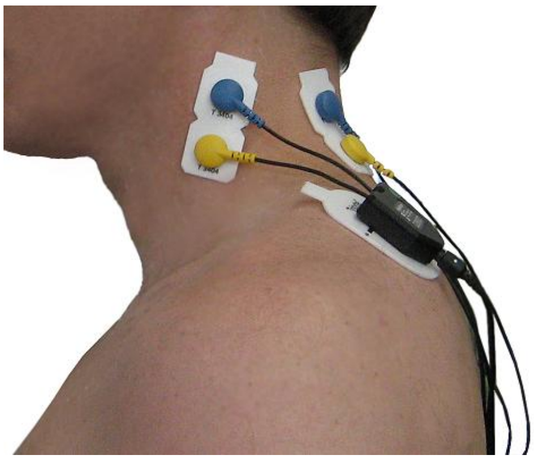
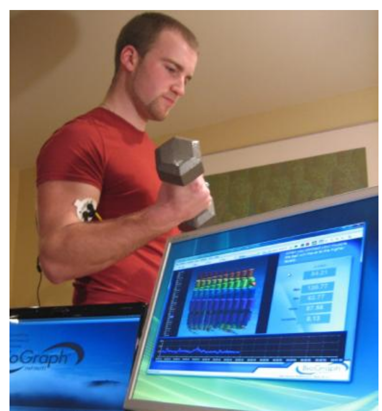
# Clinical Guide

## Physical Rehabilitation

### *Assessment & Biofeedback*

***Surface Electromyography, Range of Motion, Muscle Testing, Algometry, Respiration, Heart Rate, Skin Conductance and Peripheral Temperature***





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**SA7973 Rev 0**

# Table of Contents

# OVERVIEW

This guide was written to assist you in the use of your system and in your general practice. It is not intended to replace scientific and clinical literature (a bibliography of reference books is available at the end of this guide).

The first three chapters of the guide present general concepts:

- **Introduction to assessment and biofeedback training**: this chapter explains the principles of assessment and biofeedback.
- **Muscle properties**: this chapter recalls the main anatomical and physiological concepts that must be kept in mind when assessing and rehabilitating muscles (such as the types of contraction, types of contributions to a movement and the muscles involved in each movement).
- **Introduction to surface electromyography**: electromyography is highly powerful, but requires more knowledge than the other modalities. This chapter explains in simple words what you need to know about electromyography.

The following chapters explain the different modalities and protocols that you can use with your system:

- **SEMG assessment** (general, static and dynamic)
- **SEMG biofeedback training**
- **Range of motion assessment** (static and dynamic)
- **Range of motion therapy with biofeedback**
- **Manual muscle testing**
- **Algometry**
- **Respiration training with biofeedback** (general health, relaxation, breathing during effort)
- **Heart rate monitoring and heart rate variability**
- **Skin conductance and peripheral temperature biofeedback**

After you have become familiar with the key concepts, it is strongly recommended that you do hands-on training to gain experience with the modalities you want to learn, before using them on a real examinee. **As simple a modality can be, it still requires practice.**

You can then use this guide as a reference and also as a source of information.

# ASSESSMENT AND BIOFEEDBACK TRAINING

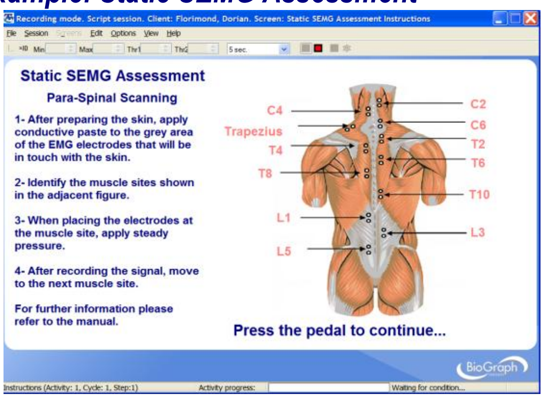
This chapter explains the principles of and interaction between assessment and biofeedback training.

## Assessment

Assessment protocols are deigned to provide measurable and objective data to augment and support the subjective reporting of the examinee and observations of the therapist.

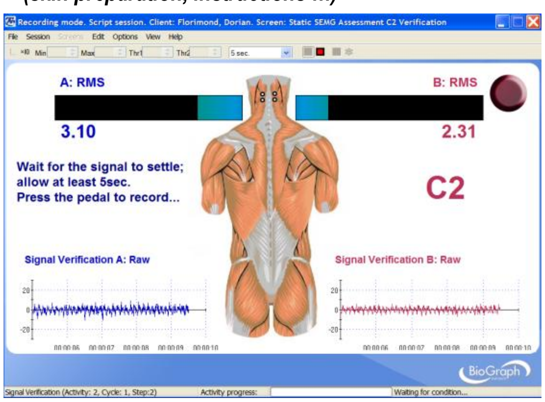
They usually follow a strict sequence of steps, in order to ensure consistency between the measures so they can be compared from session to session. Proper preparation of the examinee, handling of the instrumentation and follow-up of the procedure are essential for accurate results.

### *Example: Static SEMG Assessment*

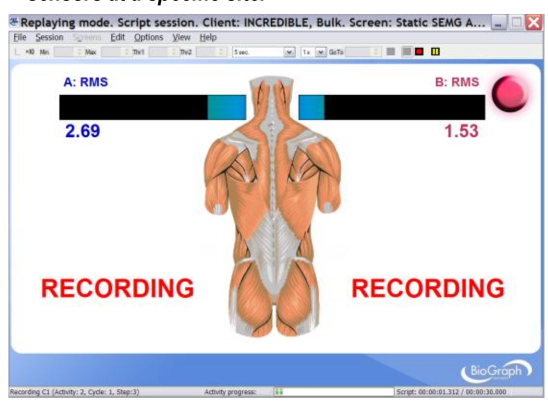



1. ***The examinee must be carefully prepared (skin preparation, instructions …)***

2. ***When ready, the examiner is instructed to place the sensors at a specific site.***

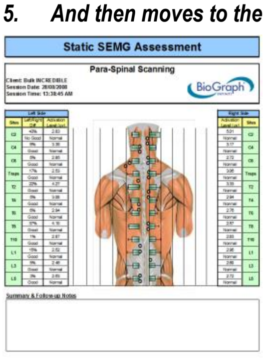



3. ***The examiner must wait for the right conditions.***




4. ***When the signal has settled, the examiner presses the pedal to record the measure.***

5. ***And then moves to the next site…***




The assessment generally ends with the generation of a report where the measures are compiled in a comprehensive way for the examiner.

# Biofeedback Training

Biofeedback is a technique that uses monitoring instruments to measure and feed back information about muscle tension, heart rate, respiration, sweat responses, skin temperature, or brain activity.

The purpose of biofeedback is to enhance an individual's awareness of physical reactions to physical, emotional, or psychological stress, and their ability to influence their own physiological responses.

Biofeedback utilizes electronic sensors, or electrodes, attached to various parts of the body to detect changes in physical responses. Signals then inform the individual of these changes by means of visual or auditory signals such as a light display or a series of beeps.

The individual uses trial-and-error to change the signals change in the desired direction.

Through training, the individual learns to control the targeted physical response and, over time, is able to recognize what is required to reduce problematic symptoms.

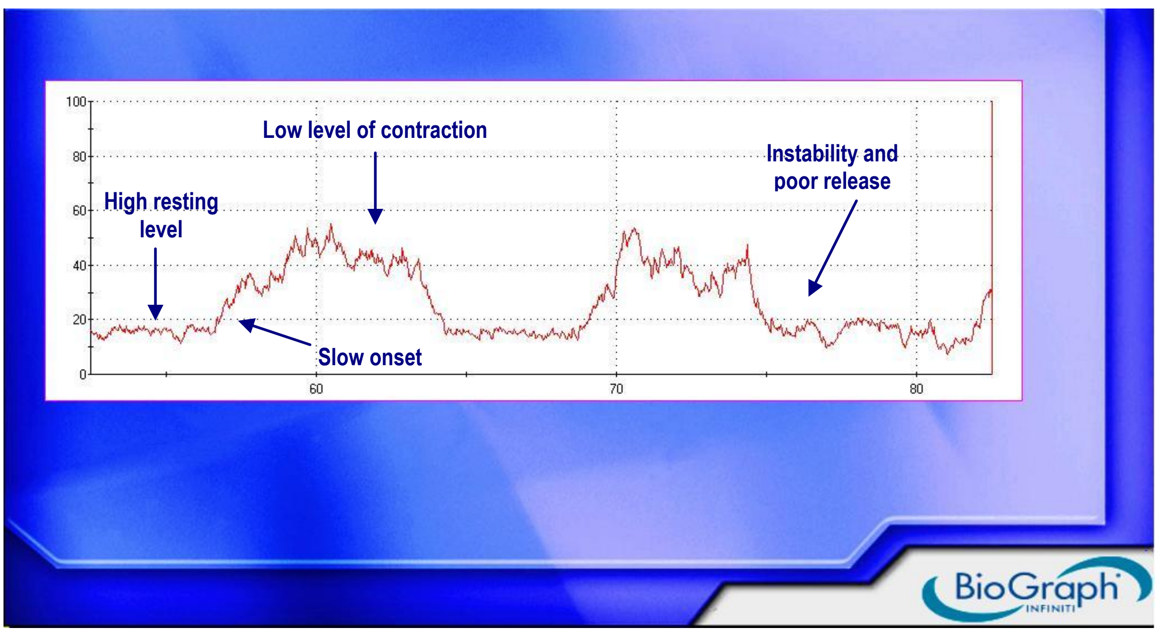
***Source: Encyclopedia of Mental Disorders***

## *SEMG Biofeedback*

**SEMG Biofeedback** is the most popular biofeedback technique in physical rehabilitation:

SEMG biofeedback involves measuring the patient's muscle tension and conveying it to them in real-time in order to raise their awareness and conscious control of the related movement. It accelerates both the therapist's instruction to the patient, and the patient's ability to complete specific movements.

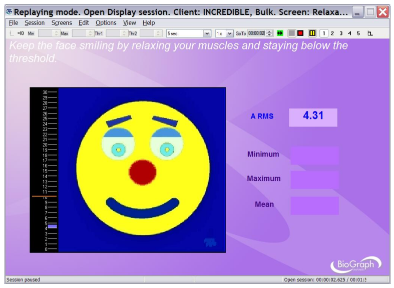
For instance, SEMG was recorded while a patient was performing few contractions (Maximal Force Assessment Protocol). We can see on the figure below that the resting level is too high, the level of contraction is very low and the muscle shows instability.



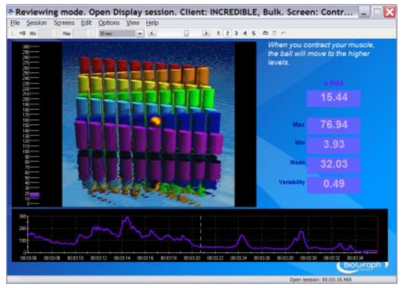

**EMG activity of an untrained muscle**

The high resting level indicates a higher muscle tone which, in most cases, will lead to muscle fatigue and/or muscle pain (the muscle never rests). In this case, the patient should first be trained to relax the muscle. If the patient also presents a poor subjective recognition of tension sensation, biofeedback should be used to improve kinesthetic awareness.

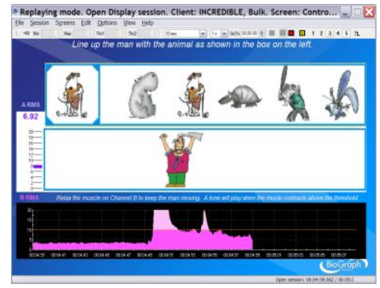
Once the muscle is able to rest, the patient should progressively be trained to increase the level of contraction and the velocity (called "uptraining"), and finally be trained to gain muscle control.




**Relaxation:** The face smiles when the EMG goes down.

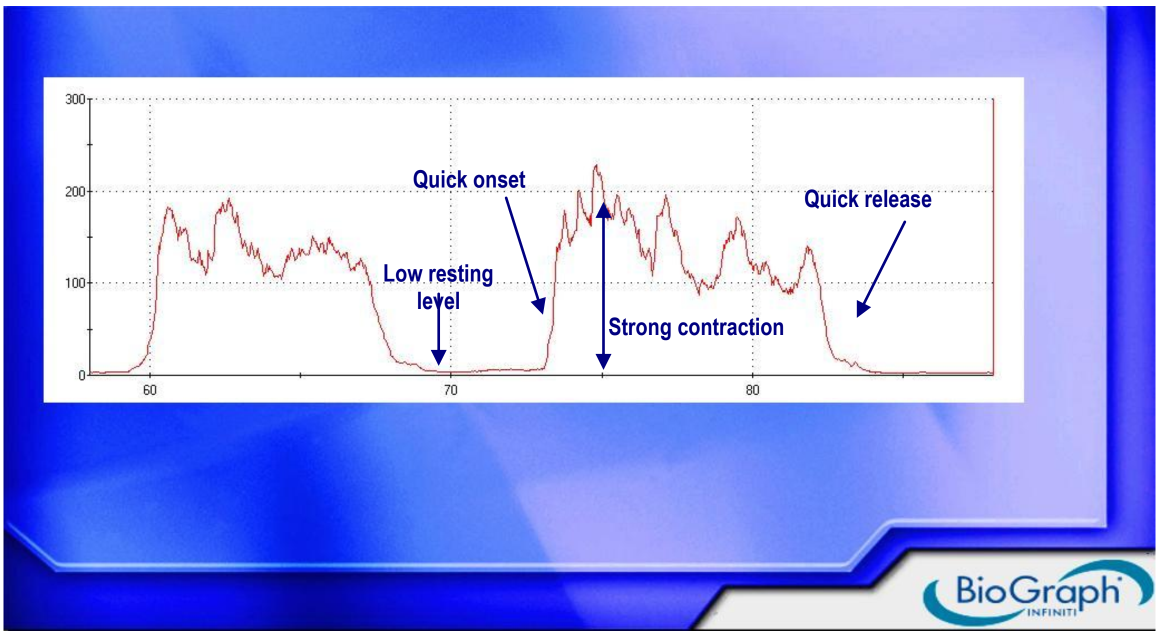



**Uptraining:** The ball climbs the tubes when the signal goes up.




**Control:** The cartoon man must be lined up with the animal in the blue square.

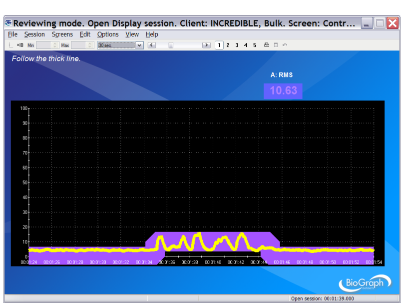
The next figure shows an SEMG recording of the same muscle after several sessions of biofeedback training. Resting level is low, onset and release are quick and the contraction is high.



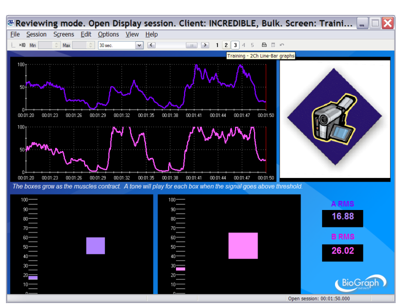

**EMG activity of a trained muscle**

***Note***: This is just an example for illustration and is not intended to be a norm for treatment.

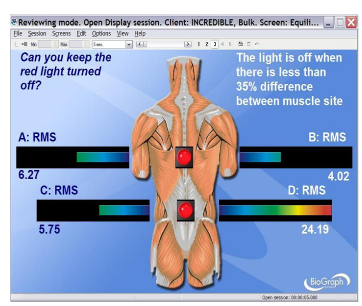
Recovery of sensation, downtraining of hypertonic muscle, uptraining of hypotonic muscle, control/coordination of movements and improvement of posture are some of the numerous training exercises involving SEMG biofeedback. They usually require the monitoring of one to four muscle sites, but in most cases 2 are sufficient and easier to be interpreted by the patient.




**Recovery of sensations**




**Coordination Training**




**Postural Training**

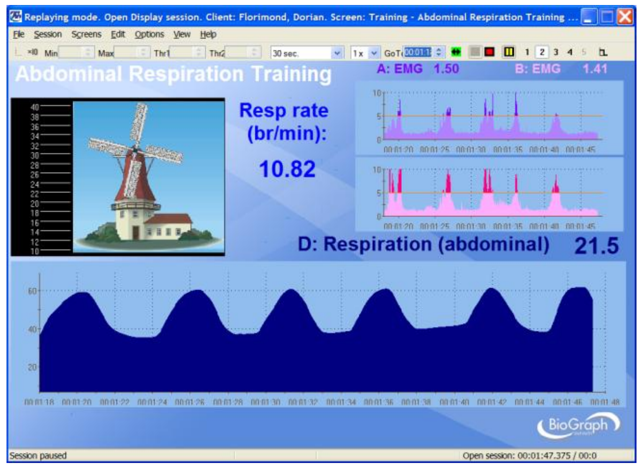
## *Beyond SEMG Biofeedback*

Other biological signals besides SEMG can be used for Biofeedback. The most common ones are electro-dermal activity, peripheral temperature, respiration and heart rate.

### Example 1: Fixing inappropriate breathing patterns

The examinee is trained to breathe abdominally rather than thoracically. The respiration sensor is placed around the examinee's abdomen. SEMG sensors are placed on upper thoracic muscles (upper trapezius, scalene or sternocleidomastoid). Visual and/or audio feedback will encourage abdominal breathing (increase of respiration amplitude) and show excessive activity of the monitored muscles.

**Respiration sensor**

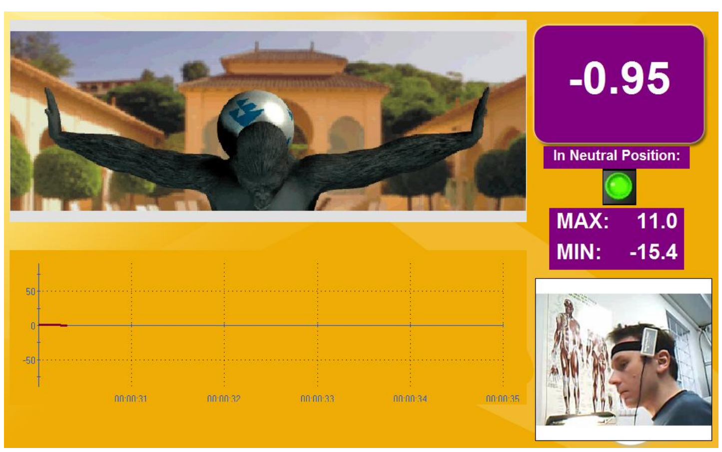



In the screen above, the greater the abdominal respiration amplitude, the faster the windmill turns.

The two line graphs on the right display the EMG of the muscles associated to thoracic breathing. If the EMG of one channel is above its threshold, the windmill will stop turning and music will be heard.

### Example 2: ROM Therapy (balance & stretching)

In ROM training, an inclinometer is attached to the joint of interest. It allows the examinee to visualize the ROM exercise and perform it in an entertaining way.



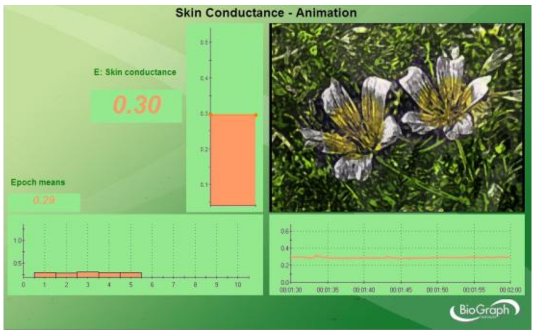

In the screen above, the examinee is being trained to keep his neck in neutral position, by keeping the ball centered behind the monkey's neck. When he is successful, the green light turns on.

## *Biofeedback and Relaxation*

Physical therapy is the most important part of treatment, though it should be noted that many examinees are incapable of participating in physical therapy. They often develop physical and psychological guarding behaviors and psychological disorders (depression, anxiety, etc) in parallel with their physical problem. Unfortunately, subsequent anxiety and inactivity can exacerbate the disease, delay rehabilitation and perpetuate the pain cycle.

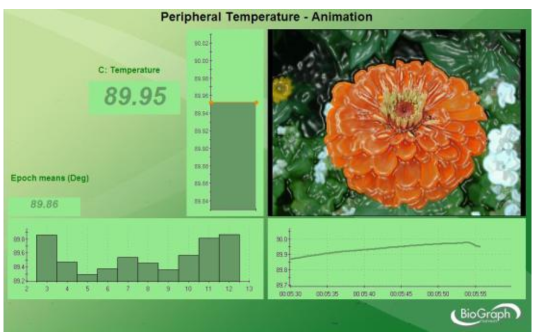
Biofeedback and relaxation are adjunctive treatments which assist coping and can help the therapist rehabilitate the examinee.

Respiration, electro-dermal activity and peripheral temperature are the biological signals of choice for relaxation training.



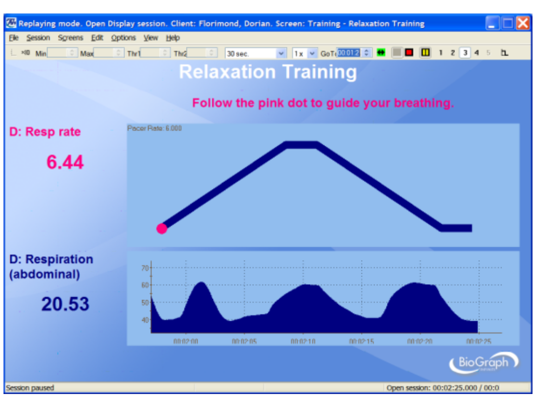

**Skin Conductance Sensor**

The screen shows a bar graph of the skin conductance and plays a song and an animation when the SC value dips below the threshold. The threshold is set to automatically follow the signal to allow for instantaneous feedback of any change of direction.




**Temperature Sensor**

The screen shows a bar graph of the temperature signal and plays a song and an animation when the signal value moves above the threshold. The threshold is set to automatically follow the signal to allow for instantaneous feedback of any change of direction.

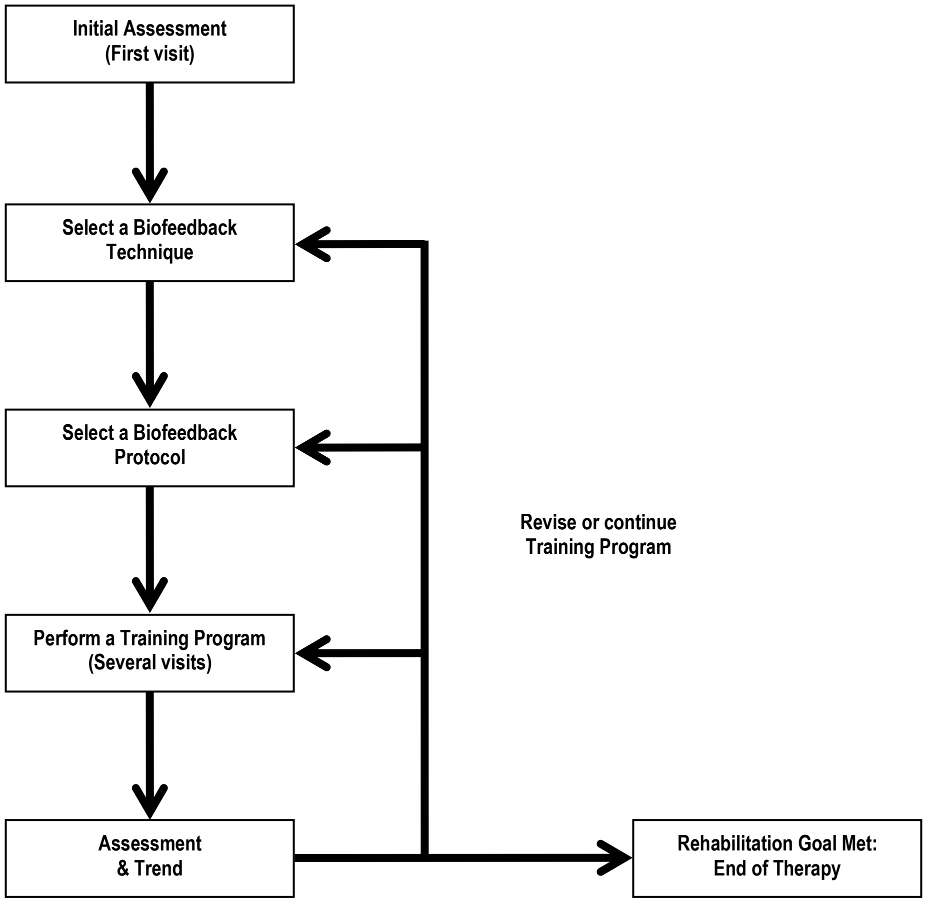



**Respiration sensor**

The examinee must follow the pink dot. This will guide them to a slow breathing rate (around 6 breath/min).

# Assessment and Biofeedback

The following chart suggests how to use the different protocols.




Assessment protocols help you to evaluate the condition of your patient and guide you in choosing the appropriate biofeedback technique.

Biofeedback can also be part of the assessment. It helps the patient to execute properly what they were instructed to do.

***Note:*** ***This chart does not represent the treatment plan; it only illustrates how to use Biofeedback as part of the treatment.***

# SKELETAL MUSCLE PROPERTIES

SEMG may be considered a "seductive muse because of its apparent simplicity" (De Luca). SEMG can be easily misinterpreted, so it is important to have a good understanding of what the signal indicates.

However, in order to understand SEMG, one must first understand muscle.

This chapter reviews the main anatomical and physiological concepts that must be kept in mind when interpreting SEMG.

## Types of Fibers

Skeletal muscles contain two main types of fibers: Slow-twitch fibers (Type I) and Fast-twitch fibers (Type II).

Type II fibers are further divided in two groups: Type IIa and IIb (sometimes a third group is mentioned: Type IIx).

Type I fibers are small, fire slowly and use the aerobic metabolism to produce energy. They can work for long periods and are very resistant to fatigue.

Type IIa fibers are intermediate fast-twitch fibers. They are of a medium size and can use both aerobic and anaerobic metabolisms to produce energy. They fire faster than the Type I fibers and can generate faster contractions. They can work for no more than 30 minutes, as they fatigue faster than the Type I fibers.

Type IIb fibers are the classic fast-twitch fibers. They are big and use the anaerobic metabolism to produce energy. They fire faster than the Type IIa fibers but are able to work only for a few minutes.

Their proportions in the muscle vary with the type of muscle and the condition of the examinee (injured, normal or athlete).

## Types of Contractions

There are three types of contractions:

- **Concentric:** The muscle shortens. This happens when the tension is greater than the load.
- **Isometric:** The muscle stays the same (no movement). The tension is equal to the load.
- **Eccentric:** The muscle lengthens. The tension is less than the load.

## Types of Contributions to a Movement

Muscles are divided in three groups according to their contribution to a movement:

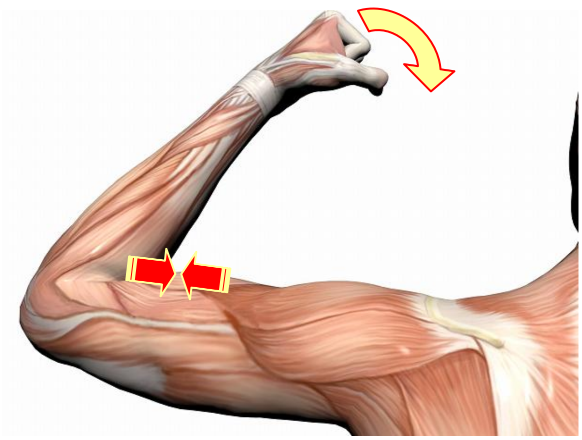
- **Agonist muscles:** The first movers, they initiate the movement; they generate most of the force.
- **Synergist muscles:** Assist the agonist muscles; they generate less force but contribute to the control of the movement.
- **Antagonist muscles:** Act in opposition to the movement; they provide a stabilizing force during the movement.

Examples of agonist/antagonist pairs:

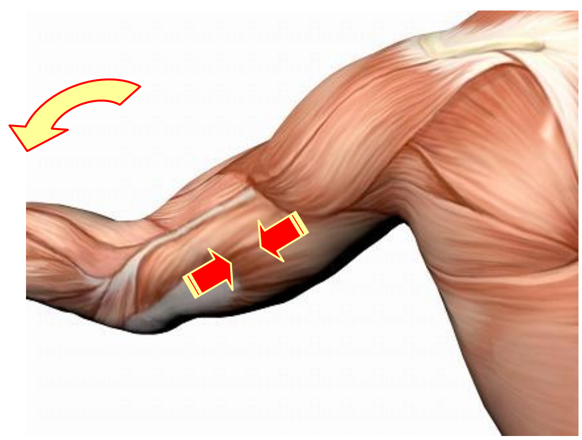
| AGONIST | ANTAGONIST |
|---|---|
| Biceps | Triceps |
| Deltoids | Latissimus Dorsi |
| Pectorals | Trapezius/Rhomboids |
| Abdominals | Erector Spinae |
| Iliopsoas | Glueteus Maximus |
| Abductors | Adductors |
| Quadriceps | Hamstrings |
| Gastrocnemius/Soleus | Tibialis Anterior |

Note that the contribution of a muscle, and consequently its assignment to a group, depends on the movement performed. Each movement has its antagonistic movement, which moves the limb in the opposite direction:

- Flexion ⇔ Extension
- Abduction ⇔ Adduction
- Inversion ⇔ Eversion
- Pronation ⇔ Supination
- Elevation ⇔ Depression
- Protraction ⇔ Retraction
- Plantarflexion ⇔ Dorsiflexion
- Left lateral flexion (spine and neck) ⇔ Right lateral flexion
- Left rotation (spine and neck) ⇔ Right rotation
- Lateral rotation (extremities) ⇔ Medial rotation



**Elbow flexion:** the biceps is the agonist and shortens (concentric contraction), which makes the elbow flex. The triceps is the antagonist. It lengthens (eccentric contraction) and its only function is to stabilize the movement by providing a force in opposition to the biceps and gravity.

