Globus Sport and Health Technologies LLC introduces

EMS DIGEST

Guide to Understanding Electro-Muscle Stimulation for Sport Training - Click here for latest update

---

Contraindications

Before stimulating muscles please read the indications for use. Always follow warnings, contraindications, and precautions prescribed by the respective manuals.

Foreword

There are several publications on electrostimulation, but unfortunately very few in North America for the sport audience. This one by Gianpaolo Boschetti is a digest of what he has explained at a workshop on Sport Electrostimulation in Europe. For cultural reasons electrostimulation use in sport is much more strongly rooted in Europe, where use among professional and elite athletes in various sport disciplines has flourished: downhill ski, volleyball, rugby, basketball, beach volleyball, to mention a few.
The workshop by Boschetti, is complete and this digest attempts to be an introductory spring board for athletes who are pioneering the concept in the USA. It will help to dispel misconceptions, and minimize improper use; it will also help to heal the black eye that electrostimulation received in this country by indiscriminate use of devices of poor quality, which, as it will be shown cannot reach the same results as professional and semi-professional electrostimulators.

Giovanni M. Ciriani – Globus Sport and Health Technologies

Please forward corrections, typos, suggestions and additions to Info@GlobusSHT.com

Table of Contents

INTRODUCTION

History

Electricity applications for health go back several thousand years. Electric eels were used in the Roman civilization to cause current in the human body to cure ailments.
In 1791 Luigi Galvani documented that electric current caused muscle contraction in the legs of a dead frog; although the mechanism of why electricity caused muscle contraction was misunderstoodm it started great scientific interest. During the 1800's seminal research established scientifically the principles of muscle contraction that are still used nowadays. At the beginning of the 1900's Weiss and the Lapiques introduced the principles of rheobase and chronaxie; these concepts are still widely used to conceive stimulation protocols in our days.
In 1971 Kots in the USSR reported increases of more than 20% in muscle strength, speed and power produced by several weeks of electrotraining. Russian athletes that had used electrostimulation, obtained excellent results at the 1972 Olympic games in Munich, (Borzov, gold medal in the 100m and 200m).
At the same time electrostimulation became a mainstream therapy method. In the 1990's the miniaturization and affordability of electronics allowed the wide experimentation of new protocols. Protocols based on square waves improved in quality and superseded the protocols invented by Kots (aka Russian currents).

BASICS OF ELECTRICITY

Electrical Interaction and Conductivity

There are two kinds of electrical charge, called by convention positive (+) and negative (-). Positive charges repel each other and are attracted by negative charges and vice versa. When a generator concentrates charges of one type at at one point and charges of the other type at another point, if there is a conducting material in between, the charges will tend to flow from one point to the other. The convention is that electrical charges flow from (+) to (-); the flow is called current intensity (amount of charge flowing in one second). For our pusposes current intensity is measured in *Ampères* or *A* for short, and denominated with the letter *I*. In electrostimulation applications, it is customary to measure intensity in thousandths of A or milli-Amps, i.e. mA.
The force that drives the flow of charges, i.e. the force that drives the current, is called electric potential, and it is measured in Volts, or *V* for short. The electric potential will distribute itself differently depending on the conductor (i.e. the muscle), and this distribution will determine how the current will distribute itself around, and where it will concentrate itself. The distribution of electric potential is called electrical field.
An important property related to an electrical field is called electrical conductivity. This property determines how easily a charge will move between two points in an electric field. Rather than referring to conductivity, it is preferable to refer to the opposite concept, i.e. the resistance to the passage of a current in an electric field. The resistance is denominated with the letter *R,* the unit of measure is the Ohm abbreviated by the letter Ω.
The relationship between the three physical concepts associated with electricity is called Ohm's law:

$$\frac{V}{I} = R$$

This means that, if the resistance *R* stays the same, when we increase the voltage *V*, the current intensity *I* increases proportionately too, and vice versa with decreasing values.
Thus if we stick two electrode pads on a limb and we connect them to a generator, the limb will oppose a certain resistance R to the current passage. If we want to obtain a certain current intensity I, we will have to generate with the electrostimulation device a voltage given by Ohm's law.
The way current will distribute itself will depend on the electric field caused by the pads. In general the field will be more intense closer to the pads and on the surface of the limb, and weaker as we go deeper into the limb's tissue.

