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**Foreword**

This therapy book consists of three parts. It has been written by a number of physiotherapists, each focussing on his or her area of specialisation.

Chapter 1 contains general information about myofeedback. The book starts with the history, followed by a description of the various possibilities of the EMG signal.

Myography for the knee, back and shoulder areas is described in Chapter 2-3.

The final chapter 4 looks at therapies that are suitable for incontinence.

We would like to thank the authors for their input and help during the development of this book.

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Surface electromyography as the stethoscope of the physiotherapist

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Myofeedback is a form of feedback, in which the patient receives electronically recorded information about his own physiological processes. The electromyographic recording used in the diagnostics and treatment of the moving mechanism is an indispensable supplement to the study of movement. When we place electrodes on the skin to obtain information from an EMG signal about the underlying musculature, we must be acquainted with the development of the EMG signal and the construction and function of the motor mechanism. Thus, properties and mutations in the musculature, the joints system, the sensory and the neural system can be found in the motor system and also in the EMG recording.

Surface EMG provides us with detailed information about the organ-specific properties of a muscle, such as:
• the activation of the muscle;
• the muscle’s capacity for relaxation;
• coordination between muscles;
• the tiredness of a muscle;
• the capacity of a muscle to lengthen.

This makes myofeedback especially suitable as a measuring instrument for charting our locomotive operations (Figure 1).

1.1 The origin of the EMG signal

A muscle is an organ with a totally mechanical function, in which electrical phenomena play an important role. A muscle is constructed of ultra-thin muscle fibres with lengths varying from around 3 to 11 centimetres. Each muscle has a muscle architecture that is adapted to the required function of that particular muscle. The muscle fibres are innervated in groups by a motor neuron. This unit of the motor anterior horn cell, the axon with its motor end plates and the muscle fibres that are controlled by the relevant motor neurons are called a motor unit (Figure 1). The number of muscle fibres per motor unit varies greatly, with about 25 in the eye musculature and many hundreds in the large muscles in the extremities. In each muscle the spread of the muscle fibres belonging to a motor unit varies. The more robust the required coordination, the more muscle fibres are controlled by the neuron, while the finer the coordination, the fewer the number of muscle fibres per nerve cell.

Figure 1: Diagrammatic representation of a motor unit
(from: Travell & Simons 1999.)
When an action potential reaches the muscle fibres in the motor end plates from the motor anterior horn cell, acetylcholine is released in the synaptic cleft. This acetylcholine causes local depolarisation of the muscle fibre membrane. After this local depolarisation, a depolarisation of the cell membrane takes place in both directions from the motor end plate – situated in the centre of the muscle fibre - across the cell membrane, towards the terminus of the muscle fibre (Figure 2). The depolarisation is immediately followed by a re-polarisation.

These potential interruptions to the muscle fibre membrane lead to the release of calcium ions in the centre of the muscle fibre, which ensure that myosine heads (cross-bridges) rise from the myosine filaments. The myosine exists at the molecular level of a bundle of rod-shaped molecules, with a head at the end. The actine (the structure at the very bottom) consists of a double-twisted 'string of pearls' of 13 ball-shaped protein molecules (Figure 3).

As the myosine head bends in relation to the actine filament at an angle of 45 degrees, a contraction takes place, in which the myosine filament is pulled between the actine filament. Due to the high-speed resorption of calcium ions, the cross-bridges release, there is a repeat of the depolarisation in the interim and the actine filament again attaches itself to the actine filament slightly further along.

During a contraction, a myosine head goes through the attach-shorten-release cycle many times. It can be compared to hauling in a rope, hand over hand. This results in a greater or lesser shortening of the sarcomer, depending on the number of depolarisations. There are 1000 to 2000 sarcomers, in series, in muscle fibre, which all shorten in a short space of time as a result of depolarisation progressing along the muscle fibre membrane. The function of this depolarisation across the muscle fibre membrane is clear: only with a practically simultaneous shortening of all the sarcomers is it possible to shorten the whole muscle fibre and thereby exert a force on the origo and insertion. The 'ebb and flow movements' of the natrium and calcium ions cause differences in potential – discernible outside the muscle fibre – that form the EMG signal.

Figure 2: Electro-chemical processes during neuromuscular transfer (from: Loeb & Gans 1986)

Figure 3: The formation of cross-bridges (from: Rozendal e.a. 1990.) Sarcomer in contracted state (top left) and in extended state (top right).

At (1) an active cross-bridge, in which the paired head of the myosine molecule is separated from the myosine filament but remains connected to it by the other part of the myosine molecule. At positions (2) and (3) the screw-shaped structure is repeated.
After intensifying the EMG signal obtained with surface electrodes, there is an unprocessed, rough EMG signal and a Rectified Averaged EMG signal, abbreviated as RA-EMG (Figure 4.) The height of the signal indicates its strength and is easier to examine than the rough signal.

An increase in the number of recruited motor units per muscle and an increase in the firing frequency per motor unit results in an increase in force, which is discerned by electrodes on the skin as an increased RA-EMG. The RA-EMG of a tensed muscle is therefore a good indicator of the activity of that muscle. The RA-EMG also has a clinical significance for the degree of relaxation. During relaxation of the muscle, the RA-EMG will normally decrease.

1.2 The EMG Signal as joint product of the motor system

The myoelectrical signal can be seen as a joint product of the motor system, so that apart from the observation of the motor system the EMG signal provides supplementary information on how precisely these motor performances are effected. The EMG signal, obtained from a number of muscles, can provide us with information on the sequence of the participating muscles and clarify the part each muscle group plays in the posture or movement. It also provides us with information about whether any adjustment of the contributing muscle groups takes place during locomotor activity. The muscular system is only one of four organ systems of the posture and locomotor apparatus.

In order to clarify the connection between the muscles and the whole motor system, the motor apparatus will be presented as a pyramid (Figure 5.)

The pyramid represents the motor apparatus as a system consisting of 4 types of organs and cells (subsystems) that are involved in the motor system:
- the muscular subsystem
- the articular subsystem
- the sensory subsystem
- the neural subsystem
The subsystems form the ribs of the pyramid. Characteristics and mutations in each of these four organ systems determine both the motor system and its associate product, the EMG signal.

Six organisational levels can be distinguished in each subsystem, from the molecular level to that at which interaction of the whole organism with its environment takes place. The four subsystems communicate intensively with each other during operations with the motor system, via electrical, mechanical or chemical signals.

The operating model (Figure 6) of the motor system shows the connection between the four subsystems that occur in the pyramid. The four ribs of the pyramid (viewed from above) are represented as a closed circuit of four blocks communicating between themselves through signals.

The closed circuit is formed by:
- the efferent signal (supplied by a motor neuron)
- the force supplied by the activated muscle
- the movement that results from this force
- the afferent signal coming from the muscle spool

There are also two return loops:
- the gamma innervation (concerned with adjustment of the muscle spools so that both large and small sensitivities are reached)
- the locomotive independence of the muscle force(s)

The moment an exerted force results in a movement, the exerted force immediately changes. Before an electrical signal is recorded close to a muscle, a complex history precedes the signal. Motor units are recruited from the central nervous system to produce a functional movement, power or a facial expression. This recruitment must take account of the architecture of the muscle and a number of physiological properties of the muscle, which together are responsible for the muscle’s power/length and power/speed relationships. The recruitment of the muscle also depends, of course, on the orchestration of the activities of other muscles and their connection with the bone/joints/connective tissue system. The complex properties of the muscle spools and many other senses all play their role in arranging movement with unexpected disruptions. The properties of neural networks are ultimately responsible for producing and arranging cyclically univocal activities, purposeful, functional handling or the adequate provision of a facial expression suitable for the situation.

Our motor system develops from childhood and attempts to find its way in the invisible world of forces, while our brain develops solutions for any motor problems that may arise. In fractions of a second, our motor system can find solutions for complicated locomotive tasks. The motor system may possess system properties that run right through the divisions between the different types of tissue. The interrelation between the EMG signal and each of the four subsystems is narrow; properties of and mutations in these subsystems can be found in an EMG recording.
Some examples are given below.

1.2.1 Muscular subsystem

When a muscle is working in an eccentric way, we record less electromyographic activity for the same force than with a concentric contraction. This is due to a muscle’s properties at the molecular level: the crossbridges. When a muscle is weakened (for example due to the presence of a myofascial trigger point), this can be seen in the increased propensity for tiredness in the relevant muscle. On the surface EMG, we can then see a strong reduction in the EMG signal for repeated contractions. The twitch response that occurs during palpation of the myofascial trigger point can also be shown electromyographically.

1.2.2 Articular subsystem

When a joint is severely limited (for example reduced glenohumeral mobility in a frozen shoulder), this is shown in the changed motor pattern of the shoulder musculature. During the EMG recording, we can see that the muscles that move the shoulder blade in protraction and in laterorotation show a strong increase in activity in relation to the muscles of a normally mobile shoulder.

Lowest extremity: in EMG recordings of foot and lower leg muscles, differences can be seen in the EMG recording between a normal foot and a flat foot.

1.2.3 Sensory subsystem

A test subject is blindfolded and asked to maintain the position of their underarm in a particular stance. The perception of the lower arm position is interrupted with vibration of the m. biceps brachii through stimulation of the muscle spools; the blindfolded test subject bends his elbow 20 degrees, despite the instruction to maintain the same position. As a result of the sensory stimulation, the test subject has the feeling that his biceps are being stretched and compensates by flexing. This influence is electromyographically deducible. The coordination and EMG recording of hand and lower arm muscles with a cold, benumbed hand, change in relation to the normal situation.

1.2.4 Neural subsystem

The immediate ‘commissioner’ of the muscles is the motor anterior horn cells, which are directed by many neurons from various motor centres in the brain, where the locomotive task is prepared. The properties of and any interruptions to these parts of the nervous system can be seen in the EMG signal. A paresis, tremor or spasm can be clearly seen in an EMG recording.
1.3 Surface electromyography in the therapist/patient relationship

When surface electromyography is added to the treatment scenario, a number of new interactions take place between the patient and therapist (Figure 7).

**1.3.1 Interactions 1 + 2**

The therapist presents strategies, from which, from his expertise, he assumes that the patient will gain benefit for his motor problems (1). In this process, however, the patient also develops his own motivation and strategies, with which the therapist is confronted (2).

**1.3.2 Interactions 3 + 4**

As soon as an EMG machine is used in treatment, it represents the physiological response of the patient (4). The EMG recording can be seen as a representation of the locomotive behaviour, whereby not only the patient is informed about his locomotive movements, but also the therapist, who previously only received directly observable information (3). This process is called myofeedback.

**1.3.3 Interactions 5 + 6**

The therapist can subsequently, by setting the equipment, select the EMG signal presented to the patient (height of tightening curve, feedback sensation in the form of sound, tightening curve or light beams) in such a way that the patient receives accurate and clear information about his locomotive behaviour (5). A very important addition for the therapist, however, is that the EMG recording provides him with additional information on the locomotive behaviour of the patient. The therapist furthermore has extra control over the effect of his own treatment, such as the effect of tapping, facilitating, verbal instructions, the effect of a mirror, etc. (6). The EMG signal can therefore be used as a didactic aid and has significant advantages over the usual methods available to the physiotherapist.

**1.3.4 The advantages of Myofeedback**

- the myofeedback signal is available instantly
- accuracy (the EMG signal is quantitatively related to the muscle activity)
- continuous availability
- ease of interpretation
- step-by-step feedback
- recordings can be obtained from several muscles simultaneously

From a didactic standpoint, Myofeedback therefore forms a qualitatively good source of information. The extra insight that the physiotherapist receives from the EMG recording into the patient’s locomotor behaviour in particular is a true eye-opener. After all, the EMG machine is the only method by which a physiotherapist can make an assessment of a patient’s muscle activity. No physiotherapist is otherwise capable of seeing the tensing of muscle that occurs...
in the lower arm of a keyboard operator when he places his relaxed fingers on a keyboard or a mouse. To avoid pressing a key or a mouse button, the keyboard operator in fact maintains an imperceptible, continuous activity in the finger extensors! Keyboard operators develop symptoms because the muscles are often stressed for prolonged periods (without a break to allow the tensed muscle to relax temporarily). The repair process is therefore slow or sometimes even impossible (unless the work situation changes or the work rhythm is adapted). Myofeedback appears to be an excellent aid for training for these micropauses.