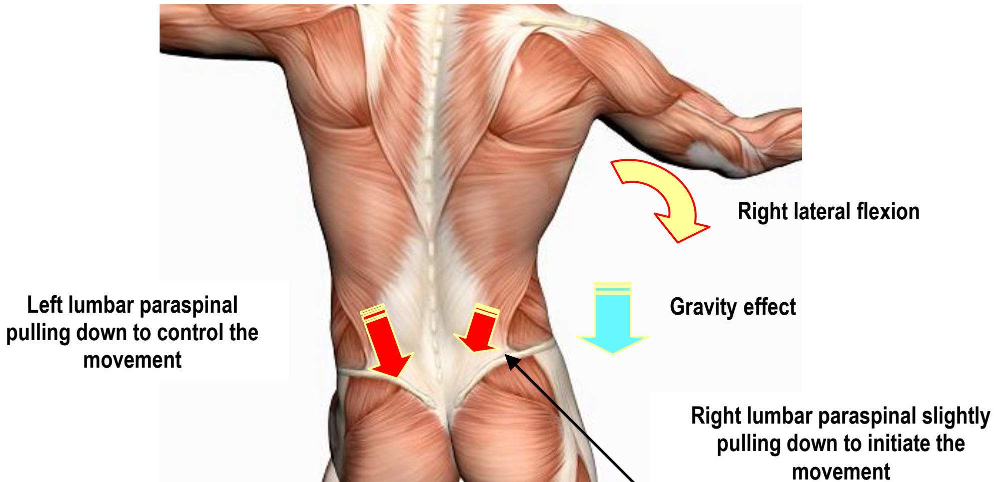


**Elbow extension:** similarly, the triceps is now the agonist and shortens, which makes the elbow extend. The biceps then becomes the antagonist and stabilizes the movement by providing a force in opposition to gravity and the triceps.

A movement typically occurs when the agonist and synergists contract while the antagonist is relaxing (but the relationship between agonists and antagonists can be much more complex).

We often think that the agonist, as a prime mover and the one who generates most of the force, is more involved than the other muscles. Gravity can also play a proactive role and be the greatest contributor to the movement, in term of force. For instance, in the case of a right lateral flexion of the back in standing position, the agonist muscle (right lumbar paraspinal) only initiates the movement, gravity generating most of the force.

Then the left lumbar paraspinal is more involved than the right one, but still plays its role of control of the flexion (antagonist) and is not the initiator of the movement (agonist): **a muscle can only pull, it cannot push**.




**Right lateral flexion of the back in standing position**

The movement pattern can be altered by muscle imbalance (agonist vs. synergists or antagonist), or disturbance in the sequence of firing.

Movement pattern disturbances may find their origins in the following phenomenons:

- **Hyperactivity:** when a muscle contracts too early, too fast or too much.
- **Hypoactivity:** when a muscle contracts too late, too slow or not enough.
- **Hypotonicity:** a diminution of the muscle tone marked by a diminished resistance to passive stretching.
- **Hypertonicity:** excessive muscle tone marked by an increased resistance to stretching and heightened reflexes.
- **Substitution:** normal muscles take over a parallel one, to protect it and unload it when injured, weak or fatigued. Note that a substitute muscle may also become fatigued and become hypotonic (muscle shutdown).
- **Co-contraction:** co-contraction is the abnormal symmetrical activation of homologous muscles during asymmetrical movements, such as rotation or lateral bending, or more generally the over-activation of the antagonist muscle in order to protect the agonist (also called muscle bracing; pain is usually observed).
- **Spasm:** a spasm is a sudden, involuntary contraction of a muscle or a group of muscles.
- **Trigger-point:** a trigger-point is a hyperirritable spot in the muscle, a spasm at the cellular level.
- **Emotional arousal (or stress):** can increase the tonus of a muscle and change timing and coordination.

# Muscles Involved in Movements

The following tables list the most common muscles involved in a movement. This is a non-exhaustive list.

## *Shoulder*

| **Movement** | **Abduction** | **Adduction** |
|---|---|---|
| **Involved Muscles** | Supraspinatus (initiates motion)<br>Deltoid (continues motion)<br>Biceps brachii | Latissimus dorsi<br>Teres major<br>Triceps brachii<br>Coracobrachialis<br>Pectoralis minor |
| **Movement** | **Flexion** | **Extension** |
| **Involved Muscles** | Coracobrachialis<br>Anterior deltoid<br>Pectoralis major<br>Biceps brachii | Posterior deltoid<br>Latissimus dorsi<br>Teres major<br>Triceps brachii |

| Movement | Lateral Rotation | Medial Rotation |
|---|---|---|
| Involved Muscles | Posterior deltoid<br>Infraspinatus<br>Teres minor | Anterior Deltoid<br>Latissimus dorsi<br>Pectoralis major<br>Subscapularis<br>Teres major |

## Elbow

| Movement | Flexion | Extension |
|---|---|---|
| Involved Muscles | Biceps brachii<br>Brachialis<br>Brachioradialis | Triceps brachii<br>Anconeus |
| Movement | Pronation | Supination |
| Involved Muscles | Pronator teres<br>Pronator quadratus<br>Anconeus<br>Brachioradialis | Supinator<br>Biceps brachii |

## Wrist

| Movement | Flexion | Extension |
|---|---|---|
| Involved Muscles | Flexor carpi radialis<br>Flexor carpi ulnaris<br>Palmaris longus<br>Flexor digitorum superficialis<br>Flexor digitorum profondus | Extensor carpi radialis brevis<br>Extensor carpi radialis longus<br>Extensor carpi ulnaris<br>Extensor digitorum<br>Extensor pollicis longus<br>Extensor indicis |
| Movement | Radial Deviation (Abduction) | Ulnar Deviation (Adduction) |
| Involved Muscles | Extensor carpi radialis brevis<br>Extensor carpi radialis longus<br>Flexor carpi radialis<br>Extensor pollicis brevis | Extensor carpi ulnaris<br>Flexor carpi ulnaris |

## Hip

| Movement | Flexion | Extension |
|---|---|---|
| Involved Muscles | Adductor brevis<br>Adductor longus<br>Iliacus<br>Pectineus<br>Psoas major<br>Rectus femoris<br>Sartorius<br>Tensor Fascia latae | Adductor magnus<br>Biceps femoris<br>Gluteus maximus<br>Semimem branosus<br>Semitendinosus |
| Movement | Abduction | Adduction |
| Involved Muscles | Gemellus inferior<br>Gemellus superior<br>Gluteus maximus<br>Gluteus medius<br>Gluteus minimus<br>Piriformis<br>Tensor fascia latae | Adductor brevis<br>Adductor longus<br>Adductor magnus<br>Biceps femoris<br>Gluteus maximus<br>Gracilis<br>Pectineus<br>Psoas major |

| Movement | Medial Rotation | Lateral Rotation |
|---|---|---|
| Involved Muscles | Gluteus medius<br>Gluteus minimus<br>Tensor fascia latae | Adductor brevis<br>Adductor longus<br>Adductor magnus<br>Biceps femoris<br>Gemellus inferior<br>Gemellus superior<br>Gluteus maximus<br>Gluteus medius<br>Obturator externus<br>Obturator internus<br>Piriformis<br>Quadratus femoris<br>Sartorius |

## Knee

| Movement | Flexion | Extension |
|---|---|---|
| Involved Muscles | Biceps femoris<br>Gastrocnemius<br>Gracilis<br>Popliteus<br>Sartorius<br>Semimembranosus<br>Semitendinorus | Rectus femoris<br>Tensor Fascia latae<br>Vastus intermedius<br>Vastus lateralis<br>Vastus medialis |
| Movement | Medial Rotation | Lateral Rotation |
| Involved Muscles | Gracilis<br>Popliteus<br>Sartorius<br>Semimembranosus<br>Semitendinorus | Biceps femoris |

## Ankle

| Movement | Dorsiflexion | Plantarflexion |
|---|---|---|
| Involved Muscles | Extensor digitorum longus<br>Extensor hallucis longus<br>Peroneus tertius<br>Tibialis anterior | Flexor digitorium longus<br>Flexor hallucis longus<br>Gastrocnemius<br>Peroneus brevis<br>Peroneus longus<br>Plantaris<br>Soleus<br>Tibialis posterior |
| Movement | Eversion | Inversion |
| Involved Muscles | Extensor digitorum longus<br>Peroneus brevis<br>Peroneus longus<br>Peroneus tertius | Flexor digitorum longus<br>Tibialis anterior<br>Tibialis posterior |

# INTRODUCTION TO SURFACE ELECTROMYOGRAPHY

## Definition and Indications

**S**urface **E**lectro**M**yo**G**raphy (SEMG) is a non-invasive technique for measuring muscle electrical activity that occurs during muscle contraction and relaxation cycles.

"Electromyography is unique in revealing what a muscle actually does at any moment during movement and postures. Moreover, it reveals objectively the fine interplay or coordination of muscles: this is patently impossible by any other means" (Basmajian, "Muscles Alive, Their Function Revealed by Electromyography").

Surface electromyography is widely used in many applications, such as:

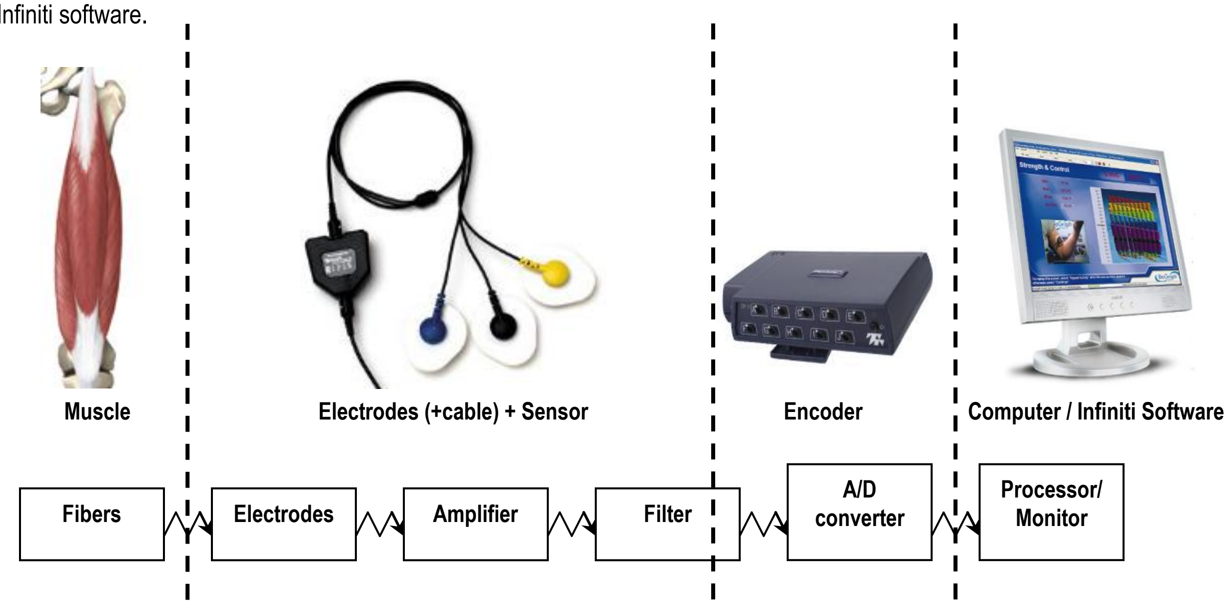
- **Physical Rehabilitation** (physical therapy/physiotherapy, kinesitherapy, chiropractic and orthopedics)
- **Urology** (treatment of incontinence)
- **Biomechanics** (sport training, motion analysis, research)
- **Ergonomics** (studies in the workplace, job risk analysis, product design and certification)
- **Psychophysiology** (stress assessment, relaxation training)

SEMG is clinically indicated for:

- **Biofeedback**
- **Relaxation**
- **Muscle re-education**
- **Treatment of incontinence**

## Detection of SEMG signal

The SEMG signal generated by the muscle fibers is captured by the electrodes, then amplified and filtered by the sensor before being converted to a digital signal by the encoder. It is then sent to the computer to be processed, displayed and recorded by the Infiniti software.



# A/D Converter (Encoder)

Thought Technology's A/D converters are called "encoders".

- **ProComp5 Infiniti** has 2 channels (A and B) sampling at 2048 samples per second and 3 channels (C to E) sampling at 256 samples/second.
- **ProComp Infiniti** has 2 channels (A and B) sampling at 2048 samples per second and 6 channels (C to H) sampling at 256 samples/second.
- **FlexComp Infiniti** has 10 channels (A to J) sampling at 2048 samples per second.


**ProComp5 Infiniti**

**ProComp Infiniti**

**FlexComp Infiniti**


**Telemetric card for wireless transmission**

The **sample rate** (for instance, 2048 samples per second) is the number of measures (samples) per second taken from the continuous signal (analog signal). In this case, the analog signal is the SEMG signal captured by the electrodes and amplified by the sensor. The series of samples constitutes the digital signal.

A **raw SEMG** signal has to be sampled at a minimum of 1000 samples per second and an **RMS SEMG** signal has to be sampled at a minimum of 32 samples per second (see definition of raw SEMG and RMS SEMG in the section "***The SEMG signal***" starting on page 21).

# Amplifier (Sensor)

Thought Technology's EMG sensors are differential amplifiers. This means that whatever electrical activity is common to both sites is rejected, and what differs is amplified. It allows the rejection of the common mode between electrode pairs.

The EMG sensors for ProComp5, ProComp and FlexComp Infiniti are:

- **MyoScan (SA9503M)** and **MyoScan-Z (SA9503Z)** which amplify and output **raw SEMG**.
- **MyoScan-Pro (SA9401M)** which amplifies raw SEMG and converts it to **RMS SEMG**.


**MyoScan (SA9503M)**
**MyoScan-Z (SA9503Z)**


**MyoScan-Pro (SA9401M)**

***Note**: MyoScan-Z is an EMG sensor with built-in impedance check*

Therefore, MyoScan and MyoScan-Z sensors are used on channels A and B of ProComp Infiniti and ProComp5 Infiniti and all channels of FlexComp Infiniti, whereas MyoScan-Pro is used on channels C to H of ProComp Infiniti and on channels C to E of ProComp5 Infiniti.

| **ProComp5** samp/s | **A** 2048 | **B** 2048 | **C** 256 | **D** 256 | **E** 256 |
|---|---|---|---|---|---|
| **MyoScan or MyoScan-Z** | ☑ | ☑ | | | |
| **MyoScan-Pro** | | | ☑ | ☑ | ☑ |

| **ProComp** samp/s | **A** 2048 | **B** 2048 | **C** 256 | **D** 256 | **E** 256 | **F** 256 | **G** 256 | **H** 256 |
|---|---|---|---|---|---|---|---|---|
| **MyoScan or MyoScan-Z** | ☑ | ☑ | | | | | | |
| **MyoScan-Pro** | | | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ |

| **FlexComp** 2048samp/s | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
|---|---|---|---|---|---|---|---|---|---|---|
| **MyoScan or MyoScan-Z** | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ |
| **MyoScan-Pro** | | | | | | | | | | |

## Surface Electrodes and Cables

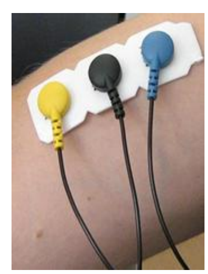
The silver-silver chloride electrodes are the part of the instrument that is in contact with the skin. They make electrical contact between the skin and the sensor. The electrodes are either directly connected to (or “snapped on”) the sensor, or indirectly connected via an extender cable. Thought Technology provides various types of electrodes.

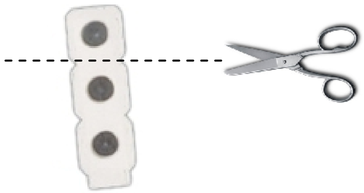
**T3402M – Triode electrode (single use):** The triode should be your first choice. It can be snapped directly on the sensor head, which makes it very easy to use and quick to position. The signal is then amplified right on the muscle site, which dramatically increases the SNR (Signal-to-Noise Ratio) and therefore limits pollution of the SEMG signal by surrounding electromagnetic fields and movement artifacts generated by wires being pulled.

The distance between the electrodes is optimal for avoiding or limiting muscle crosstalk.

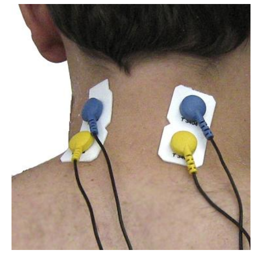
However, its size does not make it suitable for long and thin muscles with great deformation while contracting, or for wider placements. In this case, the choice of another electrode type should be considered.


**T3404 - Single strip electrodes (single use):** The single strip electrodes are the perfect choice for long and thin muscles that do not offer enough space on the belly for a triode, and/or for muscles requiring a slightly wider distance between active electrodes. Here the three electrodes are aligned, which reduces the width of the electrode area in comparison to a triode and prevents them from peeling off. An EMG extender cable (T8720M) must be connected between the electrodes and the sensor.





These electrode strips can also be cut apart, which gives total freedom in term of placement. This is ideal for a wider placement or in order to put the reference electrode at a different place.



**T3425 - UniGel electrodes (pre-gelled, single use):** The UniGel electrodes provide total freedom in term of placement. Their small size also allows placement on very tiny muscles (such as SCM). They are not attached together, which prevents them from moving on the skin when positioned on muscles with great deformation while contracting. These electrodes are pre-gelled and so do not require the addition of conductive gel, which reduces the time of preparation for this type of electrodes.

An EMG extender cable (T8720M) must be connected between the electrodes and the sensor.

## *Typical Electrode Placements*

### Skin Preparation


Proper skin preparation is important to get a good signal and avoid artifacts.

Before applying electrodes, make sure the skin surface is clean and dry:

Abrade the skin with an abrasive cream, such as NuPrep, to remove dead skin. Alternatively, you can also clean skin with an alcohol wipe and let it dry, but this is not as efficient as the abrasive cream.

If necessary, shave excess body hair.

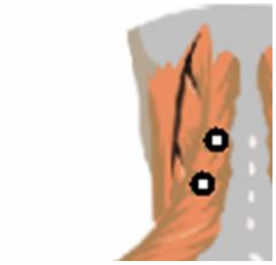
### General Recommendations for Positioning Electrodes and Cables

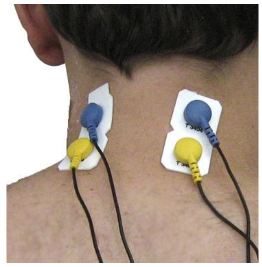
If you use single electrodes with an extender cable, start by snapping the electrodes on the cable connectors. Once the electrodes are positioned on the skin, this action may be more difficult or uncomfortable for the examinee.


It may be recommended to put conductive electrode paste or cream (such as Ten20) on the center of electrodes (grey area only) before applying them to the skin. Only a small amount is necessary.

Place the active electrodes first (blue and yellow) on the examinee. The active electrodes should be placed in line with the muscle fibers, unless specified otherwise. Then place the reference electrode (black connector) anywhere on the body.

Make sure the electrodes are placed firmly on the skin and that there is good contact between the skin and electrodes.



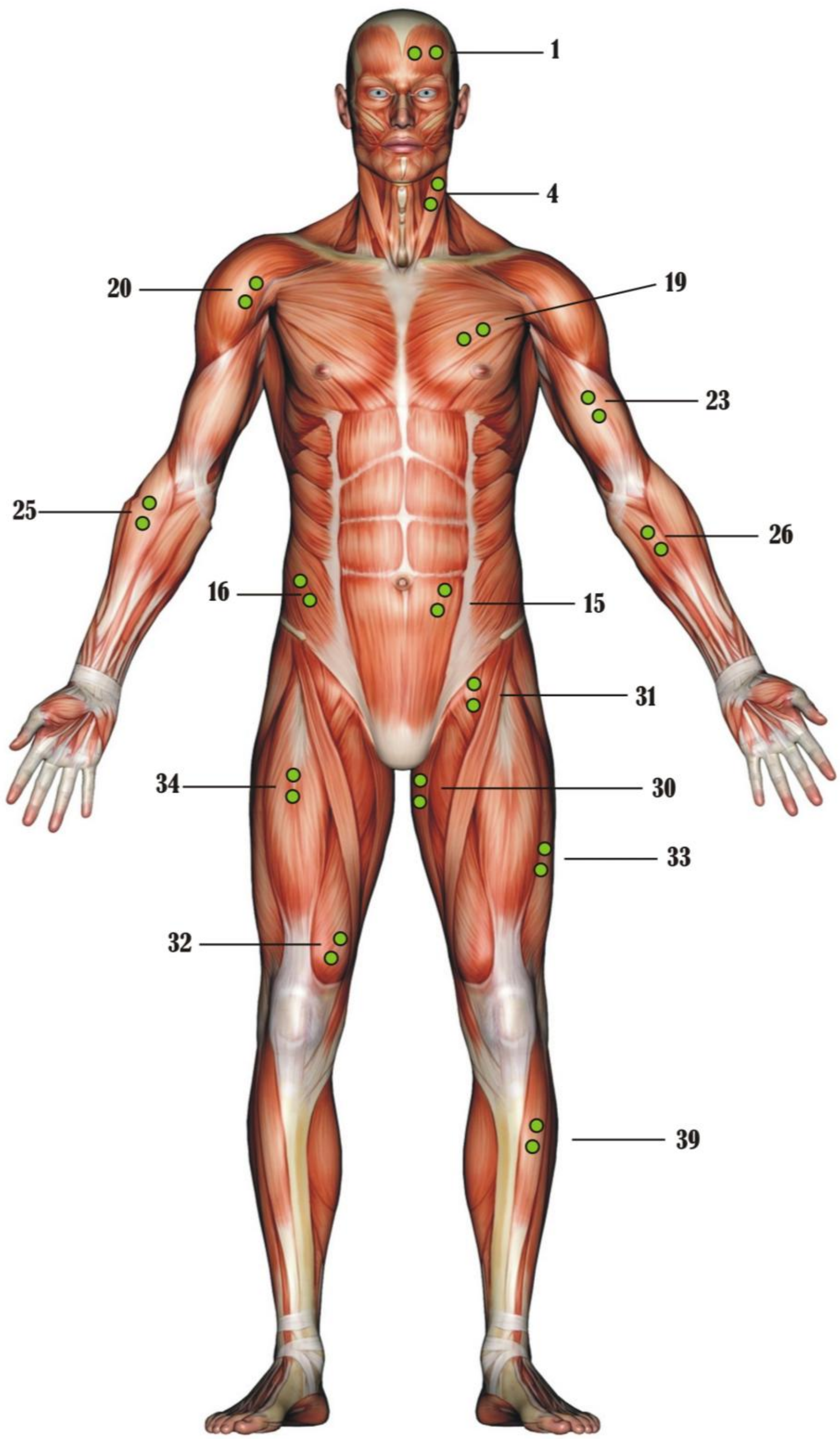


**Electrode Site** **Active electrodes** **Reference electrodes**

Immobilize the cables with tape, straps or an elastic band to prevent them from being pulled or shaken.

The following pages show electrode placement on the different body areas. For clarity, only the active electrodes are shown.

## SEMG Electrode Sites – Front View




**Head and Neck**

1. Frontalis
2. Temporalis
3. Masseter
4. Sternocleidomastoid (SCM)
5. C4 Cervical Paraspinals (CP)

**Trunk**

6. Upper Trapezius
7. Lower Trapezius
8. Infraspinatus
9. Latissimus Dorsi
10. T2 Paraspinals
11. T8 Paraspinals
12. T10 Paraspinals
13. L1 Paraspinals
14. L5 Paraspinals
15. Rectus Abdominal
16. Abdominal Oblique
17. Internal Oblique
18. Serratus Anterior
19. Pectoralis Major

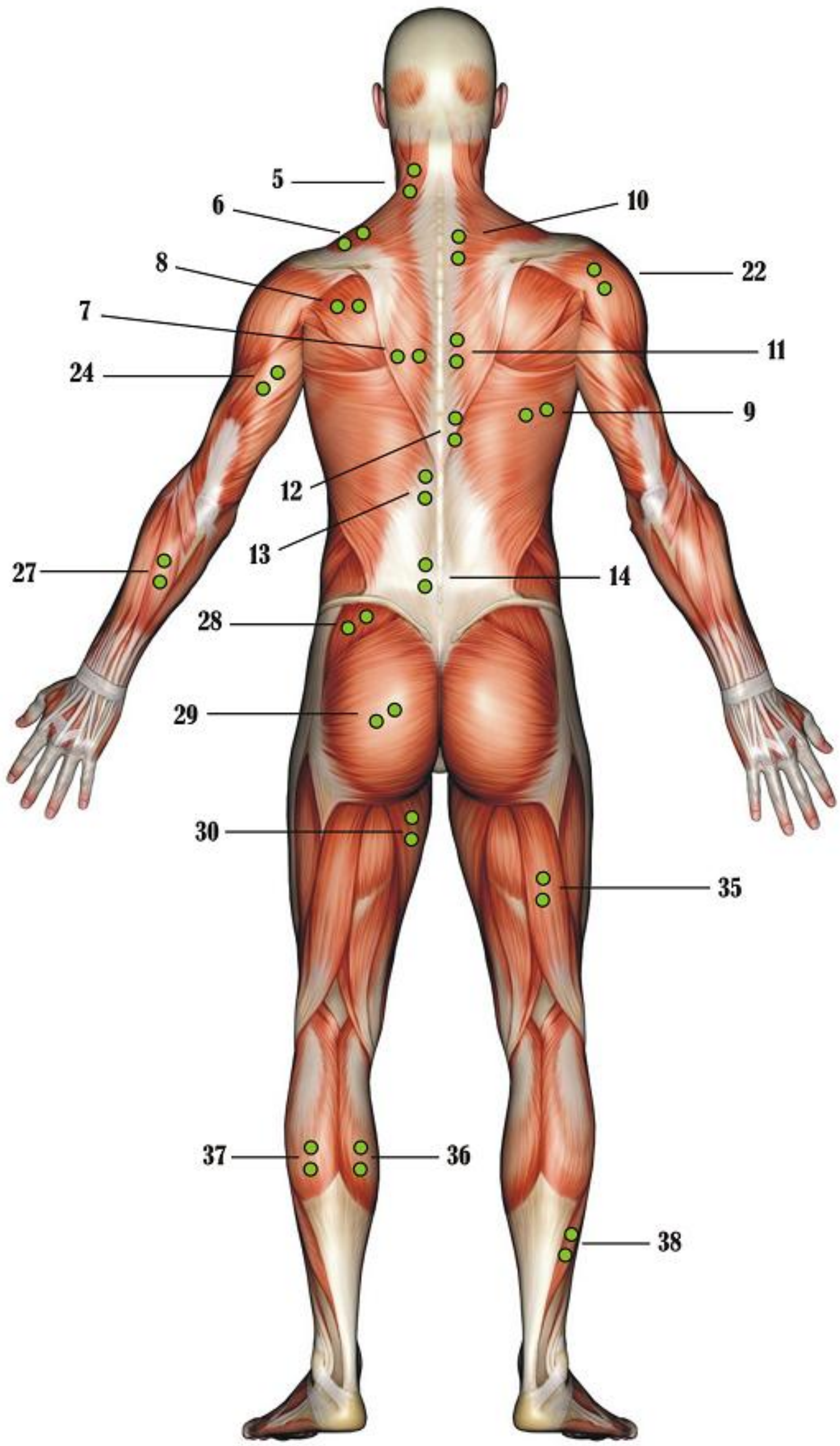
**Arm**

20. Anterior Deltoid
21. Lateral Deltoid
22. Posterior Deltoid
23. Biceps Brachii
24. Triceps Branchii
25. Brachioradialis
26. Wrist Flexor
27. Wrist Extensor

**Leg**

28. Gluteus Medius
29. Gluteus Maximus
30. Hip Abductor
31. Hip Flexor
32. Vastus Medialis Oblique (VMO)
33. Vastus Lateralis (VL)
34. Quadriceps Femoris
35. Medial Hamstring
36. Medial Gastrocnemius
37. Lateral Gastrocnemius
38. Soleus
39. Tibialis Anterior

## SEMG Electrode Sites – Back View




**Head and Neck**

1. Frontalis
2. Temporalis
3. Masseter
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29. Gluteus Maximus
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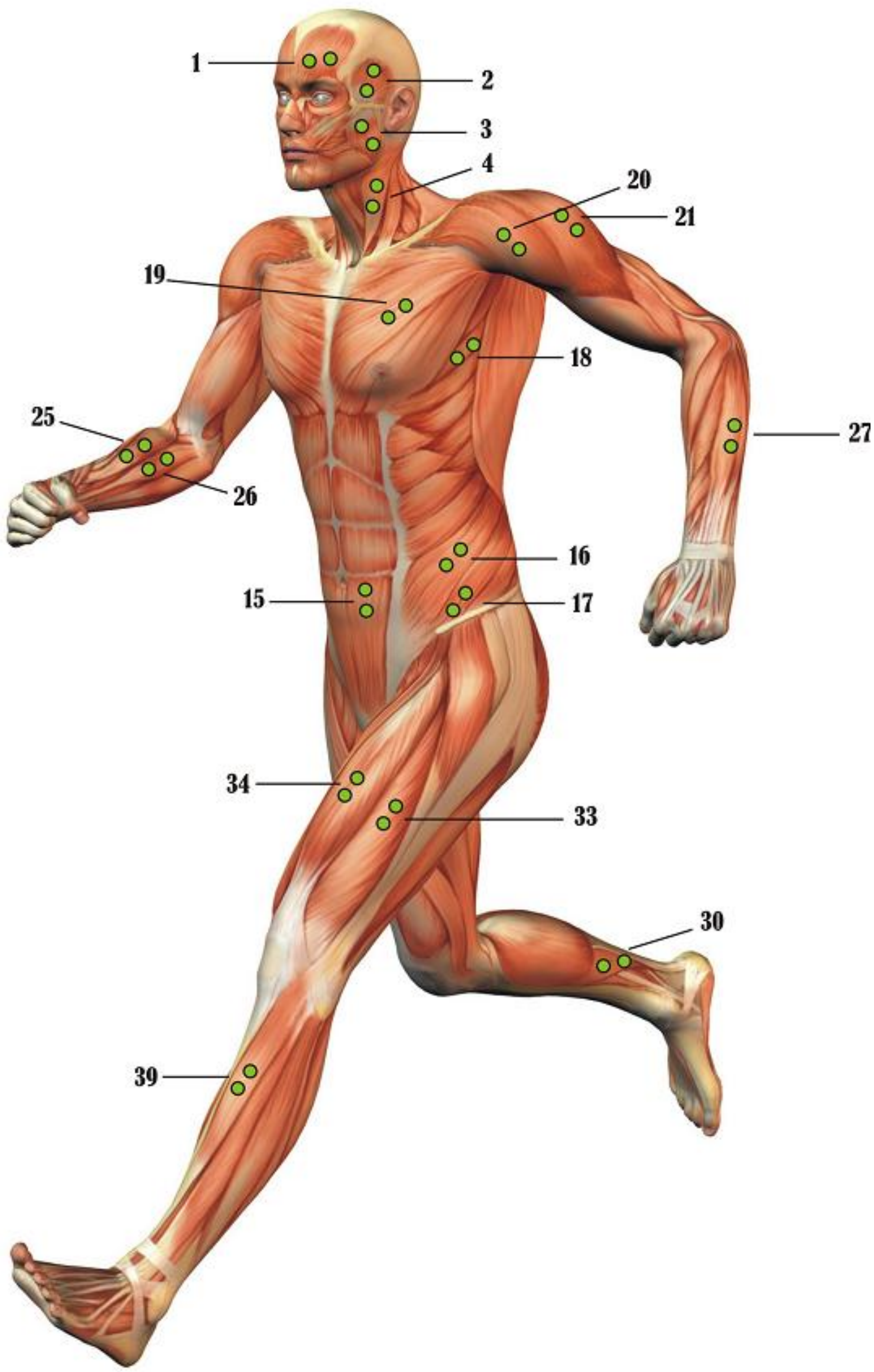
33. Vastus Lateralis (VL)
34. Quadriceps Femoris
35. Medial Hamstring
36. Medial Gastrocnemius
37. Lateral Gastrocnemius
38. Soleus
39. Tibialis Anterior

# SEMG Electrode Sites – Side View




**Head and Neck**

1. Frontalis
2. Temporalis
3. Masseter
4. Sternocleidomastoid (SCM)
5. C4 Cervical Paraspinals (CP)

**Trunk**

6. Upper Trapezius
7. Lower Trapezius
8. Infraspinatus
9. Latissimus Dorsi
10. T2 Paraspinals
11. T8 Paraspinals
12. T10 Paraspinals
13. L1 Paraspinals
14. L5 Paraspinals
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34. Quadriceps Femoris
35. Medial Hamstring
36. Medial Gastrocnemius
37. Lateral Gastrocnemius
38. Soleus
39. Tibialis Anterior

# The SEMG signal

## *Physiological Basis of SEMG*

To innervate a muscle fiber (stimulate it to contract), an electrical signal from the central nervous system must first reach an alpha motor neuron. These neurons are responsible for initiating muscle contractions.