Effects of Current Passage

Current passage is the movement of electric charges along a conductor. These charges can be in the form of free electrons, which have a negative electric charge. Free electrons in an electric field can move from one atom to the next attracted to the electric pole of opposite sign. Also atoms with one extra electron, called negative ions or anions, can move in the same fashion.

Alternatively, an atom without one of its electrons, called a positive ion or cation, could move in an electric field toward the negative pole.
Salt (NaCl) dissolved into water promptly creates ions Na^+ and Cl^-. If we place two electrodes connected to a generator in the water, the resulting electric field, tugs the Na^+ cations toward the (-) electrode, and the Cl^- anions toward the (+) electrode, and we have current passage. This is the reason why water conducts electricity, because there are always some traces of salt dissolved in it.
This current passage also results in the accumulation of the respective ions and cations at the electrodes. It eventually results in the electrochemical phenomenon called *electrolysis,* which produces Hydrochloric Acid (chemical formula HCl) at one end and Caustic Soda (chemical name Sodium Hydroxide, NaOH) at the other end. This is not good news for conducting current through the skin, because living beings' cells contain water and various salts. In short if we subjected body tissue to electric current flowing in the same direction, soon there would be enough concentration of these chemicals to affect the skin; they react with proteins of the body tissue, and will cause chemical burns. However, if the current is of short duration, and its direction is periodically inverted, the chemical reaction is reversed at each cycle and its effects are neutralized.
Another property of an electric field is its distribution. The stronger the field the more in depth in the tissue it will go, and the more muscle fibers it will affect. We will see with more detail later, that this is the reason why a higher-intensity current stimulation will affect the muscles in a stronger way. This is important to keep in mind because many mistake the cause of this effect, and are lead to wrong conclusions. In other words, more current does not cause a stronger contraction of the same muscle fiber, but the more intense the current, the greater the voltage, the deeper the electric field, and the more muscle fibers will contract.

THE MUSCLE AND ITS MOTOR FIBERS

The muscle and its motor fibers

The main characteristic of a muscle is that of shortening and moving the skeletal structure attached to it. In electrostimulation training we always refer to voluntary muscles we use for daily movement and sport.
A muscle is composed of muscle-fiber bundles; each muscle fiber in this bundle is composed of smaller elements called sarcomeres, each capable to contract. Muscle cells are cylindrical, with diameters of the order of magnitude of a thousandth of an inch (between 1/100 and 1/10 of mm), and length in the range between a fraction of an inch to an inch. The fiber receives a signal to contract from the the axon through a synapse. The axon is the extremity radiating from the neuron of which it is part, and the synapse is the interface between the axon and the muscle fiber. Contractions are directly caused by myosin chains which are part of the fiber, and are in bundles called sarcomeres. Force is produced by myofibrils, which are chains of sarcomeres running from one end of the fiber to the other. Energy for contraction comes from metabolism of fats and sugars. The amount of force production depends on the cross sectional area of the muscle, and is about 3-4 kg/cm^2. Contraction speed and excursion are related to the fiber length.
A motorneuron may have a hundred or more axons, and therefore is responsible for the contraction of the same number of muscle fibers. A single motorneuron, with all the fibers it controls, is called a motor unit. As the brain's signal for contraction increases, it both recruits more motor units and increases the *firing frequency* of those units already recruited. During a *maximal voluntary contraction*, it is unlikely that all the motor units (thus muscle fibers) are activated (according to Kots, at most 60-70%).
When the Central Nervous System (CNS) *decides* to activate a motor unit (MU), an electrical signal propagates from the CNS to the MU. This electrical signal travels at a speed between 3 and 100 m/s. The signal hops from one nervous cell to the next in a very rapid sequence. During this event each cell changes its polarity in thousandths of a second. Each nervous cell in its rest status is charged positively outside and negatively inside; the difference between the two is called action potential and its value is around 70 mV. If an electric stimulation alters the action potential beyond a threshold, a series of electrochemical events will be triggered inside and outside the cell that will propagate the electrical signal to the next nervous cell. These events involve Na^+ and K^+ ions.
The nervous cell that innervates the muscle through a neuromuscular plate is able to pass its signal via the neurotransmitters acetylcholine. The motorneuron may have several axons, and each one innervates a muscle fibers. Therefore when the signal arrives to the motorneuron, all of the fibers connected to it will get activated by the neurotransmitters.
Early on in electrostimulation research it was discovered that what caused the excitation of the nerves and of the muscle fibers were two characteristics of the current: the amount of current, and the sudden change of its intensity. It is very important to understand what causes a contraction; not only a sudden increase of current will cause a contraction, but also a sudden decrease will cause it.