1.4 Electromyographic kinesiology as a functional diagnostic aid

Muscles have five organ-specific functions:
• muscle strength
• coordination
• capacity for muscle relaxation
• muscle stamina
• the capacity for muscle extension

What additional information can surface electromyography provide with regard to these muscle-specific properties?

1.5 Muscle strength

There is a linear connection between the static force supplied by a muscle and the activation of the muscle as represented by the RA EMG of the muscle. However, if we measure an external force that is supplied by a number of muscles in a dynamic, functional movement and we take an EMG recording of one of those muscles, this linear connection does not appear to exist. There are a number of reasons for this.

One important phenomenon is that a muscle in an extended state can also exert a force without activation of that muscle. This force is supplied by the connective tissue skeleton of a muscle and increases with the extension of the muscle. This passive elastic force can be externally measured, without activity being measured on the surface by electromyography, for example during walking, immediately prior to take-off.

A second phenomenon occurs with an eccentric contraction. In this, a muscle exerts more force than during concentric contractions, so that with eccentric muscle contractions with the same force, considerably less RA-EMG is recorded.

A third phenomenon (in which the relationship between the exerted force and the recorded RA-EMG activity appear to be non-linear) is that the externally measured force always results from all the muscles and muscle groups that provide a contribution to the exertion of this force. It has been shown, for example, for the left and right part of the m. gastrocnemius and m. soleus, that none of these three muscles had a linear relationship with the externally measured force.
during plantar flexion of the ankle. However, the sum of the recordings of the RA-EMG of these three muscle groups did have this (Figure 8).

It can be concluded that with static tensing of a healthy muscle, the recording of the RA-EMG provides very reliable information on the activity of that muscle. The force that is exerted is still dependent on factors including the size of the muscle and the muscle architecture.

1.6 Coordination

The combined action of the muscles can be followed with great precision by using multichannel EMG recordings. Apart from the quantitative electromyographic contribution, the sequence of recruitment can also be established in fractions of a second. The order in which the muscles tense and whether there is any simultaneous tensing can be followed precisely. Changes and interruptions in coordination can be most easily perceived with simultaneous EMG recordings of several muscles.

1.7 The capacity of a muscle to relax

With the aid of surface electromyography, the smallest EMG activity can be made audible and visible. A relaxed muscle should be electromyographically ‘quiet’. Only so-called thermal noise can be measured with a fully relaxed muscle. This noise consists of a few microvolts, depending on the equipment used. The difference between complete resting activity and postural muscle activity can easily be determined with surface electromyography. Postural activity also does not appear to be not much higher than a few microvolts. Patients with symptoms of pain should be checked for any increase in postural EMG activity.

Two theories underline this:

• During maintained muscle contraction the same motor units are continuously active. According to Hennemann’s size principle, the recruitment sequence of the motor units stays the same. The same motor units therefore continue to be active during lightly maintained muscle activity. These so-called “Cinderella” motor units are always active during static tasks, therefore also during (unconscious) long-term tensing of the muscles. Damage to the muscle fibres has also been found in muscle biopsies (ragged red fibres). According to Hägg (1991), this implies that interrupting muscle activity (breaks) will have more effect than, for example, ergonomic measures for keyboard operators (Figure 9).

• During muscle contraction, the circulation in the muscle will reduce, and it is generally accepted that the point at which the blood flow in the tissue stagnates is reached when a muscle has reached 30% of its maximum arbitrary contractive force. In calculating muscle models, Otten (1988), found that the pressure in a unipennate muscle is not equally divided, but corresponds to the pressure lines represented in Figure 10. These
‘high pressure zones’ during a muscle contraction are situated particularly in the vicinity of the origin and insertion of the muscles. In the areas where the pressure is highest, the tissue circulation diminishes with contractions that are much less forceful than 30% of the maximum arbitrary contractive force. The importance of regular, total muscle relaxation (also during relatively light tasks, such as text processing) is once again underlined here.

The value “100” corresponds to about 2.3 atmosphere at full tensing. Consider that the blood pressure is only about 0.15 atmosphere. Right: the build-up of pressure recorded with the contracted muscle from a toad. There is a clear correspondence with the calculated build-up (figure 10).

1.8 Muscle stamina

When a muscle becomes tired, the firing frequency of the motor units goes down. A derivative of the rough EMG signal, the so-called frequency spectrum, reacts very sensitively to changes in the firing frequency of the motor units and is therefore a suitable parameter for looking at the rate at which a muscle becomes tired.

1.9 The capacity of a muscle to extend

A healthy, non-painful muscle should be relaxed in an extended state, in which no other nociceptive stimulation is being created from joint capsules, tendons or bursa. Surface electromyography is the only method of verifying that the muscle remains completely relaxed during extension. A (limited) locomotor result is only a measure of the muscle contraction if the extended muscle is in fact electromyographically still. A muscle that cannot be relaxed during extension (including during myofeedback) is characteristic of pain during muscle extension. A possible cause of this is the presence of a myofascial trigger point in the relevant musculature.
Due to the non-invasive nature of EMG recordings and the large degree of flexibility (ambulatory recordings, recordings over time, large degree of mobility), it is almost always possible to use surface electromyography.

The areas of application of surface electromyography, though seemingly endless (as far as the motor system is concerned), are particularly relevant for:

- symptoms involving pain
- disruptions in posture and coordinated movement in a healthy nervous system
- disruptions in posture and coordinated movement in an injured nervous system

A number of applications of surface electromyography, which have been used over the past few years, and which are leading to a significant rediscovery of myofeedback, are set out below.

### 2.1 Coordination training for work-related complaints (including R.S.I)

Repetitive movements, tensing and static loading all play an important role in the development of work-related disorders such as R.S.I. (Repetitive Strain Injuries). These are serious complaints affecting the neck, shoulders, arms and hands.

**Treatment:**

Myofeedback is increasingly used as an aid to teaching effective work practices to keyboard operators, whereby unnecessary, high muscle activity can be unlearned. Micropauses, which should be incorporated every 30 seconds for a few seconds to promote blood throughflow in muscle tissue, can be effectively learned with myofeedback. During a micropause, the muscles involved in the activity must totally relax for a short period of time. This can only be adequately checked by means of an EMG recording. Improving muscle awareness and making the effect of stress on tensed muscle visible can be learned fast and effectively by means of myofeedback.

In the case of violin players, myofeedback of the thumb adductor is used to unlearn excessive clenching onto the neck of the violin whilst playing. This is achieved by providing feedback on the activity of the m. adductor pollicis whilst playing. The myofeedback equipment is set at increasingly sensitive settings so that feedback can be given on increasingly smaller tensing of the thumb musculature.

### 2.2 Headaches with neck complaints

65% of patients with neck/shoulder/arm symptoms (n=2341) raise their shoulders when standing still. This indicates that it is very worthwhile to carry out an EMG recording of the m. trapezius, as continuous tensing of this muscle can greatly hinder recovery from headache and neck symptoms.

### 2.3 Bibliography:

The assessment of the quadriceps muscle can be considered as crucial in the evaluation and treatment of PFPS patients. Scientific research shows that PFPS patients very frequently present dysfunctions of the quadriceps muscle. These dysfunctions need to be distinguished from another. At first, selective atrophy of the Vastus Medialis Oblique (VMO) muscle is a very frequent problem in PFPS patients. In these patients the rehabilitation program should emphasize on VMO strengthening. Research findings indicate that no clinical exercise is able to strengthen the VMO more than the VL. As a consequence, the only way to selectively increase the strength of the VMO is the use of electrical stimulation. To gain a significant increase in VMO strength, this electrical stimulation should be applied three times a week for four weeks.

Another very frequent dysfunction of the quadriceps muscle in PFPS patients is a neuromuscular dysfunction of VMO versus VL. This neuromuscular dysfunction of the VMO versus VL identifies a disturbance in speed of contraction between these two muscle groups. Several scientific studies have determined that in healthy subjects a significant earlier firing of the VMO versus VL is present during quadriceps contraction. In PFPS patients however, a reversal of this normal firing pattern between VMO and VL is observed. In these patients a significant earlier firing of the VL compared to the VMO is identified. This altered firing pattern, or neuromuscular dysfunction is clinically important since it has a significant effect on the patellar orientation. Therefore, rehabilitation of these patients needs to emphasize on a normalization of this neuromuscular dysfunction. The use of myofeedback equipment seems very useful in achieving this rehabilitation goal.

3.2 Training to improve the voluntary VMO control

3.2.1 Patients with weak VMO control

A first step in the process of normalising the neuromuscular firing pattern of the VMO versus VL is to improve the quality of the VMO contraction. To achieve this, the patient is positioned with relaxed quadriceps and extended knees on the treatment table. Electrodes are placed on the muscle belly of the VMO. The therapist asks the patient to contract the quadriceps and to activate as much as possible the VMO during this contraction. The therapist is able to analyse the quality of the contraction of the VMO by looking at the screen of the Myomed 134.

3.2.1.1 Exercise- and equipment selection

- select in the menu EMG
- select continuous
- select 05 :00 minutes

Within one treatment session two or three myofeedback sessions with duration of five minutes can be performed. However, there should be a rest period of five minutes between the two sessions. At the start of the rehabilitation a myofeedback treatment of 15 minutes without
rest periods seems less effective than two or three sessions of five minutes. This should be maintained until the patient has good control of his VMO, and is able to keep the VMO contracted for more than five minutes. In the beginning of the rehabilitation period the threshold EMG-value should be placed at zero since most patients show only a weak VMO activation pattern. The patient should be instructed to try to contract his VMO during a quadriceps contraction. At first, the duration of this contraction shouldn’t be too long (a few seconds is enough), but the speed and the quality of this activation should be examined on the screen by the therapist. On this screen the therapist should observe a curve with a fast and smooth increase of the amplitude. Of special interest for as well the therapist as for the patient is the possibility of storing this graph in the Myomed 134.

3.2.2 Patients with very weak VMO control

Some patients hardly have any control of the VMO during a quadriceps contraction. The previous described exercises will probably be too difficult for these patients. Therefore, the use of electrical stimulation as a mean of gaining more VMO control is advisable before prescribing the above described exercises.

3.2.2.1 Exercise- and equipment selection

- select in the menu EMG+ stimulation
- select alternatively EMG-stimulation
- select EMG-work time 5-15 seconds
- select EMG rest period 10-20 seconds
- select stimulation time 10-20 seconds
- select stimulation rest period 50 seconds

During this protocol the patient will be instructed to contract the VMO (without electrical stimulation) (= EMG work time – preferably between 5 and 15 seconds in the beginning of the rehabilitation program). Then, the patient is given 10 to 20 seconds rest (EMG rest period). Next, the VMO of the patient is given electrical stimulation for 10 to 20 seconds (stimulation time). The goal of the electrical stimulation is to help the patient to voluntary control his VMO during a quadriceps contraction. During the electrical stimulation the patient should 1) remember the feeling of the VMO contraction and 2) try to voluntary contract the VMO together with the electrical stimulation.

3.2.3 Patients with normal control of the VMO

Once the patient is able to voluntarily contract the VMO adequately during a quadriceps contraction the following exercises can be given:
3.2.3.1 First phase

- At first, the therapist can work within the menu EMG with the ‘work/rest’ programme. The duration of the VMO contraction (work time) can progressively be increased from 5 seconds to 120 seconds. The rest period can progress from a long period (60s) to a short period (5-10s). This way the endurance of the VMO muscle which is of great importance during functional activities, will be improved.

- Next, the therapist can work within the menu ‘continuous’ or ‘work/rest’ with a threshold. Providing guidelines concerning setting up this threshold on the Myomed 134 is not an easy task. This is due to the fact that many variables have a significant influence on the EMG signal detection by the Myomed 134. Not all these factors can be controlled in all situations. However, as a general guideline it can be postulated that a threshold between 20 and 40 microvolt can be installed. The audio signal must be installed that the patient hears a signal the moment the EMG activity of the VMO is under this threshold. The patient must be instructed to avoid hearing the audio signal.

- As a next progression in this first rehabilitation phase the patient will be instructed to sufficiently contract the VMO during functional exercises (squatting, knee bends, forward lounges, stairs walking, mild jumping activities). Of vital importance during the performance of these exercises is the control (on the screen of the Myomed 134) of the good activation of the VMO. Progression can be made by asking the patient to perform these exercises longer (5 to 10 minutes) with less rest between the different exercises (setting up long working time and shorter rest periods on the Myomed 134). In this way the endurance of the VMO during functional exercises will be trained. The patient will also be instructed to perform these exercises at least once or twice a day. Once the patient is able to perform a good VMO contraction during these functional exercises during a longer period (5 -10 minutes) the therapist can go to the second phase of this program.

