

EMG Biofeedback – The Principles

Introduction

A fairly concise, but useful definition (Weiner) might suggest that feedback is ‘...a method of controlling a system by reinserting into it the results of its past performance.’

When applied to biomedical problems, one adapts the basic definition and adds several components such as to make things more understandable and applicable. The longer, but possibly more useful definition now runs something like ‘...a technique which enables the individual to readily determine the activity levels of a particular physiological process, and with appropriate training, learn to manipulate the same process by an internalised mechanism.’

Whilst not the most poetic of definitions, this does convey the essentials - information is detected, provided in an understandable way to the patient who can then, at their own initiation, use the information to achieve a measure of control over the same process.

It is important that the changes as a result of biofeedback are volitional - i.e. requiring effort on behalf of the patient. Regulation of such processes at the automatic level is not really clinical biofeedback, though there is plenty of room for discussion on this point.

The practice of biofeedback has developed markedly over the last few years, and many different forms of feedback are currently employed in the clinical setting. The wide range of inputs (e.g. EMG, pressure, movement, pulse, blood pressure) means that many applications can be developed from the existing equipment. The limits to biofeedback applications are largely with the therapist. Given an understanding of the basic principles of the therapy in combination with a clinical understanding of the patients problem, there are many novel applications for the therapy. Given the limited scope of this document, the following consideration will focus exclusively on EMG Biofeedback.

Biofeedback as a component of treatment

It is important at the outset to emphasise that biofeedback is not at its most effective when used as a treatment in its own right, but should be integrated with other therapeutic interventions. It acts as an enhancer of the therapy, enabling the patient (and the therapist) to make more effective and rapid progress towards the rehabilitation goal. Furthermore, it is useful in that it helps the patient to reduce their reliance on the therapist and become more reliant on their own performance. Clearly this is not fully achieved if the patient becomes reliant on the machine instead of the therapist! It can be used effectively to enable the patient to take some control or ownership over their rehabilitation - empowerment is a often used phrase in this context. The key to success of biofeedback in rehabilitation is to use the device as an adjunct to therapy, to enable the patient to gain control without reliance on the therapist, and once gained, to maintain control without either the therapist or the machine. This approach is entirely in keeping with the general aim of modern physiotherapy, and the technology is an aid to the outcome, not a magical solution.

EMG Biofeedback - Physiological Principles

The principles of EMG biofeedback (EMGBF) are usefully reviewed, as a reasonable understanding of what the machine is doing will assist the therapist in determining the most appropriate machine settings and applications.

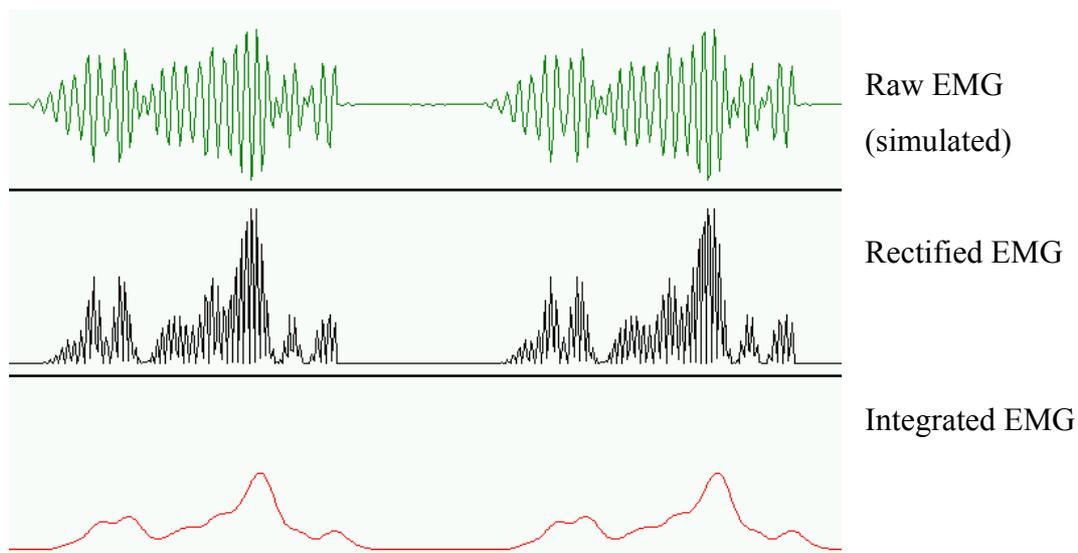
Electrodes & Signal Processing

Machines utilise surface electrodes which detect small voltage changes which arise from the working muscles. The electrodes are Silver/Silver Chloride construction which are efficient at detecting small biological electrical signals from the body surface. The use of an appropriate electrode gel helps in converting the biological (ionic) signals to electrical signals needed by the machine, and will also help to reduce some 'noise'.

The use of surface electrodes results in a broadly sourced signal which will not be specific to a particular motor unit or even a specific muscle. The signals reaching the electrodes need to be processed before they are of any real value to the patient.