Stimulation can also be direct or indirect. Direct stimulation is defined as the stimulation that triggers directly the muscle fiber. Indirect stimulation is defined as the stimulation that excites the nervous cells, which will in turn trigger the contraction of the muscle fiber. Normally an indirect stimulation is better, because it causes the nervous fibers to affect more motor units, and it generates a stronger contraction.

TRAINING

What is Training

With training we refer to the adaptation of the body to external physical stimuli. Living organisms posses the capability to stay in equilibrium with the environment. This property is called homeostasis, and is attained by the body by changing some of its characteristics: body temperature, heart beat rate, concentration in the blood of naturally produced substances, are all manifestations of homeostasis.

General Adaptation Syndrome

This term, coined by physician Hans Selye, describes all sorts of body's reactions to a stress, including a sport stress. Training can be considered as a stressor to produce an adaptation for the targeted sport activity. The whole body is involved in this response.
In general we can observe the following sequence:

- Training stimulus
- Fatigue and performance decrease
- Progressive recovery from fatigue, and return of performance capability.
- Increase of performance capability above the initial level, thanks to body adaptation.

Adaptations and Changes Induced by Training

Training-induced adaptations include the following.

- Anatomical changes: heart size, i.e. hypertrophy; size of skeletal muscles; body fat decrease.
- Structural changes: mitochondrial changes; muscular fibers of type II into type I.
- Biochemical changes related to enzyme activity.
- Functional changes: O_2 consumption; heart flow; recruitment of motor units.

Training Load

The training load is in general defined by the volume of exercise (repetitions, distance, weight), and by its intensity (speed, power, frequency). These parameters completely define a particular training and allow for comparisons over time. In practice this may not be 100% true, as the same training parameters may have different effects on different individuals, and even on the same individual as time passes.
From these considerations comes the need of defining external load and internal load. The former is defined by physical concepts as in the previous paragraph; the latter is defined as resulting from the stresses caused by the external load, and the psyco-physical conditions the body is in at that particular instant.

The repetition of an external load in the correct sequence causes in time adaptation, and consequently a performance increase; excessive or incorrect utilization of this external load causes instead a maladaptation and a worsening of performance.

TRAINING PRINCIPLES

Load Specificity

Adaptation happens mainly in the organs subject to the external load. Thererfore Anaerobic and Aerobic exercise cause metabolic and physiologic changes completely different from each other.

Frequency

It is necessary to stimulate the selected organ repeatedly, at regular intervals determined to provide the best cumulative effect of the individual stimulations. This is also determined by the type of training, by the functional needs, by the characteristics of the sport and the athletic level.

Load Progressivity

Training loads have to be continually changed, as a function of the evolving physical condition of the athlete. The increase is determined through a periodic functional testing of the athlete.

Continuity

Training should not be interrupted, but continued in several cycles, since adaptation is reversible. Interruptions cause a decay of the performance increase, in proportion to the duration of the interruption.

Variety

This principle is to utilize several training means to improve the sport performance.

Individuality of Loads

Each individual athlete is unique and responds tro training differently. Therefore training has to be conceived individually, even considering timing for the same athlete (season) to ensure the best result.