3.2.3.2 Second phase

In this phase the therapist will not only focus on the quality of VMO contraction, but especially emphasize on the speed of VMO contraction compared to the speed of VL contraction. To obtain this goal the patient will initially be positioned with extended knees and relaxed quadriceps on the treatment table. Electrodes will be placed on the muscle belly of VMO and VL. The patient will be instructed to contract the quadriceps but during this contraction the patient should try to contract the VMO before or simultaneously with the VL activation. The Myomed 134 program ‘continuous 1+2’ or ‘work/rest 1+2’ can be used for this purpose. Using the Myomed 134 during this task will give the patient and the therapist a more accurate reflection of the patient’s ability to activate the VMO fast enough compared to the activation of the VL. Since the onset of activation of the VMO and VL during quadriceps contraction will be almost simultaneously, it is very useful to save the curves in the Myomed 134 so these can be analysed at any time.

Once the patient is able to perform a quadriceps contraction with a correct timing of VMO and VL on the treatment table, progression is made by instructing the patient to perform this during more functional positions. The aim of the exercises remain to train the quadriceps so that the VMO contracts before/or together with the VL. The patient...
will be asked to perform this during stance, a squat, a lounge, or during stairs walking. By using the Myomed 134 the therapist and the patient get feedback concerning the timing of VMO and VL during these functional exercises. The use of this information will considerably shorten this motor learning process. In addition to the performance of these rehabilitation exercises in the physical therapy office, the patient is instructed to perform these daily at home. After some time, the use of the Myomed during the exercises will be decreased. The patient needs to learn to relate the external feedback (from the Myomed) with the internal feedback (given by his proprioceptors). This linking can be positively influenced by asking the patient to perform an exercise, but looking intermittent to the screen.

After performing several exercises without looking at the screen of the Myomed 134, the patient will stop the exercise and analyse the saved information in the Myomed 134 concerning the timing of VMO and VL during the functional exercises. If the information identifies that the patient performed the exercises with a correct VMO/VL timing, the therapist will instruct the patient to perform a more difficult functional exercise. Again, the latter exercise will at first be performed with continuous feedback on the screen, but progressively this feedback will be decreased. Towards the end of his rehabilitation period, the patient will perform some exercises with immediate feedback at the beginning of the rehabilitation session. If these exercises are carried out with a correct VMO/VL timing the patient will do the rest of his exercises within that rehabilitation session without feedback of the Myomed 134, but with focus on the correct timing. At the end of that rehabilitation session, the patient will perform some exercises with feedback of the Myomed to ensure that the exercises are performed with the correct VMO/VL timing. This way the patient is learned to become independent of the Myomed 134, while performing his exercises with a correct neuromuscular VMO/VL timing.

3.3 Rehabilitation of patients with an anterior cruciate ligament (ACL) deficiency

3.3.1 Introduction

The benefit of using the Myomed 134 in the rehabilitation of patients with an ACL deficiency is comparable with its advantage in the treatment of patients with patellofemoral pain syndrome. In patients with an ACL deficiency the emphasis will be placed on a qualitatively good and fast hamstring activation. Research identified that direct stimulation (stress) of the ACL results in a reflexive hamstrings contraction. The purpose of this hamstring contraction is to decrease the amount of stress placed on the ACL. Research on patients with an ACL deficiency showed that these patients have a delayed timing of the hamstrings to ACL stress (anterior translation of the tibia ing-reflex). Moreover, these patients have not only a delayed ACL-hamstring-reflex, but the activation timing of the quadriceps compared to the hamstrings as a consequence of anterior tibial translation seems to be disturbed.

In a healthy population an anterior tibial translation activates at first the hamstrings, and then the quadriceps. This muscular timing pattern seems to be the most effective to withstand the anterior translation of the tibia. However, in ACL deficient subjects a quadriceps activation is observed first as a result of a anterior tibial translation followed by a delayed hamstrings contraction. ACL deficient subjects with a normal fast activation pattern of the hamstrings as a reaction to an anterior tibial translation report a subjective stable knee. The faster the hamstrings contraction was, the more stable these patients felt.
Therefore, an important aim of the rehabilitation of an ACL deficient patient is the normalisation of the reflexive hamstring activation. How this can be achieved is described in the following section (reflective proprioceptive training programme –RPT).

3.3.2 Learning of voluntary hamstring activation (co-contraction)

In addition to a delayed hamstring contraction, ACL patients frequently show an insufficient activation of the hamstrings during functional exercises. Yet, a sufficient activation is imperative for a subjective feeling of stability in the knee. Therefore, at first emphasise should be given to train ACL patients to sufficiently activation their hamstrings.

3.3.3 Training hamstrings control

The patient is in a standing position. He/she is learned to palpate the hamstrings and is asked to perform a knee flexion. During this movement the patient feels how a hamstrings contraction feels like. Consequently, the patient is instructed to perform an isometric hamstrings contraction during stance. Once the patient can perform this, he/she will be instructed to contract the hamstrings isometrically during a short arc knee bent (20-30°). By doing so, the patient performs a co-contraction of the hamstrings during a eccentric contraction of the quadriceps.

The goal of the previous exercise was to exercise the patient to maintain a co-contraction of the hamstrings during a quadriceps activation. In this way the knee stability will be optimised and minimal anterior tibial translation will occur. Once the patient is able to perform this exercise, the knee flexion angle and speed of knee bending will progressively be increased (depending on the postoperative period). In addition to knee bends, other functional closed kinetic chain exercises can be given to the patient like lounges in several directions, turning, stairs etc.

The aim of these exercises remains to maintain the co-contraction of the hamstrings during these functional movements. Controlling the amount of co-contraction can be achieved by using the Myomed 134. These first series of exercises emphasise on the amount of hamstrings co-contraction. If these are performed correctly the stability of the knee joint will be increased during functional exercises.

The benefit of using the Myomed 134 in this learning process is identical to its use in patients with patellofemoral pain syndrome and is described in the previous chapter.

3.3.4 Exercises with controlled tibial translations

After the previous phase the patient should be able to co-contract the hamstrings during functional exercises. The next step is to ask the patient to perform a functional exercise and to provoke a tibial translation during this exercise. In this way the patient is trained to reflexively contract the hamstrings to a given tibial translation. Examples of these exercises are lounges with change of direction and moderate to high speed, jumping, running, change of direction, trampoline exercises, wobble board exercises…

Important is that the patient is told that the goal of these exercises is to stabilise the knee (with a reflexive co-contraction of the hamstrings). The patient needs to know that these exercises are not simply strengthening exercises.
3.3.5 Concrete exercise

As described in chapter 3.4., the Myomed program “continuous 1+2” or “work/rest 1+2” can be very useful in neuromuscular training program. In the ACL deficient patients electrodes are placed on the hamstrings and quadriceps. This way the patient and the therapist obtain an objective impression of the activation timing of these muscles in functional movements. Since the onset of activation of the hamstrings and quadriceps during functional movements will be almost simultaneously, it is very useful to safe the curves in the Myomed 134 and analyse these later.

3.3.6 Literature


3.4 THE USE OF MYOFEEDBACK IN SHOULDER INJURIES

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3.4.1 Introduction

The shoulder is a very mobile joint. Throughout human evolution the shoulder has lost a major proportion of its structural stability in favour of its mobility. Because of this inherent instability the shoulder has to rely on his coordinated muscle function for optimal functional performance. In addition, the arm uses the mobility of the scapulothoracic joint in order to obtain maximal range of motion. This joint is not, like other joints in our body, a true articular junction with capsular and ligamentous restrictions. Consequently, the scapula relies on muscle function to obtain stability as well as to perform movements necessary for normal upper limb function. In summary, it can be stated that the quality of the movements of the arm primarily depends on coordinated muscle function, in the glenohumeral as well as in the scapulothoracic joint.

In the shoulder and in the scapula, muscle function is characterized by the presence of force-couples. In the glenohumeral joint, the rotator cuff muscles provide the most important force-couple. Co-contraction between subscapularis on one hand and infraspinatus/teres minor on the other hand guarantee glenohumeral stability in the transversal plane. This coordinated muscle contraction keeps the humeral head centred into the glenoid fossa during arm motion. In addition, a second force-couple, composed by the deltoid muscle on one
hand and all rotator cuff muscles on the other hand, provide stability in the frontal plane. This force couple prohibits extreme translation of the humeral head in superior or inferior direction. In summary, the glenohumeral force-couples, in which the rotator cuff plays a crucial role, centre the humeral head into the cavitas glenoidalis and avoid impingement of soft tissue during arm movements.

The force-couple in the scapulothoracic joint is the result of muscle activity of the upper and lower portions of the trapezius muscle and the serratus anterior. During overhead motions of the arm, the scapula has to perform a three-dimensional movement, consisting of upward rotation (cavitas glenoidalis is directed superiorly), posterior tilt (acromion is moved posteriorly), and external rotation (glenoid more laterally oriented). These movements are the result of a coordinated action of the upper trapezius and the lower digitations of the serratus anterior. Co-contraction of the lower trapezius muscle ensures smooth movement regulation. This muscle part presumably has a more stabilizing role than an prime mover function in the scapular muscle activity pattern.

If neuromuscular coordination is disturbed in one of these force couples, functional stability is jeopardized in the scapulothoracic joint. These functional impairments may lead to structural injuries in the glenohumeral joint.

3.4.2 Glenohumeral joint: shoulder instability and shoulder impingement.

Depending of the direction of instability, shoulder instability is classified into anterior, postero-inferior, and multidirectional instability. Although this pathology is characterized by a lack of capsular and ligamentous restriction, it is often accompanied by poor muscle function in the glenohumeral muscles.

3.4.2.1 Anterior instability

Anterior instability is often associated with muscle dysfunction in the rotator cuff muscles. Subscapularis, as well as supraspinatus and infraspinatus may be involved. In recent literature it has been suggested that there specifically is insufficient activity of the infraspinatus in anterior shoulder instability. This muscle has to provide a posteriorly directed action on the humeral head to avoid abnormal anterior translations during arm movements. Neuromuscular dysfunction is characterized, not only by a lack of muscle force, but also by a delay in muscle activation and muscle imbalances between external and internal rotators. Although the final goal of our rehabilitation program is to regain automatic muscle control during all daily and sport specific activities, training of muscle control should be started with exercising the voluntary conscious activation of this muscle. This improves the proprioception and kinaesthesia preparatory to functional stability training. Myofeedback can be useful in this stage to enhance this neuromuscular process.

Training of glenohumeral muscle control should emphasize simultaneous co-contraction of all rotator cuff muscles. However, it is very difficult to measure muscle activity in the subscapularis en supraspinatus with surface-EMG. Therefore, co-contraction of the rotator cuff will be controlled through EMG-feedback on the infraspinatus muscle.

3.4.2.2 Postero-inferior instability

In a shoulder with postero-inferior instability, the humeral head is positioned too much inferiorly and posteriorly in relation to the glenoid fossa. Muscle training to restore humeral head centering consists of improving muscle control in the m. deltoideus. This muscle provides a superiorly directed force on the humeral head, thus translating it in an upward direction.
Especially the posterior part of the deltoid should be trained in this pathology since this muscle additionally migrates the humeral head in anterior direction. In the initial phase of rehabilitation, rotator cuff training should be performed with caution or be avoided, since this muscle group pulls the humeral head inferiorly, thus jeopardizing glenohumeral stability.

### 3.4.2.3 Multidirectional instability

In multidirectional instability, the humeral head moves abnormally in all directions. Muscle training consists of restoration of muscle control in all muscles that centre the humeral head. This means that rotator cuff as well as all three deltoid parts should be trained. Myofeedback control can be performed through EMG registration of two muscles: infraspinatus (representative for rotator cuff and posterior muscle group) and the anterior portion of the deltoid muscle (representative for deltoid and anterior muscle group).

### 3.4.3 Shoulder impingement

Shoulder impingement refers to clinical symptoms related to impingement of soft tissue (rotator cuff tendons) between the humeral head and the acromion (subacromial impingement) or the postero-superior rim of the glenoid (internal impingement). Literature classifies this pathology into structural (primary) impingement, and functional (secondary) impingement. In the latter group the impingement is not the result of a structural obstruction in the subacromial space, but rather the consequence of abnormal translations of the humeral head in superior and anterior (subacromial impingement) or posterior (internal impingement) direction. These abnormal translations may be caused by a subtle form of instability. In the rehabilitation emphasis goes to the restoration of normal glenohumeral kinematics to avoid impingement. This should be performed by exercising muscle control in the rotator cuff muscles. Myofeedback can be used in the initial phase on the infraspinatus to enhance cocontraction between the rotator cuff muscles.

