units fire together to obtain speed and precision.

## Muscle Sounds in Physical Medicine and Rehabilitation

Barry *et al.* (1985) found that human muscle sounds were intrinsically tied to contraction and that sound amplitude declined during muscle fatigue while the surface EMG signals did not decline. Therefore, the ration of acoustic amplitude to EMG amplitude can be used as a measure of the loss of electromechanical coupling that accompanies muscle fatigue. The data shows that the acoustic signal RMS amplitude increases with increasing force of contraction. The dynamic range of this signal from biceps brachii with the arm at rest versus supporting a 20 pound load is approximately 25. The relationship of RMS amplitude to load is approximately linear in the mid range, with non-linearities appearing in both low load and high load conditions. (See Figures 1 and 2 below.)

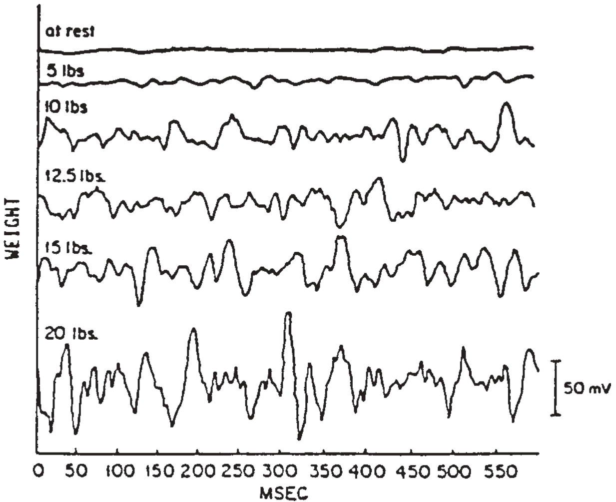


*Figure 1.*

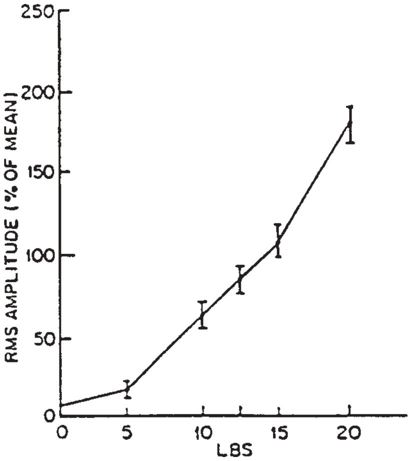


*Figure 2.*

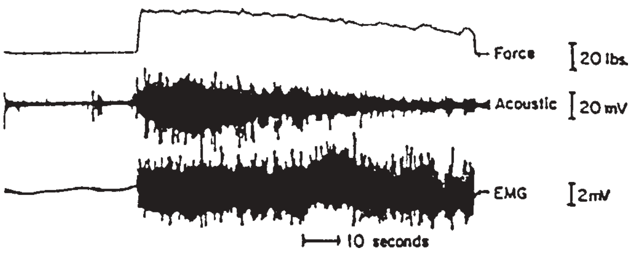


*Figure 3.*

The acoustic myograph signal, produced with maximal isometric effort, parallels declining force with fatigue. Figure 3 above shows the relationship of the AMG and EMG signals to force during sustained maximal effort as force drops from 75% to 35% maximal voluntary contraction (MVC). The AMG signal follows the decline in force whereas the EMG signal drops only below 45% MVC which is about 75% of the mean force. It can be shown with decreased effort that the AMG, EMG and force levels all decrease simultaneously.

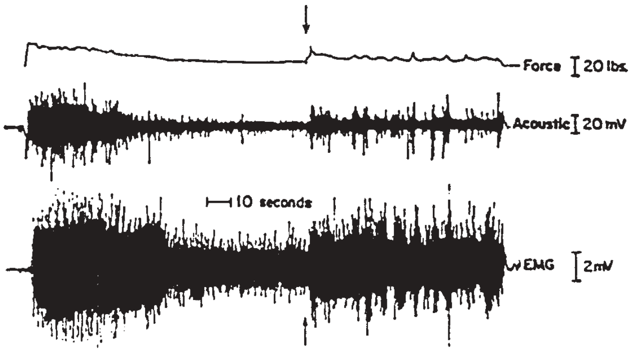


*Figure 4.*

Comparing the AMG and EMG amplitudes provides an indicator of volition. When a subject chooses to reduce effort, the EMG, AMG, and force amplitudes decline simultaneously. This could be a valuable parameter in distinguishing motor unit fatigue from lack of effort. See Figure 4 above.

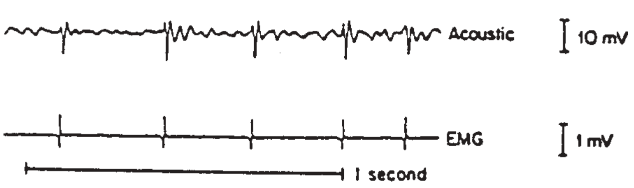


*Figure 5.*

Using a technique of recording simultaneous AMG and needle EMGs, a motor unit can be seen in both tracings. (See Figure 5 above.) For this, the microphone must be placed directly over the needle, and both systematically varied to obtain the simultaneous signals. The detection of individual acoustic spikes that correlate with needle EMG confirms that individual motor units can be resolved acoustically.

AMG represents a new modality for analyzing muscle activity. It allows *in vivo* measurements of the dissociation of electrical and mechanical events in muscle with fatigue. The demonstration of resolving individual motor units makes it possible to use this technique to reveal prognostic or diagnostic information.