WORKLOAD CHARACTERISTICS

The three main characteristics of the workload are: quantity, intensity, and frequency.

Quantity

It is measured in:
- Distance (resistance training);
- Total weight lifted (strength training);
- Work time;
- Number of sport action sequences;

Intensity

Intensity defines either the level of engagement in performing a particular workload, or the percentage of the maximum capability of the athlete.
- Speed of the movement (m/s)
- Engagement percentage (%)
- Distance to attain (m in throws)
- Height to overtake (cm in jumps)

Quantity and intensity are interrelated, and adaptation to these parameters allows an improvement of the athlete's performance.

Density

Density represents a further way of increasing the workload. It is measured by the ratio between work and rest periods during the same training session. It is incremented for athletes of medium and high level.

How to Select a Training Program

A training program has to be adequate to the goal, and has to deliver the proper exercise systematically. Some analysis to research the performance increment is in order, considering:
- The type of sport movement;
- The number, type and location of the interested muscles;
- The level and type of force produced;
- Speed and range of movement;
- Intensity and duration of the sport activity;
- Coordination between movements;
- Energy demand.

Once these characteristics are established, one can research and determine the most indicated training program.

PERSONALIZATION OF TRAINING IN A SPORT ENVIRONMENT

Training has to be adjusted to the genetic predispositions of an athlete (genotype). The way the organism will respond to training will determine the phenotype. Exactly because genotypes may be very different and the training goal may be similar, training should be different between individuals.

STRENGTH

Strength is the ability of a muscle to exert a certain force. Its characteristics can be defined according to different classifications.

Based on muscle length (according to Zatsiorskij)

- Static;
- Concentric;
- Eccentric.

Based on the type of muscle fiber recruitment

- Tonic-explosive (against high resistance and with fast recruitment);
- Reactive-balisitic (against small resistance preceeded by a stretch);
- Explosive-Balistic (against limited resistance preceeded by a stop movement).

Based on time during which it is applied (according to Harre)

- Maximum Strength;
- Fast Strength;
- Special Strength;
- Absolute Strength;
- Relative Strength.

Based on type of force

- Isotonic
- Isometric
- Auxotonic

Based on the Force-Speed Relationship

Force-Speed curve of a muscle characterizes the force that can be developed by a muscle at different speeds: contracting a muscle slowly one can produce more force than when the movement is performed very fast. Bosco classified strength according to this relationship.
Isometric Force: 100% of 1 maximum repetition, without movement.
Eccentric Force: 120-130% of maximum repetition, during lengthening. The muscle extends developing a force higher than an isometric contraction.
Maximum Force: 90-100% of 1 maximum repetition. The muscle shortens as it overcomes high external resistance; the effort is so strong that it cannot be repeated immediately.

Maximum Dynamic Force (maximum power): 55-80% of 1 maximum repetition. Contraction speed is approximately $^1/_3$ of maximum speed. Close to this point the muscle develops its maximum power (by definition the product of speed by force).
Fast Force: 30-60% of 1 maximum repetition. It corresponds to a very high contraction speed, close to maximum speed.
Resistance to Fast Force: Work with heavy loads has to go hand in hand with fast-force training, because the metabolic processes of resistance and hypertrophy, although on different parts of the curve, are interconnected.

THE MECHANISM OF FORCE

Cometti subdivides the mechanisms of force in three basic categories: structural, nervous and stretching factors.

STRUCTURAL FACTORS

Hypertrophy

The factors of muscle mass increase are:

- Increase of myofibrils dimension with 10 repetitions of 10 series of maximum concentric training;
- Vascularization increase with loads at 70-80% of maximum, repeated til fatigue;
- Increase of connective tissue;
- Increase of the number of myofibrils, caused by intense training which woul induce micro scars, and subsequent splitting of cells into two or more; this mechanism is not accepted by all researchers.
- Speed of exercise: the details and differences between fast fibers and slow fibers are explained in a later section; however, many researcher found that fast fibers are trained more effectively by high-intensity contractions (> 80% maximum force) at maximum speed.