### 3.4.4 Scapulothoracic dysfunction

Scapular dyskinesis may be caused by poor muscle coordination in the scapulothoracic force couple. In addition, soft tissue inflexibility, such as tightness of the pectoralis minor or the levator scapula may also result in abnormal movement patterns of the scapula during arm motion. These abnormal movement patterns mainly consist of lack of posterior tilt (often called tipping of the scapula since the inferior border is prominent, type I), decreased external rotation (winging or prominent medial border, type II), or insufficient upward rotation (prominent superior medial border, type III). However, patients often showed combined disturbances in scapular movement patterns. This scapular dyskinesis is mainly the result of a delay in activation and a lack of sustained activity in the lower trapezius and serratus anterior, coupled with a hyperactivity and predominance of the upper trapezius muscle. During rehabilitation of muscle control, lower trapezius activity should be enhanced, whereas upper trapezius activity should be inhibited. Although these muscle dysfunctions are common, all the muscles surrounding the scapula may be inhibited or predominant. Clinical observation of abnormal movement patterns and muscle activation patterns should determine the actual treatment strategy. Myofeedback is used in the initial phase of the rehabilitation, in order to enhance muscle activation as well as muscle inhibition.
3.4.5 Training modalities

3.4.5.1 Anterior shoulder instability and impingement: rotator cuff - m. infraspinatus

Electrode placement: on the muscle belly of the infraspinatus with one cm interelectrode distance, perpendicular to the spine of the scapula, lateral of the muscle fibres of the trapezius, and medial of the muscle fibres of the latt dorsi and posterior part of deltoid. (figure 13)

Initiation: patient is standing or sitting, arm in neutral position, elbow flexed 90°. Therapist gives a slight resistance against external rotation of the shoulder, thus asking a contraction of the infraspinatus. This contraction is controlled by the patient on the EMG-screen. Treshold of muscle activity is set on the level of activity, sustained for 5 seconds. Then the therapist asks the patient to sustain the contraction of the muscle, and removes the resistance given at the wrist against external rotation. In this way, the patient performs a cocontraction between infraspinatus and subscapularis in order to maintain this position.

Progression:
- muscle contraction without preceding manual resistance
- isometric muscle contraction in other shoulder positions (abducted 90°/neutral rotation; abducted 90°/external rotation; forward flexion 90°...)
- sustained isometric muscle control during movements of elbow and hand (supination against resistance, elbow flexion against resistance...)
- muscle control during dynamic arm movements in limited ROM (<90°) (elevation in the frontal, sagittal and scapular plane)

3.4.5.2 Postero-inferior instability: m. deltoideus pars posterior

Electrode placement: on the muscle belly with one cm interelectrode distance, approximately two fingers width inferior of the angulus acromialis, in the direction of the muscle fibres (figure 13).

Initiation: patient is sitting, arm is resting on the thigh (to avoid excessive inferior translation of the humeral head in rest); therapist gives resistance to extension of the arm while patient observes muscle contraction on the EMG-screen. Treshold of EMG-activity is set on contraction sustained for 5 seconds. Then the therapist asks the patient to sustain the contraction of the muscle, and removes the resistance given at the elbow against extension. This conscious activity of the posterior deltoid actively translates the humeral head in an upward and forward direction.

Progression:
- muscle contraction without preceding manual resistance
- muscle contraction while patient is standing, arm hanging beside body
- isometric muscle contraction in other shoulder positions (abducted 90°/neutral rotation; forward flexion 90°; forward flexion 90°/internal rotation...)
- sustained isometric muscle control during movements of elbow and hand (supination against resistance, elbow flexion against resistance...)
- muscle control during dynamic arm movements in limited ROM (<90°) (elevation in the frontal, sagittal and scapular plane, external rotation)
3.4.5.3 Multi-directional instability: rotator cuff + m. deltoideus

**Electrode placement:**
- m. infraspinatus: *cfr supra* (figure 13)
- m. deltoideus pars posterior: *cfr supra* (figure 14)
- m. deltoideus pars anterior: on the muscle belly with 1 cm inter-electrode distance, midway between the distal end of the clavicle and the tuberositas deltoidea, following the direction of the muscle fibres.

**Initiation:** the learning process has two phases: first muscle control is trained within the rotator cuff, following the guidelines described above, then co-contraction of the deltoid is trained. Electrodes are placed on both muscle parts. Patient is sitting with the arm sustained on the thigh or on the table, patient learns to consciously contract both muscles, and controls the muscle activity on the EMG-screen. Threshold is set on sustained contraction for 5 seconds. Both muscles should be contracted simultaneously and equally in intensity.

**Progression:**
- simultaneous co-contraction of rotator cuff and deltoid. One set of electrodes is placed on the infraspinatus, the second set is placed on the anterior part of the deltoid patient standing.
- arm hanging beside body.
- isometric muscle contraction in other shoulder positions (abducted 90°/neutral rotation; abducted 90°/external rotation; forward flexion 90°; forward flexion 90°/internal rotation…)
- sustained isometric muscle control during movements of elbow and hand (supination against resistance, elbow flexion against resistance…)
- muscle control during dynamic arm movements in limited ROM (<90°) (elevation in the frontal, sagittal and scapular plane, external rotation)
3.4.5.4 Scapulothoracic dysfunction: upper and lower trapezius muscle

*Electrode placement:* m. trapezius pars descendens: midway a horizontal line between the spinous process of the 7th cervical vertebra and the acromion.
m. trapezius pars ascendens: proximal of a horizontal line between the angulus inferior of the scapula and the corresponding spinous process, the first electrode lateral of the spine just proximal of the line, the second more superior and lateral, following the muscle fibres of the lower trapezius (figure 14).

*Initiation:* the patient is learned to consciously contract the lower trapezius, without additional muscle activity in the upper trapezius. If the upper trapezius shows too high basic activity or displays abnormal increases during the exercise, the patient is learned to consciously inhibit muscle activity in this muscle. Two treshold are set on the EMG-feedback system: a lower bounder to keep muscle activity of the lower trapezius above this level (set on 5 seconds of sustained muscle activity), and an upper bounder to keep activity of upper trapezius below this level. This treshold is set on basic activity in rest, however, it may be slightly increased during active movements of the arm.

*Progression:*
- normalized muscle activation in push-up positions (against the wall, four point kneeling)
- sustained normalized muscle activity during various body movements, walking, head movements...
- sustained normalized muscle activity during movements of elbow and hand (supination, elbow flexion...)
- sustained normalized muscle activity during movements of the arm in limited ROM (external rotation, elevation in the scapular, frontal and scapular plane)
3.4.6 Literatuur

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3.5 Use of EMG biofeedback in the rehabilitation of dynamic stabilization of the lumbar spine

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3.5.1 Introduction

The performance of voluntary trunk movements as well as the maintenance of trunk stability requires muscular activity. Every movement is dependent on a specific coordination of the trunk muscles to produce a resultant force (torque) which has to be tuned with the variations in external and internal forces to give a smooth and appropriate movement.

Recent studies suggest that the abdominal and back muscles may not be considered as one muscle group, and that different abdominal and back muscles may have quite specific functions 1,4,9,10.

The concept of different trunk muscles playing different roles in the provision of the dynamic stability to the spine was proposed by Bergmark 1. He hypothesized that two muscular systems were involved in the maintenance of spinal stability.

- The global muscle system consists of large, torque-producing muscles that act on the trunk and spine without being directly attached to it. These muscles include the rectus abdominis [RA], external oblique [EO], and the thoracic parts of the erector spinae, e.g. iliocostalis lumborum pars thoracis [ICLT]. The global muscles provide general trunk stabilization, but they are not capable of exerting a direct segmental influence on the spine.

- The local muscle system consists of muscles that directly attach to the lumbar vertebrae, and are responsible for providing segmental stability and directly controlling the lumbar segments. By definition, the lumbar multifidus [MF], transversus abdominis [TA], and internal oblique [IO] form part of this local muscular system 9.

Epidemiological studies suggest that abdominal and paraspinal muscle dysfunction may be important in the aetiology of low back pain. However, the muscular activity in relation to back pain may not be uniform amongst all the lumbopelvic muscles 3,5,6. There is clinical and scientific evidence that mainly the local, stabilising muscle system is affected in LBP patients. Research into muscle impairment in LBP has realized that there is a specific impairment in the deep muscles of the trunk, notably TA and the MF.

Randomized clinical trials have evaluated the efficacy of specific rehabilitation that focuses on co-activaton of these deep muscles. Evidence suggests that it is very important that these
deep muscles are targeted specifically in rehabilitation, i.e. that their action is ensured separately from other trunk muscles 6,7. Thus, monitoring the behaviour of individual muscles may be necessary for an accurate assessment and rehabilitation of trunk muscle function 8. EMG biofeedback during muscle contraction is a useful tool for this purpose.

3.5.2 Procedure

There are possibly many ways of approaching the treatment of muscle disfunctions in LBP patients. The approach described here is well illustrated in literature and has proven to be effective in clinical practice. The exercises performed can be described as the training of a specific motor skill. Such a motor skill is rehabilitated through a motor relearning process rather than through conventional exercises for increasing the strength and endurance of muscles. Control of the lumbar spine in a neutral or midposition and precise co-contraction of trunk muscles (which would include the TA and the MF) independently of the global muscles are essential components of the stabilisation training.

In the case of the MF, research has shown that the effect on the muscle following injury is rapid and very specific. The approach to exercise therapy needs to be very precise as the other parts as the other muscles such as the thoracic components of the erector spinae will be more easily activated when rehabilitation is attempted.

In the case of the TA, it is apparent that if separate control of this muscle is lost, a generalized activation of more superficial abdominal muscles will ensue. Thus, this type of exercise should be well controlled. EMG biofeedback permit real-time control of the activity of the different muscles.

3.5.3 Methods

3.5.3.1 Electrode placement

The electrodes are positioned within the borders of the muscles and in alignment with their orientation.
RA: The electrodes for RA were placed midway between the umbilicus and the processus xiphoideus, two cm lateral to the midline 8
EO: 15 cm lateral to the umbilicus 4,8
TA: midway between the iliac spine and symphysis pubis, above the inguinal ligament 4
MF: just lateral to the midline of the body, above and below a line connecting both posterior superior iliac spines 5
ICLT: above and below the L1 level midway between the midline and the lateral aspect of the body 4,5,
3.5.4 Isolated cocontraction

The first step is to train the ability to recruit the stabilising muscles at an appropriate level. Therefore an electrode can be placed on the TA or MF. The therapist learns the patient to develop the accurate neuromuscular strategy in order to recruit the appropriate muscle and ask to increase activity. The aimed intensity varies in function of starting position and interindividual differences in body composition. But on average an tonic, continuous contraction of 10-15 % of maximum voluntary contraction is adequate.

In this condition, using biofeedback, it is useful to set a threshold for the stabilising muscle. An visual or acoustic signal can be given when not enough activity of the local muscle is measured by the electrode.

When the patient uses substitution strategies for the correct abdominal or back muscle action, these can be identified by placing electrodes not only on the stabilising (MF-TA), but also on the surrounding torque producing back or abdominal muscles (ICLT – RA/EO).

In this condition it is useful to set a threshold for both muscles separately. For the stabilising muscle an visual or acoustic signal can be set below the threshold, for the muscles recruited by a substitution strategy an visual or acoustic signal can be set above the threshold. In summary, in this condition visual or audial feedback is given when an inaccurate neuromuscular strategy is used (not enough activity of the local muscles or too much activity of the global muscles).

These exercises can initially be performed in lying or four point kneeling, and later progressed to weight-bearing positions (sitting – semistanding – standing).
It is not uncommon to find that patients often experience initial difficulty in activating the muscle pattern of the TA and/or the MF, and patients will readily substitute with the RA-EO and/or the ICLT respectively. It is therefore important that in the beginning the patient has a conscious awareness and perception of the correct neuromuscular pattern of contraction and can themselves detect when their performance is incorrect or insufficient. In this phase of the muscle rehabilitation program EMG biofeedback can be very useful.

The ultimate goal of the first phase of “isolated co-contraction” is to have the motor skill of performing an isometric continuous co-contraction of TA and the MF without significant interference of the global muscles. Here, it can be useful to set a separate threshold for both stabilising muscles. To control the amount of co-contraction, both stabilising muscles can be real-time measured. For both muscles a feedback signal can be set below the threshold.