## Using Muscle Sounds in a Myoelectric Prosthesis

Barry *et al.* have reported the use of the AMG signal as a control signal for a standard myoelectric prosthesis. In this experimental arrangement, the acoustic signal is sensed by a conventional phonocardiograph microphone and the electrical signal is amplified, band pass filtered, full wave rectified and filtered to produce a control signal. Additional circuitry is used to discriminate between active muscle sounds and environmental noise. The signal is used with a standard myoelectric prosthetic hand.

**Advantages of the AMG driven prosthesis are:**

1. Because there is no direct skin contact, it is possible to have materials such as a stump sock or dressing between the microphone and the stump.
2. Electrode impedance variation due to sweating, etc. is not a problem when sensing with a microphone.
3. The AMG signal is larger than the EMG signal making shielding much less of a problem.
4. The AMG signal is less sensitive to precise placement over the muscle allowing more freedom in selection of transducer sites.
5. Microphones can be integrated into the prosthesis and by shaping transducer material to the form of the individual muscles, higher signal-to-noise ratios will be attainable.

**Some disadvantages are:**

1. Extraneous environmental noise can interfere with the AMG signal. Sustained loud low frequency sound can activate the prosthesis unless special filtering techniques are used.
2. Using AMG control will incur initial manufacturing costs. These initial tooling charges, however, can be offset by the reduced shielding and amplification electronics required by the AMG signal.

## About this Demo

This demonstration shows the relative ease of recording the AMG. AMG recordings of the dorsal interrosseus muscle between the thumb and forefinger are made simultaneously with the surface EMG in response to index finger lateral movement. Recordings are made with a Grass PolyVIEW® Digital Data Acquisition System. See Figure 6.

A microphone is placed over the dorsal interrosseus muscle and secured with double-sided adhesive collars. The surface EMG recording site is prepared by first removing skin oils with an alcohol prep pad. After drying, 10 mm diameter silver-silver chloride disc electrodes are applied with double-sided adhesive collars. Electrode gel is applied to lower the contact electrode impedance. Three electrodes are used. The active electrode is placed on the dorsal interosseus muscle next to the microphone. A reference electrode is placed lower near the thumb and a grounding electrode is placed at the wrist.

The microphone is connected to a Grass Model LP511 AC Amplifier. The EMG electrodes are connected to a second LP511 AC Amplifier. When force is recorded, a Grass Model FT03 Transducer is connected to a Grass Model LP122 AC/DC Amplifier.

The AMG signal is connected from the LP511 analog output to both a Grass Model AM10 Audio Monitor and one channel of the PolyVIEW input. The Audio Monitor provides monitoring the audible sounds. With this arrangement, a pair of headphones can be substituted for private listening, if desired. The EMG signal is connected from the second LP511 analog output to a second input channel of PolyVIEW. Both the AMG and the EMG are displayed on the PolyVIEW screen.

When stimulation to produce muscle twitches is desired, a Grass electrical stimulator, stimulus isolation unit, and a bipolar stimulating electrode is used. Brief monophasic pulses are delivered to the stimulating electrode placed at the wrist over the ulnar nerve. The stimulus intensity is adjusted to produce a supramaximal response.The onset of the stimulus is displayed on a third PolyVIEW channel.

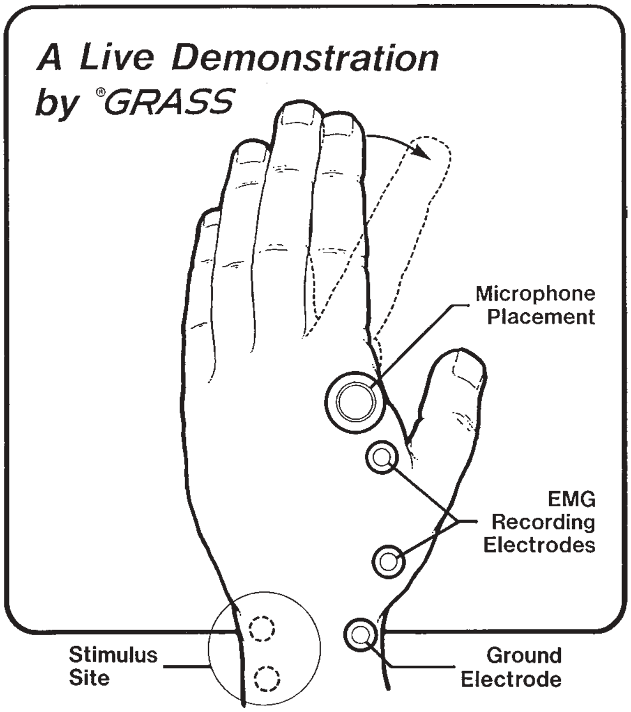


*Figure 6.*

In some demonstrations, a specially constructed hand holder, with built-in force transducer, is used. This arrangement simplifies the recording and makes the correlation of force, EMG, and AMG a simpler task.

**References**

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2. Barry DT, Geiringer SR, Ball RD: Acoustic Myography: A Noninvasive Monitor of Motor Unit Fatigue. *Muscle & Nerve* 8:189-194, 1985
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5. Barry DT: Acoustic Signals From Skeletal Muscles. News in *Physiological Sciences* 5:17-21, 1990

This demonstration and handout is based on the work of and designed with the aid of Daniel T. Barry, M.D., Ph.D., Department of Physical Medicine and Rehabilitation, The University of Michigan, Ann Arbor, Michigan 48109-0042.

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