Sarcomeres

An increase of the number of sarcomeres in the muscle fiber can be done in the following ways

- In parallel: increasing the number of sarcomeres parallel to each other will increase the cross section of the muscle, and the force it develops.
- In series: the shortening of sarcomeres attached to each other as in a long string, determines the shortening of the muscle fiber; if the number of sarcomeres can be increased the shortening will be greater, and the speed of contraction will increase too.

NERVOUS FACTORS

Recruiting

In voluntary muscle activation, the number of muscle motor units and percentage of muscle fibers increases with the load on the muscle. Therefore voluntary muscle-fiber recruitment goes in progression according to their size: first smaller-size fibers, then larger fibers.
Because slow-twitch muscle fibers (type I), are smaller than fast-twitch fibers (type IIa and IIx), a slight load will recruit only slow fibers, and a high load will recruit both slow- and fast-twitch fibers.

It will be explained in later sections, how EMS disrupts this recruitment order and indiscriminately activates neurons. Therefore EMS, with the proper current intensity, obtains a much higher recruitment and training effect. What discriminates in EMS between the different types of fibers is frequency.

Frequency

Frequency is the number of times per second the motoneurons are excited. A higher frequency is generally associated with higher force. (because of the way each subsequent twitch adds to the previous one).

Synchronization

Synchronization refers to the fact that training teaches several motor units to contract together. Plyometry is considered the best training to improve synchronization.

Intermuscular Coordination

Through timely coordination between different muscles, it is possible to improve the overall force of the sport movement.

STRETCHING FACTORS

Myotactic Reflex

It is a reflex generated during the eccentric phase which attempts contract the muscle concentrically. Plyometric exercise inhibits it.

Elasticity

It is the natural tendency of muscle fibers to get back to their rest position. Elasticity is caused by connective the tissue parallel to the fibers, by the tendons, and by microscopic filaments in the fibers (at the molecular-level of actin-myosin).

Thanks to elasticity the muscle accumulates and gives back energy according to time, amplitude and speed.

METHODS OF FORCE DEVELOPMENT

Most recent improvement in sport has been obtained with training improvement in various methods of force development.
Maximum effort:

- Maximum Isometric Contraction;
- Maximum Eccentric Contraction;
- Maximum Concentric Contraction;
- Sub-Maximum Concentric Contraction;

The main purpose is that of activating the nervous system to involve the highest number of motor units. These methods are effective for force development, but do not cause muscle hypertrophy, and therefore are best to contain body weight within limits. The nervous factor is predominant over the metabolic factor.
The loads utilized are percentage wise very close to maximum, with few repetitions and full long rest in between.

Maximal Isometric Contractions

In this training method the load is unmovable and the exercise is performed at specific joint angles.

Maximal Eccentric Contractions

In this training method, the athlete slows down in extension loads that are higher than maximum.

Maximal Concentric Contractions

In this training method, the athlete first slows down a load eccentrically, then concentrically reverses the direction of movement and accelerates it at maximum.

Sub-Maximal Concentric Contractions

The utilization of concentric training methods at load below the maximum, allows the athlete to adjust all the other training parameters, to come up with a specific training program, depending on the training goals, as follows:

- Repeated efforts
- Dynamic efforts
- Concentric Contractions close to maximum

Repeated efforts

The load is repeated until the muscle is exhausted.

Dynamic Efforts

The repetitions are performed at maximum speed.

Concentric Contractions close to maximum

The load of few initial repetitions is progressively increased, to arrive at a single maximal repetition.

TRADITIONAL TRAINING METHODS

Bulgarian Method

During the training session high loads are alternated with light loads, at the maximum execution speed.

Pyramidal Method

This method progressively trades off quantity for load intensity. The pyramid can be truncated, normal, double truncated, or double normal (see figure).
For instance, utilizing 10-12 repetitions at 70-85% of maximum load, will increase the size of the muscle (hypertrophy); 3-5 repetitions at 90-100% of maximum load, will increase the maximum force of the muscle.