Trunk muscle control in a neutral position of the lumbar spine is trained in a variety of body positions. Four-point kneeling, supine, sitting and standing. When the co-contraction of the TA and the MF are isolated the holding capacity is trained by asking the patient to perform their maximum number of 10-second holds. It is useful to monitor the stabilising muscles using EMG feedback. This will ensure that the appropriate contraction is maintained. When the stabilising muscles become fatigued, a possible compensating strategy, is that the large torque producing muscles take over.
3.5.5 Integration into function

Once the patient can perform 10 repetitions of 10-second holds of co-contraction the stabilization program is progressed. Following their activation in isolation, the TA and the MF are trained in their stability role under more functional conditions. The aim is to enhance muscle control during low-load exercises. Therefore, in a variety of body positions, MF and TA co-contraction in the neutral position of the lumbar spine is combined with leg- and arm-loading activities. The level and effectiveness of the patient’s muscles control for stabilization can be monitored objectively with EMG-feedback. The use of such a device ensures that the trunk muscle control is at an appropriate level and balanced between the different muscles.

3.5.6 Conclusions

Physical therapists worldwide recognize the importance of retraining active trunk stabilization within the total management program of a large group of LBP patients. Real time EMG-feedback is a very useful modality in the initial phase of rehabilitation. This feedback feature facilitates not only an adequate muscle activation, it enables the therapist to objectively control the quality of the contraction and the coordination with the surrounding muscles.

3.5.7 Literature

4.1 General information

Since the beginning of the nineties, the use of myofeedback, pressure feedback and electrotherapy has become increasingly important within the physiotherapeutic diagnostic process and the treatment of clients with complaints caused by pelvic floor dysfunctions. Pelvic physiotherapy is regularly quoted in the literature as the first choice of treatment where the conservative treatment of pelvic floor problems is concerned.

The equipment is becoming increasingly advanced and offers the therapist a wide range of options to diagnose and treat as effectively as possible. Extensive software means that treatments can be evaluated in a straightforward way. The information that is obtained with the aid of the software can also be exported to a spreadsheet (such as MS Excel) and individual graphics created. This is an extremely useful function, considering the development for increasingly evidence-based treatment.

The pelvic floor is an unknown muscle for many people. There are no visual stimuli and it can also be difficult for people to feel where the muscle is and what its function is. It is precisely these factors that make the pelvic floor muscle especially suitable for treatment with myofeedback, pressure and/or electrotherapy.

4.1.1 Advantages of myofeedback:

- Increases awareness and confirms correct muscle activity. Many people are unaware of increased basic activity or incomplete relaxation of the pelvic floor. Good relaxation forms the basis of the training.
- It is possible to adapt pelvic floor exercises as regards force, duration, coordination and relaxation.
- Objective recording – makes progress visible. Professional support during exercising provides encouragement and often has a positive effect on the treatment.
- The belief and confidence of the therapist in myofeedback has a positive effect on the patient (motivation factor).
- Empirical findings: in a short space of time, with good results.
- No side effects, no irreversible changes.
- Painless.
4.1.2 Probes

Intra-vaginal and intra-anal probes can be used in the treatment of pelvic floor problems. A wide range of equipment is available for this purpose (Figure 22), which means that there should be a suitable probe for every type of patient.

In selecting the type of equipment, the purpose of the treatment (electrotherapy, EMG, pressure, ambulatory EMG) as well as anatomy will play a role. A ring and shield probe generally give a lower value than a (vaginal) probe with a bent electrode surface (see Figure 23). This latter type makes more contact and is therefore more suitable for ambulatory recordings.

The vaginal electrode with disposable sleeves (Figure 24) are especially suitable for recording muscle asymmetry, because simultaneous EMGs can be made of the left and right side of the pelvic floor muscle.

It must be borne in mind that the greater the contact of the electrode, the more reliable the measurement. In order to obtain a good recording, the recording part of the probe must be placed as closely as possible against the muscular tissue.

4.1.3 Pressure

Pressure is not often used in pelvis physiotherapy. In certain cases, however, the use of pressure can be of particular value:

4.1.3.1 Vaginal

- in the treatment of clients in whom the vagina is too wide (for example after parturition) for an EMG probe to make sufficient contact. As a pressure probe can be topped up with air, it can make better contact with the vaginal wall and therefore also with the pelvic floor muscles. This allows the advantages of myofeedback to be utilised for the motor learning process in cases of bad proprioception.

- pressure feedback can provide a solution for women with a wide diastase in the levator plate and a poor closing function during contraction. While a surface EMG makes electrical, and therefore also static movement in the muscle visible, pressure reacts particularly to movement. Such movement, particularly the closing of the diastase in the levator plate during contraction, can be practised very effectively with the aid of a pressure probe.

A further application of pressure is when instead of a pressure probe a silicon balloon is connected to the equipment. The advantage of a balloon is that it has a very small diameter, which makes it suitable for use as a pressure probe for vaginistic women, for whom a normal probe is too hard and too thick. The balloon therefore functions as a pressure probe, enabling relaxation of the pelvic floor to be recorded.
4.1.3.2 Rectal

Pressure can be used rectally to make the distension reflex visible in combination with a rectal balloon. The balloon is filled with air. When the stimulus threshold of the stretch receptors of the rectum is exceeded, the internal anal sphincter reacts with a resulting reduction in pressure in the anal canal. Pressure is a very useful aid for helping clients to become aware of these physiological changes. Being able to see the reduction in pressure also promotes the feeling of the reduction in pressure. From there, someone can be taught to tense the muscles at that point.

Pushing technique can be taught with the aid of pressure feedback. At the point of pushing a reduction of pressure should take place in the anal canal. This can be clearly seen when pressure is used.

However, in practice pressure is not often used to obtain normal values. A client must be compared to himself in this application.

4.1.4 Differences between EMG and Pressure measurements

How does an EMG measurement differ from a pressure measurement?
An intra-anal or intra-vaginal pressure measurement, as the term suggests, measures the differences in pressure in the anus or vagina that could be the result of pelvic floor muscle activity. A pushing force on the stomach (from coughing, talking, holding breath or pushing) can also cause changes in pressure.

An EMG measurement measures the motor unit activity of a muscle, which changes with contraction and relaxation and becomes visible as a curve on the screen. The variability in the curve indicates the quality of contraction and relaxation. A change in calibration (for example from 4-20 microvolts) can influence the quality of the feedback. For example, someone with weak contractions will see more variability in amplitude on a screen with a calibration of a few microvolts, than if the calibration were set, for instance, at 10 microvolts.

Incomplete relaxation can be seen less precisely with a setting from, for instance, 20 microvolts and will appear reasonable, while the same quality of relaxation with a setting of, for instance, 8 microvolts, will be seen as insufficient.

With pressure recordings, the variability in amplitude (motor unit activity) during contraction and relaxation of the pelvic floor is less precise, so that coordination and relaxation problems are more difficult to recognise.

Practising with a pressure electrode (probe) can sometimes be useful, for instance postpartum, if you want to influence the propriocepsis. A pressure electrode is made of flexible material and can be filled with air so that it makes better contact intra-vaginally. By tensing the pelvic floor the exerted force can be felt more easily on the vaginal wall. The rectal reflex balloon (PelviTec) can be used as a vaginal pressure probe for women with vaginism. The small size of the probe means that for these women (if internal treatment forms one of the options) pressure feedback is also a treatment option.
In order to be able to carry out an internal examination and/or treatment of clients with a complaint or disorder based on a pelvic floor problem, it is essential that a training course recognised by the NVFB (Netherlands Association of Physiotherapy for Pelvic Floor Problems in pre- and postpartum health care) has been completed. Only those physiotherapists who are demonstrably competent in internal examinations and treatment of the pelvic floor area, for both palpitation and the use of apparatus, may apply this treatment. One must be aware at all times that one is working in an extremely vulnerable area. This requires the greatest care.

Feedback, electrotherapy and pressure are not the first option in the treatment of pelvic floor problems for patients with a problematical sexual history. These patients are only examined or treated internally in consultation with the person who made the referral and other medical practitioners. There are still patients who relive their original trauma as a result of careless action on the part of the doctor or physiotherapist treating them.

Treatment with feedback is not effective for people with a cognitive dysfunction.

4.2 Anatomy and physiology

To carry out internal treatment with (myo)feedback and stimulation apparatus, knowledge of the location and the function of the muscles is essential. A brief summary of the most important muscles, their location and their function is given below.

4.2.1 The pelvic floor musculature

The pelvic floor consists of 3 superimposed muscles, which contain a large amount of connective tissue and run into the infundibular pelvic outlet. The muscles are made up of 80% slow twitch and 20% fast twitch tissues.

At rest the pelvic floor muscles provide active support to the abdominal organs. An increase in intra-abdominal pressure strengthens the contraction of the muscles. The pelvic floor functions as it were like a trampoline and thereby has an effect on the anatomical position of the bladder, the womb and the intestines.

The pelvic floor consists of three layers:
- a superficial layer
- a middle layer
- a deep layer
4.2.2 The superficial layer

The superficial layer consists mainly of the Sphincter Ani Externus and the external genital musculature (see Figure 25).

The Sphincter Ani Externus is a voluntary orbicular muscle that closes the anal canal. At the front, the fibres run towards the centrum tendineum, a connective tissue structure just in front of the anus. The centrum tendineum is also the place of attachment of other muscles, further increasing the support function. At the back the fibres run towards the os coccygis.

External genital musculature:
- m. ischiocavernosus
- m. bulbocavernosus
- m. transversus perinei superficialis

The muscles referred to above have a function particularly in sexual response, despite the fact that they are sometimes referred to as important for closing the vaginal introitus. However, they are too weak to be effective as regards a support or closing function.

4.2.3 The middle layer

The middle layer, or Diafragma Urogenitale, is situated immediately below the m. levator ani and is formed by the m. transversus perinei profundus and the m. sphincter urethrae externus (see Figure 26).

m. transversus perinei profundus
The muscle has its origin on the ramus ossis ischii and on the ramus inferior ossis pubis.
It is strengthened at the front by the ligamentum arcuatum pubis and the ligamentum transversus perinei. It has a support function and closes the middle part of the urethra and vagina. This muscle is also thought to have a sexual function.

m. sphincter urethrae externus
The muscle surrounds the urethra for several centimetres. It closes the urethra and as such is important in the treatment of urine incontinence.
4.2.4 The deep layer

The deep layer, or the Diafragma Pelvicum, is constructed from the m. levator ani and the fascia lying above and below it and the m. coccygeus (see Figure 27).

m. levator ani
The muscle again consists of three different parts:

a) m. puborectalis
The muscle has its origin on the dorsal side of the os pubis and part of it runs like a loop around the rectum (see Figure 28). During a contraction the rectum is pulled inwards and forwards. The muscle is responsible for strengthening the ano-rectal point that is important in holding up faeces.

b) m. iliococcygeus
The muscle originates at the height of the spina iliaca posterior superior, the fascia obturatoria up to the spina ischiadica and is attached to the ligamentum anucoccygeum and to the os coccygis.

c) m. pubococcygeus
The muscle originates on the dorsal side of the os pubis, on the outside of the m. puborectalis. The fibres run from the os pubis in a sagittal direction to the os coccygis.

m. coccygeus
The muscle fibres run from the spina ischiadica and the lig. sacrospinale to the sacrum and the side edges of the os coccygis.
4.2.5 Innervation of the pelvic floor

The bladder wall consists of smooth muscular tissue (m. detrusor). The sensory paths from the m. detrusor follow the parasympathetic route via the n. pelviscus to the spinal cord segments S2-S4. The motor nerve paths to the detrusor are parasympathetic and originate in the sacral segments S2-S4. They run predominantly via the n. pelviscus. The nerve paths to the m. sphincter internus originate in the orthosympathetic system from segments Th10-L2 and run via the n. hypogastricus.

The motor paths to the horizontally striped muscle fibres of the m. sphincter externus and peri-urethral musculature run predominantly via the n. pudendus and originate in segments S2-S4. The nn. pudenda end as the plexus sacralis.

