Introduction to EMG

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This lecture can be found at:

`http://mac-huwis.lut.ac.uk/~wis/lectures/`

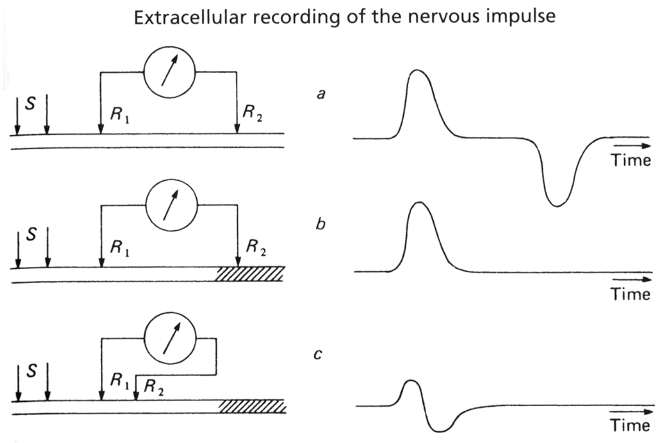

Figure 1 Extracellular recording [Keynes & Aidley 2001]

In the muscle physiology lecture I showed you how an externally measured action potential from a single muscle fibre produced a characteristic biphasic waveform. Imagine what happens when a recording is made externally to the muscle in a living subject. Instead of recording from a single muscle fibre you are recording from thousands of muscle fibres and instead of recording just next to the fibre you are recording some distance away through various layers of connective tissue and skin. This means that instead of a nice clean signal of about 100 mV you get a much more complex signal of about 5 mV. The actual size of the signal is highly variable and depends on the thickness of the connective tissue, the quality of the contact between the electrode and the skin, the size of the electrodes and the sizes and time courses of the individual motor unit action potentials. These will vary from experiment to experiment so the size of an EMG is a largely qualitative measure although it does increase in size with the activation level of a muscle.

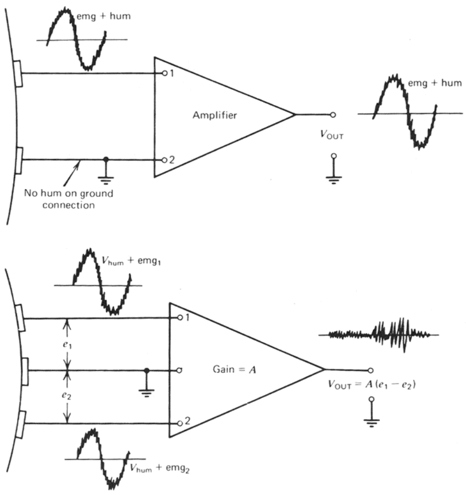

Figure 2 Differential Amplification [Winter 1990]

5 mV is quite a small signal. In a laboratory surrounded by lots of electrical equipment the human body makes a good aerial and picks up some quite strong electrical signals – perhaps as much as a volt or two. If we tried to measure the electrical signal using two electrodes as shown at the top of figure 2 most of what we would measure would be this electrical noise and we would be lucky if we could measure the much smaller signal from the muscles. The solution to this is shown in the bottom half of the figure. By using three terminals, two placed over the muscle and the other placed anywhere on the body, we can take two sets of measurements which can be subtracted. The noise signal is exactly the same in each measurement so that it disappears when the two measurements are subtracted. This is a very common approach when measuring small electrical signals (for example high quality microphones work this way). It is done using a **differential amplifier** and how well it performs this subtraction is known as the **Common Mode Rejection Ratio** (**CMRR**). It is important that the correct electrodes are used: the earth electrode can go anywhere on the body but the two active electrodes must be placed over the body of the muscle a few centimetres apart.

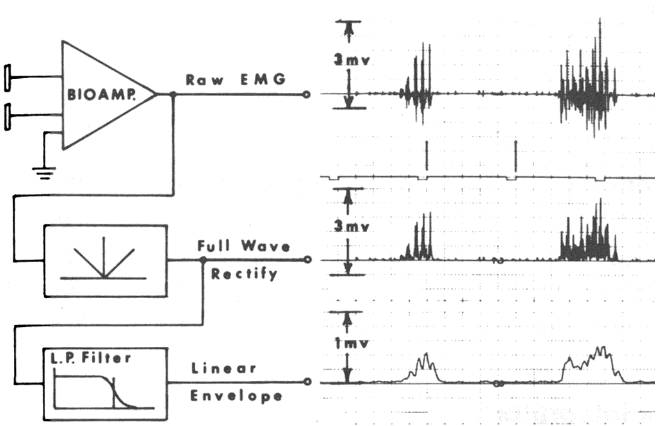

Figure 3 Signal Processing [Winter 1990]