Circuit Method

In this method, several independent exercises for different muscular groups are performed in a continuous sequence. 6-12 exercises are performed without breaks until the circuit is completed. The series is repeated 3 or 4 times, with a rest of 2–3 minutes between each. One can perform different circuits for force, fast force, or resistance.

Isometric Training Methods

Isometric training methods are either maximal or total.
Maximal: the resisting force cannot be overcome.
Total: when the isometric phase is performed in the middle of a workout with dynamic contractions (concentric or excentric).

Eccentric-Concentric Training Method

It consists of repetitions with an eccentric load 100% of maximal helped by a partner, and then 5 to 6 concentric repetitions with a load less than maximal. Very popular is the 120-80 combination, with an eccentric load 120% of maximal and then a concentric load 80 % of maximal.

Plyometric Training Methods

Simple plyometrics include jumps, rope jumping, running in leaps, jumps from an 8”-tall beam, bench jumping and low-rise obstacles.
High-rise plyometrics include jumps from a 2’-3’-foot-tall beam with different knee angles.
Plyometry with loads consists is performed squatting and springing back in one or more rebounds. Plyometry is the best training for explosive force potentiation.

TRAINING METHODS FOR HYPERTROPHY

Hypertrophy is based on destruction and reconstruction of muscle fibers to create new fibers by overcompensating adaption. Two conditions are necessary:

- Load: 70-85% of maximal.
- Volume: 6-10 series of 6-12 repetitions.

Zatsiorky’s 10 X10 Method

This method consists of 10 series of 10 repetitions with a load 70% of maximal, at maximum speed, and 45-90 seconds between series.

INTENSIVE TECHNIQUES FOR MUSCULAR HYPERTROPHY

The following techniques emphasize the muscular adaption.

Post-Fatiguing

After the specific training perform a shorter exercise on only one of the joints: e.g. 10 maximal squats followed by 6 repetitions on a leg extension machine.

Pre-Fatiguing

Identical to post-fatiguing but reversing the order: e.g. 6 repetitions on a leg extension machine preceding 10 maximal squats.

Super Series

Antagonist: pair an exercise for the agonist muscle, followed by an exercise for its antagonist: e.g. 10 repetitions of leg extension, and 10 leg curls.

Burns

After 10 maximal repetitions, the training continues for additional 5-6 maximal repetitions on a reduced range of motion.

Forced Series

After 10 maximal repetitions, the exercise continues with the help of a training buddy for additional 2-3 maximal repetitions.

Gigantic Series

4 - 6 series of 10 repetition each on the same muscle group with different machines (different workouts) without rest.

BIOLOGICAL EFFECTS OF ELECTRIC CURRENT

Electric Current's Biological Effects

There are different effects caused by electric current, some wanted and some unwanted.

Thermal Effect

As it traverses a conductor, electric current transforms its energy into heat. To put this into perspective, a typical high level explosive-force program will produce approximately 0.5 W on average (at 50 mA), which will be dissipated through the muscle fibers. (Note: 120 Hz, 450 µs chronaxe, 2000 Ohm muscle resistance which is typical of quadriceps muscles)

Chemical Burn

Particular electrical characteristics may cause chemical changes in the tissue traversed so as to cause a localized caustic reaction and a burn. However, modern EMS devices reverse the direction of current passage at each pulse which reverses the chemical reaction, eliminating this effect.

Galvanic Effect

Electric current facilitates the movement of ionized molecules. This is utilized for the administration of therapeutic drugs specifically prepared in ionized form.

Excitatory Effect

Some tissue can be excited by the passage of electric current. This can be done directly at the muscular level bypassing the nerves innervating the tissue in question, or indirectly exciting the nerves that innervate the tissue to be excited. The latter is the focus of this digest.

MEMBRANE POTENTIAL

Membrane Potential at Rest

Organic tissue is characterized by electrical charge in it. The cell membrane, known as *sarcoplasmatic* membrane, has electrochemical mechanisms that manage to keep negative charges inside, and positive charges outside. The accumulation of opposite charges on the two sides of the membrane creates an electrical field across it which, as any electrical field, is characterized by an electric potential. Each living cell is characterized by this potential, which is known as *membrane potential*. Its value at rest is different from the value during excitation.