As the contraction signal spreads from the alpha motor neuron across the muscle fiber, a series of electrophysiological and electrochemical processes takes place. This produces an electrically measurable depolarization and repolarization event known as the action potential.

SEMG looks at the action potential signals from a number of innervated muscle fibers located near the pickup electrodes. In the SEMG signal these action potentials from different muscle fibers appear together, all on top of each other.

In general terms, contraction intensity is controlled by how often the nerve impulse arrives and innervates the muscle fibers. Each action potential generates a certain amount of energy in the SEMG signal. So as the action potentials arrive more often, the muscle contracts harder and the SEMG signal level increases. This is how SEMG serves as a direct, quantitative, objective and reliable measure of contraction intensity.

## *Signal Processing*

Different signal processing methods provide different ways to look at an SEMG signal.

**Raw SEMG** is an unprocessed SEMG signal, which consists of a collection of positive and negative electrical signals. Their frequency (how often they occur), and their amplitude, give information on the contraction or rest state of the muscle. Figure 1 shows a raw SEMG signal.

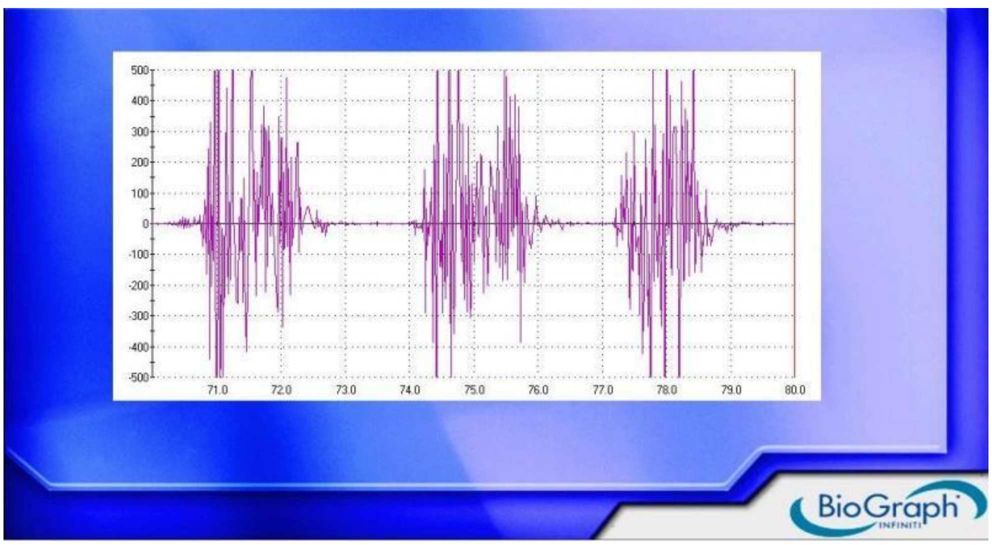



**Fig. 1. Raw EMG (three contractions)**

In the raw graph the X axis displays time and the Y axis displays amplitude in µV (micro-Volts), both positive and negative, about the axis which centers on zero. As the subject contracts the muscle, the number and amplitude of the lines increase; as the muscle relaxes, they decrease.

**RMS** or **R**oot **M**ean **S**quare is a technique for rectifying the raw signal and converting it to an amplitude envelope, to make it easier to view. It represents the mean power of the signal. Figure 2a shows an RMS signal.

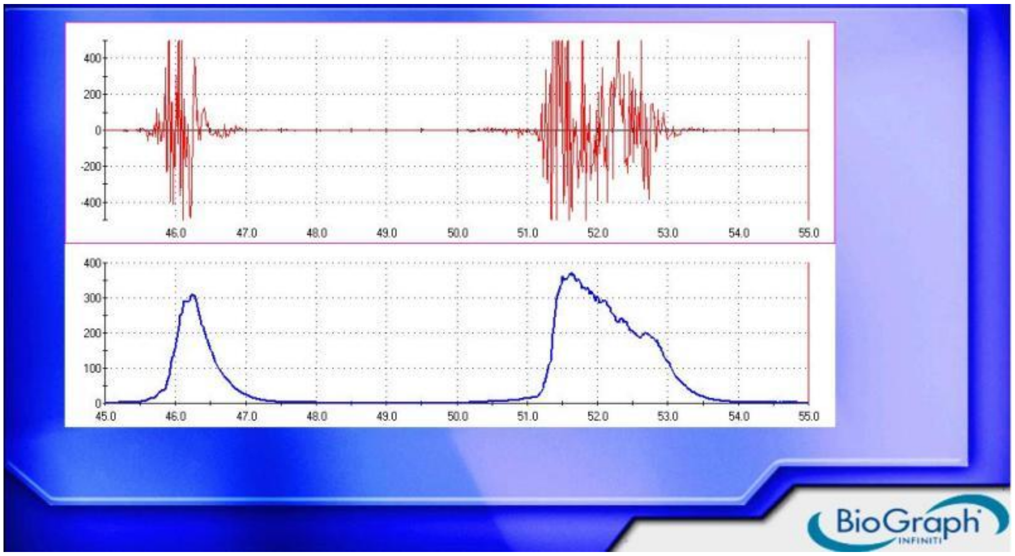



**Fig. 2a. Raw EMG in red (top) and equivalent RMS EMG in blue (bottom)**

The level of **smoothing** can be adjusted in the RMS signal. The smoother the signal is, the less "jitter" it has. But the smoother the signal is, the "slower" it is also. The ideal level of smoothing depends on the application. For biofeedback, for instance, the jitter should be limited. However it has to be balanced with the delay induced in the feedback.

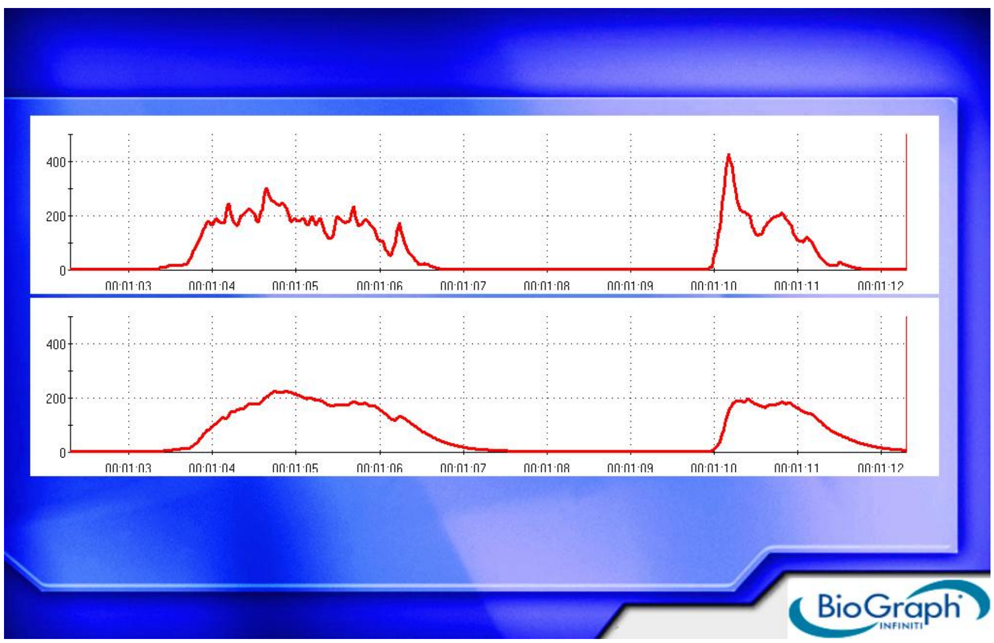



**Fig. 2b. RMS EMG with low smoothing (top) and with high smoothing (bottom)**

**Frequency Domain:** The raw and RMS displays both show the signal in the time domain. The signal can also be shown in the frequency domain. The signal is comprised of many electrical firings; these firings occur at different rates and the overall signal in the time domain is a composite of these multiple frequencies. Frequency is measured in Hertz (Hz) and is the number of events (firings, in this case) per second.

It is commonly accepted that relevant SEMG frequencies are between 20 and 500Hz. It is possible to display and represent the signal in its frequency domain by separating out the individual frequencies. It is interesting, for instance, to separate the activity of the slow-twitch fibers from the fast-twitch fibers. Publications generally say that slow-twitch fibers fire between 20 and 90Hz and fast-twitch fibers frequencies between 90 and 500Hz.

The raw signal is converted into the frequency domain by passing all the data points through a Fast Fourier Transform calculation (FFT); this mathematically isolates each of the frequency bands.

Figure 3 shows an SEMG signal in the frequency domain.

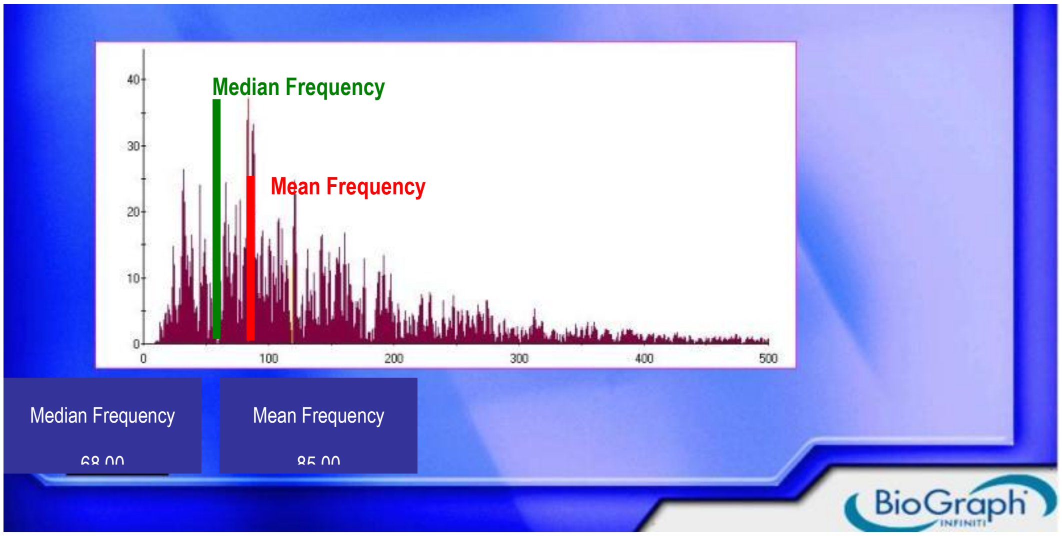



**Fig. 3. Frequency spectrum with mean and median frequencies**

The X axis displays frequency in Hz and the Y axis displays relative amplitude. Different information can be gathered from the frequency domain that is not as readily available from the time domain, such as muscle fatigue. As a muscle fatigues, the frequency of firings decreases, but total amplitude in the time domain can remain constant (so that the muscle fatigue cannot be seen in the time domain). The important measures for muscle fatigue are the **Median Frequency** indicated by the green bar in Figure 3 and the **Mean Frequency** denoted by the red bar.

- The median frequency is the frequency that divides the power density spectrum into two sections with the same amount of power.
- The mean frequency is the frequency where the product of the frequency value and the amplitude of the spectrum is equal to the average of all such products throughout the complete spectrum.

As a muscle fatigues, the power density spectrum shifts to the left side of the frequency scale and, consequently, the median and mean frequencies decrease. Note that mean and median frequencies are relevant muscle fatigue indicators only for isometric contractions (sustained contraction with no movement).

### Uses of the different views of the SEMG signal:

- To measure the activation timing of a muscle: **raw signal or RMS**
- To verify the signal quality and detect the presence of artifacts (see next section): **raw signal**
- To measure the level of activation of a muscle: **RMS**
- To measure the resting level of a muscle: **RMS**
- For Biofeedback: **RMS**
- To measure the recruitment of the different types of fibers: **raw signal** or **frequency/power spectrum**
- To monitor the fatigue of a muscle: **median frequency** or **mean frequency**

### Uses of the EMG sensors for the different views:

| | Raw | RMS | Power spectrum | Median frequency | Mean frequency |
|---|---|---|---|---|---|
| **MyoScan or MyoScan-Z** | ☑ | ☑ | ☑ | ☑ | ☑ |
| **MyoTrac Infiniti** | ☑ | ☑ | ☑ | ☑ | ☑ |
| **MyoScan-Pro** | | ☑ | | | |
| **MyoTrac3** | | ☑ | | | |

## *SEMG Artifacts*

Artifact is unwanted information contained within a signal. An EMG signal is very tiny and sensitive to artifacts. This section presents the different artifacts, how to detect them and how to prevent them.

### Line interference (50/60Hz noise):

This is the most common artifact. It comes from the power line and is transmitted by electrical devices (such as the computer) placed near the EMG data acquisition device (such as your Infiniti device). Figure 4 shows an example of line interference.

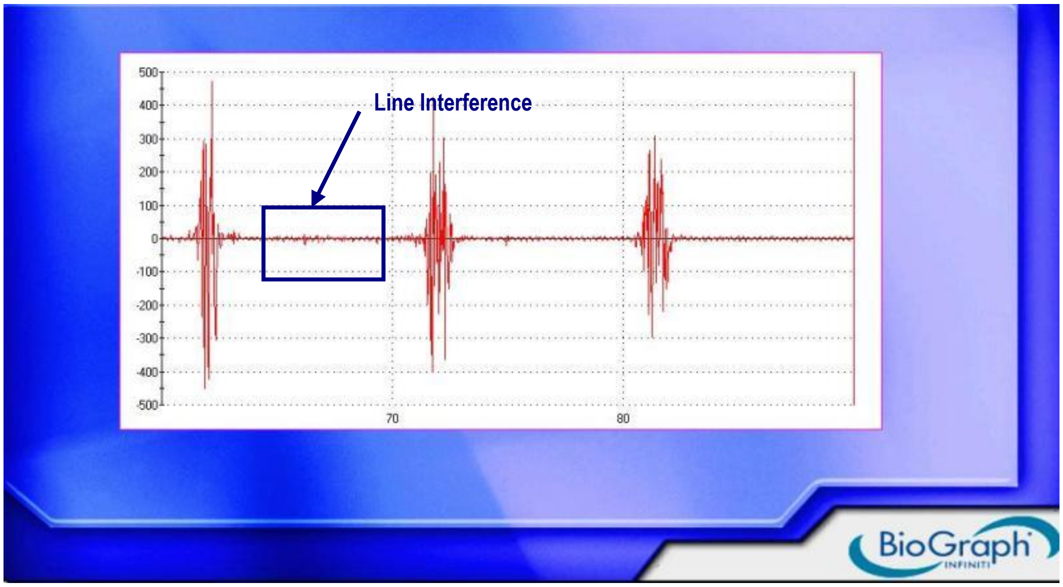



**Fig. 4. Raw EMG signal with line interference**

This problem can be fixed by applying a Notch filter to the signal, which will remove the 60/50Hz component of the signal. (The choice of 50 or 60Hz depends on the power transmission frequencies used in your region; you must configure your software accordingly.)

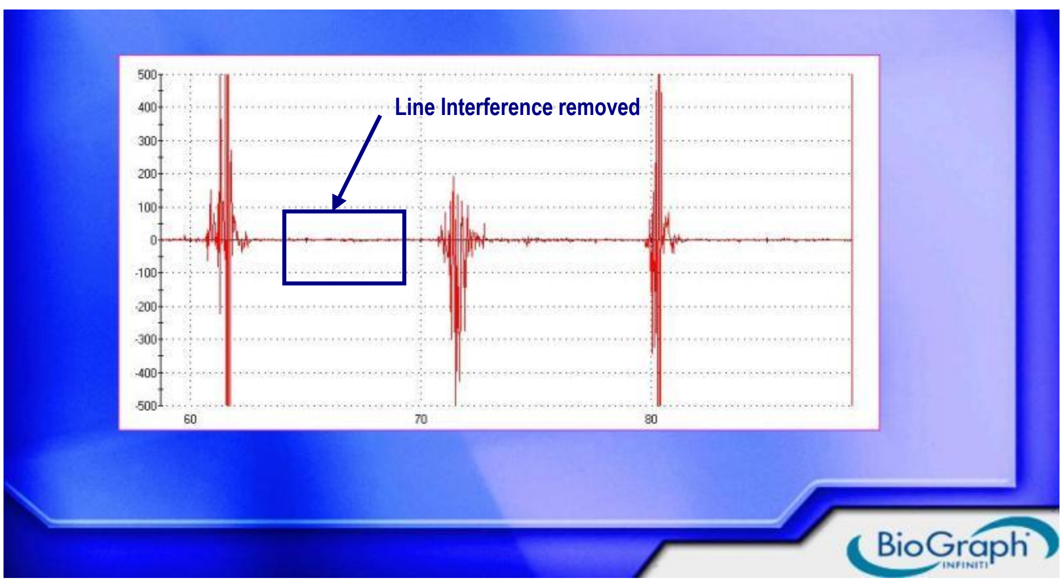



**Fig. 5. Raw EMG signal with Notch filter**

Electronic devices also generate their own frequencies that will not be removed by the Notch filter.

Additional precautions must be taken, such as keeping the device 3 feet (1 meter) away from any electronic equipment and 10 feet (3 meters) away from any radio transmitting devices.

### EKG (ECG) artifacts:

EKG signal is generated by the heart. It can be picked up with the EMG signal. Figure 6 shows an example.

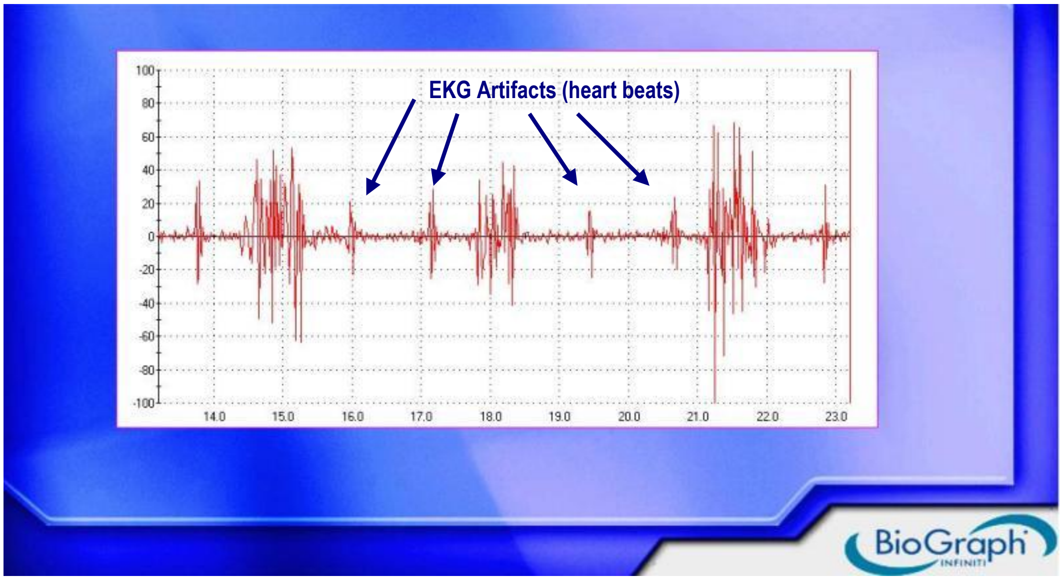



**Fig. 6. Raw EMG signal with EKG artifact**

EKG artifacts are very difficult to remove from the EMG signal. But they can be avoided by placing the electrodes so that they are not aligned with the axis of the heart activity (avoid transthoracic placement, for instance). Placing the electrodes on the same side of the body usually reduces or removes these artifacts.

If these precautions are not enough, a high-pass filter at 100Hz can be applied to the signal. However, this filters extremely low frequencies from the EMG signal and may remove important information.

### DC offset artifacts:

This is caused by the difference in the impedance between the skin and the electrodes. It adds an offset to the raw signal (which is normally centered on 0). Proper skin preparation and firm placement of electrodes on the skin generally prevent the problem. If necessary, conductive gel can be added.

### Muscle crosstalk:

Muscle crosstalk is caused by EMG signals coming from other muscles than the one being monitored. Crosstalk can be avoided by choosing the appropriate inter-electrode distance (around 2 centimeters) and by placing electrodes at the middle of the muscle belly. Note that, since EMG is picked up at the surface of the skin, it may not be possible to prevent crosstalk in some regions of the body.

### Movement artifacts:

During patient movements, the electrodes can move or the cables be pulled or be shaken, which may create artifacts in the EMG signal. An example can be seen in Figure 7.

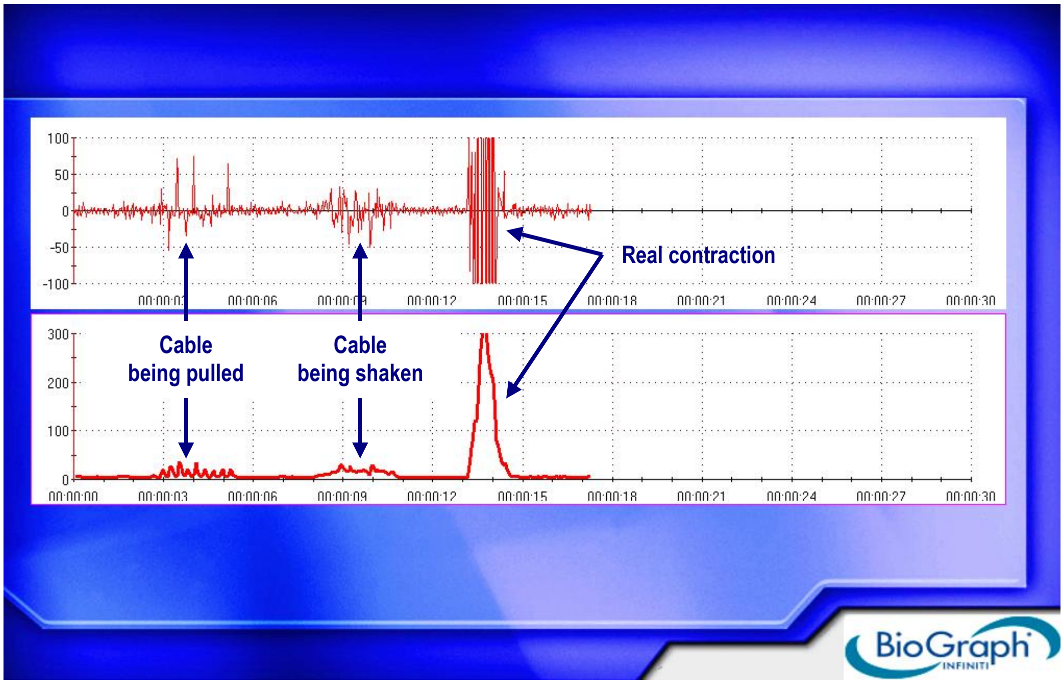


Fig. 7. Raw and RMS EMG signals with movement artifacts

An artifact caused by pulling or shaking can be avoided by using tape or an elastic band to fasten the cables. Electrode movement can be avoided by choosing the right electrode type and placing the electrodes firmly on the skin to avoid them peeling off. Inter-electrode distance must also be chosen so that electrodes do not push against each other during movement.

A high-pass filter at 20Hz can be applied to the signal (hardware or software) to remove the residual artifact.

These artifacts can also be manually removed from the statistics calculation during the review of the session.

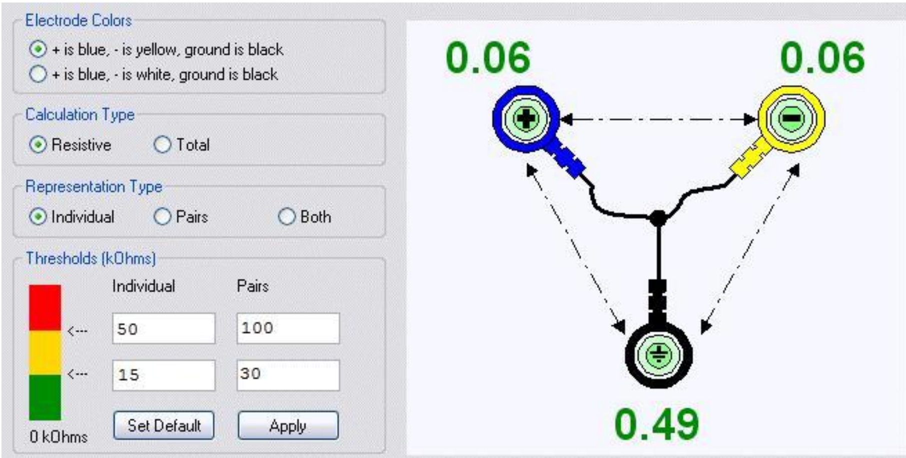
## *Impedance Check*

Good preparation of the skin for contact is necessary for accurate results and prevention of artifacts. Measuring the impedance between the electrodes is the recommended way to verify good contact.

This measure is performed with an impedance meter. The table below gives the recommended ranges.

| | | |
|---|---|---|
| (green) | 0 to 15 kOhms | Recommended for assessment |
| (yellow) | 15 to 50 kOhms | Acceptable for Biofeedback training but not recommended for assessment |
| (red) | > 50 kOhms | Not recommended |

The impedance check can also be done with MyoScan-Z, our EMG sensor with built-in impedance check.




**BioGraph Infiniti – Impedance Check Screen**

The advantage of MyoScan-Z is that you do not have to handle the patient and the cables between the impedance check and the real session. You can also run an impedance check during the session without disconnecting any cable. This is faster and more reliable than using a regular impedance meter.

### *Normalization Methods*

SEMG measures must be compared to a reference in order to be meaningful. The drawback of SEMG measures is that they can vary significantly between subjects (age and type of skin), muscles, electrode placements (on the same muscle), and from day to day.

Several normalization methods exist; the two most common ones are the following:

- **Bilateral comparison**: the involved site is compared to the uninvolved site.
- **MVC-normalization**: MVC is **M**aximal **V**oluntary **C**ontraction. The amplitude is compared to MVC and can be rescaled to % of MVC. MVC is obtained by recording several isometric contractions in the muscle test position (at least three repetitions are required). The maximum values of each repetition are averaged to give the MVC. A variant is **SMVC-normalization** (Sub-Maximal Voluntary Contraction), for patients who cannot reach MVC.

## Summary of Recommendations

Here is a summary of recommendations to ensure proper use of SEMG and the capture of a good quality signal:

- Good skin preparation
- Impedance check
- Fixed electrode spacing (ideally 0.75 in or 2cm) between bilateral sites and from time to time
- Fixed location from time to time (ideally at the middle of the muscle belly, parallel to muscle fibers)
- Notch filter enabled at the proper frequency (50Hz or 60Hz)
- Signal filtered between 20Hz and 500Hz
- Electromagnetic interferences minimized: keep the device 3 feet (1 meter) away from any electronic equipment and 10 feet (3 meters) away from any radio transmitting devices
- SEMG view properly chosen (raw, RMS, power spectrum etc …) for the intended use
- Consistency in the selection of hardware and software settings (signal processing settings, selected normalizations and statistics) from time to time.

# SEMG ASSESSMENT

"Electromyography is unique in revealing what a muscle actually does at any moment during movement and postures. Moreover, it reveals objectively the fine interplay or coordination of muscles: this is patently impossible by any other means" (Basmajian, "Muscles Alive, Their Function Revealed by Electromyography").

The first section of this chapter presents the general concepts of SEMG analysis and the basic assessment techniques. These basic techniques can be considered as "static", "dynamic" or "combined" SEMG; however, there is no real consensus on the way to categorize them.

The two next sections review the two main assessment categories: Static SEMG and Dynamic SEMG. These two categories contain only techniques that have been commonly accepted as either "static" or "dynamic" SEMG.

## SEMG Signal Analysis: General Concepts

SEMG signals can be viewed in three different dimensions: amplitude, time and power spectrum. Important information can be gathered in each dimension. SEMG analysis can be then separated in three groups: amplitude analysis, temporal analysis and spectral analysis.

**Amplitude analysis:**

- **Baseline or resting level**: the level of SEMG when the muscle is totally relaxed. It is generally accepted that the SEMG of a muscle at rest should be below 5μV.
- **Averaged contraction (mean of SEMG during contraction)**: this is a good indicator of the level of muscle strength and endurance **(while performing an isometric contraction)**.
- **Peak or maximum**: this is the maximum SEMG amplitude the muscle can generate.
- **Variability**: is a good indicator of the neuromuscular stability.
- **Area or iEMG (integrated EMG)**: this is the mathematical integral of the EMG amplitude, which corresponds to the area under the curve, for a given period of time. It is a good indicator of the amount of energy produced during that period of time.

**Temporal analysis:**

- **Onset time or activation time**: the time it takes for the muscle to contract.
- **Release time or deactivation time**: the time it takes for the muscle to go back to rest.

**Spectral analysis:**

- **Mean/Median frequencies**: their rate of decrease is a good indicator of muscle fatigue **(while performing an isometric contraction)**.

Figure 10 is an illustration of the measures.