The signal is amplified, and usually filtered and then processed. The result of these actions is to produce a time varying electrical voltage which can be displayed to the patient by means of a series of lights, varying tones, numbers on the LED display or through a computer link once it has been converted from an analogue to a digital form.

Although this electrical processing means that the patient does not get to see their 'real' electrical muscle activity, it is actually more useful in its processed form. The graphs below illustrate the results of these processes on a simple EMG recording.



Electrode Placement

The surface electrodes used for EMGBF record a broad electrical picture of the electrical activity from the underlying tissues. It is not possible with this electrode arrangement to identify with certainty that a particular signal is coming from a specific muscle, but judicious electrode placement will influence the specificity of the displayed data.

The muscle fibres nearest the electrodes will have the greatest influence on the combined signal. Distant muscle signals will have an effect on the overall picture, but their influence will be diminished due to dispersion of the signal in the tissues and the reduction in signal strength due to the impedance of the tissues.

Wide electrode spacing will increase the volume of tissue from which the signals are collected, and will therefore increase the number of muscles which will influence the displayed data and conversely, narrower spacing (i.e. closer electrodes) will reduce the tissue which influences the signal, making it more specific. Even with close spacing over superficial muscles, it is not possible to be sure that the signals are only derived from a particular muscle.

Noise which arises due to movement of the electrodes or the electrode leads (often referred to as motion or movement artefact) can make the signal quite dirty, and thus harder for the patient to comprehend. There are several simple things which should be routinely carried out to minimise motion artefact. Firstly, the electrodes should be cleaned after each application, and a good ionic conductive gel applied at each use. Maintaining electrode position with quality adhesive tape or self adhesive electrodes makes a significant difference to this type of noise, and where significant movement of the limb may occur, it is a wise precaution to lightly tape the electrode leads the skin surface as this will reduce drag on the leads and therefore reduce movement between the electrode and the skin surface. Some authorities advocate light abrasion of the skin surface prior to electrode placement, but therapists may not find this to be an essential component of treatment preparation.

The orientation of the electrodes with the muscle in question is a well argued point, but it is generally agreed that wherever possible, the active electrodes should be placed in parallel with the dominant muscle fibres as this minimises signal cancellation and maximises the sensitivity of the biofeedback system.

Features of the EMG Devices

Gain settings :

All biofeedback devices offer an adjustable gain setting which affects the basic sensitivity of the machine. On low gain settings the machine will require a greater signal before the output changes - in other words, it is less sensitive. On higher gain settings, a small amount of EMG activity will be easily seen by the patient. By adjusting the gain settings of the machine, it is possible for the display to respond to very different magnitudes of muscle activity. On high gain settings, small muscle flickers will produce a large response, and this is especially useful for paretic or very weak muscles, for example following a peripheral nerve lesion.

On low gain settings it is possible to make considerable muscle effort before the display is fully activated. This is useful at the other end of the rehabilitation scale, with for example, later stage rehabilitation of the quadriceps muscles, where the patient is encouraged to make a maximal effort during a particular movement.

Appropriate adjustment of the gain settings is an important feature of effective EMG biofeedback therapy. If the device is not sufficiently sensitive, the patient will become frustrated and fail to gain the maximum benefit. If on the other hand, the machine is too sensitive, it will be too easy to achieve full scale activation, and no real benefit will be gained. The therapist is encouraged to try the range of settings on themselves prior to use with a patient in order to be fully conversant with the options offered by the machine.

Sound :

Most EMG biofeedback devices offer an audible feedback in addition to the visual information. Some patients find this to be particularly valuable, whilst others find it quite annoying. Machines allow the facility to be turned on or off, and for the volume to be adjusted with ease. With most devices, the change in sound is such that the frequency of the 'beeps' increases with increased EMG activity.

Threshold :

One of the essential features of a biofeedback system is the incorporation of a threshold system to enable patient targets to be set. The audible signal can be adjusted so that it will only be heard if the patient achieves a preset activity level.

With a patient who is trying to achieve an increase in muscle activity, the threshold can be set so that the audible feedback only comes on when 50% of the scale has been achieved, and this level can of course be modified with the gain setting. Alternatively, the audible signal can be reversed so that the sound is only heard when the signal is in the lower 50% of the scale - a feature which can be used for patients who are attempting to reduce resting tone.

Peak Hold facility :

Some devices offer a peak hold facility which enables either the signal to be fed back on a continuous basis (Peak Hold OFF) or by providing the peak signal over a slower time frame (e.g. 3 seconds). With the Peak Hold ON, the display does not change instantly, but reports the peak activity in the previous 3 second recording period. This facility can be useful especially in later stage recovery or rehabilitation, when sustained activity is more important than instantaneous EMG spikes. In early rehabilitation, or for patients who are struggling to achieve any significant EMG activity, it is preferable to use the instantaneous feedback as it is far less confusing (i.e. Peak Hold OFF).