Purpose of the Membrane Potential

Membrane potential acts as a filter. If the stimulation is small it cannot penetrate it and nothing happens. If the stimulation is large enough, it can overcome the membrane potential, penetrate inside the cell and activate it. Therefore it filters out signals that are not strong enough.

Threshold Level

The value of the electric potential, which determines whether signals are strong enough or not to be further transmitted is the threshold value. Both muscular tissue and motorneurons have a threshold potential of -55 mV (milli-Volt). However, their rest values are different: -70 mV for nervous tissue and - 90 mV for muscular tissue. This is the reason why it's easier to stimulate muscles through their respective nerves.

Action Potential

When a stimulus decreases the membrane potential below its threshold value the cell membrane inverts its polarity. That is, as soon as the membrane potential is lowered from -55 mV to a value closer to zero, the membrane triggers an automatic ion-exchange mechanism across itself, which switches the membrane potential from negative to positive. This polarity inversion is called *Action Potential*.

Purpose of the Action Potential

Action Potential acts as the messenger of a nervous signal. The polarity inversion switches the membrane of the next cell below its threshold level; this in turn causes another action potential in the next cell, and so on as in a chain reaction.

Sequence of Action Potential Generation

- At rest the membrane potential is -70 mV.
- External perturbation, i.e. stimulus, changes the membrane potential to -55 mV.
- Beyond the threshold value the ion exchange mechanism triggers polarity inversion, i.e. the action potential, which is transmitted along the nervous fiber.
- The action potential excites the membrane of the next cell, propagating the action potential mechanism to the target fiber.

What Happens if the Threshold is not Reached

If the initial stimulus does not reach the threshold value, there is no transmission of action potential, and the stimulus causes only a local effects.

ELECTROSTIMULATION-INDUCED CONTRACTION

Electrostimulation-Induced Contraction

Voluntary skeletal muscle contractions result from impulses commanded by the Central Nervous System (CNS) and transmitted through the nerves as electrical signals and eventually recruiting the desired muscles. The same can be achieved starting from an external electric impulse replacing the voluntary signal.

Tissue Sensitive to Induced Electrical Stimuli

Electrical impulses activating nerves are similar to electrical impulses activating muscles. Therefore one can decide whether to stimulate nerves and indirectly stimulate the muscles, or directly stimulate the muscles. However, there are differences between the two.

Direct Stimulation through Muscle Fibers

Direct stimulation of the muscle fibers bypasses all the rest of the CNS. However, this choice, even though possible, activates the muscles as if in a lab setting, by themselves and a bit out of of context, which is less conducive to training.

Difference between Rest and Threshold Potentials in Muscle

The other important factor is that the difference between rest potential and threshold of muscle fibers, i.e. the difference between -90 mV, and -55 mV, is 35 mV. In other words the electrostimulator will have to overcome this difference to stimulate muscle fibers.

Difference between Rest and Threshold Potentials in Nervous Fiber

The membrane potential of nervous fibers at rest is -70 mV, and the threshold to trigger an action potential is -55 mV. Therefore to excite nervous fibers it is necessary to change the potential of the membrane by only 15 mV. Comparing this value to the 35 mV calculated for muscle fibers, the difference is huge: one will need 57% less potential to stimulate nervous fibers.

Applying Electrostimulation on Nervous Motor Units Fibers

The diameter of motor nervous fibers is larger than other nervous fibers'. They are also characterized by an insulating liner that allows for faster transmission of action potentials, insulation from outside impulses and a very precise selection of which fibers are going to fire. This insulation effect tends to insulate nervous fibers even from the stimulus of an electrostimulator. Fortunately there is a gap just before the nervous fiber reaches the muscle, and from here it is possible to send an external electrical impulse to the muscle. In addition the neuromuscular plate is situated on the muscle surface, closer to the outer skin. Therefore the electrical signals to stimulate the muscle do not need to be to strong, and it is possible to limit side effects.

Position of the Neuromuscular Plate

The neuromuscular plate is present on the whole surface of the muscle. However, it is more concentrated where the muscle reaches its maximum cross-section.