<table>
<thead>
<tr>
<th>Nerve path</th>
<th>Nervous system</th>
<th>Segment(s)</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>n. Pelviscus</td>
<td>Autonomous</td>
<td>S2-S4</td>
<td>Parasympathetic</td>
</tr>
<tr>
<td>n. Hypogastricus</td>
<td>Autonomous</td>
<td>Th10-L2</td>
<td>Orthosympathetic</td>
</tr>
<tr>
<td>n. Pudendus</td>
<td>Somatic</td>
<td>S2-S4</td>
<td>Locomotive</td>
</tr>
</tbody>
</table>

The m. levator is innervated from the caudal area by the rami musculares of the ventral rami of the n. pudendus and from the cranial area by the rami musculares of the nn. Sacrales, which also innervate the m. coccygeus. The muscles of the diafragm urogenitale are all innervated by the rami musculares of the n. pudendus (Verboon and van Dolder, 1987).

4.2.6 Function of pelvic floor musculature

The most important function of the pelvic floor is to support the organs situated in the pelvis and to keep the filling organs adequately closed. Good relaxation of the pelvic floor is important for complete emptying of the filling organs.

The pelvic floor also plays a role in breathing, circulation (muscle pump), postural balance and sexuality.

About 30% of the urethral closing force is produced “at rest” by the external sphincter, the peri-urethral muscles and the m. levator ani. The other 70% is mainly supplied by the internal sphincter. As pressure in the bladder also increases greatly during intra-abdominal increase in pressure, the urethral closing pressure has to rise substantially. The peri-urethral muscles and the m. levator in particular are responsible for this. At the point of this increase in pressure a myotatic reflex will occur, as a result of a sudden stretching of the pelvic floor (see Figure 30).
4.2.7 Dysfunctions of the pelvic floor musculature

Dysfunctions of the pelvic floor musculature can lead to a wide range of complaints, which can often be traced back to muscle insufficiency, coordination disorders and a loss of proprioception.

• Muscle insufficiency:
  o Overly weak sphincters and insufficient trampoline function increase the chance of incontinence and prolapse.
  o Insufficient relaxation of the sphincters and pelvic floor increase the chance of urine retention, recidivistic urinary passage infections, constipation, peri-anal pain, dyspareunia or vaginism.

• Coordination disorders:
  o For instance paradoxical contractions of the pelvic floor during micturation and/or defaecation resulting in incomplete evacuation of faeces or incomplete emptying of urine. An inverted perineal movement occurs when there is a pushing reaction instead of a contraction of the pelvic floor.

• Loss of proprioception:
  o Insufficient awareness of contraction and relaxation of the pelvic floor.

**Pelvic floor dysfunction can often result from:**

• Traumata
  o in women as a result of parturition
  o in men after a surgical procedure on the prostate
  o after surgical procedures in the anorectal and urogenital area
  o sexual misuse

• Radiotherapy

• Overloading
  o excessive coughing
  o incorrect and excessively heavy lifting
  o standing for a long period
  o practising a sport involving a lot of jumping movements with an already weakened pelvic floor
  o adipositas

• Incorrect toilet behaviour
  o excessive haste
  o overlong retention
  o pushing for too long or incorrectly

• Hormonal changes
  o Oestrogen deficiency after the menopause, leading to atrophy of the peri-urethral and vaginal tissues.

• Incorrect use of breath
  o unnecessary pushing
  o holding the breath while pushing hard or with trunk-constricting movements such as bending over and bending down
  o lack of diaphragmatic breathing

• Aging
  o general reduction in tissue quality
  o inactivity

• Neurological disorders
  o central
  o peripheral
4.3 The physiotherapeutic diagnostic process

Whether a client suffers from stress incontinence, constipation or pain in the pelvic (floor) region, it is important to be able to relate the symptoms to a pelvic floor dysfunction with the aid of diagnostics. This chapter presents the various methods that are important for a thorough diagnostic examination.

The first part sets out the diagnostic process in a general sense. In the following part it will become clear that the use of EMG in particular is an excellent way of looking at all the facets muscle function in a detailed way.

4.3.1 The diagnostic process - general

Diagnostics in relation to the functioning of the pelvic floor can consist of the following elements:

<table>
<thead>
<tr>
<th>Diagnostic element</th>
<th>When used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anamnesis</td>
<td>always</td>
</tr>
<tr>
<td>General examination</td>
<td>always</td>
</tr>
<tr>
<td>Specific examination (if internal examination is indicated)</td>
<td>always</td>
</tr>
<tr>
<td>Examination using palpation (if internal examination is indicated)</td>
<td>always</td>
</tr>
<tr>
<td>Examination using myofeedback (if internal examination is indicated)</td>
<td>always</td>
</tr>
<tr>
<td>Examination using pressure (if internal examination is indicated)</td>
<td>depending on symptoms</td>
</tr>
</tbody>
</table>

4.3.1.1 Anamnesis

Extensive questioning on micturition, defecation patterns and sexuality. ICP (International Classification of Physiotherapy).

4.3.1.2 General examination

• Type
• Posture
• Breathing
• Loading of the pelvic floor while sitting and standing. With the pelvis tilted forwards, under increased lordosis, the pressure on the diaphragm urogenitalia is considerable. When the pelvis is tilted backwards there is more gravity exerted on the dorsal part of the pelvic floor.

4.3.1.3 Specific examination

• External genitalia
• Skin
• Scars
• Discharge
• Prolapsus during rest and during movement
• Movement:
  o contraction
  o after relaxation
  o during pushing
  o coughing
  o co-contractions

Examination by means of palpation
• Tissue of the tissue
• Scar tissue
• Sensitivity (essential for the application of intra-vaginal and/or intra-anal electro-stimulation)
• Tonus
• PERFECT scheme (Jo Laycock) for both urogenital diaphragm and pelvic diaphragm and possibly anorectal for EAS (external anal sphincter) and m. puborectalis.
• Using the PERFECT scheme, the muscle is screened for the following characteristics:

P = Power: the power of the contraction (scale 0-5).
E = Endurance: How long can a contraction be maintained with the power determined above?
R = Repetitions: How often can a contraction with the above power and endurance be repeated? A rest of 4 sec. is used between two consecutive contractions.
F = Fast: How often can a fast contraction of 1 sec. be repeated? It is important that the muscle returns to the resting value after each fast contraction.
C = Contraction is
T = Timed. Between R and F there is 2 min. rest. The notation system is as follows: P/E/R/F/E/C/T.

To give an example: the levator ani is able to contract 4x with power 3 and a stamina of 4 seconds, without loss of power and/or stamina. The muscle is also capable of providing 3 fast contractions after a 2 minute rest, with good coordination. This is written as follows in the PERFECT scheme: 3/4/4/3

4.3.1.4 Examination with the aid of myofeedback

Muscle function can be portrayed using palpation. However, it is impossible to assess the timing of a contraction when using palpation, nor can an opinion on the resting tonus be arrived at with the use of palpation. Palpation is furthermore a subjective tool. EMG gives a much more reliable picture of the resting tonus before and after activity. It is also possible to portray the muscle activity during ADL activities in an objective way with the use of EMG. Furthermore, most symptoms relating to pelvic floor dysfunctions occur in ADL, not while lying on an examination couch.

We still do not know if the measured power of the pelvic floor is a reliable variable in the continence mechanism. Someone with a recorded power of 6 microvolts may be bone dry, while someone else with the same power suffers from stress incontinence.

We do know that becoming aware of the pelvic floor area, plus regular practice of random contractions and relaxation of the pelvic floor, has a proven positive effect on the continence mechanism.
Compared to palpation, EMG recordings not only provide a much better analysis of the pelvic floor, but they also enable an opinion to be made on the functioning of the pelvic floor muscles.

4.3.2 The diagnostic process (using EMG)

To arrive at an adequate plan of treatment, the muscle must be tested for a number of essential physiological aspects.
- the resting tonus
- the ability to contract
- selective ability to contract
- fast twitch activity
- slow twitch activity
- capacity for relaxation before and after contraction (both fast and slow)
- reflex activity

In order to chart these aspects, the following 13-step protocol has been developed:
1. 2-minute recording of the resting value
2. 5 contractions of 1 second with 10 seconds pause
3. 30 seconds rest
4. 5 contractions of 1 second with 1 second pause
5. 30 seconds rest
6. 5 maximum contractions, lasting 6 seconds, pause of 6 seconds
7. 30 seconds rest
8. 3 submaximum contractions of 20 seconds with 20 seconds pause
9. 30 seconds rest
10. 3 times 5 seconds pushing with 5 seconds pause
11. 10 seconds rest
12. coughing
13. 1 minute rest

Step 1: Measuring the resting value for 2 minutes
Objective: to assess the resting tonus.
At the start of the session, measure the resting activity for 120 seconds (allow the client time to get used to the electrode). Do this in various postures (lying, sitting, standing).

A normal resting activity has an amplitude of 1-2 microvolts or is 10% of the maximum power. This will also depend on the anatomy and the type of probe used. Generally, values obtained from different people cannot be compared, as individual recordings are involved here. In other words, the resting value of patient A must never be compared with that of patient B. However, the resting values taken at different times for patient A can be compared.
Assessment of the resting tonus (see Figure 31):

How high is the resting tonus?
With a ring or plate electrode this is 1-2 microvolts, with the use of an anuform or periform electrode the values may be higher. Depending on the type of contact of the electrode, the resting value with these probes can be up to 8 microvolts.

Is the line displayed on the screen steady?
Look at the variability/deviation. A relaxed pelvic floor does not have a lot of variability/deviation. A restless pelvic floor can be recognised by a strongly fluctuating amplitude.

Does the tonus go down?
In other words: can a falling line be seen during the 2 minutes? It may be that the patient is becoming used to the situation and able to relax better.

Does the tonus go up?
Does the patient become tense at the prospect of the procedure?

What happens to the resting tonus whilst speaking?
People with a lot of tenseness in the vocal cords will increase the tonus of the pelvic floor whilst speaking.

Does the manner of breathing affect the resting tonus?
In combination with high breathing (i.e. chest breathing instead of stomach breathing) the tonus of the pelvic floor will always be higher. Ensure that the posture in which recordings are taken is comfortable for the patient and that this is the same for subsequent recordings.

Step 2: A series of 5 contractions of 1 second with 10 seconds rest
Objective: to measure the speed of contraction of the fast twitch tissue.

How fast is the contraction and relaxation?

A fast contraction has a non-jagged amplitude and is followed by a fast and complete relaxation and good resting activity. The onset time (reaction speed; from rest Æ max. tensing) of a healthy muscle is 0.2 sec. or less. With stress incontinence a delayed onset time is often a problem (see Figure 32). This loss of timing cannot be shown with palpation but plays an essential role in the repair of muscle function.

With a loss of coordination there is often a delayed contraction (the onset time is increased), the amplitude is jagged and/or the relaxation is delayed. The release time (the opposite of onset time) is increased and under normal circumstances consists of 0.2 seconds or less. The amplitude slowly decreases to the basic activity. It can also take a little while before the resting activity shows less variability.

Figure 32
Step 3: 30 seconds rest
Look at the quality of the resting tonus in relation to the resting measurement at the start. It is important for the purpose of the therapy to have a clear picture of how the resting tonus responds to the muscle activity. In particular a subsequent increase in tonus means that there is insufficient relaxation. Consideration must be given as to how the muscle can be allowed to perform in an optimal way. In most cases, however, the resting tonus will be lower.

Step 4: A series of 5 contractions of 1 second with 1 second pause (fast twitch)
Objective: to assess coordination on the basis of the speed of relaxation after several fast contractions. The same situation applies here as with the series of contractions in step 2, but with the difference that here the series is consciously kept very short. For good coordination it is important that the relaxation takes place within 0.2 seconds. If the muscle does not relax quickly enough after a contraction, it will become increasingly difficult to apply the next contraction in a fast and satisfactory way. The resting tonus will then increase (see Figure 33). A coordination problem is easier to spot with this series, while with the series with pauses of 10 seconds it is less obvious.

Step 5: 30 seconds rest
Again the quality of the resting tonus is looked at in comparison with the resting measurement at the start. It is important for the purpose of the therapy to have a clear picture of how the resting tonus responds to the muscle activity. A subsequent increase in tonus in particular means that there is insufficient relaxation.

Step 6: A series of 5 maximum contractions of 6 seconds with a pause of 6 seconds (fast twitch)
Objective: assessing propriocepsis on the basis of maximum contractions, where fast twitch and slow twitch activity play a role. A good contraction is fast and not jagged, is easily maintained for 6 seconds with a high amplitude, with little deviation, and relaxes quickly to a basic activity with little deviation in the rest amplitude.