As you can see from figure 3 the EMG signal is a complex spiky signal that can be difficult to interpret. We can use a variety of signal processing techniques to make is easier to read. Probably the commonest is to extract the **linear envelope** (often confusingly called an

integrated EMG). This can be done electronically but nowadays is usually done digitally in software. There are two stages. Firstly the signal is rectified – in other words the negative values of the signal are converted to positive values by taking the absolute value. Secondly the resultant signal is passed through some sort of low pass filter which acts to smooth the high frequency peaks and produce a slowly varying trend. This is shown in figure 3. This filter is often a moving average or it can be a digital low-pass filter. The important parameter here is the **cutoff frequency**. If this is too high then the signal will still be very spiky. If it is too low then the signal will be smoothed away to nothing. Generally speaking since we are interested in how muscles contribute to human movement and we know that human movements do not have components faster than 10 Hz then a cutoff frequency of less 10 Hz is often a good choice – Winter recommends 3 to 6 Hz but it obviously depends on the exact movement.

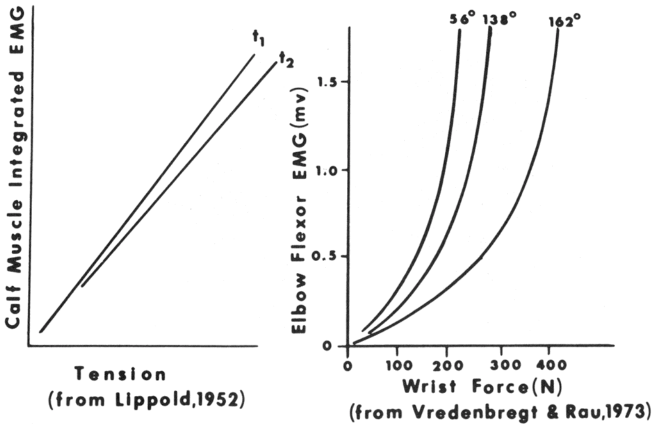

Figure 4 EMG and Tension relationships [Winter 1990]

It would be convenient if there was a straightforward relationship between the EMG signal and the tension generated in a muscle. Sadly this is not the case. As was mentioned earlier EMG signals vary from experiment to experiment, individual to individual, and even over time in the same experiment (the effectiveness of the contact between the skin and the electrodes tends to increase over the first 30 minutes or so and then decreases) so there is no absolute calibration. How about a relative calibration? In a short period of time does a double EMG equate to doubled tension? The answer here is possibly. Some authors have found linear relationships in some muscles and others have not (see figure 4).

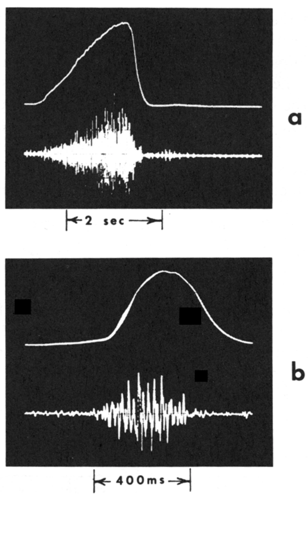

Figure 5 EMG Timing [Winter 1990]

The timing of the EMG signal is rather better understood. When there is little muscle tension there is virtually zero electrical activity. As the EMG increases after a short lag the tension increases. Depending on the timescale of interest this lag can easily be irrelevant. In figure 5 the top chart shows a slowly increasing muscle tension matched by a slowly increasing EMG. However when looking at a sudden tension change in the lower chart (note the scale difference) the time lag can be clearly seen.

In summary:

- EMG provides good semi-quantitative data on muscle use
- A 3 electrode system is necessary to cancel out background noise
- Linear envelope processing with a 3 to 6 Hz cutoff is a good processing option
- There is a variable (~50 ms) time delay between the electrical activity and tension

Bibliography

Keynes RD, Aidley DJ. *Nerve and Muscle*. 2001 Cambridge: Cambridge University Press.

Winter DA. *Biomechanics and motor control of human movement*. 1990 (2nd ed.) New York: John Wiley & Sons.