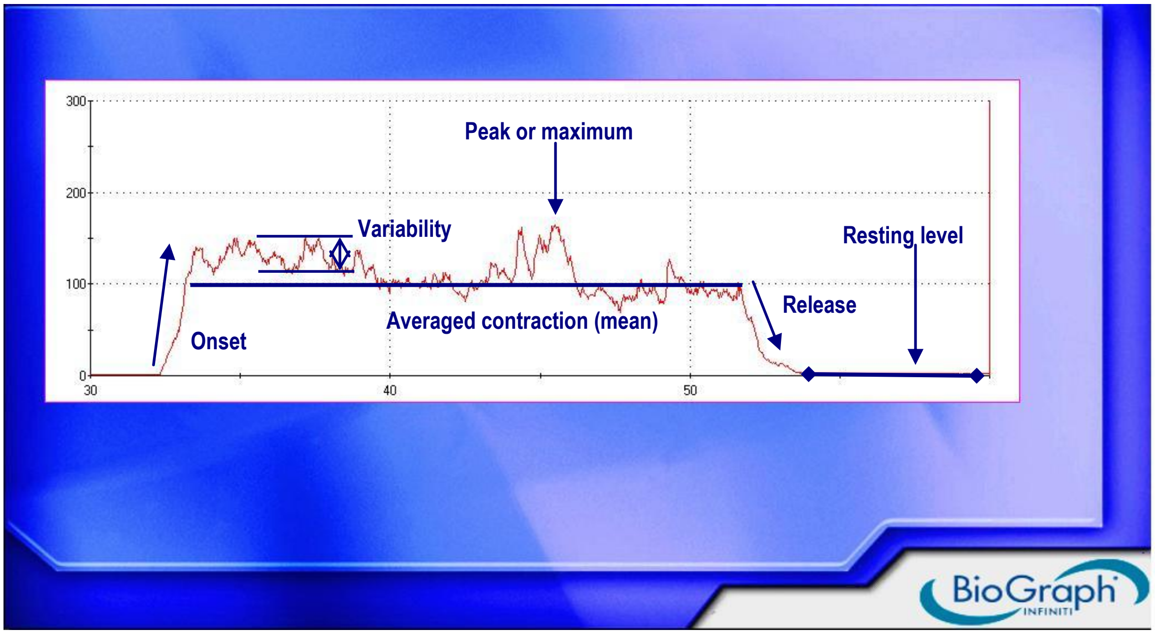



**Fig. 10. SEMG measures**

The following protocols are very common assessment techniques. They can be performed at the beginning of each visit. They allow you to quickly assess the examinee's muscle condition and determine the training parameters of the day (since an examinee's condition can change over time).

**Baseline (pre/post)**: this protocol measures the resting level of the muscle. The examinee must be asked to totally relax the muscle. Comparison of resting levels (pre/post) assesses the ability to recover.

Note that low SEMG levels may be observed, despite the examinee complaining about pain. A possible reason is that a muscle in hyperactivity for a long period of time can fatigue and become electrically silent (**muscle shutdown**). These levels are generally lower than a muscle in actual rest. Trigger points can be another reason.

- Statistics: Mean and variability (neuromuscular stability).

**Maximal force:** the maximal force is the highest level of voluntary contraction that a person can achieve without inducing unacceptable pain. The examinee contracts the muscle to a high but comfortable level, and then relaxes. This is repeated only few times to avoid fatiguing the muscle. This monitors the recruitment of both types of fibers.

- Statistics: Maximum contraction, variability (neuromuscular stability), area (energy) and onset time (muscle activation velocity) during work period, and release time (muscle deactivation velocity), variability (neuromuscular stability) and mean (resting level) during rest period.

**Endurance:** the examinee contracts as strongly as they can during an extended period (about 20 seconds). This monitors the recruitment of the slow twitch fibers (muscle endurance) and the muscle fatigue. **The contraction should be performed against static resistance (isometric contraction)**.

- Statistics: Mean (averaged contraction), variability (neuromuscular stability), area (energy) and mean/median frequency.

**Fast flicks (or rapid contractions):** the examinee repetitively contracts as quickly and strongly as they can. This monitors the recruitment of the fast twitch fibers (muscle activation intensity and velocity). This should be done prior to any other assessment, since these fibers are the first to get fatigued.

- Statistics: Maximum contraction and onset time (muscle activation velocity).

# Static SEMG Assessment

## *Definition*

Static SEMG scanning assesses the resting level of the muscle in static position.

## *Principle*

Static SEMG assessment, combined with palpation, provides an objective assessment of the muscle condition and leads to the proper treatment.

If the muscle is **hard to the touch** and **SEMG levels** are **above normal** in resting state, it may be considered **hyperactive** (chronic hyperactivity as well as muscle spasm).

If the muscle is **hard to the touch**, but with **low SEMG level**, it is not hypertonic but is in **shortened resting length**. This is usually due to a lack of use or an incomplete range of use.

Each condition requires a different treatment.

It can also detect **antalgic postures**. When the examinee experiences a painful condition, they may unconsciously adopt a postural shift in order to move away from the sensation of pain. This behavior leads to activation of muscles that should normally be at rest.

In this case, it may require monitoring left and right sides at the same time and multiple sites in order to describe completely the antalgic posture.

## *Limitations*

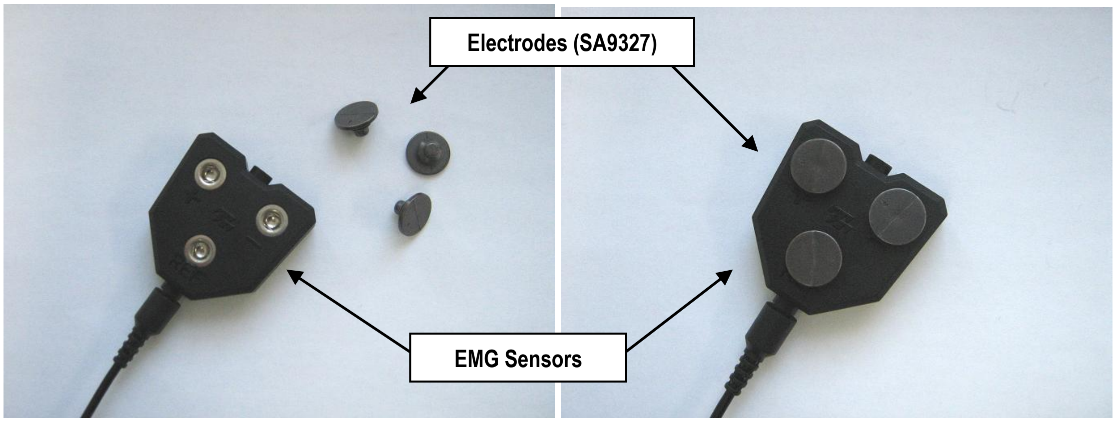
Static SEMG scanning cannot detect all the problems. For instance, muscles may look normal and produce low SEMG levels, despite the examinee complaining about pain. The reason is that a muscle in hyperactivity for a long period of time can fatigue and become electrically silent. Then **Dynamic SEMG assessment** should be performed.

## *Analysis of the Results*

- Normal levels should be below 5µV.
- Very high levels (>25µV): possible artifacts due to poor contact with the skin; check raw EMG (see the chapter ***Introduction to Surface Electromyography*** for more details).
- Very low levels (below 1µV): possible electrode bridging with the conductive paste; clean skin and redo measurement.
- Symmetry: left/right difference should be < 40%.
- Result must be consistent with palpation.

## *Para-spinal Scanning*

Para-spinal scanning is the most common procedure. Twelve site pairs (left and right) have to be measured. Due to the numerous sites, only one site pair is measured at a time. The operator uses a pair of EMG sensors (such as SA9503M MyoScan or SA9503Z MyoScan-Z) and the electrodes shown below; the sensors are held in place by the operator. The operator moves them from one site to the next.



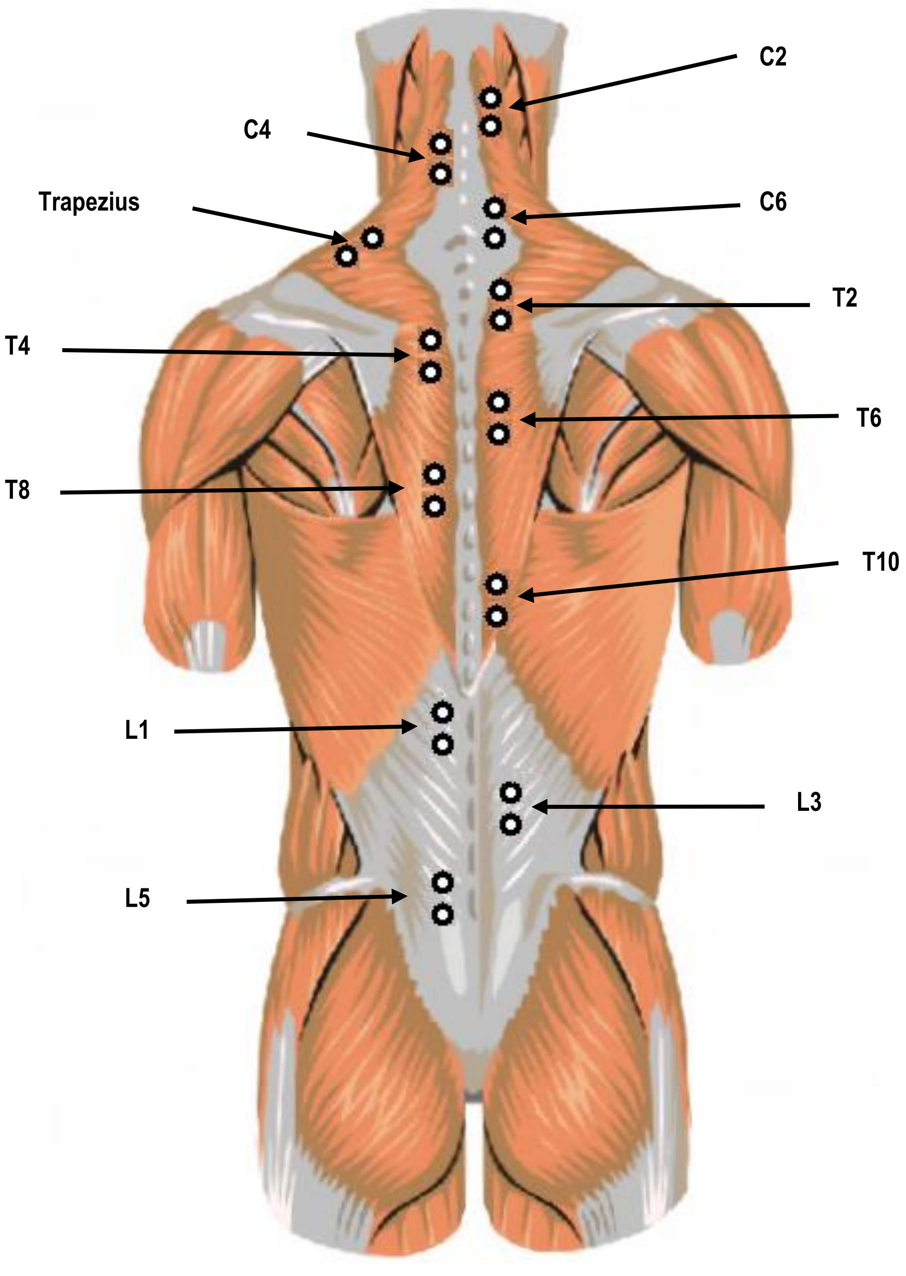

## Procedure

- Explain the procedure to the examinee.
- Ask the examinee to strip to the waist and put on a gown.
- Abrade the skin along the examinee's spine. Make sure the skin surface is clean and dry. If necessary, shave excess body hair.
- Identify anatomical landmarks for positioning the electrodes.
- Have the examinee stand upright.
- Affix the electrodes on the two MyoScan or MyoScan-Z (EMG) sensors.
- Put conductive electrode paste or cream on the EMG electrodes (grey area only).
- Position yourself next to the examinee, the encoder attached to your belt, with the pedal near your foot.
- Place the active electrodes (positive and negative) in alignment with the spine (except for trapezius), at a distance of 3 cm out from the vertebral ridge, and at the site shown on the screen.
- Position your hands so that the electrodes remain stable and do not move, as shown in the picture below. Apply gentle pressure on the sensor so that the 3 electrodes make good contact with the skin.

- Ask the examinee to relax their muscles.
- Wait for the signal to settle; allow at least 5 seconds before recording the data. But do not wait more than 30 seconds; the signal will not settle more and you risk creating movement artifacts by holding the electrodes too long.
- Press the foot pedal to record.

## *Scan Sites*

The picture below suggests placements for para-spinal scanning.




***For reasons of clarity, active electrodes are shown only on one side of the spine.***

## *Analysis*

Jeffrey R. Cram and Glenn S. Kasman propose in "*Introduction to Surface Electromyography*" a method to detect abnormal levels of activation or inhibition along the spine.

Each site is compared to a mean and standard deviation (StD.). For instance, if the result is greater than the mean + 2 StD., the muscle is considered as hyperactive.

They propose the following decision table:

| | |
|---|---|
| Between Mean – 1 StD. and Mean + 1 StD. | **Normal** |
| Between Mean + 1 StD. and Mean + 2 StD. | **Mid Activation** |
| Between Mean + 2 StD. and Mean + 3 StD. | **Moderate Activation** |
| Greater than Mean + 3 StD. | **Severe Activation** |
| Less than Mean – 1 StD. | **Mid Inhibition** |

They measured the EMG levels of 104 persons they considered as "normal", meaning without "*pain-related problem requiring a physician's visit for at least two years*".

However, the percentage of body fat affects the signal. Lack of adipose tissue creates higher level readings than normal, even if the examinee is in normal condition. Conversely, excess of adipose tissue acts as an isolator and creates lower readings. So they consider that this database cannot be used with extremely thin (<15% body fat), or extremely obese (> 50% body fat) people.

# Dynamic SEMG Assessment

## *Definition*

Dynamic SEMG assesses muscle tension through various movements, such as flexion/extension, adduction/abduction, lateral bending or rotation.

## *Principle*

Dynamic SEMG is used to examine the muscle in various conditions: when firing, when going back to rest, when acting as agonist, synergist or antagonist.

It allows detection of impairments such as muscle imbalance (between symmetric muscles or agonist/antagonist), co-contraction, poor recovery of baseline level (resting level), irritability, and timing issues in the recruitment pattern (too early, too late, too short or too long).

Dynamic SEMG measures are qualitative, unlike static SEMG measures, which are quantitative.

The types of muscles, the types and sequences of firing are too numerous and complex to be compared to normative data. There is also great variance from one person to another.

At least two muscle sites are monitored (symmetric muscles, agonist/antagonist or agonist/synergist).

The selection of the sites is usually driven by the examinee's complaint (pain, for instance) or the location of the injury.

Several repetitions of the movement must be performed. This allows verifying that the movement has been properly performed (within the limits of the examinee's capabilities), that the impairment can be seen in a consistent manner (and is not in fact an artifact), and the level of consistency in muscle patterns.

## *Limitations*

SEMG only measures muscle tension. It does not measure force, muscle length, joint position, pain or anxiety. The evaluation of the examinee should be completed with using other techniques, such as **muscle testing** and **range of motion assessment**.

## *Procedure*

- Explain the procedure to the examinee.
- Have the examinee to do warm-up exercises.
- If necessary, ask the examinee to strip to the waist and put on a gown.
- Select the proper electrodes and cables (see the section ***Surface Electrodes and Cables***).
- Identify the muscles by palpation.

- Abrade the skin. Make sure the skin surface is clean and dry. If necessary, shave excess body hair.
- Apply the electrodes. Make sure the electrodes are placed firmly on the skin and that there is good contact between the skin and electrodes. General electrode placements are available in the chapter ***Introduction to Surface Electromyography*** (pages 18, 19, and 20). Specific ones are presented below.
- Attach the encoder to the examinee's belt or waistband.
- Verify that the signal is free of artifacts (the artifacts are listed on page 24 in the chapter ***Introduction to Surface Electromyography***).
- Instruct the examinee in the movement and ask them to do it a couple of times before starting the recording. Instruct the examinee to perform the motion slowly, until they feel restriction, tightness or discomfort.
- Record several repetitions of the movement. If the software does not (no predefined protocol), mark the different stages of the movement with event makers (events can be marked by hitting the space bar or a key of the keyboard that you would have preliminarily labeled with the name of the event). Video is also a great asset.

## Analysis of the Results

The concepts described in the first section (SEMG Signal Analysis) can be applied to muscles in motion. This section describes their application to dynamic SEMG analysis and the impairments that it can help to detect.

**Poor baseline recovery:** normal muscle should return to initial baseline when going back to neutral position. Injured muscles may show elevated resting levels after the movement.

**Tonic baseline during relaxation phase of a movement:** the muscle are supposed to rest at some stages of the movement, such as lumbar muscles when the back is fully flexed, cervical para-spinal muscles when the head is fully flexed. Impaired muscles may show elevated tonic baseline during the relaxation phase.

**Hypoactivity:** homologous muscles should generate similar peak amplitudes in symmetric movements. A difference greater than 35% shows hypoactivity.

**Co-contraction:** co-contraction is the abnormal symmetrical activation of homologous muscles during asymmetrical movements, such as rotation or lateral bending.

**Instability (irritability):** a muscle in normal condition fires smoothly. Injured muscle seems to be more spasmodic. Its SEMG looks “noisier” and its variability is higher (see the SEMG Signal Analysis section for more information). SEMG variability of homologous muscles should be compared.

**Inconsistency in amplitude and time (peak, onset/release time):** healthy muscles generally fire in consistent manner in amplitude and time. Injured muscles show a greater variability from repetition to repetition.

**Agonist/Antagonist Issues:** agonist/antagonist reciprocation should be examined. Poor imbalance leads to limited or no movement. For instance, flexor and extensor interact in both flexion and extension. A high level of recruitment of the flexor during extension would go against the action of the extensor and would limit the overall torque generated. So, limited range of motion could be caused by hyperactivity of the antagonist muscle, rather than hypoactivity of the agonist muscle. However, when gravity is involved, the agonist muscle only initiates the movement, gravity generating most of the force. The antagonist muscle is then more involved than the agonist (generates more EMG than the agonist), but still only plays its role of control. It is not the force producer: **a muscle can only pull, it cannot push**.

**Agonist/Synergist Issues:** Evaluation of agonist/synergist patterns is very complex. Synergies vary with joints and their relative movements. SEMG allows seeing if the muscle is recruited at the right time, for the right duration. The easiest way is by comparing the two sites.

Some synergy patterns have been studied and very simple verifications can be performed:

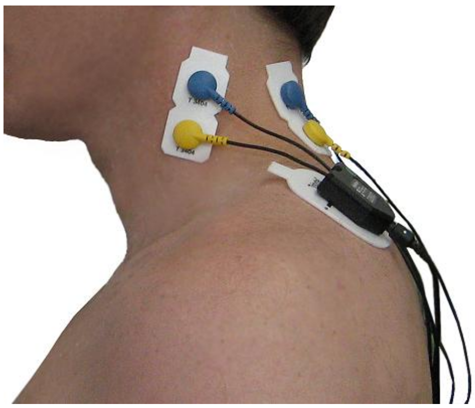
- Will Taylor (in “*Clinical EMG for Surface Recording: Volume 2*”) demonstrates that the ratio between upper trapezius and lower trapezius during shoulder abduction should be less than one-to-one.
- EMG studies of non-painful knees show that the ratio of VMO to VL activity is one-to-one and that VMO is tonic in nature. The ideal is two-to-one. In knees with patellofemoral pain the ratio is less than one-to-one.

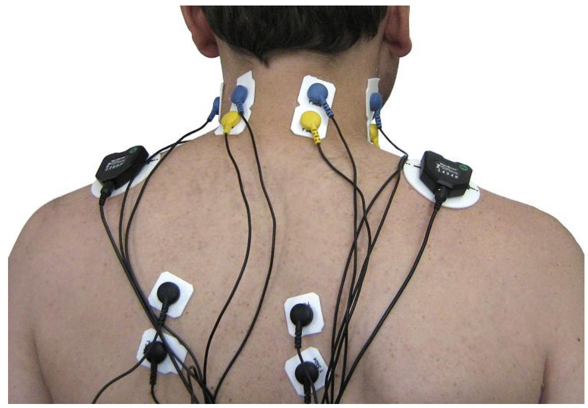
The following pages present the most common applications of dynamic SEMG assessment. But they can be applied to any part of the body. Many books have been published on this topic. We recommend, among others, "*Clinical Applications in Surface Electromyography: Chronic Musculoskeletal Pain*" (see bibliography at the end of the guide).

## *Cervical Spine Assessment*

Many assessment methods are available for cervical dysfunction and pain: muscle testing, shoulder range of motion, muscle palpation and more. SEMG assessment is a great asset to observe muscle recruitment pattern and detect aberrant muscle activity.

Cervical Spine Assessment is performed with monitoring the cervical paraspinals (CP) and either the sternocleidomastoids (SCM) or the upper trapezius.

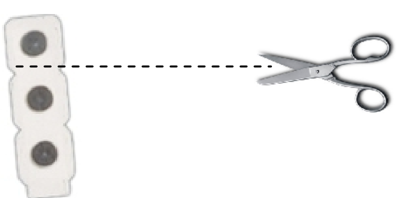




**Placement of the electrodes for Cervical Paraspinals (CP)**

For cervical paraspinals, you need to connect the extender cable to the MyoScan sensor.

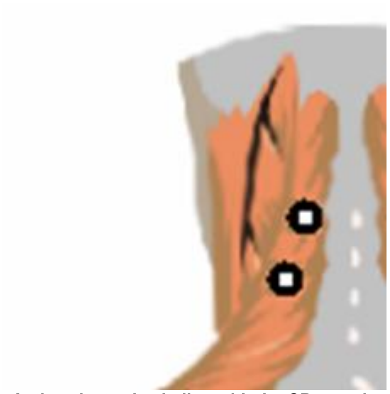
You will also need the strip electrode shown on the left.



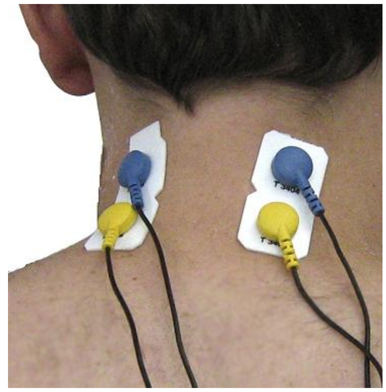
Cut one electrode from the strip as shown on the left. This single electrode will be used to connect the reference.

The twin electrodes will be the active electrodes, connected to the CP muscles.

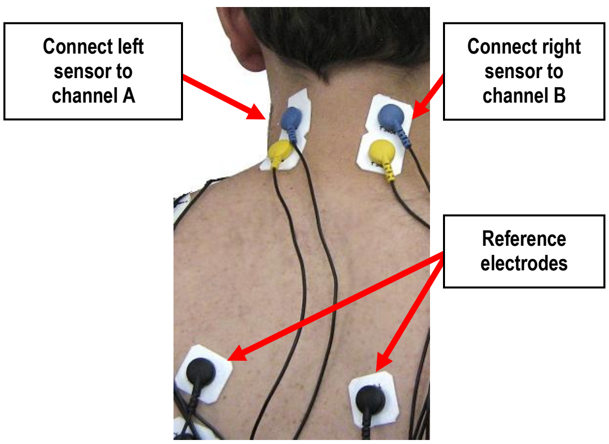
- Snap the twin active electrodes to the blue and yellow connectors of the cable.
- Snap the single electrode to the black connector.
- Place the active electrodes in line with the CP muscle, as shown below.



Active electrodes in line with the CP muscle



Note that the electrodes should be placed symmetrically (same distance from the spine) with the cables facing down, as shown above.



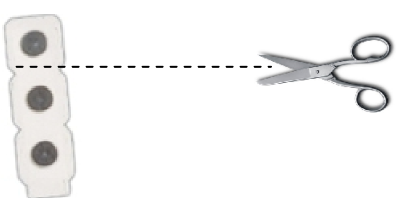

Then place the reference electrode on the examinee's back as shown.

Make sure the electrodes are placed firmly on the skin and that there is good contact between the skin and electrodes.

### Placement of the electrodes for Sternocleidomastoids (SCM)

For cervical paraspinals, you need to connect the extender cable to the MyoScan sensor.

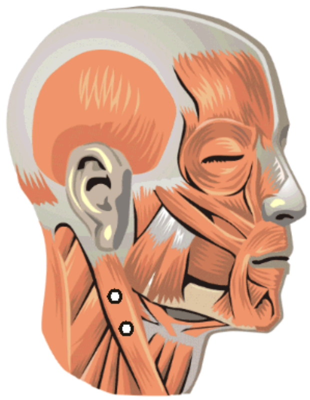
You will also need the strip electrode shown on the left.

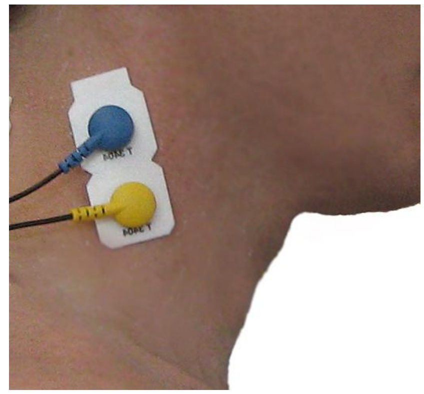


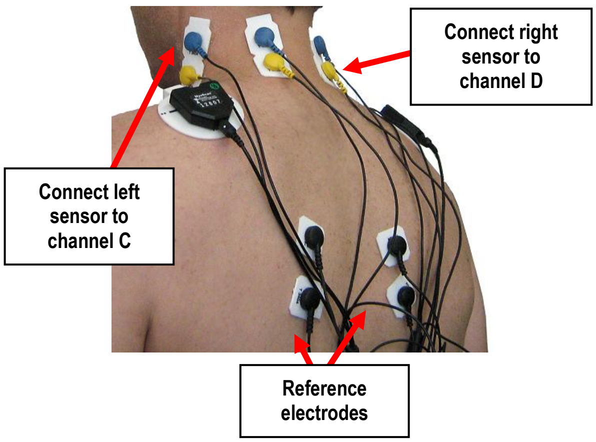
Cut one electrode from the strip as shown on the left. This single electrode will be used to connect the reference.

The twin electrodes will be the active electrodes, connected to the CP muscles.

- Snap the twin active electrodes to the blue and yellow connectors of the cable.
- Snap the single electrode to the black connector.
- Place the active electrodes in line with the SCM muscle, as shown.








Then place the reference electrode on the examinee's back as shown.

Make sure the electrodes are placed firmly on the skin and that there is good contact between the skin and electrodes.

### Placement of the electrodes for Upper Trapezius

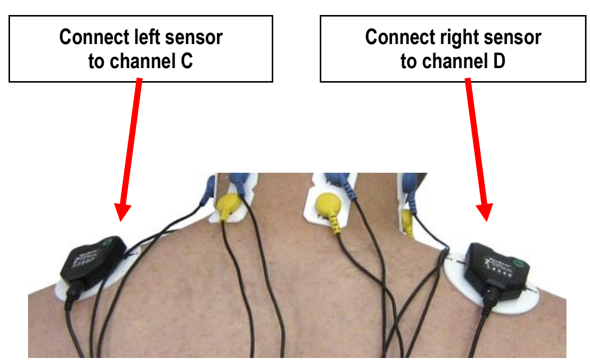
Affix a triode on each MyoScan sensor.


**MyoScan Sensor**

**Triode**

Place the sensors on the upper trapezius muscles with active electrodes (marked by a "+" and a "-") in line with the muscle, as shown below.

**Active electrodes (marked by "+" and "-") in line with the muscle**




**Place the sensors symmetrically (same distance from the spine) with the cable facing down, as shown.**

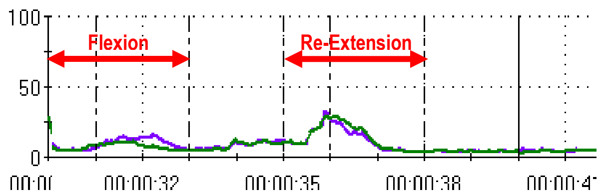
Make sure the electrodes are placed firmly on the skin and that there is good contact between the skin and electrodes.

### Flexion/Re-extension:

The examinee bends their head forward and holds at the lowest point until prompted to return to neutral position. This range of motion is repeated three times.

During flexion, CP are the agonists (prime movers) and SCM the antagonists (stabilizers). The role is reversed during re-extension.

- **Relaxation phases**: the muscles should be relaxed (EMG activity below 5µV) in neutral position (including pre- and post-baselines) and during full flexion. EMG activity should also be smooth (with very little jitter).
- **Parallel symmetry**: both sides should fire symmetrically (time and amplitude) during motion. Peak amplitudes should be within 35% difference.
- **Flexion peak vs. re-extension peak**: CP flexion peak should be significantly lower than re-extension peak.
- **Recovery**: in post-baseline the muscles should return to the same resting level as in pre-baseline.




**CP during flexion/re-extension**

### Left/Right Lateral Flexion:

The examinee bends their head to the left as far as they can and holds the position until prompted to return to neutral position. This range of motion is repeated three times.

Then the examinee bends their head to the right as far as they can and holds the position until prompted to return to neutral position. This range of motion is also repeated three times.

- **Relaxation phases**: the muscles should be relaxed (EMG activity below 5µV) in neutral position (including pre- and post-baselines) and during full lateral flexion. EMG activity should also be smooth (with very little jitter).
- **Mirror symmetry**: During left flexion, left CP and SCM should fire while right CP and SCM remain relatively quiet, and vice versa. During left flexion the left upper traps also should be slightly active while the right traps should be quiet (and vice versa). Firings of homologous muscles should be symmetric (within 35%) when compared to the opposite side during the opposite movement (look for potential co-contraction).
- **Recovery**: in post-baseline the muscles should return to the same resting level as in pre-baseline.

### Left/Right Rotation:

The examinee rotates their head maximally to the left and holds the position until prompted to return to neutral position. This range of motion is repeated three times.

Then the examinee rotates their head maximally to the right and holds the position until prompted to return to neutral position. This range of motion is also repeated three times.

- **Relaxation phases**: the muscles should be relaxed (EMG activity below 5µV) in neutral position (including pre- and post-baselines). EMG activity should also be smooth (with very little jitter).
- **Mirror symmetry**: During left rotation, left CP and right SCM should fire in a significant manner while right CP and left SCM show very little activity, and vice versa. During left rotation the right upper traps also should be slightly active while the left traps should be quiet (and vice versa). Firings of homologous muscles should be symmetric (within 35%) when compared to the opposite side during the opposite movement.
- **Recovery**: in post-baseline the muscles should return to the same resting level as in pre-baseline.

## *Lumbar Spine Assessment*

According to the American Academy of Orthopedic Surgeons, "four out of five adults will experience significant low back pain sometime during their life". According to a study from 2006, that included 46,000 people across 16 countries, one in five European adults is suffering from pain and the most common source of pain is back pain (24 %).

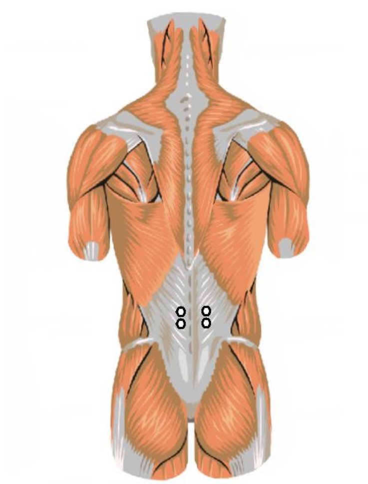
### Placement of the electrodes:

Affix a triode on each MyoScan sensor.