Proprioceptive problems can easily be indicated with this:
- Can the patient tense quickly and selectively?
- Can the contraction be maintained for 6 seconds?
- Does the muscle relax quickly and completely?
With light hypertonicity, a delay or even a post-contraction is often visible at the point of relaxation. In the case of loss of coordination, delayed contraction and relaxation will be visible. In the case of tiredness, there will be a lot of variability in the maximum amplitude (see Figure 34).

This image is often also seen in the case of reduced power and reduced stamina. If the tonal muscle activity is insufficient, the fast twitch tissue will attempt to keep the attained contraction level high through alternating tensing. In this case the deviation will be very high. With a relaxation problem, the amplitude will be delayed and incomplete (see Figure 35). A fast start to a contraction is often also delayed. A good ‘lift movement’ of the pelvic floor during the contraction phase can make complete relaxation easier.

**Step 7: 30 seconds rest**
Again, the quality of the resting tonus is looked at in comparison with the resting measurement at the start. It is important for the purpose of the therapy to have a clear picture of how the resting tonus responds to the muscle activity. A subsequent increase in tonus in particular means that there is insufficient relaxation.

**Step 8: A series of 3 sub-maximal contractions of 20 seconds and a pause of 20 seconds**
Objective: in this series the tonal activity in the muscle is looked at. In the literature this form of contraction is seldom described. Generally, a training series is given of 8-12 maximum contractions of 6-8 seconds, 30 seconds rest, followed by one or two repetitions of the series (Kari Ba). Note any tiredness during the series. Follow the height of the contraction and note any change in deviation. What does the resting activity following the long contractions show? Hypertonicity that was not visible in the series above can be recognised by an increase in the resting tonus after a long contraction.

**Step 9: 30 seconds rest**
Again, the quality of the resting tonus is looked at in comparison with the resting measurement at the start. It is important for the purpose of the therapy to have a clear picture of how the resting tonus responds to the muscle activity. A subsequent increase in tonus in particular means that there is insufficient relaxation.

**Step 10: 3 series of 5 seconds pushing with a 5-second pause**
Objective: to assess relaxation and inverted perineal movement.
Five seconds of pushing followed by a rest period of 5 seconds. Repeat this 3 times.

Look for any change in the tonus. The resting tonus normally goes down. It may be that a slight increase of the tonus will be visible. This is caused by contraction of the m. ischiococcygeus which supports the rectum during pushing. As not everyone is capable of activating this muscle during pushing, it is not always visible. With a strong increase in EMG activity there is an inverted perineal movement.
Step 11: 10 seconds rest
The resting tonus is looked at in comparison with the resting measurement at the start. This time the rest period is only 10 seconds.

Step 12: Coughing (3x)
Objective: to assess reflex activity
Ask the patient to cough 3 times. Does the muscle react to the increase in pressure by tensing? With a well functioning muscle there are 3 peaks in the EMG image for 3 coughs.

Step 13: 1 minute rest
What is the quality of the resting tonus in relation to the resting measurement at the start? It is important for the purpose of the therapy to have a clear picture of how the resting tonus responds to the muscle activity. A subsequent increase in tonus in particular means that there is insufficient relaxation. Consideration must be given here as to how to allow the muscle to perform in an optimal way. In most cases, however, the resting tonus will be lower.

4.3.3 Examination using myofeedback
An examination using resting pressure can take place in the same way as the diagnostic process with EMG. It must be taken into account here, however, that the results are less reliable. This is therefore more useful as a therapeutic measure.
4.4 Physiotherapeutic treatment: the therapy

In principle, symptoms related to a dysfunction of the pelvic floor muscles can be reduced to muscular level. On the basis of the diagnostic protocol referred to above (the 13-step protocol), the muscle function can be looked at in detail, after which a suitable treatment protocol can be devised.

4.4.1 General guidelines for the use of myofeedback, pressure and electrotherapy

With regard to the client:
• Safeguard the client’s privacy.
• Give detailed information and explanations about the proposed treatment.
• Request permission from the client for an internal examination and treatment and record this in the case history. Permission must also be obtained from the doctor who made the referral. The doctor must also be kept informed of the treatment.
• The client has the option to halt the treatment at any time.
• Do not carry out internal examinations or treatment if there is a problematical medical history (see comments in Chapter 1). Consult with referring doctor.

With regard to the treatment area:
• Make sure the treatment room/cubicle is private. Intimate questions and treatment will occur during the anamnesis and treatment and it is not pleasant for the patient if others are able to listen.
• Ensure that the treatment area is clean and work in a hygienic way (follow the appropriate guidelines for hygienic procedures in the pelvic area issued by the relevant governing body).

With regard to treatment:
• Use a new probe for each client and clean it after use according to the relevant guidelines.
• Choose a probe that is suitable for the client’s build and for the treatment.
• As far as possible use the same physical posture during measurements.

With regard to treatment using electrostimulation:
• Use alternating currents (Interference current, TENS type of current, etc.)
• Use the recommended duration and frequency of phases. If the client finds the current unpleasant, it is possible to:
  o shorten the duration of the phase
  o change the frequency (a higher frequency is generally considered more pleasant)
  o move the probe / change the position (in the case of CC equipment first change the current back to zero)
• Use the standard Constant Current (CV) for intra-vaginal/intra-anal applications.
• Explain clearly what can be felt and what is going to happen.
• The current must never be an unpleasant experience. It must not chafe, burn or prickle.
• There may be a feeling of pressure or pushing; this is not a problem.
• The client has the option to discontinue the treatment at any time.
4.4.2 Dysfunctions and the therapeutic consequences

First normalise the resting tone if it is heightened.

This can be done, for example, by asking for a 1 sec. contraction followed by sufficient time (for instance 10 seconds) for relaxation. Moving the muscle makes relaxation possible. If the muscle is not actually hypertonal but the relaxation is insufficient, the muscle will be able to ‘let go’ in an effective way with this method. This is less effective for hypertonicity. Working via breathing and increasing awareness is preferable in this case.

4.4.2.1 Heightened resting tonus – therapeutic options

- breathing
- general relaxation
- lengthening peripelvic muscles
- creating awareness of pelvic floor (practice therapy, digital palpation, EMG and/or pressure)
- pelvic floor relaxation (practice therapy, digital palpation, EMG)

a) Heightened resting tonus – Increasing awareness of pelvic floor using EMG

Select the menu: EMG Continuous.
- Is the patient able to change the image?
- Does what the patient is experiencing correspond to what is displayed on the screen?
- Is there a contraction?
- If so, what is the relaxation like?
- Can the patient feel the difference between tensing and relaxing?

b) Heightened resting tonus – Pelvic floor relaxation using EMG

Select the menu: EMG Continuous.
Is the patient able to change the resting tonus during the therapy? The Myomed 134 has an adjustable threshold. By setting the threshold at the level of the resting tonus at the start of the therapy, any increase or decrease in the tonus can be seen. The effects of breathing and relaxation exercises at the height of the resting tonus can also be assessed in this way.

c) Heightened resting tonus – ADL training with EMG

Select the menu: EMG Continuous.
The patient must be able to feel the tensing of the pelvic floor in ADL in order to be able to lower it at will. Ambulatory recordings are not a problem with the Myomed 134. Each ADL activity, including urinating, can be looked at. Apart from increasing awareness by means of the image and/or acoustic signal, the accent is also on feeling, reacting and on coordination.

4.4.2.2 Lowered resting tonus – therapeutic options

- breathing
- awareness of the pelvic floor (practice therapy, digital palpation, EMG and/or pressure, electrotherapy)
- increasing the tonus through specific training of the slow twitch activity (practice therapy, digital palpation, EMG, pressure and/or electrotherapy)
- ADL training (practice therapy, functional EMG training)
a) Lowered resting tonus - Awareness of pelvic floor with EMG
Select the menu: EMG Continuous.
- Is the patient able to change the image?
- Does what the patient is experiencing correspond to what is displayed on the screen?
- Is there a contraction?
- If so, what is the contraction like and what is the relaxation like?
- Can the patient feel the difference between tensing and relaxing?
- Does the contraction happen fast or does the patient have to try hard before there is a reaction?
- Are there any co-contractions?

If the patient uses a lot of co-contractions (stomach muscles, buttock muscles, adductors) to tense the pelvic floor, a second EMG channel can be used to show the muscle activity of these muscle groups.
In this way the patient can see what he is doing wrong.

b) Lowered resting tonus – Pelvic floor awareness with electrotherapy
Select the menu: EMG + Stimulation.
To promote awareness with the aid of electrotherapy, it is preferable to use a low frequency (from 35 Hz). This will address the slow twitch component in the muscle. As a result, tiredness will not occur quickly.
This is beneficial, as the patient will receive sufficient time to experience what is happening during a contraction. In the first instance, set the phase at 300ms. If the current with this setting is felt to be too severe, the duration of the phase can be reduced. The therapy must always be comfortable for the patient. The frequency can also be adapted to promote a comfortable feeling. The current should be turned up to a good contraction. The patient must first concentrate on what he can feel. Later he can be asked to participate during the current.

Comment: The option ‘Current via EMG channel 1’ can also be used.
It is preferable, however, to use the EMG Current combination because in this menu the resting tonus between two contractions initiated by a current can be displayed on the screen.
Settings for screen 1 with a duty cycle of 6-6.

c) Lowered resting tonus – Heightening tonus with EMG
Select the menu: EMG Work-Rest.
Long slow twitch contractions are used to increase the tonus. The resting time is the same as or twice the working time. The number of contractions that are carried out depends on the condition of the muscle (it is assumed that the therapist has a knowledge of muscle physiology and training education).

d) Lowered resting tonus – Heightening tonus using electrotherapy
Select the menu: EMG + Stimulation.
Again, long contractions should be initiated here, as the objective is to heighten the tonus. The frequency is low (35 Hz) due to the addressing of the slow twitch tissue which is responsible for maintaining the tonus. Set the duration of the phase to 300 ms. The setting for the
work/rest ratio will depend on the condition of the muscle. If the muscle is capable of tensing by itself for 3 seconds, an active current time of 5 seconds can generally be selected. This means a contraction time that is 2 seconds longer than what the muscle itself can do.

e) Lowered resting tonus – ADL training with EMG
Select the menu: EMG Continuous.
The patient must first become aware of the tensing of the pelvic floor during ADL activity so that this can be consciously heightened where necessary. A lowered tonus sometime results after parturition, prostate operations or prolapsus. It is important that the client learns to heighten the tonus at times when there is extra pressure on the pelvic floor. As the Myomed 134 is very suitable for ambulant use, it is possible to practise this effectively. Apart from increasing awareness by means of the image and/or acoustic signal, the accent is also on feeling, reacting and on coordination. A second EMG channel can also be used here to reduce excessive co-contractions as much as possible.

4.4.2.3 Disrupted fast twitch activity

- breathing
- awareness of the pelvic floor (practice therapy, digital palpation, EMG and/or pressure, electrotherapy)
- first treat any reduction in tonal activity (practice therapy, digital palpation, EMG, pressure and/or electrotherapy)
- treat fast twitch (practice therapy, digital palpation, EMG, pressure and/or electrotherapy)
- ADL training (practice therapy, functional myofeedback)

a) Disrupted fast twitch activity – treatment with EMG
Start with the menu ‘EMG Continuous’ and then select ‘EMG Work-Rest’. Work with the ‘EMG Continuous’ menu is started before working with work-rest. If the coordination is not yet good, a screen showing a lot of lines will be confusing for the client. In this case it is better to look in a relaxed way at the behaviour of the muscle during a fast twitch contraction, with a continuous EMG signal. Explain to the client what is happening and the purpose of the exercise. Be aware of the timing. The resting tonus must remain low. After this, the ‘EMG Work-Rest’ menu can be used. Select alternating 1 second rest and 1 second work. This often goes well if the patient was reasonably successful with ‘EMG Continuous’ to make short contractions and was able to return well to the resting tonus. A further useful exercise is a contraction lasting a maximum of 5 seconds, including 5 efforts to take the contraction as high as possible.

b) Disrupted fast twitch activity – Treatment with electrotherapy
Select the menu: EMG + Stimulation.
In contrast to slow twitch tissue, which is addressed with a low frequency, the fast twitch tissue is addressed with the higher frequency of 50-70 Hz.
The duration of the phase is set at 300ms and the frequency to 70 Hz. Select a work/rest ratio of 6/6.
c) Disrupted fast twitch activity – Treatment with ambulant EMG
Start with the menu ‘EMG continuous’ and then select the menu ‘EMG Work-Rest’. Objective: creating awareness of the pelvic floor activity during pressure-increasing moments and learning the knack of tensing the pelvic floor prior to an increase in pressure. With the Myomed, the client has direct feedback as to whether the muscle is functioning or not during ADL activities in which there is an abdominal increase in pressure.