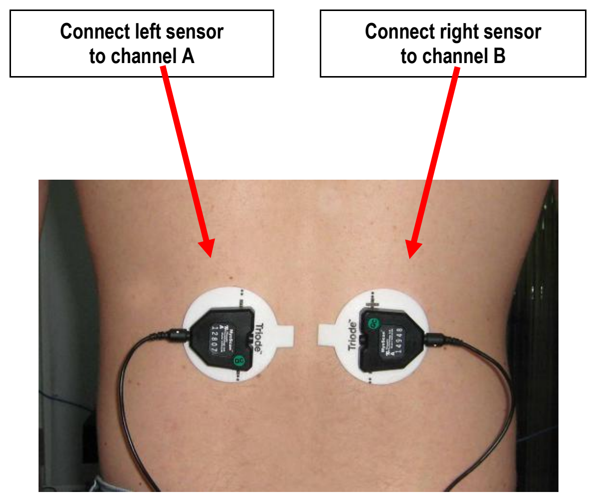
**MyoScan Sensor**

**Triode**

Place the sensors on the erector spinae muscles with active electrodes (marked by a "+" and a "-") in line with the spine and facing L3, as shown below, with the examinee in a slightly bent position to stretch the skin and aid adhesion.



**Active electrodes (marked by "+" and "-") in line with the spine and facing L3**



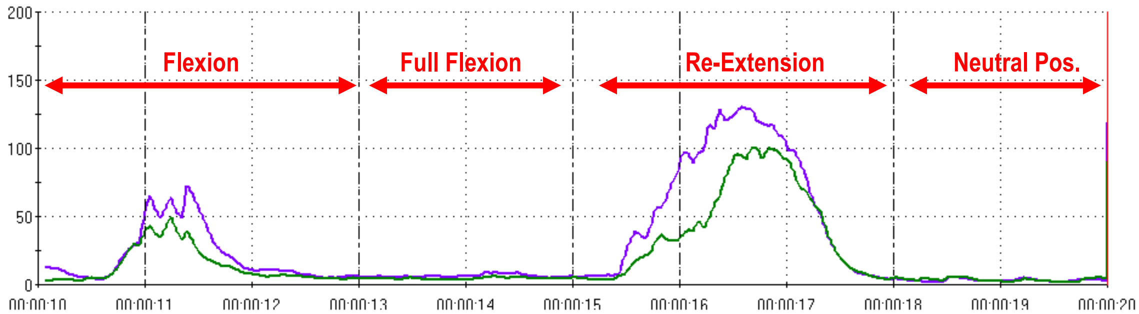

**Place the sensors to mirror one another, as shown.**

Make sure the electrodes are placed firmly on the skin and that there is good contact between the skin and electrodes.

### Flexion/Re-extension:

The examinee bends forward and holds at the lowest point until prompted to return to neutral position (upright position). This range of motion is repeated three times.

- **Relaxation phases**: the muscles should be relaxed (EMG activity below 5μV) in neutral position (including pre- and post-baselines) and during full flexion. EMG activity should also be smooth (with very little jitter).
- **Parallel symmetry**: both sides should fire symmetrically (time and amplitude) during motion. Peak amplitudes should be within 35% difference.
- **Flexion peak vs. re-extension peak**: flexion peak should be significantly lower than re-extension peak.
- **Recovery**: in post-baseline the muscles should return to the same resting level as in pre-baseline.




### Left/Right Lateral Flexion:

The examinee bends to the left as far as they can and holds the position until prompted to return to neutral position. This range of motion is repeated three times.

Then the examinee bends to the right as far as they can and holds the position until prompted to return to neutral position. This range of motion is also repeated three times.

- **Relaxation phases**: the muscles should be relaxed (EMG activity below 5µV) in neutral position (including pre- and post-baselines) and during full lateral flexion. EMG activity should also be smooth (with very little jitter).
- **Mirror symmetry**: during left flexion, left side should fire while right side remains relatively quiet, and vice versa. Muscle firings should be symmetric (within 35%) when compared to the opposite side during the opposite movement (look for potential co-contraction).
- **Recovery**: in post-baseline the muscles should return to the same resting level as in pre-baseline.

### Left/Right Rotation:

The examinee rotates the trunk maximally to the left and holds the position until prompted to return to neutral position. This range of motion is repeated three times.

Then the examinee rotates the trunk maximally to the right and holds the position until prompted to return to neutral position. This range of motion is also repeated three times.

- **Relaxation phases**: the muscles should be relaxed (EMG activity below 5µV) in neutral position (including pre- and post-baselines). EMG activity should also be smooth (with very little jitter).
- **Mirror symmetry**: During left rotation, left side should fire in a significant manner while right side shows very little activity, and vice versa. Muscle firings should be symmetric (within 35%) when compared to the opposite side during the opposite movement.
- **Recovery**: in post-baseline the muscles should return to the same resting level as in pre-baseline.

## *Anterior Knee Assessment*

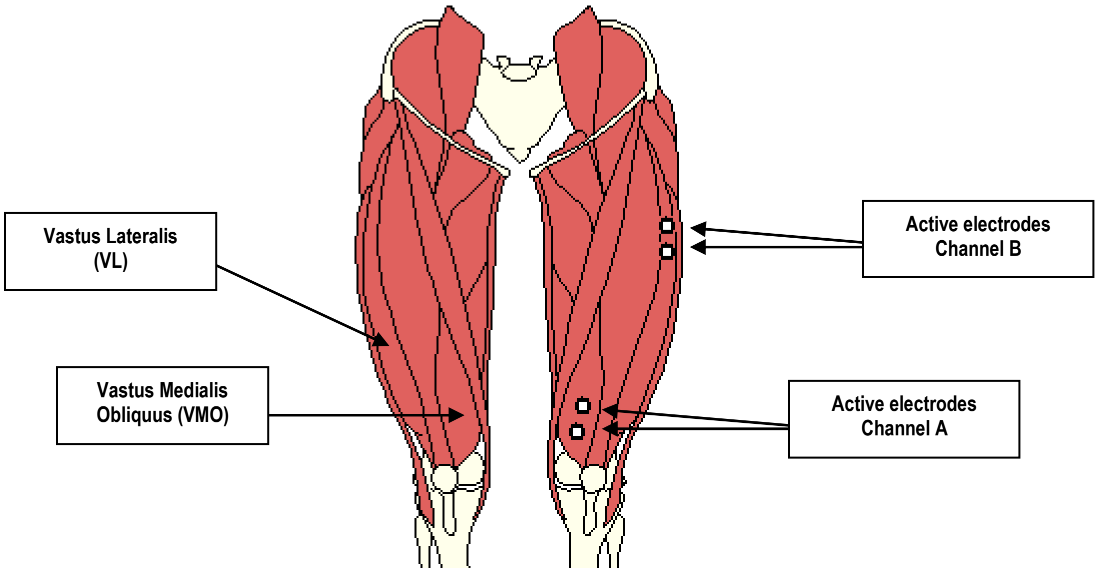
Patellofemoral pain is a common ailment affecting one in four of the general population. It is caused by a variety of factors including abnormal lower limb mechanics, Vastus Medialis Obliquus (VMO) insufficiency, tight lateral structures and tight anterior and posterior muscles.

The condition often develops gradually and is characterized by a diffuse ache of the anterior knee. Note that another common pain is Chondromalacia, which is distinct from Patellofemoral pain. The former is caused by a softened and fissured patellar under-surface as seen during diagnostic imaging or surgery.

The VMO muscle is the only dynamic medial stabilizer of the patella, and is active throughout the full range of the extension of the knee.

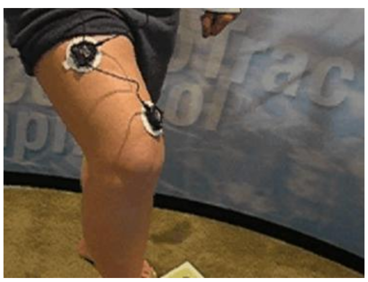
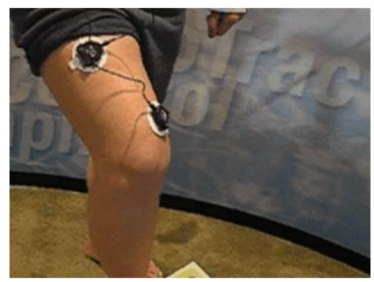
### Placement of the electrodes:

Place the active electrodes of channel A on the Vastus Medialis Obliquus (VMO) and the active electrodes of channel B on the Vastus Lateralis (VL), as shown in the picture. The reference electrodes have to be placed proximally (above the active electrodes, closer to the trunk).



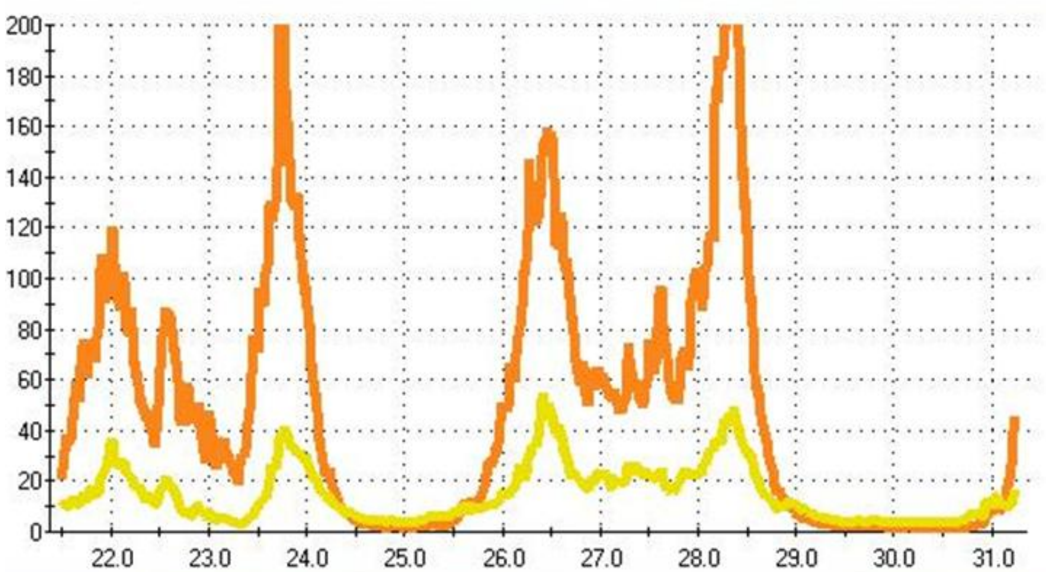

### Step-down Exercise:

The involved leg should remain on the step block. The good leg steps up, joining the other leg, then steps down.

|  |  |  |
| --- | --- | --- |
| **Start with leg down** | **Step up** | **Then step down** |

### SEMG shows:

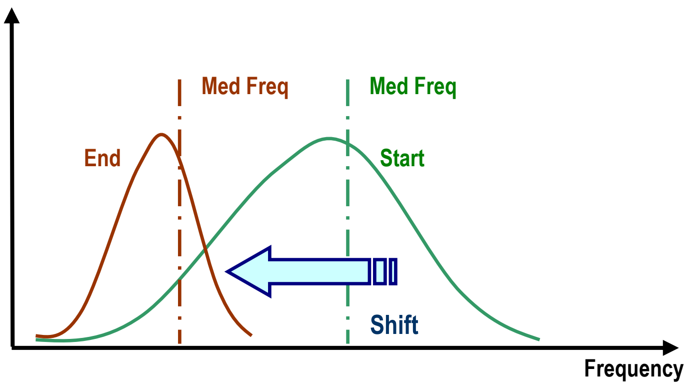
EMG studies of non-painful knees show that the ratio of VMO to VL activity is one-to-one and that VMO is tonic in nature. The ideal is two-to-one. In knees with patellofemoral pain the ratio is less than one-to-one.



# Muscle Fatigue Monitoring

SEMG can be used as an indicator of muscle fatigue.

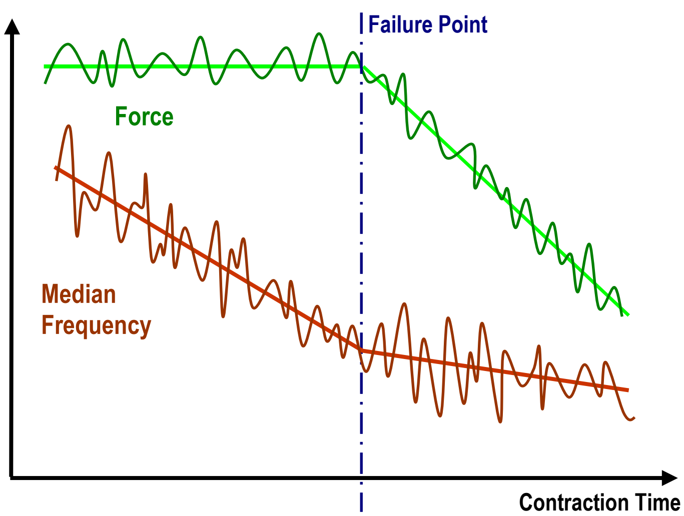
During **isometric submaximal contraction**, muscle fatigue is accompanied by a decrease in motor unit firing rate and conduction velocity.




EMG Power Spectrum over time

Thus the EMG power density spectrum shifts to the lower frequencies and, consequently, the median frequency and mean frequency decrease.

Median and mean frequencies are therefore considered as good indicators of muscle fatigue. **Median vs. Mean:** Median frequency is found less sensitive to noise and signal aliasing and more sensitive to biomechanical and physiological factors, but more variable at lower frequencies (De Luca).



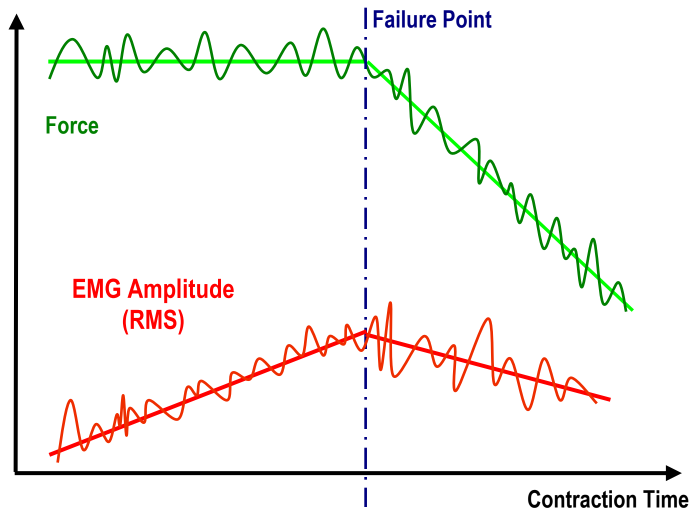

Contractile fatigue (force) vs. metabolic fatigue (EMG median frequency)

With EMG, fatigue can be detected **before** the failure point, at which the contractile force can no longer be maintained. While force remains constant, the median frequency starts decreasing.

Force monitors the contractile fatigue, EMG monitors the metabolic fatigue.

This is a very important control parameter for **prevention of injury or re-injury** in clinical, ergonomics and sports applications.

As the muscle fatigues, additional fibers must be recruited in order to generate the same force. This results in an increase of the EMG amplitude.



EMG amplitude increasing with fatigue

EMG amplitude as a fatigue indicator is used when movement is required, such as in fitness exercises. Note that fatigue is not always something that we want to prevent. For instance, in muscular training, short-term fatigue is a necessity for muscle growth and is actually looked for.

# SEMG BIOFEEDBACK TRAINING

SEMG biofeedback involves measuring the patient's muscle tension and conveying it into an easily comprehensible visual and/or audio feedback. This raises their awareness and conscious control of their muscles, and creates an objective interaction between the patient and the SEMG signal. SEMG biofeedback motivates the patient to play an active role in the rehabilitation process. It also aids the therapist to instruct the patient more efficiently.

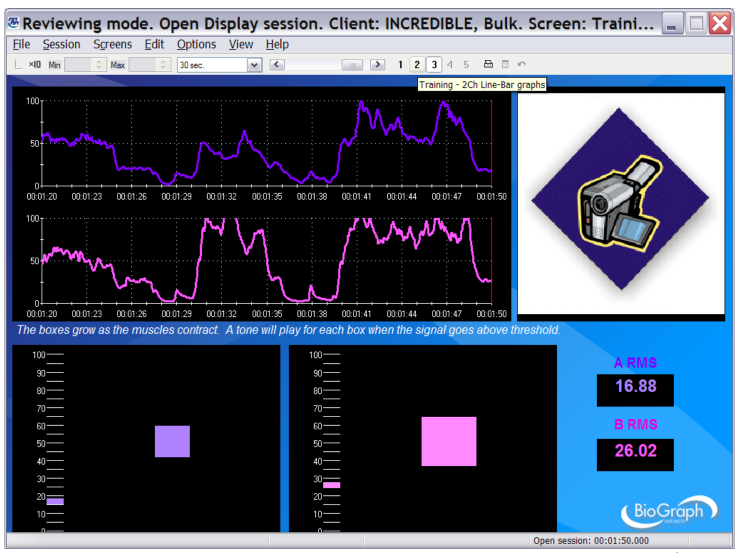
This section suggests several training techniques and examples that will enhance and speed up the rehabilitation thanks to SEMG Biofeedback.

## General Training Techniques

These techniques have been developed by Jeffrey R. Cram and Glenn S. Kasman in “*Clinical Applications in Surface Electromyography”* (referenced at the end of this guide).

### *Isolation of Target Muscle Activity*

The goal of this training protocol is to teach the examinee how to activate the target muscle without co-activating the neighboring muscles or the contra lateral homologous muscles (for instance, contracting the lower trapezius without co-activating the upper trapezius).



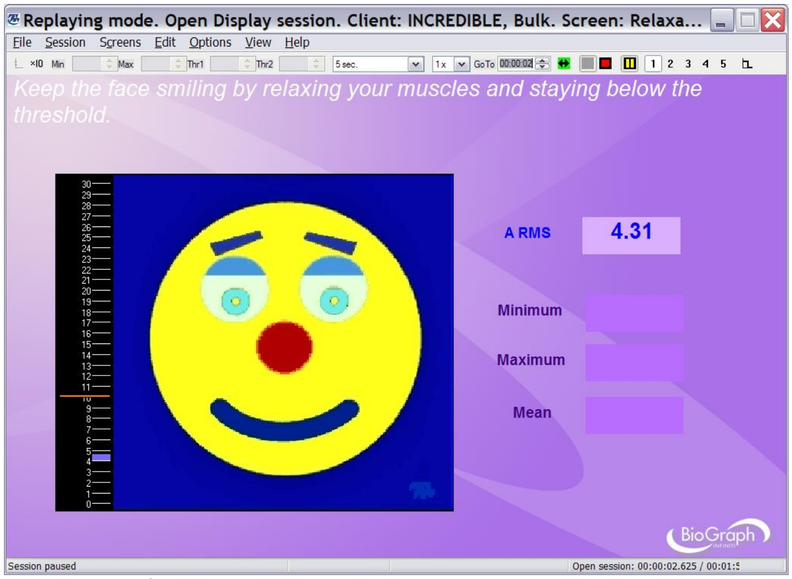

**A proportional sound is played when the square expands past the limit (red line). The left square is for channel A and the right square for channel B. The signals are also displayed on a line graph.**

### *Threshold-based Relaxation Training*

The goal of this training technique is to teach the examinee how to relax hyperactive muscles.

The threshold should be set at about 20%, or a few microvolts below the baseline. The examinee should deactivate the muscle until they reach the threshold.

When the threshold is achieved, progression should be made to more challenging values until a normal resting baseline is achieved (below 5 microvolts).



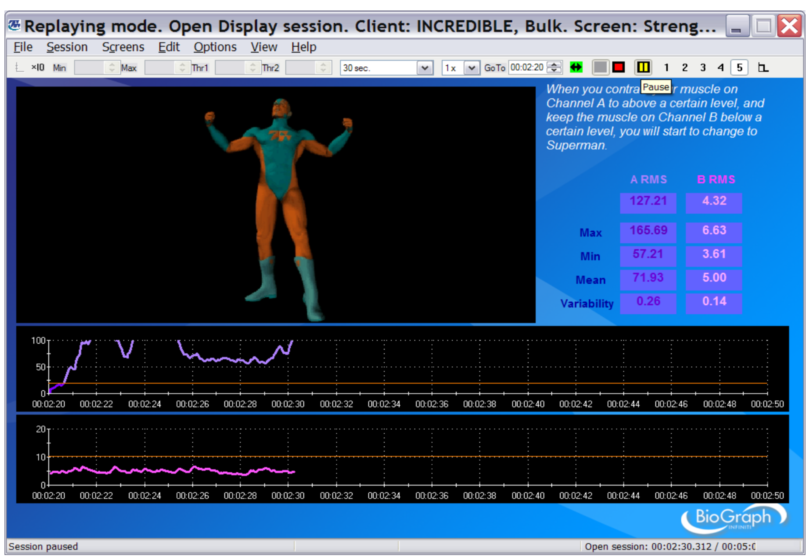

The face will smile when the channel A signal is below the threshold.

## Threshold-based Strengthening

This technique is used to train the examinee to increase the activation of a weak or hypoactive muscle.

The threshold should be set at about 20%, or a few microvolts above the maximum contraction. The examinee should activate the muscle until he reaches the threshold.

When the threshold is achieved, progression should be made to more challenging values. If published standards of muscle activity are not available, compare the muscle with the uninvolved side (maximal force).

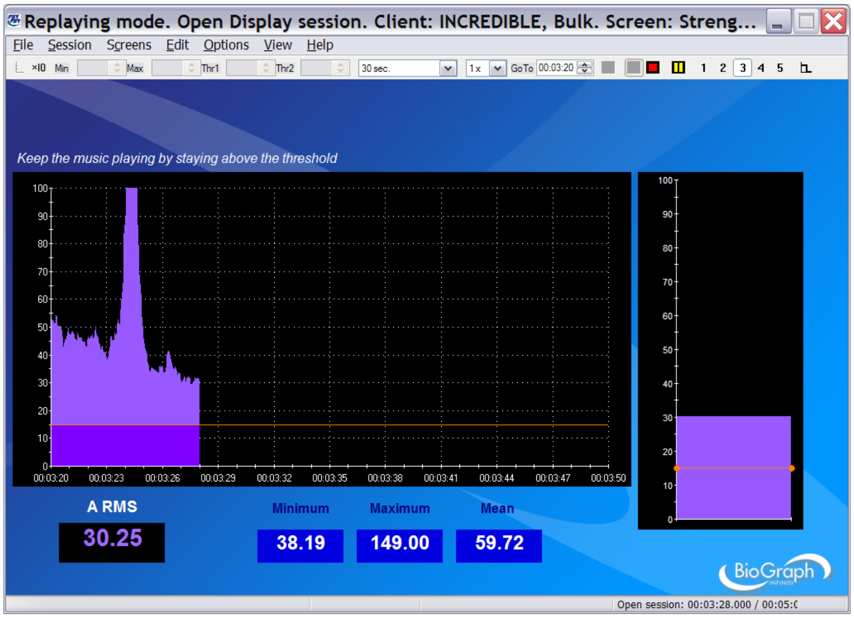



The animation is connected to channel A, and is threshold dependent. Once the signal goes above its threshold the boy slowly morphs into a superman. The complete animation cycle is about 14 seconds. An audio tone is heard when the signal is above the threshold.

## Tension Recognition

When the examinee presents a focally elevated muscle activity with poor subjective recognition of tension sensations, training should be designed to facilitate kinesthetic awareness of tension at an initial change from the baseline level.

The threshold should be set at a small value above the resting baseline. The examinee should activate the muscle until they reach the threshold and maintain this activity for a few seconds. The examinee should pay attention to internal sensations related to joint position and tension. When the examinee has a good control of this technique they should try to tense the muscle to the same value they have been practicing without looking at the SEMG feedback. If the examinee achieves a good result then the threshold value should be lowered, and all the procedures should be repeated.



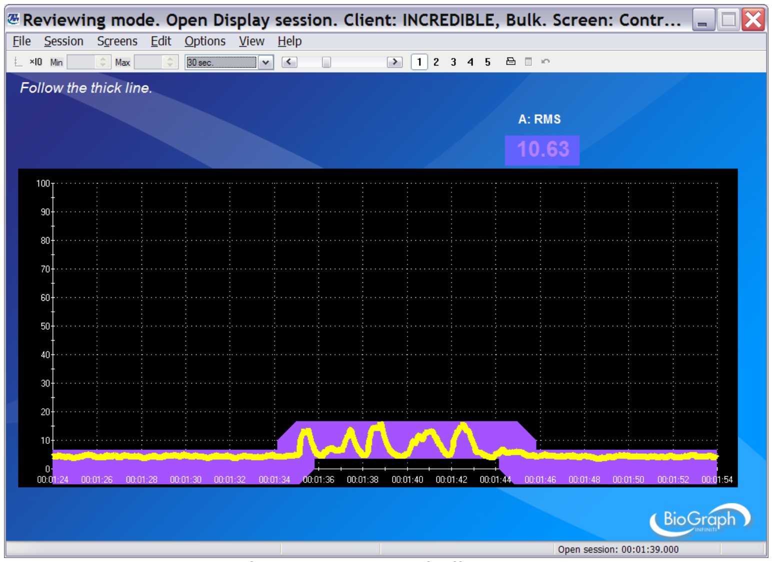

**The signal changes color, and music plays, when channel A goes above the line graph threshold. The bar graph also displays the EMG levels in real time.**

## *Tension Discrimination Training*

This technique is similar to the previous one, except that multiple goal criteria are used, and at higher amplitude values. The intention is that examinees internalize the microvolt scale as they pay attention to the intrinsic kinesthetic feedback. This exercise acts as a precursor to dynamic coordination training.

When starting this exercise, the threshold should be set at 10% of the maximum recruitment ability (or maximal force). The examinee should hold the contraction for about ten seconds and then rest for about 15 seconds. This should be trained several times (10) until the examinee has the ability to match the goal in a consistent manner. Then the threshold should be set at 50 to 75% of the initial threshold, and 10 more trials should be trained.

Then the series should be repeated at smaller values, until 3 to 5 goal points have been trained. The next step is to reproduce each goal level in consecutive 5-second steps without resting periods. Then the order should be reversed so that SEMG activity "ramps" down. In the next step the thresholds should be set in random order. In the final step the examinee should train to activate to a specific threshold without having external feedback.

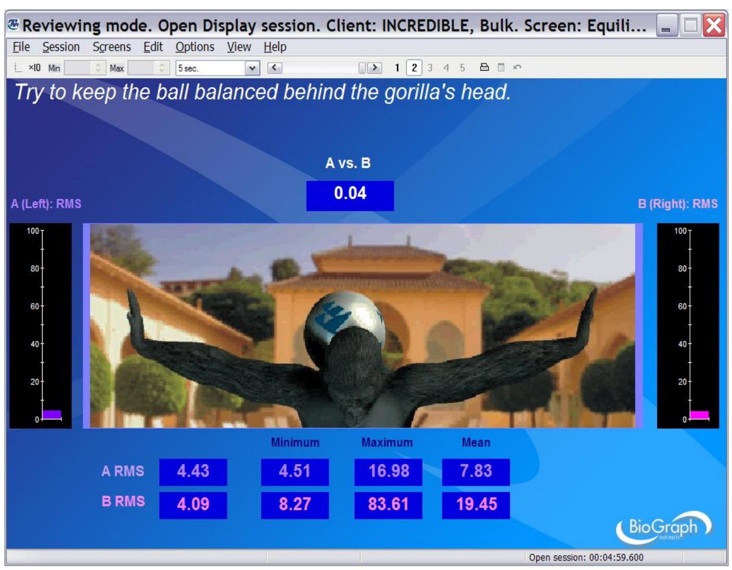



**Each screen contains a template to follow. Three levels of difficulty are available. You can also adjust the level of difficulty by adjusting the graph scale.**

## *Bilateral Equilibration Training*

When homologous muscles act differently during symmetric movement, equilibration training should be performed. (Equilibration refers to bringing the muscles back into equilibrium.)

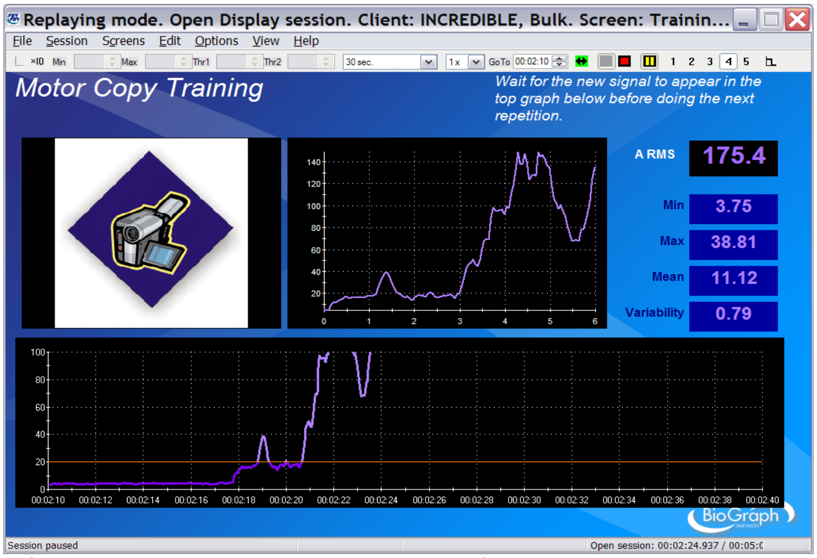
The fastest way to achieve this is to uptrain the muscle that apparently displays hypoactivity. Several authors have noticed that high side activity spontaneously decreases as low side activity is uptrained. Note that the examinee should be able to correctly perform the previous 6 training exercises before being trained in this technique.




**When the muscles are in equilibrium, the ball is balanced on the gorilla's shoulders. When the ball is off to one end or the other, the muscles are progressively more out of balance.**

## *Motor Copy Training*

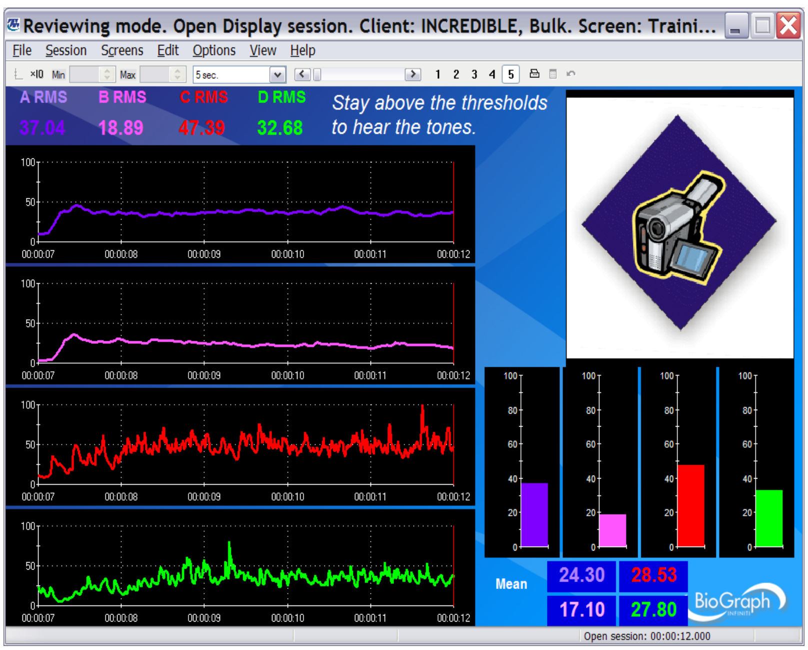
The purpose of this procedure is to train the muscle coordination of the involved side by matching the SEMG pattern of the uninvolved side.




Do the first repetition with the uninvolved side, and then wait for the new signal to appear in the top graph below before doing the next repetition. Then try to reproduce it with the involved side.

## Promotion of Correct Muscles Synergies and Related Coordination Patterns

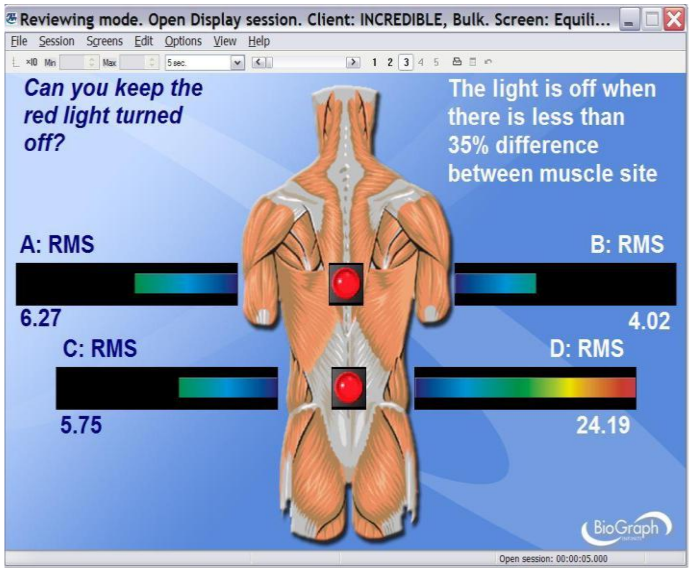
This procedure should be used when the relationship of different muscles in the execution of a specific task is altered. If published standards of muscle activity are not available, compare with the uninvolved side.




The four channels are displayed on a line graph and a bar graph.

## Postural Training

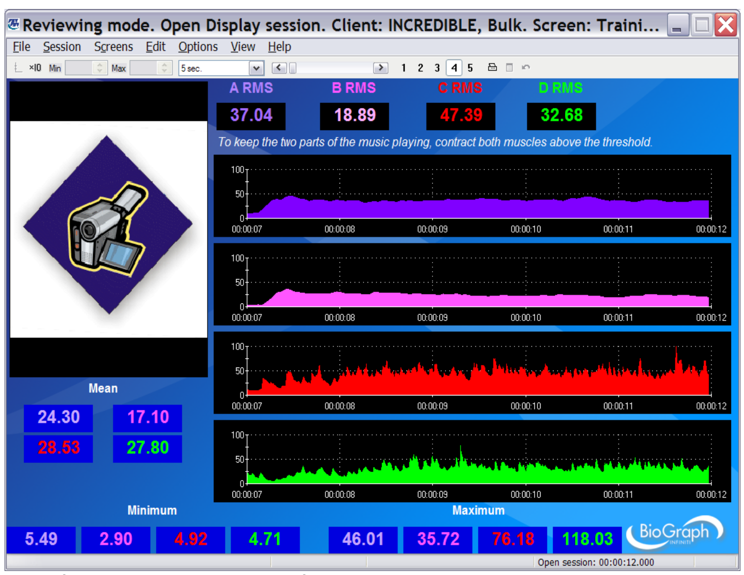
The goal of this technique is to reinforce good posture. The examinee should be trained first with visual and/or audio feedback and then without. Training screens with immediate feedback are recommended.




**The light turns red when the difference is greater than 35%. Both signals are also displayed in the same line graph and bars for comparison.**

## *Selection of Therapeutic Exercises*

The use of SEMG can be very helpful in selecting specific exercises and instructing the examinee on how to do them. SEMG can be used to evaluate the usefulness of a specific exercise and the intensity it should be done at. Training screens that plot the actual signal in a line graph and display real-time statistics are recommended.




**Four filled line graphs display the four channels, with a color change at the threshold.**

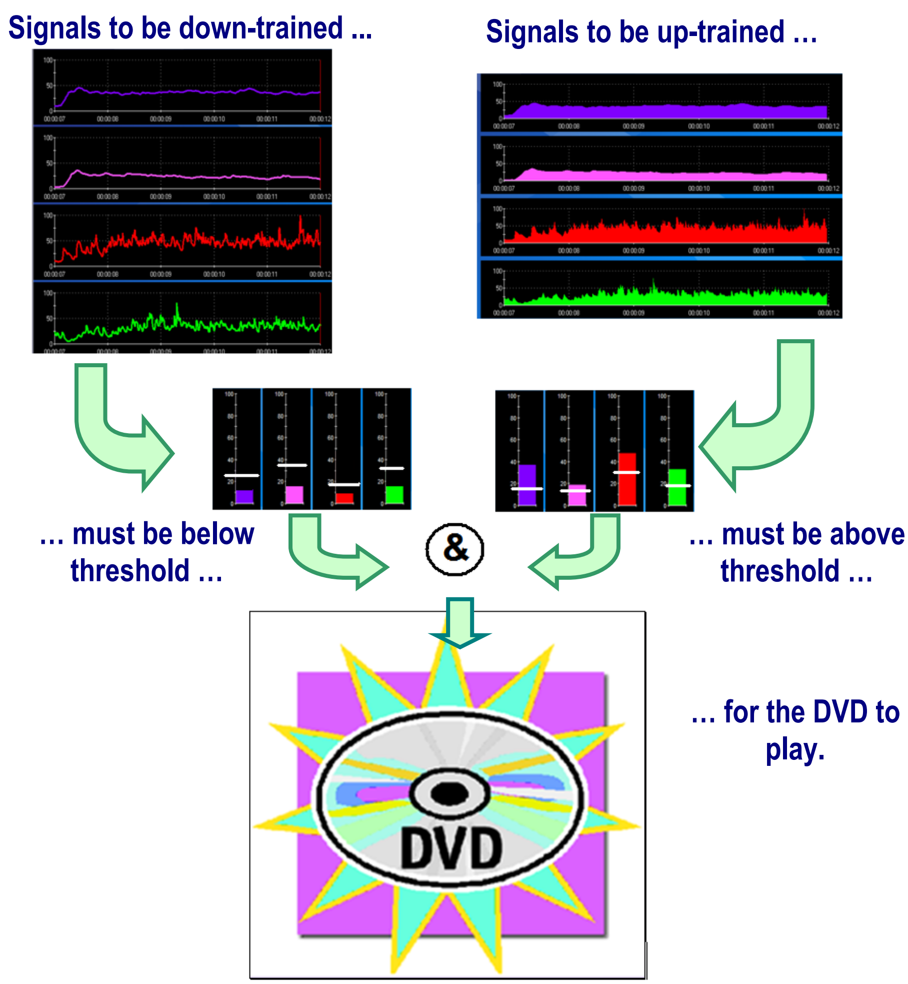
# Restoration of Motor Function

Motor function involves a group of numerous muscles working together in order to perform the movement. Providing independent feedback on each signal is acceptable when there are only a few (generally up to four). When the number of signals becomes significant, as in motor re-education, the patient may feel overwhelmed by the numerous graphs they have to look at and discouraged by the challenge they have to face.

Here, the feedback is given on the ensemble of the signals. The patient gets a reward only if all the muscles simultaneously follow their correct activation pattern. The muscles and their corresponding signals are sorted into two groups: the up-trained and the down-trained. The up-trained muscles are the ones that will be encouraged to fire, such as the agonist and synergists. The down-trained muscles are the ones that will be discouraged to fire, such as the antagonist or substitutes.

"The patient works to master the 'feel' of the muscles when the video is on. Such a task is impossible if the patient needs to rely on watching the jumble of activity of 14 muscle readings on a monitor." (Dr Jeffrey Bolek, Cleveland Clinic Children's Hospital for Rehabilitation, 2007).

When the EMG of the up-trained muscles goes above a threshold and the EMG of the down-trained muscles goes below a threshold, the patient gets a reward. The reward must be motivating and varied.




**Example with 4 signals (screen from Thought Technology's Rehab Suite)**

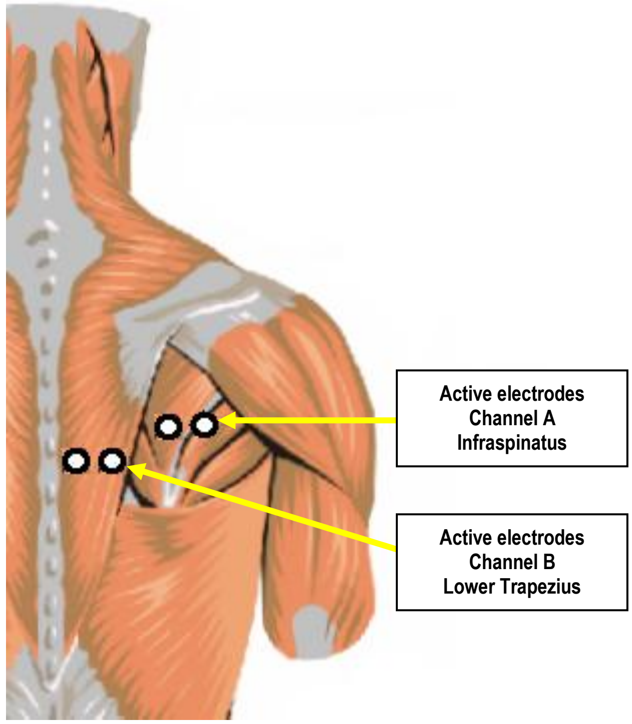
The above screen shows that the patient must relax the muscle connected to signal D (red bar at the bottom-right corner) to perform the correct movement. But the patient does not have to focus on "getting this red bar green, while keeping the 3 green bars green". They only need to focus on finding the way to get the DVD (firemen) to resume.

# The Unstable Shoulder

Anterior shoulder instability is a common athletic complaint associated with overuse, joint laxity, post-traumatic dislocation and muscle imbalance. This protocol uses targeted muscle feedback of external rotators to perfect motor skills.

### Placement of the electrodes:

Place active electrodes horizontally over Infraspinatus (channel A) and the lower trapezius (channel B), as shown in the picture. Do not place them over the posterior deltoid. Place the reference electrodes below the active ones, as far as you can.




### Exercises:

The following exercises guide you through the range of motions that the patient will work through over time, as they develop the control to maintain the correct position with the aid of EMG feedback. The key aim is to ensure that the patient can maintain control within the limits that they have set during the range of motion. If they can, they should move on to increasingly complex movements.


#### Range of Motion 1: Tightening of Rotator Cuff

Guide the patient to pinch their shoulder blades together to the neutral position, in order to glide and hold the humeral head back. When held in this position, note the EMG level. This must be successfully performed 100 times in sets of 10 prior to progressing to the active movements (next exercises). This may take several sessions.


#### Range of Motion 2: Forward Flex, Flexed Elbow

Instruct the patient to forward flex the adducted and neutral rotated shoulder to 90 – 100 degrees, with the elbow in flexion.

As the shoulder is flexed, ensure the patient is still pinching the shoulder blades to achieve the threshold setting noted in Range of Motion 1.

When the patient can perform 100 repetitions, move on to the next exercise.


## Range of Motion 3: Forward Flex, Straight Elbow

Instruct the patient to forward flex the adducted and neutral rotated shoulder to 90 – 100 degrees, with the elbow held straight.

As the shoulder is flexed, ensure the patient is still pinching the shoulder blades to achieve the threshold setting noted in Range of Motion 1.

When the patient can perform 100 repetitions, move on to the next exercise.


## Range of Motion 4: Abduction with Flexion

Instruct the patient to abduct their arms with the arm bent from their slides, while maintaining the shoulder blade pinched.

When the patient can perform 100 repetitions, move on to the next exercise.


## Range of Motion 5: Abduction, Straight Elbow

Instruct the patient to abduct their arms from their slides with the arm straight, while maintaining the shoulder blade pinched.

When the patient can perform 100 repetitions, move on to the next exercise.


## Range of Motion 6: Abduction from Flexion

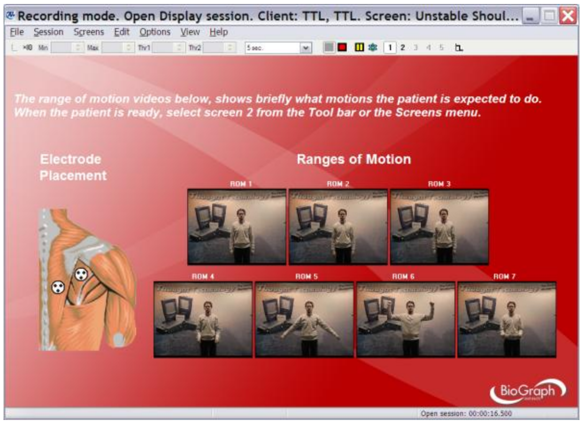
Instruct the patient to abduct their arms from flexion with the arm bent, while maintaining the shoulder blade pinched.

When the patient can perform 100 repetitions, move on to the next exercise.

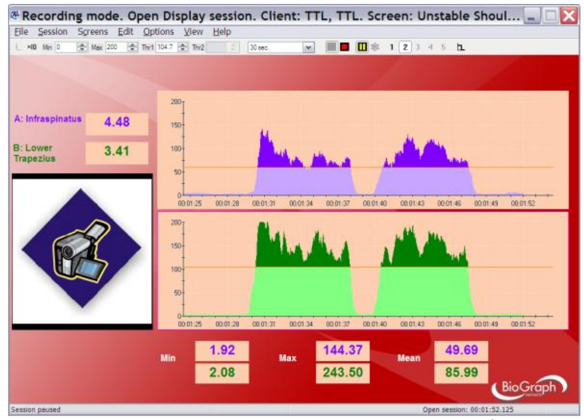

## Range of Motion 7: Abduction from Flexion with Reach-Back

Instruct the patient to abduct their arms from flexion with the arm bent and continue the motion by reaching their hand behind their head, while maintaining the shoulder blade pinched.

When the patient can perform 100 repetitions, move on to the next exercise.




Videos recall the different ranges of motion




A video camera helps the examinee to see themselves performing the motion, while audio and visual feedbacks are given on the Infraspinatus and Lower Trapezius

# RANGE OF MOTION ASSESSMENT

## Principle

Range of Motion (ROM) assessment evaluates the ability of the examinee to achieve the full range of movement for a given part of the body. It allows the therapist to locate and quantify muscle and tendons impairments.

An inclinometer (single or dual) is used for measuring the angle between the neutral position and the maximum range of motion position that the examinee can achieve until they feel restriction, tightness or discomfort.

Two kinds of range of motion are usually assessed:

- **Passive range of motion** (the therapist moves the joint).
- **Free active range of motion** (the examinee moves the joint themselves). "Free" means that the only resistance is the weight of the part of the body. **Resisted active range of motion** (resistance is applied to the limb, such as weights, stretch band or pressure from the therapist) is not used in assessment. It is used in **ROM Therapy** to increase strength and endurance.

It also exists a third kind of ROM which is a tread-off between the two: the **assisted active range of motion**. The therapist applies a force to the limb that helps the examinee to complete the movement.

The previous editions of AMA guides used to favor active range of motion against passive range of motion. Since the 6$^{th}$ edition, they recommend to perform both:

- Active motion may be limited by the muscle (or tendon and/or nerve) failing to execute the motion. In presence of pain, motion may also be limited by muscle guarding or the examinee themselves (self-inhibition).
- Passive motion implies that the muscles are relaxed and the motion is executed by an external force (produced by the therapist). Limitation of passive motion may be caused by a fixed contracture or an impaired antagonist muscle holding back the motion.

Active range of motion should be performed first, because a joint with full active range will have full passive range. In this case, passive range of motion assessment is no longer necessary.

The system proposes two ways of assessing range of motion: **Static ROM** and **Dynamic ROM**.

"Static" means that the measures are taken in static position after the movement is completed, while "dynamic" means that the measures are taken throughout the motion. Dynamic ROM also uses SEMG.

### *Neutral Position Adjustment*

Both use the world standard **Neutral Zero Reference** method. This method defines the 0° angle as referring to the neutral position of the joint.

In the case where the examinee is unable to reach the neutral position, the reference position (when zero button is pressed) can be chosen otherwise and adjusted by software. In this case, one of the measures will be reported negative. For instance, the examinee is able to flex the neck to 50° but not to reach the neutral position (they reach only 15°, for example). Since the neck will stay in flexion, the extension measurement will be negative (-15° in this example). The minus sign is only a convention and has no mathematical meaning.

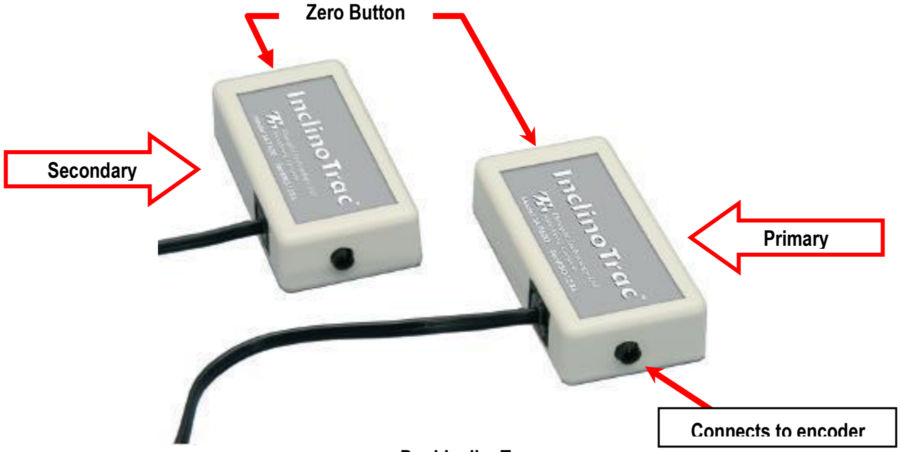
## General Recommendations

This section gives recommendations for ensuring accuracy and consistency of measurement.

### *Being familiar with the tools*

The single inclinometer is called InclinoTrac.

The dual inclinometer is called Dual-InclinoTrac (see picture below), and is two InclinoTracs connected together.

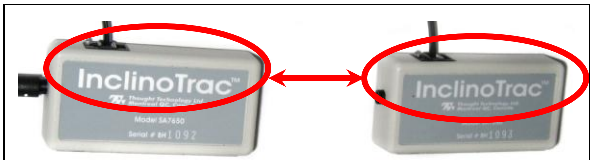


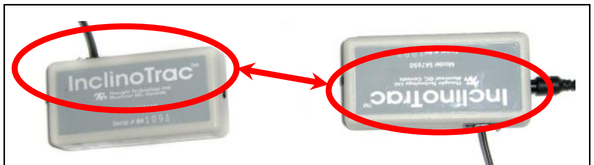
Dual-InclinoTrac

The plug at one end is used to connect the inclinometer to the encoder. The Zero button at other end is used to mark the neutral zero.

Two devices are connected together by a cable. The connector is on the side of the device (see picture above). The inclinometer connected to the encoder is then called the "**primary**". The other one is called the "**secondary**".

The dual inclinometer outputs the angle between the primary and secondary devices. The primary and secondary must be oriented so that the "InclinoTrac" labels face the same way. Either zero button can be used to mark the neutral position.


Correctly oriented


Incorrectly oriented

## *Calibrating the Inclinometer (zeroing)*

Make sure your inclinometer is properly calibrated. The inclinometer must be calibrated when, if you press the zero button, the screen does not display the value "0" (zero).

## *Straps or No Straps?*

That is the question. Straps were designed to be used for dynamic ROM assessment, ROM therapy and for the static ROM assessment of the extremities. Holding manually the inclinometers is strongly recommended in the case of static spine assessment. However, straps may be used to assist you in holding the inclinometers (on the head, for instance) and avoid them to slip, or when you assist the examinee in a passive motion.

If you manually handle the inclinometers, make sure you apply a constant pressure throughout the range of motion.

If you use a strap to attach the inclinometer, make sure that the strap is secured and cannot move against the body part during the motion.

Also check that the inclinometer is firmly fixed to the strap. To do this, press it against the strap and twist it sideways two or three times, so that the hooks and loops are thoroughly enmeshed.

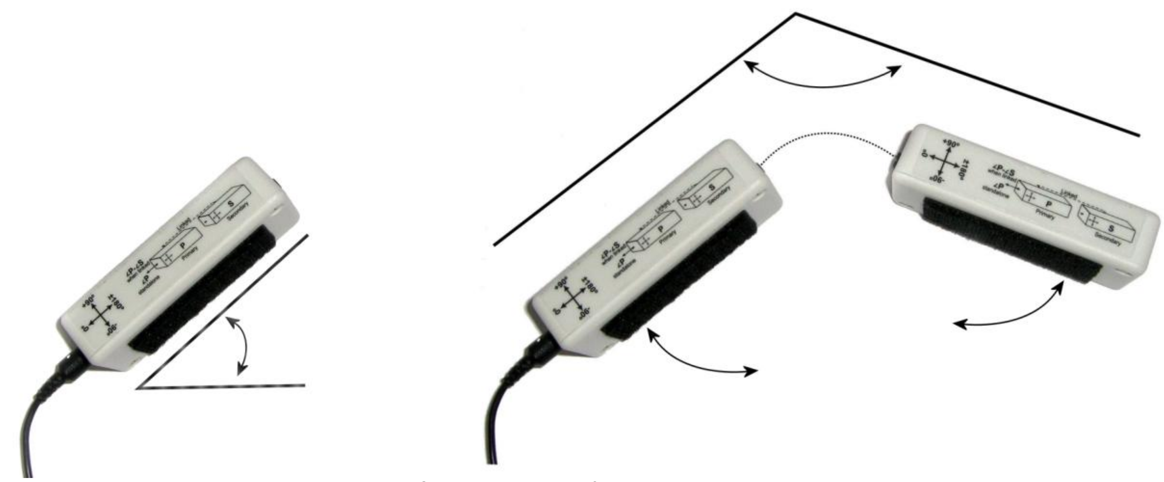

Twist the inclinometer sideways two or three times while holding it firmly against the strap

This will ensure the inclinometer keeps the same orientation against the body part in motion and does not slip from its original position.

## *Proper orientation*

The guide suggests positions of the inclinometers for each range of motion. You may find that different positions are more convenient for you or the examinee.

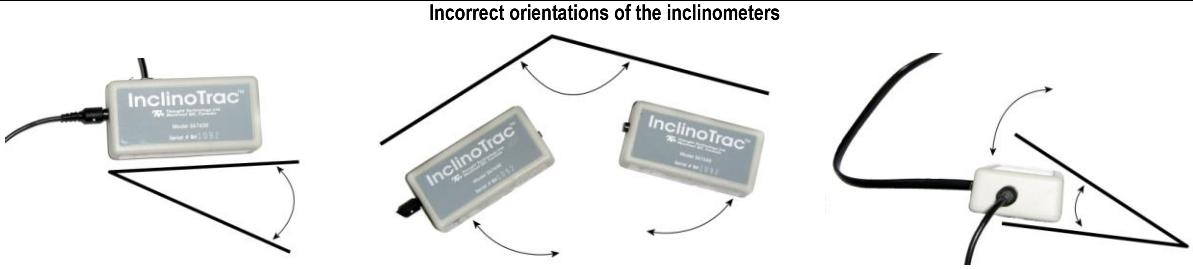
However, you have to pay attention to the orientation of the inclinometers. The **first motion** of the two (for instance, “flexion” in “flexion/extension”) must give a **positive angle** and the **second motion** (“extension”) a **negative angle**. The system will rectify the angles in the report according to this rule.



Correct orientation of the inclinometers

Always keep the side with the inclinometer plug within 45° of the vertical plane and parallel to the plane of motion.

Incorrect orientations of the inclinometers




## *Preparing and Instructing the Examinee*

The examinee should be physically prepared with warm-up exercises.

The examinee should also be instructed that the exercise is simple and not painful. The exercise should be demonstrated and explained. This will reduce the examinee's anxiety and increase their cooperation to the exercise.

# Static Range of Motion Assessment

"Static" refers to the fact that the measures are taken in static position after the movement is completed. Static ROM is a quantitative measure of the range of motion. It does not assess the way the motion is performed, as **Dynamic ROM** does.

Static ROM should be preferred when accuracy is required. Static ROM procedure allows the therapist to stabilize the position at the end of the range of motion, which is required for consistency in the measurement.

Static ROM is required when the examinee is unable to perform an active motion.

Static ROM should be correlated with other results, such as from **general SEMG assessment**, and, if the examinee is able to perform an active motion, **dynamic SEMG assessment** or **dynamic range of motion** with SEMG. SEMG may help to see muscle hypotonicity or hypertonicity, muscle guarding (co-contraction) or antagonist muscle impairment.

## *Procedure*

Positioning and selection of the type of inclinometer are specified for each joint and motion later in this chapter.

***Preparing for measurement with a dual-inclinometer***

- Prepare the examinee (instruction and warm-up)
- Identify anatomical landmarks for positioning the dual-inclinometer. Affix the straps if any.
- Position yourself next to the examinee, with the pedal near your foot.
- Position and stabilize the examinee in neutral position.
- Position the dual-inclinometer on the examinee and press the Zero button (on the primary or secondary, whichever is more convenient for you).

***Preparing for measurement with a single-inclinometer***

- Prepare the examinee (instruction and warm-up).
- Affix the strap to the joint.
- Affix the encoder on your belt and position yourself next to the examinee, with the pedal near your foot.
- Affix the inclinometer on the strap.
- Position and stabilize the examinee in neutral position.
- When the position is stabilized, press the Zero button.

***Measuring***

- Instruct the examinee to perform the motion slowly, until they feel restriction, tightness or discomfort.
- Make sure the inclinometer does not move against the body part during the motion.
- When the position is stabilized, press the pedal to record the measure.
- Instruct the examinee to go back to neutral position. **Do not press the Zero button again**.
- Repeat the exercise.

Multiple measurements are recommended to limit variation in the results. The system takes six measurements and keeps only the three last consecutive valid measures. Measures are considered as valid if they are within +/-5° or +/-10% of the average of the three.

## *Analyzing the results*

This guide proposes AMA normative data for comparison with the measures. They may also be compared to the opposite extremity if not involved or previously injured.