4.4.2.4 Disrupted tonal activity

- breathing
- awareness of the pelvic floor (practice therapy, digital palpation, EMG and/or pressure, electrotherapy)
- train tonal activity (practice therapy, digital palpation, EMG, pressure and/or electrotherapy)
- ADL training (practice therapy, functional myofeedback)

a) Disrupted tonal activity – Treatment with EMG
Select the menu: EMG Work-Rest.
Long slow twitch contractions are used. The resting time is the same as or two to three times the working time. The number of contractions that are carried out depends on the condition of the muscle (knowledge of muscle physiology and training education are assumed here).

b) Disrupted tonal activity – Treatment with electrotherapy
Select the menu: EMG + Stimulation.
In this menu the resting tonus between two passive (= initiated by current) contractions are displayed. At a later stage an active contraction can be asked for in the time between the 2 passive contractions. If there is sufficient self-induced activity in the muscle, it is useful to set the contraction initiated by the current 2 seconds longer than the active contractions.

It is preferable to use a low frequency (35-40 Hz). This will address the slow twitch component in the muscle. The duration of the phase will in the first instance be set at 300ms. If the current at this setting is experienced as too severe, the duration of the phase can be reduced. The therapy must always be comfortable for the patient. The frequency can also be adapted to promote a comfortable feeling. A higher frequency is generally felt to be more pleasant than a low frequency. The current is turned up to a good contraction. The client must try to participate actively during the current phase. During the whole session, attention must be focused on the pelvic floor.

c) Disrupted tonal activity – ambulant EMG
Select the menu: EMG Continuous.
The patient must become aware of the tensing of the pelvic floor during ADL activities so that they can be consciously heightened where necessary. A lowered tonus sometime results after parturition, prostate operations or prolapsus. It is important that the client learns to heighten the tonus at times when there is extra pressure on the pelvic floor. This can be practiced very effectively with the aid of the Myomed 134, as it allows ambulant recordings.
Apart from increasing awareness by means of the image and/or acoustic signal, the accent is also on feeling, reacting and on coordination. A second EMG channel can also be used here to reduce excessive co-contractions as much as possible.

### 4.4.2.5 Inverted perineal movement during pushing

- breathing
- awareness of the pelvic floor (practice therapy, digital palpation, EMG, pressure and/or electrotherapy)
- conscious relaxation of the pelvic floor
- learning the correct pushing technique (“bulging and bracing”). This means: bulging the stomach during pushing (particularly just above the pubis) and then spreading the flanks. The pelvic floor will relax and only m. ischio-coccygeus will show any activity. Sit with the knees a little higher than the hips, front of the feet on the floor and the lower arms resting on the upper legs. The action is bulging the stomach, flanks spread, anus open and gently maintaining this.
- Coordination training (practice therapy, EMG, pressure, with rectal approach possibly a rectal balloon)
- ADL training (practice therapy, functional myofeedback)

#### a) Reverse perineal movement during pushing – treatment with EMG

Select the menu: EMG Continuous. Learning the correct movement with visual checking. A 2nd channel may be used on the stomach muscles to reduce excessive stomach muscle activity.

#### b) Reverse perineal movement during pushing – treatment with ambulant EMG

Select the menu: EMG Continuous. Learning how to push in the toilet position. A 2nd channel may be useful for the stomach muscles. Ambulant EMG is very useful here. After all, nobody pushes while lying down.

### 4.4.2.6 Lack of reflex activity during coughing

See fast twitch activity, Chapter 4.4.2.3.

### 4.4.2.7 Detrusor inhibition

- breathing
- awareness of pelvic floor (practice therapy, digital palpation, EMG, pressure and/or electrotherapy)
- if necessary restore the pelvic floor function (see above)
- ADL training (see above)
- electrostimulation to inhibit the detrusor

#### a) Detrusor inhibition – treatment with electrostimulation

Select the menu: EMG + Stimulation. Set the phase duration to 500ms and select a frequency of 5-10 Hz. The duration of the treatment is 20 minutes. The treatment should preferably take place daily.
As a derivative of SANS* (where stimulation is provided via the nervus perineus by means of a needle) TANS** is applied, where a skin electrode is placed on S3 and a skin electrode on the nervus tibialis posterior, just behind the medial maleolus. The duration of the phase is 100 ms and the frequency is 20 Hz. The duration of the treatment is 20 minutes. A thorough investigation of this has not yet been carried out, but in clinical trials the effects appear to be positive.

* Stoller Afferent Nerve Stimulation (200us 20 Hz via the ntibialis posterior)
** Transcutaneous Afferent Nerve Stimulation sticker S2-S3 and 1 sticker on the ntibialis posterior

4.4.2.8 Pain

- breathing
- awareness of the pelvic floor (practice therapy, digital palpation, EMG, pressure and/or electrotherapy)
- massage
- electrotherapy

a) Treatment of pain with electrotherapy
For pain symptoms, an internal approach with intra-vaginal or intra-anal electrodes can be used. However, skin electrodes can also be used. We will only deal with the application of intra-vaginal and intra-anal electrodes here, as the application of skin electrodes does not differ from that for the treatment of the rest of the body.

b) Acute pain (A-tissue pain)
Pain quality: sharp, stinging, circumscript.
Pain reduction by means of Conventional TENS (Gate control; Melzack/Wall)
Select the menu: EMG+Stimulation.
- Duration of phase 50ms
- Frequency 50-100Hz
- Intensity: low (2-3x sensory stimulation threshold value) In practice the intensity is increased to where it is just not felt (sub-threshold method.)
- Duration of treatment: 30-60 minutes

c) Chronic pain (C-tissue pain)
Quality of pain: nagging, throbbing, diffuse.
Reduction of pain by means of Acupuncture-like TENS (Endorphine Release)
- Select the menu: EMG+Stimulation.
- Duration of phase 250ms
- Frequency 1-4 Hz
- Intensity: high (3-5 x sensory stimulation threshold value)
  In practice, the intensity is increased to where it is just bearable (pain tolerance level.)
- Duration of treatment: 20-30 minutes

In pelvic physiotherapy, biphasal impulses with a phase duration of 250 ms and a frequency of 20 Hz are also used to reduce pain. Both intra-vaginal and intra-anal electrodes are used.
4.4.3 Electrostimulation: summary

4.4.3.1 Stimulation below the threshold

This application is used to train slow twitch tissue, particularly with clients for whom the support function of the pelvic floor is reduced, as with a prolapsus, for example. A person must be capable of keeping the pelvic floor tensed during moments of increased pressure such as lifting. This requires stamina. If someone is actively capable of tensing the muscle for 4 seconds and the objective in the treatment is to be able to tense for at least 10 seconds, then stimulation below the threshold option can be used to achieve this. The working time is then set to 10 seconds, for example. The threshold is set in such a way that the patient can reach this quickly, in an active way. The client actively tries to keep the muscle above the threshold. When this is no longer possible, the current takes over.

Stimulation above the threshold

This option can be used as a transition between electro-stimulation and myofeedback. At the point that someone is able actively to tense the pelvic floor for a brief period, but cannot maintain this, one can opt for stimulation above the threshold. The client tenses actively and at the point that this reaches the threshold, the current takes over so that the contraction remains longer than would have been possible actively. As soon as someone is able to tense actively for longer than 2-3 seconds, it is preferable to use stimulation below the threshold, or myofeedback.

4.4.3.2 Improvement of proprioceps:

- depolarisation of efferent paths (motor; α2 motor neurons) whereby a muscle contraction is created
- depolarisation of afferent sensory tissues (Aγ-, Aα-, Aδ- and C-tissues)

<table>
<thead>
<tr>
<th>Duration of phase</th>
<th>100-400ms (250-300ms is optimal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>35-40 Hz</td>
</tr>
<tr>
<td>Work / Rest ratio</td>
<td>hold 6 seconds – relax 6 seconds. Pause (relax) can optionally be increased. A longer pause prevents tiredness, but is not totally necessary. What matters is gaining awareness.</td>
</tr>
<tr>
<td>Cycles</td>
<td>15-20</td>
</tr>
<tr>
<td>Intensity</td>
<td>until clear contraction (around 2x sensory threshold)</td>
</tr>
</tbody>
</table>

4.4.3.3 Improving the fast twitch response

- depolarisation of efferent paths (motor; α1 motor neurons) whereby a muscle contraction is created
- depolarisation of afferent sensory tissues (Aγ-, Aα-, Aδ- and C-tissues)

<table>
<thead>
<tr>
<th>Duration of phase</th>
<th>100-400ms (250-300ms is optimal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>50-100 Hz (70 Hz )</td>
</tr>
<tr>
<td>Work / Rest ratio</td>
<td>hold 6 seconds – relax 6 seconds</td>
</tr>
<tr>
<td>Cycles</td>
<td>15-20</td>
</tr>
<tr>
<td>Intensity</td>
<td>until clear contraction (around 2x sensory threshold)</td>
</tr>
</tbody>
</table>
4.4.3.4 Improvement of tonal component

- depolarisation of efferent paths (motor; a-2 motor neurons) whereby a muscle contraction is created
- depolarisation of afferent sensory tissue (A-, A- and C-tissues)

<table>
<thead>
<tr>
<th>Duration of phase</th>
<th>100-400ms (250-300ms is optimal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>35-40 Hz</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>hold 6 seconds – relax 6 seconds. The contraction time (hold) can optionally be increased.</td>
</tr>
<tr>
<td>Cycles</td>
<td>15-20 (possibly 2 series with 1-minute pause inbetween)</td>
</tr>
<tr>
<td>Intensity</td>
<td>until clear contraction (around 2x sensory threshold)</td>
</tr>
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</table>

4.4.3.5 Detrusor inhibition

- depolarisation of afferent inhibition reflex

<table>
<thead>
<tr>
<th>Duration of phase</th>
<th>500ms</th>
</tr>
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<tr>
<td>Frequency</td>
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<td>Duty cycle</td>
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<td>Cycles</td>
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</tr>
<tr>
<td>Intensity</td>
<td>clearly felt</td>
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<td>Duration</td>
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4.4.3.6 TANS

<table>
<thead>
<tr>
<th>Duration of phase</th>
<th>100ms</th>
</tr>
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<tbody>
<tr>
<td>Frequency</td>
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</tr>
<tr>
<td>Duty cycle</td>
<td>none (continuous)</td>
</tr>
<tr>
<td>Cycles</td>
<td>N/A</td>
</tr>
<tr>
<td>Intensity</td>
<td>current felt in toe</td>
</tr>
<tr>
<td>Duration</td>
<td>20 minutes</td>
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</table>

4.4.3.7 Acute pain

<table>
<thead>
<tr>
<th>Duration of phase</th>
<th>50ms</th>
</tr>
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<tbody>
<tr>
<td>Frequency</td>
<td>50 – 100 Hz</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>none (continuous)</td>
</tr>
<tr>
<td>Cycles</td>
<td>N/A</td>
</tr>
<tr>
<td>Intensity</td>
<td>2 – 3 times sensory sensation threshold value</td>
</tr>
<tr>
<td>Duration</td>
<td>30 – 60 minutes</td>
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4.4.3.8 Chronic pain

<table>
<thead>
<tr>
<th>Duration of phase</th>
<th>50ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>50 – 100 Hz</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>none (continuous)</td>
</tr>
<tr>
<td>Cycles</td>
<td>N/A</td>
</tr>
<tr>
<td>Intensity</td>
<td>2 – 3 times sensory sensation threshold value</td>
</tr>
<tr>
<td>Duration</td>
<td>20 – 30 minutes</td>
</tr>
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</table>
4.4.3.9 TANS (to reduce pain in the pelvic region)

<table>
<thead>
<tr>
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<th>Specification</th>
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<tbody>
<tr>
<td>Duration of phase</td>
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<tr>
<td>Frequency</td>
<td>20 Hz</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>none (continuous)</td>
</tr>
<tr>
<td>Cycles</td>
<td>N/A</td>
</tr>
<tr>
<td>Intensity</td>
<td>current felt in toe</td>
</tr>
<tr>
<td>Duration</td>
<td>20 minutes</td>
</tr>
</tbody>
</table>

4.4.4 Bibliography

1. Franssen JLM. Handboek oppervlakte-elektromyografie. Utrecht: De Tijdstroom, 1995; Hoofdstuk 11, 308