# SROM – Cervical Spine

### *Flexion/Extension*

***Neutral Position***

***Flexion***

***Extension***

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer | | |
| **Examinee Position:** | Seated on a chair or standing upright | | |
| **Inclinometer Position:** | Primary back on T1 parallel to the spine; secondary back on the top of the head, perpendicular to the shoulders. | | |
| **Normal ROM:** | Flexion | 50° | **Validity of the trials:** |
| | Extension | 60° | Within 5° or 10% of another |

### *Left/Right Lateral Flexion*

***Neutral Position***

***Left Lateral Flexion***

***Right Lateral Flexion***

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer | | |
| **Examinee Position:** | Seated on a chair or standing upright | | |
| **Inclinometer Position:** | Primary side on T1 parallel to the spine; secondary on the head | | |
| **Normal ROM:** | Left Lateral Flexion | 45° | **Validity of the trials:** |
| | Right Lateral Flexion | 45° | Within 5° or 10% of another |

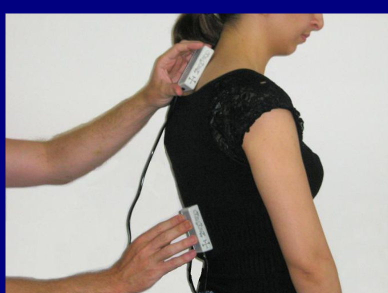
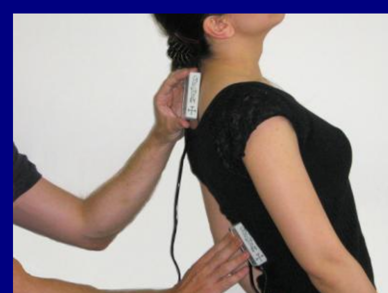
### *Left/Right Rotation*

| ***Neutral Position*** | ***Left Rotation*** | ***Right Rotation*** |
|---|---|---|
|  |  |  |

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer | | |
| **Examinee Position:** | Knees and hands on the floor, head horizontal, or in supine position | | |
| **Inclinometer Position:** | Primary side on T1 perpendicular to the spine; secondary on the head | | |
| **Normal ROM:** | Left Rotation 80°<br>Right Rotation 80° | | **Validity of the trials:**<br>Within 5° or 10% of another |

## SROM – Thoracic Spine

### *Flexion/Extension*

| ***Neutral Position*** | ***Flexion*** | ***Extension*** |
|---|---|---|
|  |  |  |

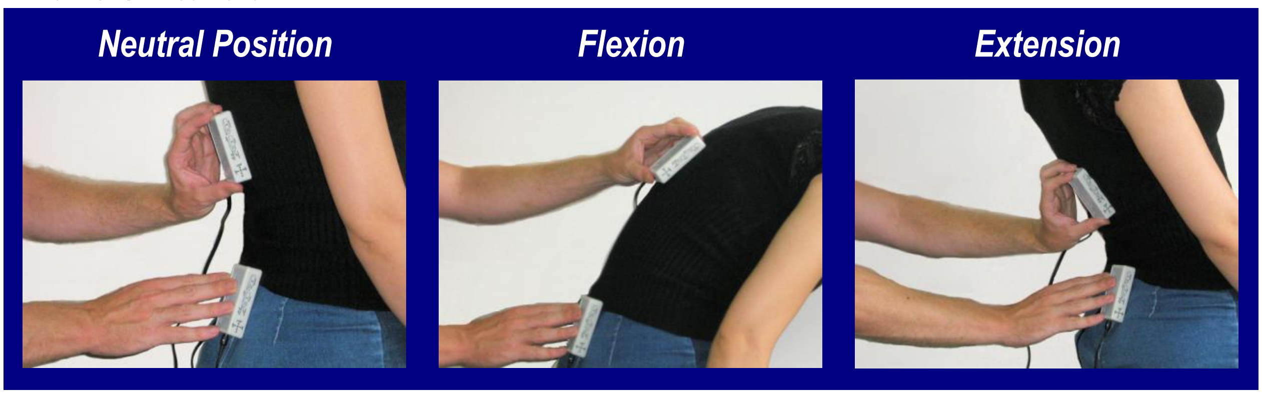
| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer | | |
| **Examinee Position:** | Standing upright | | |
| **Inclinometer Position:** | Primary on T12 and secondary on T1; both parallel to the spine. | | |
| **Normal ROM:** | Flexion 60°<br>Extension 10° | | **Validity of the trials:**<br>Within 5° or 10% of another |

### *Left/Right Rotation*


| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer | | |
| **Examinee Position:** | Standing position, bending forward | | |
| **Inclinometer Position:** | Primary on T12 and secondary on T1; both perpendicular to the spine. | | |
| **Normal ROM:** | Left Rotation | 30° | **Validity of the trials:** |
| | Right Rotation | 30° | Within 5° or 10% of another |

## SROM – Lumbar Spine

### *Flexion/Extension*




| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer | | |
| **Examinee Position:** | Standing upright | | |
| **Inclinometer Position:** | Primary on S1 and S2, secondary on T12; both parallel to the spine. | | |
| **Normal ROM:** | Flexion | 50° | **Validity of the trials:** |
| | Extension | 20° | Within 5° or 10% of another |

### *Left/Right Lateral Flexion*

| *Neutral Position* | *Left Lateral Flexion* | *Right Lateral Flexion* |
|---|---|---|
|  |  |  |

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer | | |
| **Examinee Position:** | Standing upright | | |
| **Inclinometer Position:** | Side of primary on S1 and S2, side of secondary on T12; both parallel to the spine, front facing left. | | |
| **Normal ROM:** | Left Lateral Flexion<br>Right Lateral Flexion | 30°<br>30° | **Validity of the trials:**<br>Within 5° or 10% of another |

## SROM – Shoulder

### *Flexion/Extension*

| *Neutral Position* | *Flexion* | *Extension* |
|---|---|---|
|  |  |  |

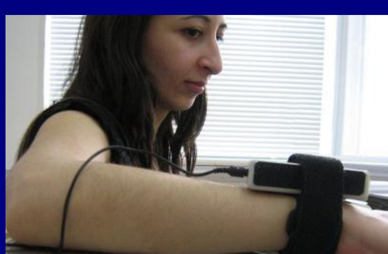
| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer with strap | | |
| **Examinee Position:** | Seated, uninvolved shoulder flexed 90°. | | |
| **Normal ROM:** | Flexion<br>Extension | 180°<br>50° | **Validity of the trials:**<br>Within 5° or 10% of another |

## Abduction/Adduction in 30° Flexion

| Neutral Position | Abduction | Adduction |
|---|---|---|
|  |  |  |

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer with strap | | |
| **Examinee Position:** | Seated, uninvolved shoulder abducted 90°.<br>For adduction: involved shoulder flexed 30°. | | |
| **Normal ROM:** | Abduction 160°<br>Adduction 30° | | **Validity of the trials:**<br>Within 5° or 10% of another |

## External/Internal Rotation

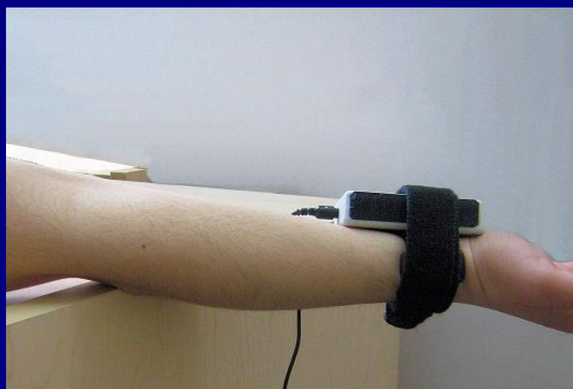
| Neutral Position | External Rotation | Internal Rotation |
|---|---|---|
|  |  |  |

| | | |
|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer with strap | |
| **Examinee Position:** | Seated, shoulder abducted 90° and elbow flexed 90°. | |
| **Normal ROM:** | External Rotation 90°<br>Internal Rotation 90° | **Validity of the trials:**<br>Within 5° or 10% of another |

# SROM – Elbow

## *Flexion/Extension*

***Neutral Position***



***Flexion***

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer with strap | | |
| **Examinee Position:** | Seated, or supine position with elbow stabilized on examining table. | | |
| **Normal ROM:** | Flexion<br>Extension | 135°<br>0° | **Validity of the trials:**<br>Within 5° or 10% of another |

# SROM – Forearm

## *Supination/Pronation*

***Neutral Position***

***Supination***

***Pronation***

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer | | |
| **Examinee Position:** | Seated, elbow flexed 90°, uninvolved side abducted 90°. | | |
| **Normal ROM:** | Supination<br>Pronation | 90°<br>90° | **Validity of the trials:**<br>Within 5° or 10% of another |

# SROM – Wrist

## *Flexion/Extension*

***Neutral Position***

***Extension***

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer | | |
| **Examinee Position:** | Seated, or with pronated forearm stabilized on examining table. | | |
| **Normal ROM:** | Flexion<br>Extension | 50°<br>60° | **Validity of the trials:**<br>Within 5° or 10% of another |

## *Radial/Ulnar Deviation*

***Neutral Position***

***Radial Deviation***

***Ulnar Deviation***

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer | | |
| **Examinee Position:** | Seated, or with forearm stabilized on examining table. | | |
| **Normal ROM:** | Radial Deviation<br>Ulnar Deviation | 20°<br>30° | **Validity of the trials:**<br>Within 5° or 10% of another |

# SROM – Hip

## *Flexion/Extension*

***Neutral Position***

***Flexion***

***Extension***

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer with strap | | |
| **Examinee Position:** | For flexion: in supine position with pelvis and lower extremities stabilized on the table<br>For extension: trunk and pelvis in prone position on the table, uninvolved hip in 90° flexion. | | |
| **Normal ROM:** | Flexion<br>Extension | 100°<br>30° | **Validity of the trials:**<br>Within 5° or 10% of another |

## *Abduction/Adduction in 30° Flexion*

***Neutral Position***

***Abduction***

***Adduction***

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer with strap | | |
| **Examinee Position:** | Side-lying on the table. | | |
| **Normal ROM:** | Abduction<br>Adduction | 45°<br>30° | **Validity of the trials:**<br>Within 5° or 10% of another |

### *External/Internal Rotation*

| *Neutral Position* | *External Rotation* | *Internal Rotation* |
|---|---|---|
|  |  |  |

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer with strap | | |
| **Examinee Position:** | Supine | | |
| **Normal ROM:** | External Rotation | 50° | **Validity of the trials:** |
| | Internal Rotation | 40° | Within 5° or 10% of another |

## SROM – Knee

### *Flexion/Hyperextension*

| *Neutral Position* | *Flexion* |
|---|---|
|  |  |

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer with strap | | |
| **Examinee Position:** | Prone, with foot vertical in rest position and knee beyond the end of the table. | | |
| **Normal ROM:** | Flexion | 150° | **Validity of the trials:** |
| | Hyperextension | 0° | Within 5° or 10% of another |

# SROM – Ankle

## *Flexion/Extension*

| ***Neutral Position*** | ***Flexion*** | ***Extension*** |
|---|---|---|
|  |  |  |

| | | | |
|---|---|---|---|
| **Type of Inclinometer:** | Single-Inclinometer | | |
| **Examinee Position:** | Prone, with foot vertical in rest position (beyond the end of the table) | | |
| **Normal ROM:** | Flexion | 40° | **Validity of the trials:** |
| | Extension | 20° | Within 5° or 10% of another |

# Dynamic Range of Motion Assessment

Dynamic Range of Motion assesses the examinee throughout motion and is mostly qualitative (how the movement is produced). It combines inclinometry and SEMG. It allows the therapist to assess the contribution of the tendons and the muscles to the movement. It highlights hesitation in the movement, and how and when the muscles fire during the movement.

# *Limitations:*

Examinee must be able to perform active ROM. SROM is still required for passive ROM. If accurate measure of ROM is required, SROM is still recommended.

# *Procedure*

Examples of positions of the inclinometer are shown later in this chapter.

The muscles involved in the motion are listed in the chapter "Muscle Properties" and recommendations for electrode placements in ***Introduction to Surface Electromyography***. It is also recommended to be familiar with the section "Dynamic SEMG Assessment".

### *Preparing for measurement*

- Prepare the examinee (instruction and warm-up)
- Prepare the skin for SEMG and position the electrodes.
- Affix the strap to the joint or the workout machine, and the inclinometer on the strap.
- Affix the encoder on the examinee's belt.
- Position yourself next to the examinee.
- Position and stabilize the examinee in neutral position.
- When the position is stabilized, press the Zero button.


**Single-InclinoTrac positioned on a workout machine**

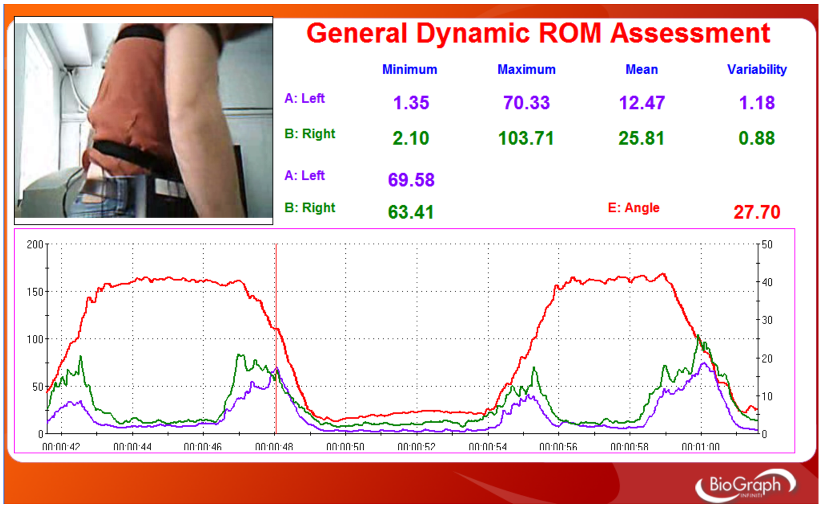
**Dual-InclinoTrac positioned along the spine**

### *Measuring*

- Instruct the examinee to perform the motion slowly, until they feel restriction, tightness or discomfort.
- Make sure the inclinometer does not move against the body part during the motion.
- Instruct the examinee to go back to neutral position. **Do not press the Zero button**.
- Instruct the examinee in the movement and ask them to do it a couple of times before starting the recording.
- Record several repetitions of the movement. If the software does not (no predefined protocol), mark the different stages of the movement with event makers (events can be marked by hitting the space bar or a key of the keyboard that you would have preliminarily labeled with the name of the event). Video is also a great asset.

## *Analyzing the results*

The analysis is qualitative and is similar to the Dynamic SEMG Assessment. The inclinometer also allows the therapist to see if the examinee is able to complete the motion and repeat it consistently.

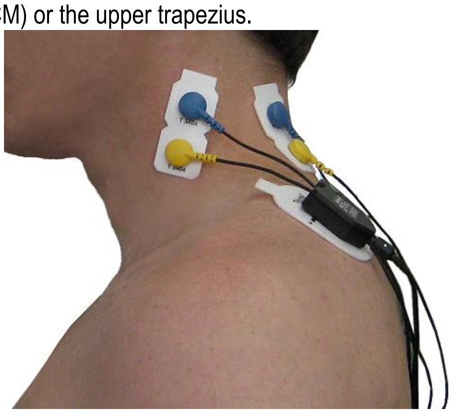


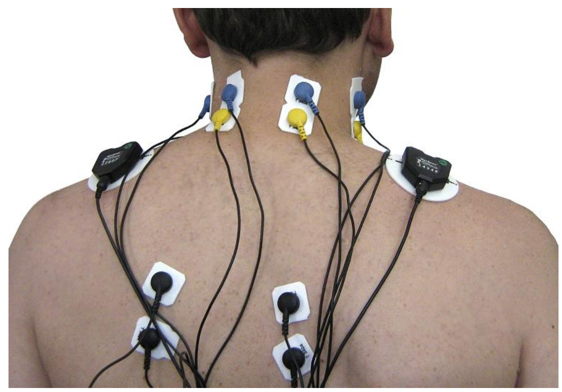
Inclinometry (red line) with 2 SEMG and video for lumbar flexion/extension

# DROM – Cervical Spine

## *EMG Sites*

Cervical Spine Assessment is performed with monitoring the cervical paraspinals (CP) and either the sternocleidomastoids (SCM) or the upper trapezius.





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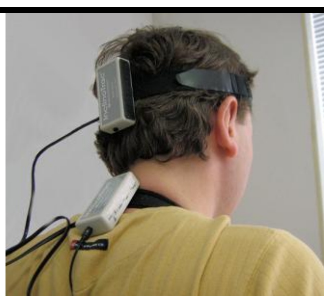
**Note:** *For illustrative purposes, this image shows electrode placement for both sternocleidomastoids and upper trapezius. In a clinical situation, you would monitor either SCM or trapezius, but not both.*

---

## *Flexion/Extension*


Position of the Inclinometer

| | | |
|---|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer | |
| **Examinee Position:** | Seated on a chair or standing upright | |
| **Inclinometer Position:** | Primary manually held on T1 parallel to the spine; secondary strapped on the head. | |
| **Normal ROM:** | Flexion | 50° |
| | Extension | 60° |

## *Left/Right Lateral Flexion*

**Position of the Inclinometer**

| | |
|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer |
| **Examinee Position:** | Seated on a chair or standing upright |
| **Inclinometer Position:** | Primary manually held on T1 perpendicular to the spine; secondary strapped on the head |
| **Normal ROM:** | Left Lateral Flexion 45° |
| | Right Lateral Flexion 45° |

## *Left/Right Rotation*

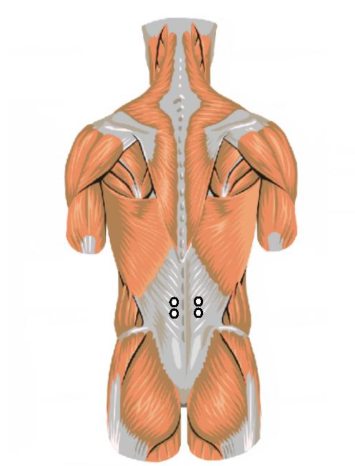
**Position of the Inclinometer**

| | |
|---|---|
| **Type of Inclinometer:** | Dual-Inclinometer |
| **Examinee Position:** | Knees and hands on the floor, head horizontal, or in supine position |
| **Inclinometer Position:** | Primary side on T1 perpendicular to the spine; secondary on the head |
| **Normal ROM:** | Left Rotation 80° |
| | Right Rotation 80° |

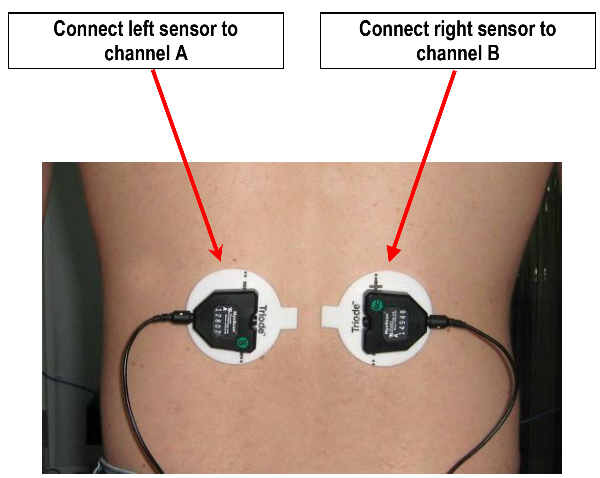
# DROM – Lumbar Spine

## *EMG Sites*

Place the sensors on the erector spinae muscles with active electrodes (marked by a "+" and a "-") in line with the spine and facing L3, as shown below, with the examinee in a slightly bent position to stretch the skin and aid adhesion.



**Active electrodes (marked by a "+" and a "-") in line with the spine and facing L3**




**Note that the sensors should be placed to mirror one another, as shown.**

## *Flexion/Extension*

| | | | |
|---|---|---|---|
|  Position of the Inclinometer | **Type of Inclinometer:** | Dual-Inclinometer | |
| | **Examinee Position:** | Standing upright | |
| | **Inclinometer Position:** | Primary on S1 and S2, secondary on T12; both strapped parallel to the spine. | |
| | **Normal ROM:** | Flexion | 50° |
| | | Extension | 20° |

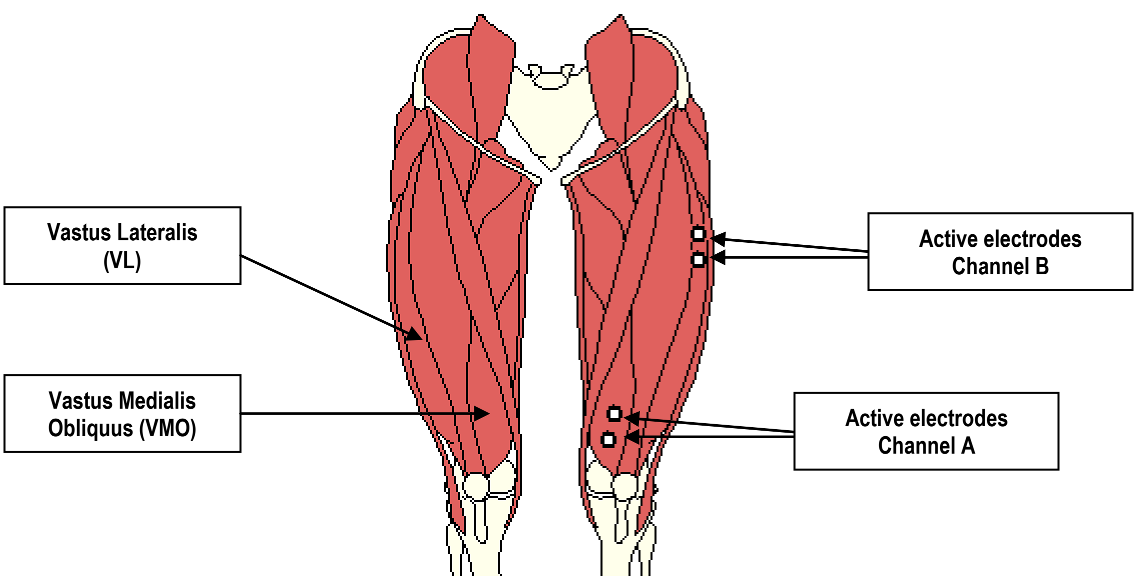
## *Left/Right Lateral Flexion*

| | | | |
|---|---|---|---|
|  Position of the Inclinometer | **Type of Inclinometer:** | Dual-Inclinometer | |
| | **Examinee Position:** | Standing upright | |
| | **Inclinometer Position:** | Side of primary on S1 and S2, side of secondary on T12; both parallel to the spine, front facing left. | |
| | **Normal ROM:** | Left Lateral Flexion | 30° |
| | | Right Lateral Flexion | 30° |

# DROM – Anterior Knee

## *EMG Sites*

Place the active electrodes of channel A on the Vastus Medialis Obliquus (VMO) and the active electrodes of channel B on the Vastus Lateralis (VL), as shown in the picture. The reference electrodes have to be placed proximally (above the active electrodes, closer to the trunk).



## *Position of the Inclinometer*

| | | |
|---|---|---|
| <br>**Position of the Inclinometer** | **Type of Inclinometer:** | Dual-Inclinometer |
| | **Examinee Position:** | Standing upright |
| | **Inclinometer Position:** | Primary on upper leg, secondary on lower leg. |

# RANGE OF MOTION THERAPY WITH BIOFEEDBACK

## Overview

Range-of-motion therapy usually consists of simple exercises to increase the range of motion, flexibility, strength, endurance and control over the movement.

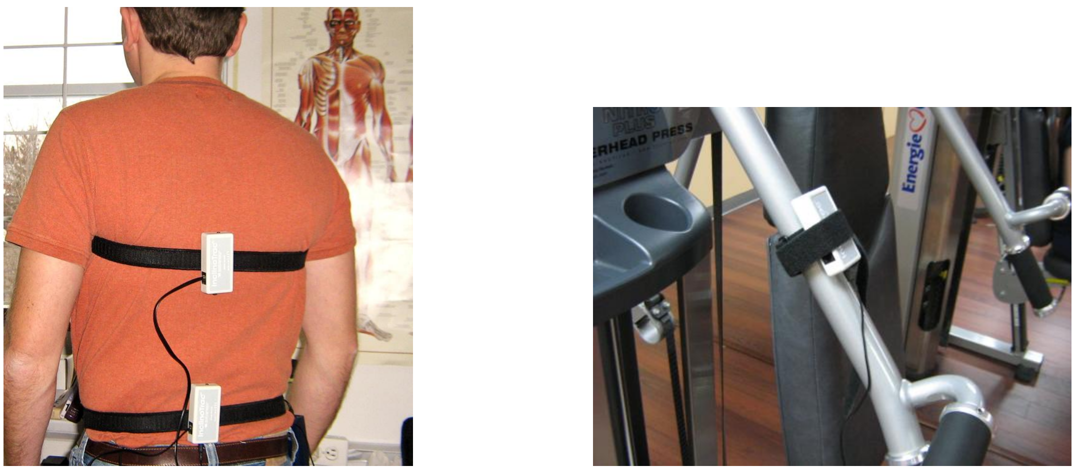
The difficulty of the exercise will vary by the degree of resistance (assisted, free or resisted movements). Assisted and free active movements are used to increase range of motion, strength and flexibility. Resisted active movement exercises are used to increase strength and endurance. Isometrically resisted active movements are used to increase strength and control.

High-repetition exercises are more recommended than intensive exercises, since muscles fatigue rapidly after injury. General postural training is as important as strengthening and stretching.

Painful or forced stretching must be avoided. It will trigger muscle guarding and activation of the spasm/pain cycles.

## How does ROM Therapy benefit from Biofeedback?

The inclinometer used for assessment can also be used for training. It allows the examinee to visualize the exercise and perform it in an entertaining way.



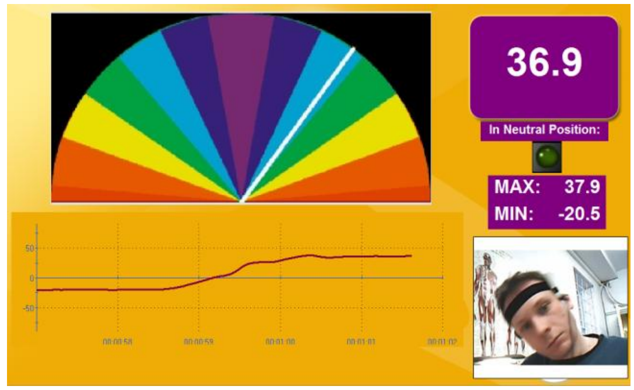

**The inclinometer can be positioned on the examinee or the workout machine**

Biofeedback is known to:

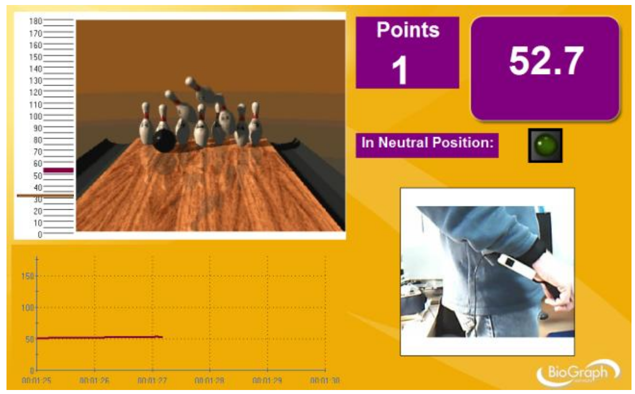
- Raise the examinee's awareness and conscious control of the related movement.
- Accelerate the therapist's instruction to the examinee, and the examinee's ability to complete specific movements.
- Increase the examinee's motivation and their implication in the rehabilitation process.

In this screen, the examinee is being trained to keep his neck in neutral position, by keeping the ball centered behind the monkey's neck. When he is successful, the green light turns on.

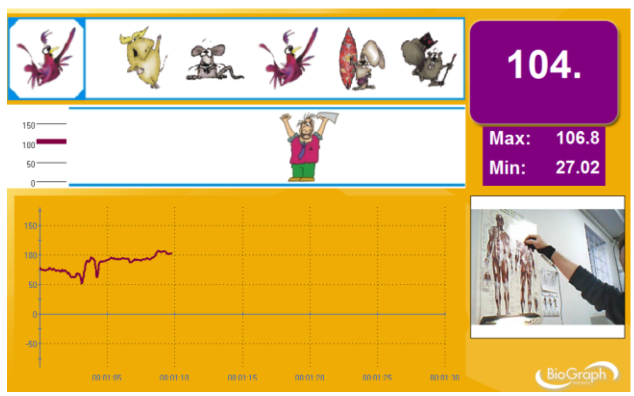
Here is a stretching exercise. The examinee is told to reach a given color on the rainbow, by flexing laterally his neck.




This is a threshold-based exercise. The examinee must flex the elbow until a threshold is crossed. When this happens, the animation starts and the bowl is thrown. The examinee must hold the position during 5 seconds to do a strike and get a point. He must then go back to neutral position (elbow extended) to restart.

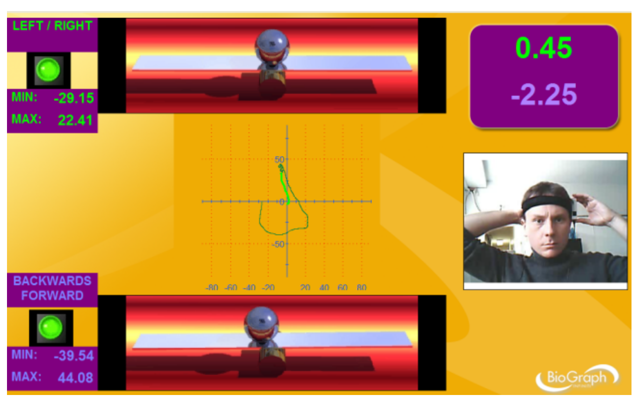



Here, the examinee has to align the character with the animal appearing in the left box, by moving his forearm up and down (for shoulder flexion, abduction or rotation).

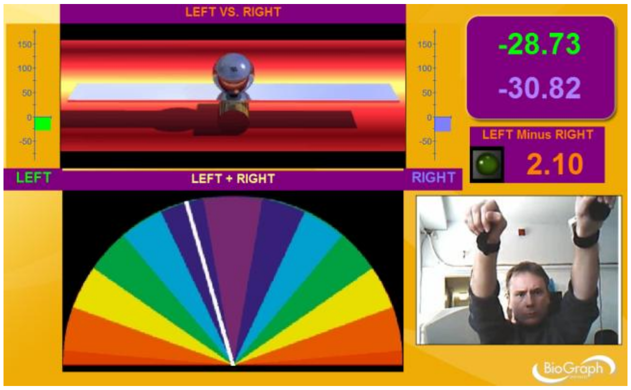



The second part of the dual-InclinoTrac can also be used as a single one. You can use them jointly, either for working on the three dimensions or bilateral training.

In this screen, the inclinometers are positioned at the back and the left of the head. The examinee can train to keep his head straight (line in the center of the lissajous graph, the balls in the middle of the balance and the green lights turned on). He can also roll his head around his neck and see where his ROM is limited.



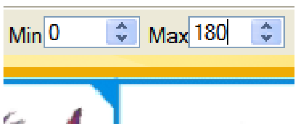
The inclinometers are here attached to his wrists. He has to elevate both arms in the same time to keep the ball centered on the balance. The line on the rainbow gives the averaged angle between the two sides.




## Procedure

- Prepare the examinee (instruction and warm-up).
- Affix the strap to the joint or workout machine and the inclinometer on the strap.
- Affix the encoder on the examinee's belt.
- Position yourself next to the examinee.
- Position and stabilize the examinee in neutral position.
- When the position is stabilized, press the Zero button.
- Adjust the sensitivity of the animation on the screen in order to reflect the range of motion of the joint that you are training.
    - Select the animation by clicking on it. A thin red frame will appear around it.


    - Then type the desired range of motion in **Min** and **Max**.



# MANUAL MUSCLE TESTING

## Overview

Manual muscle testing is the assessment of muscles and tendons and their ability to generate force. Computerized manual muscle testing improves and enriches a method that has existed and evolved for almost a century, by replacing subjective factors with objective data.

## Warnings and Precautions

Manual muscle testing requires skill and experience. The examiner needs training and a lot of practice to be able to perform accurate testing.

This guide is not intended to replace literature on the subject. It only gives general guidelines and recommendations for the accurate use of computerized instruments along with traditional muscle testing. However, if the muscle testing technique has been mastered, the use of the computerized system is fairly straightforward.

Manual muscle testing requires specialized skills. The system is intended only to capture an objective record of force applied during testing, rather than to reduce the risk of injury. **Therefore the ultimate responsibility for risk of injury rests with the examiner**.

The examinee should be monitored closely and tests should be terminated immediately if there is any evidence of pain.

## Limitations

Manual muscle testing assesses the activity of a group of muscles, as well as tendons. In spite of all precautions to isolate the prime mover (agonist), it cannot always prevent the recruitment of synergist muscles, which is inherent to joint motion. Stronger muscles could also substitute for a weak agonist (despite all precautions). Or the antagonist could thwart the agonist muscle. In this case, the impaired muscle may be the antagonist and not the agonist. The only way to differentiate the activity of each muscle is by performing **SEMG assessment**.

Muscle Testing is also of fairly limited value when there is no contraction or poor contraction (Grades 0 and 1). In this case, SEMG would be preferred.

**Range of Motion assessment** is also needed for a complete evaluation.

The system also proposes to look at **SEMG activity** during manual muscle testing. It can be used to make sure there is no substitution by **monitoring potential substitute muscles** or to evaluate the level of participation of the recruited muscles to the force production by measuring the **SEMG-to-Force ratio**.

## General Recommendations

### *Muscle Testing Grading System*

Traditionally Manual Muscle Testing comes with a grading system for documenting muscle impairment.

**Note that muscle testing with the system is allowed only for grades 4 and 5.**

**Grade 5**: Examinee is able to perform the movement through the full range of motion against gravity, and can tolerate maximum resistance against the examiner.

**Grade 4**: Examinee is able to perform the movement through the full range of motion against gravity, and can tolerate moderate resistance against the examiner.

**Grade 3**: Examinee is able to perform the movement through partial or full range of motion against gravity, but cannot tolerate any resistance.

**Grade 2**: Examinee is able to perform the movement through partial or full range of motion when gravity is eliminated.

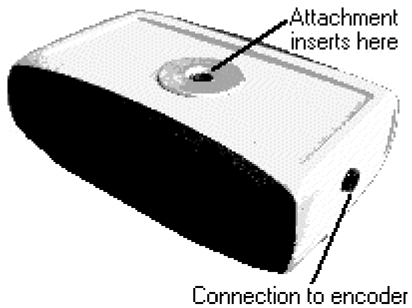
**Grade 1**: No visible movement but slight contraction can be detected by palpation when gravity is eliminated.

**Grade 0**: No contraction can be palpated.

## *Test Procedure*

The system has been designed for the traditional "**Break Test**" procedure. The examinee is asked to complete the range of motion and stabilize their position. The examiner can also place the limb or body part at the end of the range of motion. Next the examinee is asked to hold the position while the examiner tries to "break" the position by applying a force in opposition to the contracting muscle.

The examiner positions the ForceTrac transducer (see picture below) between the limb or body part where the resistance will be applied and the hand applying the resistance.

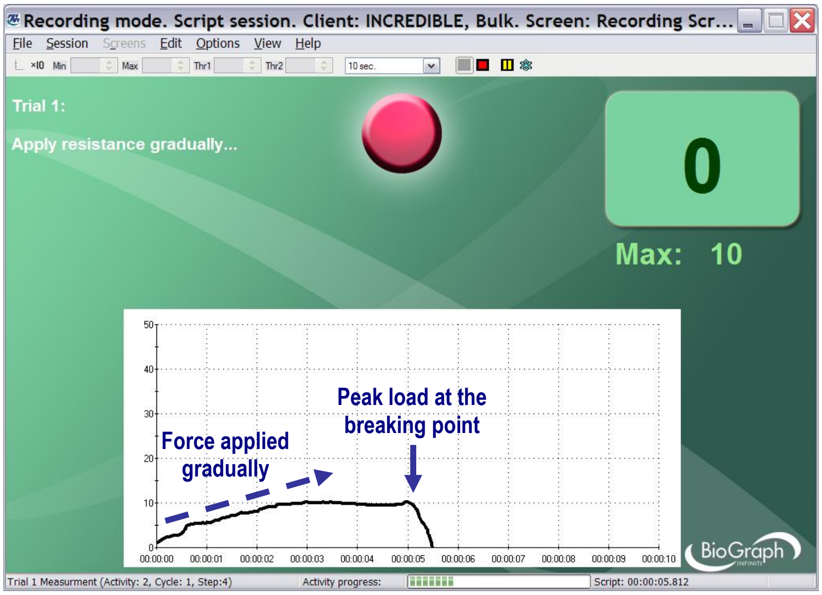



**The ForceTrac comes with three attachments: rod attachment (for algometry only), flat and curved probes for manual muscle testing.**

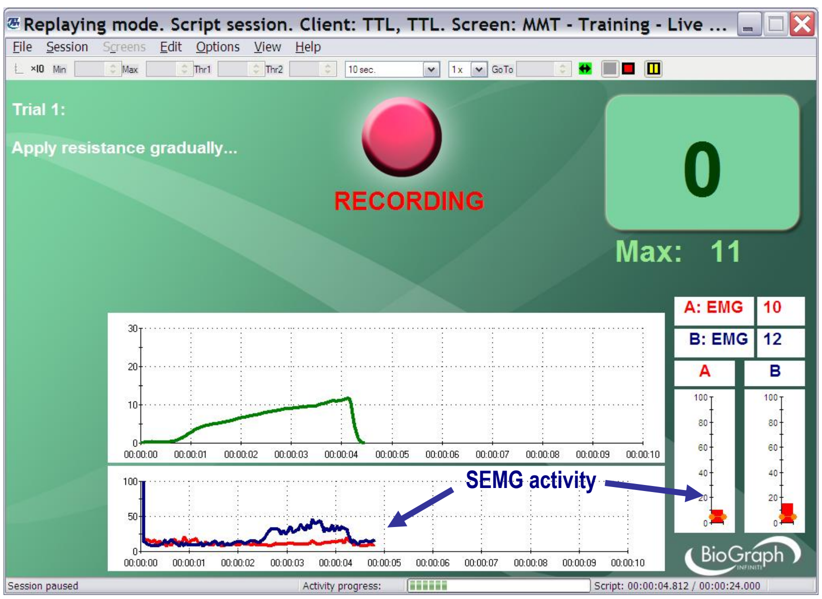
The flat probe is recommended for the trunk and large limbs, while the curved probe is recommended for the head and thin limbs.

The examinee should be instructed first on the exercise to perform and what to expect. A test trial should be performed at 50% of resistance.

Resistance should always be applied gradually (not sudden) and in the direction of the motion ("line of pull" of the muscle). The break usually happens within 2 or 3 seconds. A shorter break time may lead to re-injury. A longer break time may lead to fatigue.




Potential muscle substitution should be investigated by palpation and position should be re-adjusted accordingly. If the examinee has difficulty holding the position, potential substitute muscles should be monitored with SEMG during the test.




**Potential substitute muscles being monitored with SEMG during the test.**
**A tone can be heard when the SEMG goes above a threshold.**

Since strength varies greatly from person to person, it is highly recommended to perform bilateral testing (left and right) when possible, and compare both results.

## *Test Accuracy*

These are general rules to help perform an accurate and repeatable test:

- The ForceTrac transducer must be placed at the same location from test to test.
- The ForceTrac transducer must remain positioned on the limb between the repetitions.
- The start position and the direction of the applied resistance must be the same from test to test and repetition to repetition.

## *Analysis of the Results*

The important data is the **peak load** before the break. The test is valid if there is less than 15% between two consecutive repetitions and if the overall variation (coefficient of variation) is also less than 15%.

In case of bilateral test, the **percentage of deficit** is also computed. This is the difference in percent between the maximum repetition of the right side and the left side.

# ALGOMETRY

## Overview

Algometry measures Pressure Threshold (PTM). It quantifies the sensitivity of para-spinal tissues and their tenderness.

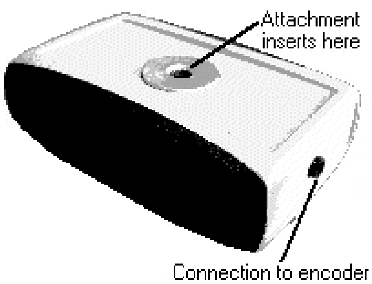
## General Recommendations

The sensitive areas should be identified by palpation.

Then two reference points should be selected for each area. As a general rule, the exact opposite area on the contra lateral side should be selected. A second reference should be chosen in the same region of the spine (cervical, thoracic or lumbar).

## Procedure

- Affix the rod attachment to the ForceTrac.

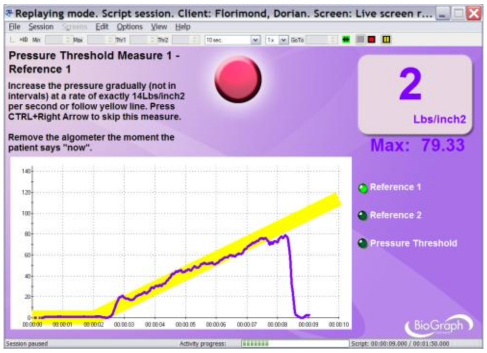



**The ForceTrac comes with three attachments: rod attachment (for algometry only), flat and curved probes for manual muscle testing.**

- Explain the exercise to the examinee. In particular, the examinee should be instructed on what to expect.
- Tell the examinee to say “now” when they start to experience discomfort.
- For better accuracy, the algometer should be applied directly on the skin. Ask the examinee to strip to the waist and put on a gown.
- Identify sensitive areas by palpation and identify anatomical landmarks (for sensitive areas and references).

**ForceTrac with rod attachment**

- Hold the ForceTrac in your hand.
- Position yourself next to the examinee, with the FlexComp attached to your belt, the pedal near your foot and the ForceTrac in the palm of your hand.
- Repeat the following sequence for the two references and the PTM:
  - Apply the tip of the algometer over the marked area and perpendicular to the surface of the skin.




- When ready to measure, press the foot pedal.
- Increase the pressure gradually at a rate of exactly 14Lbs/inch$^2$ or 10Kg/cm$^2$ or follow the yellow line. Remove the algometer at the moment the patient says “**now**”.

## *Analysis of the Results*

According to the literature, the following conditions are considered a positive finding:

- The difference between the PTM and the opposite side or surrounding muscle, in the same patient, exceeds 2 kg/cm$^2$ (28.5 Lbs/inch$^2$).
- The PTM is less than 3 kg/cm$^2$ (42.7 Lbs/inch$^2$).

# RESPIRATION TRAINING WITH BIOFEEDBACK

Respiration training should be considered as part of the rehabilitation program:

- Proper breathing during effort enhances the efficiency of the contraction and therefore the efficiency of the training.
- Proper breathing is necessary for overall health and speeds up healing.
- Respiration training may also help the examinee to relax before therapy (reduces anxiety).

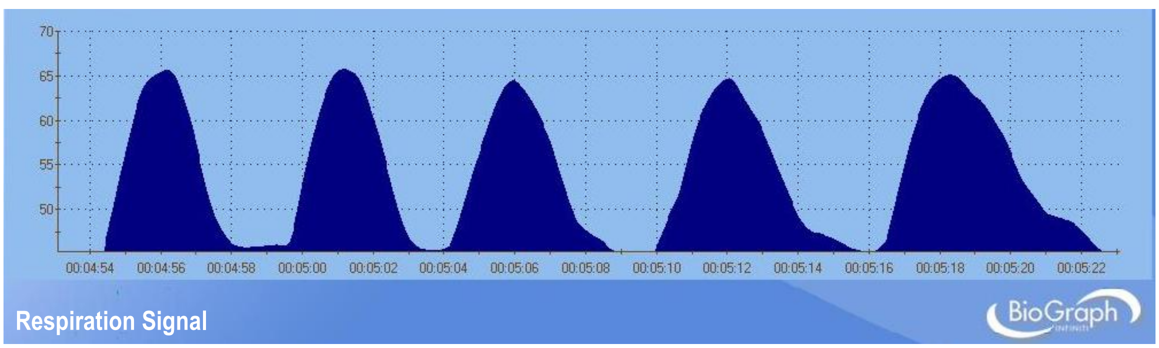
## Principle of Respiration Monitoring

The respiration signal is a relative measure of abdomen expansion.

The sensor consists mainly of a long strap that is stretched around the examinee's abdomen. When placing the sensor on the examinee, ask for a full expiration and quickly fasten the strap with just a small amount of tension at that time. The sensor should not be loose when the examinee breathes out completely. The sensor's rubber tube and circuit box should be placed in the front, as illustrated. The sensor can be placed on top of clothing, if not too bulky.

**The rubber strap stretches when the abdomen expands during breathing.**

**Note:** **The tube is made of natural rubber and some people may be allergic to rubber. Please verify your examinee's allergic conditions before using the respiration sensor.**




Commonly, there is a fast rise that slows near the top of the breath and this is followed by a fast fall that slows near the end of the breath.

Typically, respiration rate (breaths per minute), respiration amplitude and location of breathing movement during the breathing process are observed. For example, the assessment of respiratory patterns includes observing the location of predominant breathing movement (thoracic or abdominal), the presence or absence of upper thoracic muscle activity (upper trapezius, scalene and sternocleidomastoid) as well as the timing, flow and pause rates of breathing during inhalation and exhalation. Whereas the process of observing the location of respiratory activity focuses on muscle movement, the assessment of the timing, flow and pause rates focuses on evaluating the quality of the breathing process.

The typical untrained respiration rate is 10 to 16 breaths per minute. By contrast, during slow diaphragmatic breathing through the nose, the respiration rate may range between 3 to 8 breaths per minute. Over breathing or hyperventilating, on the other hand, often exceeds 20 breaths per minute (Fried, 1999). Respiration rate varies with each individual and depends on many factors such as age, height and weight, health and fitness level (e.g., asthmatic versus elite athletes), cognitions (e.g., thoughts and emotional reactions to circumstances) and the environment (e.g., altitude). Breathing is a dynamic process and should be able to adapt to changes in metabolic demands. It should never be constrained to a fixed pattern.

## Breathing during Exercise

Muscles need oxygen to function; it is their source of energy. Type I and Type IIa fibers use the aerobic metabolism to produce energy, so the necessary amount oxygen must be delivered at the right time. It has also been observed that an increased oxygenated blood flow slows down muscle fatigue. A proper breathing helps delivering the oxygen to the muscle at the moment it needs it the most and consequently makes the exercise more efficient.

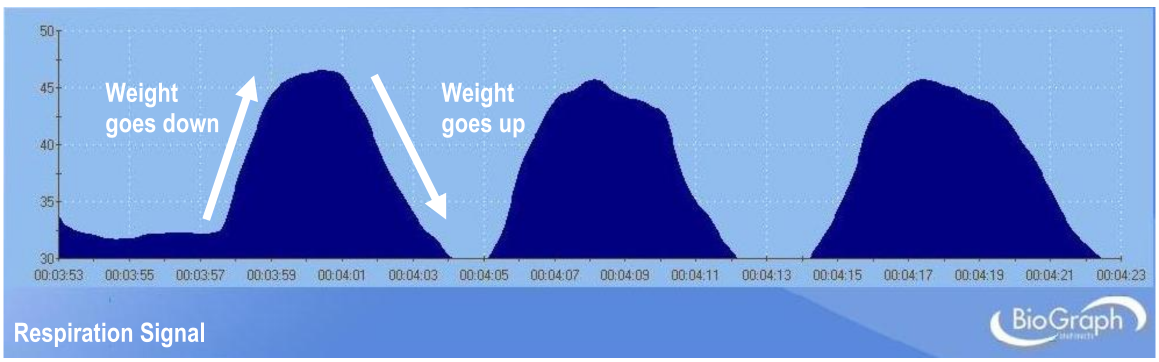
The examinee should first take few deep breaths before the exercise. It helps focusing on the exercise and brings more oxygen to the muscles before the effort.

During the exercise, the examinee should exhale on the power stroke of the movement, when they produce most of the effort. It is also important that they control their breathing, so they take a single breath per repetition.

Respiration Biofeedback is very helpful for that matter. It helps the therapist to monitor and correct the examinee's respiration. It also helps the examinee to focus on their breathing and adjust it in real time. They should be trained first with visual and/or audio feedback and then without.

### Example: bicep curls

The examinee inhales as the weight goes down towards their lower body and exhales as they pull it up.




## Fixing Inappropriate Breathing Patterns

Breathing is efficient when the diaphragm muscle is predominantly used to pull air into the lungs (abdominal breathing). When breathing is disordered, the upper thoracic muscles (upper trapezius, scalene and sternocleidomastoid) are predominantly used to raise the thoracic cage (thoracic breathing).

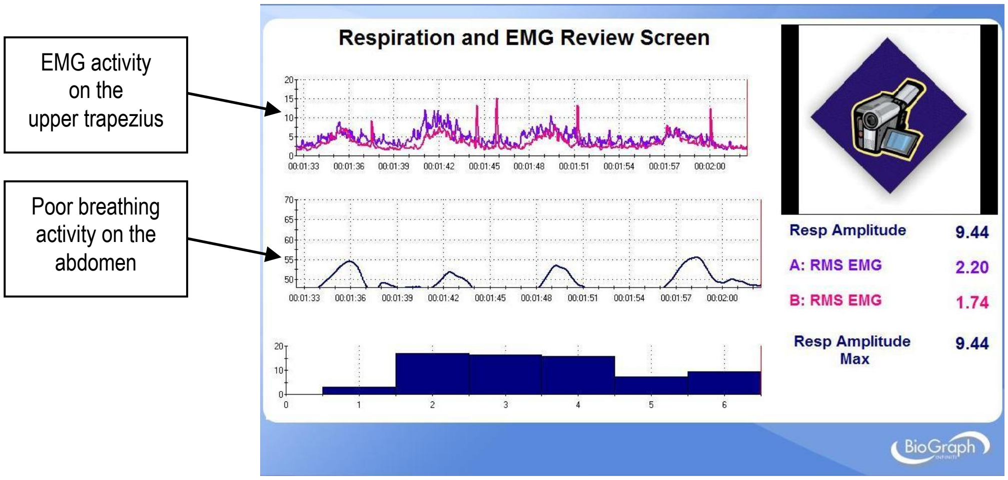
Thoracic breathing overworks the upper thoracic muscles, which may lead to neck and/or shoulder tension or pain. Abdominal breathing reduces the metabolic demand of the breath and brings more oxygen to the body, which is important in the healing process in general.

The respiration sensor is placed around the examinee's abdomen. SEMG sensors are placed on upper thoracic muscles (upper trapezius, scalene or sternocleidomastoid). Visual and/or audio feedback will encourage abdominal breathing (increase of respiration amplitude) and show excessive activity of the monitored muscles.

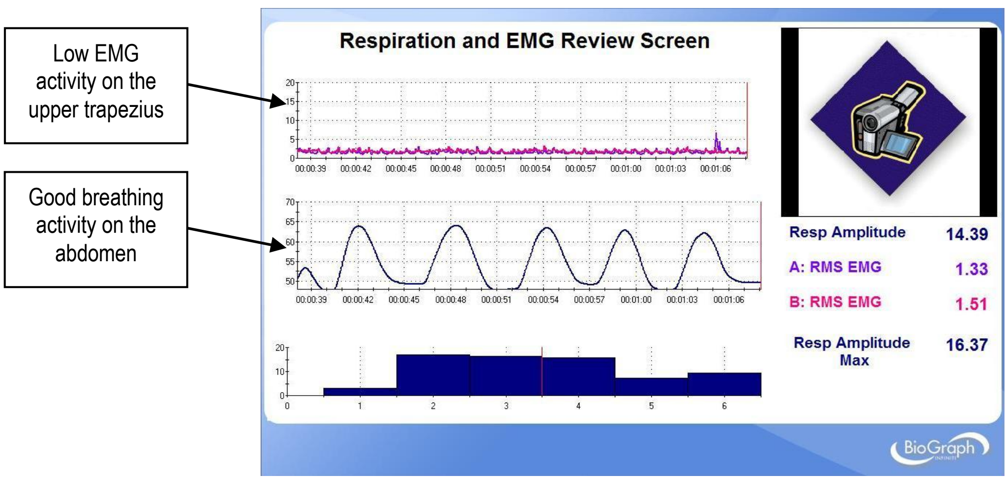
The examinee should be trained in different positions (supine, sitting or standing), with biofeedback and then without.

**If the abdominal respiration training does not fix the anomaly, or makes it worse, a respiratory therapist should be consulted.**

In the following examples, respiration sensor is placed around the abdomen and SEMG sensors on the upper trapezius.




**Thoracic breathing**




**Abdominal breathing**

# Relaxation Training

The examinee may come to the visit with a high level of anxiety, due to pain or trauma caused by the injury or simply the fear of having to go to therapy. It may challenge their involvement in the rehabilitation process and make it longer and/or less efficient. Relaxation training should be then considered.

Abdominal respiration training is a simple and efficient relaxation technique. The more freely the thoracic cage moves, the deeper the breathing is. Slow and deep breathing usually leads to relaxation.

There are various ways to perform respiration training for relaxation and many books have been published on the subject. But the key point of all of them is to teach the examinee to breathe slowly, deeply and abdominally.

The sensor is placed around the examinee's abdomen. The examinee may lie in supine position for the comfort of the position. The therapist could apply a light pressure on the abdomen and ask the examinee to breathe from where they feel the pressure. They are then asked to breathe naturally, letting their body find the right rhythm. Visual and/or audio feedback will lead them to a slower and deeper breathing.

# HEART RATE MONITORING AND HRV

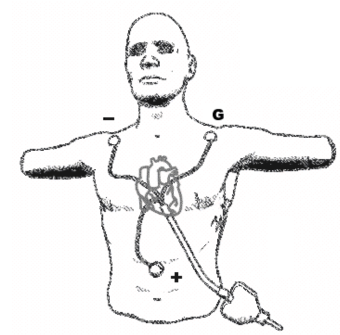
The system allows the therapist to monitor rapid changes in the heart rate. It gives the choice of gathering the heart rate from **EKG (electrocardiogram)** or **BVP (Blood Volume Pulse).**

The EKG sensor is a pre-amplified electrocardiograph sensor, for directly measuring the heart's electrical activity. Connects via extender cables for a single channel hook up.

A 3-snap extender cable is provided with your sensor.

For optimal signal quality, we recommend using UniGel electrodes and placing them on the chest, as shown in the illustration. In case a chest placement is not possible, you can move the black and blue electrodes to the left forearm and the yellow electrode to the right forearm.

Cleaning the skin with an alcohol pad, prior to applying the electrodes helps improve the signal.




EKG Wrist Straps (P/N: SA9325) come in a kit containing reusable medical-grade, non-latex straps and replaceable silver/silver-chloride electrodes.

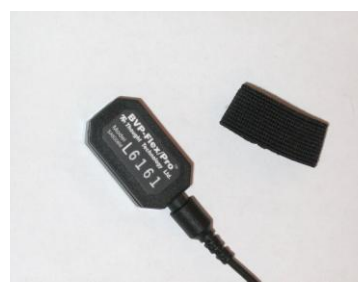
They provide fast, convenient placement of electrodes for measuring EKG from the wrists.


The HR/BVP sensor is a blood volume pulse detection sensor (otherwise known as a PPG sensor) housed in a small finger worn package, to measure heart rate (HR) and provide BVP amplitude, BVP waveform, HR and heart rate variability feedback.

An elastic strap is provided with the sensor.

Place the sensor against the fleshy part of the first joint of any finger. The middle finger is recommended for better compatibility with the other sensors when they are all placed on the same hand.

***Note**: Place the sensor label up, so that the electronic sensor components (the two small square openings) on the back of the sensor (not shown) are against the finger.*



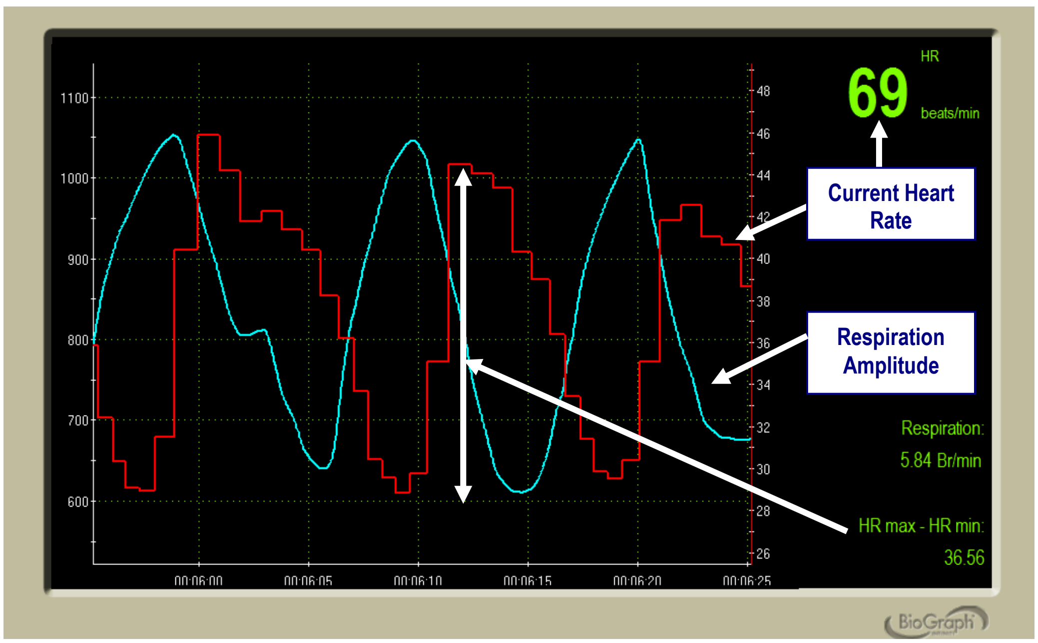
With elastic strap

As an alternative, Coban (3M) self-adhesive tape can be used to provide a more secure fit attachment.

With Coban tape

The system also displays **HR Max - HR Min**, which is a HRV (**Heart Rate Variability**) measure.

**HR Max - HR Min** is the difference between the highest and the lowest heart rate value at each breath. This is gathered from respiration, with the respiration sensor, and heart rate from BVP or EKG.

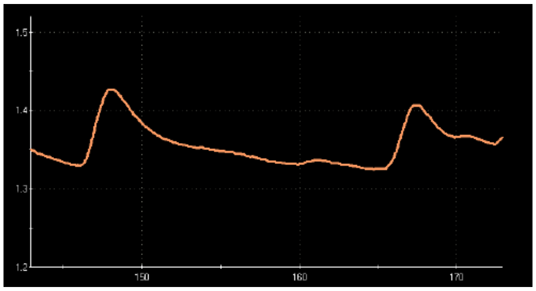


# SKIN CONDUCTANCE AND PERIPHERAL TEMPERATURE BIOFEEDBACK

## Principle

Skin conductance and peripheral temperature biofeedback is useful when training of overall physiology is desired, as it incorporates two modalities with simple correlations to relaxation: skin conductance (lower) and temperature (raise). When these physiological measures meet the biofeedback conditions, the subject is in a general state of relaxation. These physiological measures can also be used to assess the level of stress of the examinee during the examination.

### *Skin Conductance*

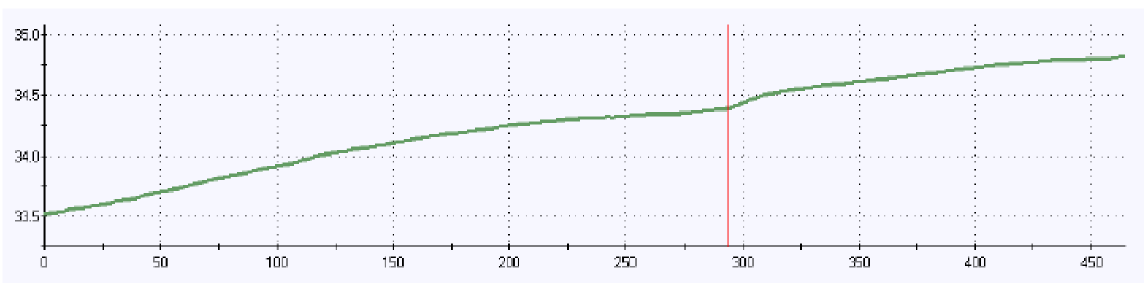



Skin Conductance (SC) is an index of sympathetic nervous system (SNS) activation and emotional arousal. To measure skin conductance, a very small electrical voltage is applied between two electrodes strapped or taped to the palmar aspect of the dominant hand (right hand for right-handed people) and a measure of how well the current is conducted between the electrodes is obtained.

Although the exact physiological mechanism is not clearly understood, it is generally accepted that SC varies directly with the amount of sweat secreted by the skin and indirectly with the number of sweat glands that are activated by the SNS activation. The biofeedback applications of SC generally have to do with reducing stress levels and training adaptability. It is also useful for verifying the effectiveness of relaxation practices. As the amount of stress increases, so does the skin conductance level. Relaxation decreases SC. Because it is highly sensitive to instantaneous emotional changes, SC is frequently used to reflect such reactions as anger, fear, sexual feelings and to measure the startle response (response to a visual or auditory stimulus). This measure is an important component in lie detection systems (polygraph).

### *Peripheral Temperature*

Peripheral temperature (Temp) is an index of sympathetic arousal as it affects vasoconstriction in the extremities (reduction in blood flow).




To measure skin temperature, a small thermistor (electronic device sensitive to thermal variations) is taped to the side or top of the dominant hand's index or middle finger and detects very small changes in skin warmth. Sympathetic nervous system (SNS) arousal causes an increase in peripheral vasoconstriction, which decreases the perfusion of blood in the tissues and causes a cooling down of the skin. This is part of the normal fight or flight response to stress.

The biofeedback applications of temperature generally involve warming up ones hands or feet, in order to learn stress control. As relaxation increases, so does the peripheral temperature. Because it is an indirect measure of blood circulation, it is also useful as an adjunct therapeutic method for circulatory problems, such as Raynaud's disease or migraines. One important characteristic of finger temperature biofeedback is that changes are very slow to occur. The reaction to a stimulus or a change in mental state may take a few seconds to show-up as a change in temperature.

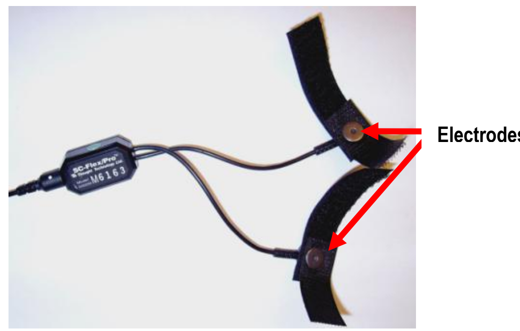
# Positioning of the Sensors

## *Skin Conductance Sensor (P/N: SA9309M)*

The Skin Conductance sensor measures the conductance across the skin, and is normally connected to the fingers or toes.

There are two finger straps attached to the skin conductance sensor.

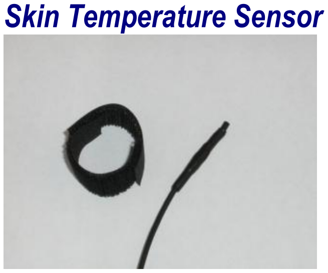
The conductive electrode in each finger strap should be placed against the inside part of the finger.




A good choice for placement is to use the index and ring finger. Close the hook and loop fasteners around the fingers so that contact is snug yet comfortable.

Placement with the cables directed inwards (shown) is practical for keeping the cables out of the way.

## *Skin Temperature Sensor (P/N: SA9310M)*

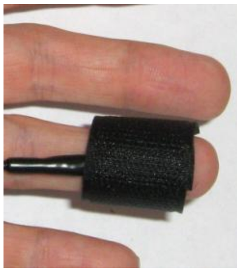


The Temperature sensor measures skin surface temperature between 10°C – 45°C (50°F – 115°F). It is supplied with a self adhering band for easy finger placement.

A hook and loop fastener is provided with the sensor.

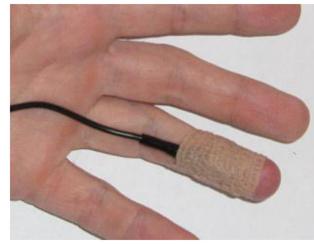
Ensure that the end of the temperature sensor makes solid contact with the finger. Any finger can be used.

Shown here is the ring finger.



With hook and loop fastener

As an alternative, Coban self-adhesive tape (3M) can be used to provide a more secure fit attachment.



With Coban tape

### *Using the Sensors Together*

This configuration is suggested for placing skin conductance and temperature sensors on the same hand.

In this configuration, the temperature sensor is tucked under the ring finger strap of the skin conductance sensor.

This is a practical way to combine these sensors, but care must be taken to ensure that the end of the temperature sensor is secured firmly against the skin.

Also note that the cables are all directed inwards and Coban tape is used to secure the cables to the wrist.


## Procedure for Relaxation

- Explain the training method to the examinee.
- Connect the sensors as shown above.
- Have the examinee sit comfortably and adjust cable placement accordingly if necessary. Excessive movement should be discouraged, so comfort is essential.
- Encourage the examinee to produce feedback by remaining calm and still (and hence lowering skin conductance and raising hand temperature).

## Procedure for Assessment

- Explain the training method to the examinee.
- Connect the sensors as shown above.
- Have the examinee sit comfortably and adjust cable placement accordingly if necessary. Excessive movement should be discouraged, so comfort is essential.
- Adjust the webcam and microphone.
- Observe the examinee's physiological changes as you are working with them.
- Place markers at the moments you may find relevant, for further review.

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