Similarity between Neuromuscular Stimulation and Direct Physiological Stimulation

Stimulation performed on nervous fibers, utilizes the same physiological mechanisms to transform nervous impulses into chemical impulses. Therefore all the physiological effects that would happen with voluntary stimulation and training of the same tissues take place.

It is also more convenient, as seen in a previous paragraph, to stimulate muscle fibers indirectly, through the nervous fibers, because of the lower membrane potential change needed (15 mV vs 35 mV needed for direct muscle stimulation). Another factor that makes it even more convenient is greater comfort. The lower potential difference required means that also nerves carrying pain (nociceptive nervous fibers) are stimulated less.

Consumer Products for Electrostimulation

Most electrostimulator commercially available are designed for indirect stimulation. They are certified by the FDA in distinct classes of use: either without prescription for muscle-training-only purposes; or for therapy use with medical prescription.
Direct electrostimulation is reserved for special cases of therapy, under the guidance of a doctor or authorized practitioner.

The Mechanism to Induce Muscle Stimulation

Once the electrical stimulus reaches the nervous tissue, it triggers the membrane potential above the threshold of 70 mV. The action potential propagates along the nervous fiber similarly to what happens for a stimulus generated by the CNS. The impulse arrives to the interface between the nerve and the muscle fiber, i.e. the synapse, where it is transformed in a chemical impulse.
The contraction at this point is regulated naturally in exactly the same mode that a voluntary contraction would be regulated. Therefore a contraction induced by electrostimulation is regulated by the same exact mechanisms and produce the same physiological effects, including muscle adaptation and training effects.

DIRECT STIMULATION OF MUSCLE FIBERS

When Muscle Fibers are Stimulated Directly

Direct stimulation of muscle fibers is possible, even though one would need special electrostimulators, capable to supply a sufficient quantity of current and in the right place, bypassing the nervous fibers. For sport training this is never necessary, because it is more comfortable and easier to stimulate indirectly.
However, there are situations in which direct stimulation may be convenient or even irreplaceable. This is done for therapeutic or aesthetic reason, and it is mostly utilized when the nervous fiber is interrupted.

Electrostimulation for Therapy

Electrostimulation can be used for therapeutic reasons, to speed recovery of atrophied muscles. In case of neuro-muscular damage, in which voluntary muscle movement is impaired, it is possible to contract the affected muscle through electrostimulation. Involuntary contraction in turn will help to maintain muscular tone, and may help the healing process of the damaged nerves.

Electrostimulation for Aesthetics

The toning effect of electrostimulation is used by those who want to improve particular appearance qualities related to the tone of the muscle.

Electrostimulation for Denervated Muscles

Denervated muscles are mentioned here, but are not an objective of this digest.
Electrostimulation can also be used as a therapy for denervated muscles, i.e. voluntary muscles that cannot be contracted voluntarily anymore. The therapy may have the objective of maintaining the tone of a muscle that cannot be exercised otherwise; or it may have the objective of regaining some voluntary control of the muscle. However, the properties of denervated muscles are very different from those of innervated muscles, and require particular programs, application protocols, and knowledge for the therapy to be effective.

CURRENTS

To obtain the desired contraction effect of electrostimulation, the current level will have to reach a compromise between a high enough current level to generate a strong contraction, and limited enough to exclude undesirable effects.
The current will have to be high enough. The excitation of the muscular tissue will be maximum when the electric current suddenly changes from zero to a certain value, and also when it suddenly changes from that value to zero.
Muscle fibers also have adaption capability, which means that they will tend to adapt to a certain current level. This means that if the current increase is too gradual muscle tissue will adapt to it, and the current will not elicit any contraction. Therefore the change of current will have to be sudden.
The type of current that reflects the characteristics just listed is a rectangular waveform, for which the current increase is practically instantaneous, which also has the following advantages:

- Limited polarization effect
- Limited nervous fiber adptation
- Good recruiting of nervous fibers
- Low current level

Excitation Mechanism and Necessary Impulse

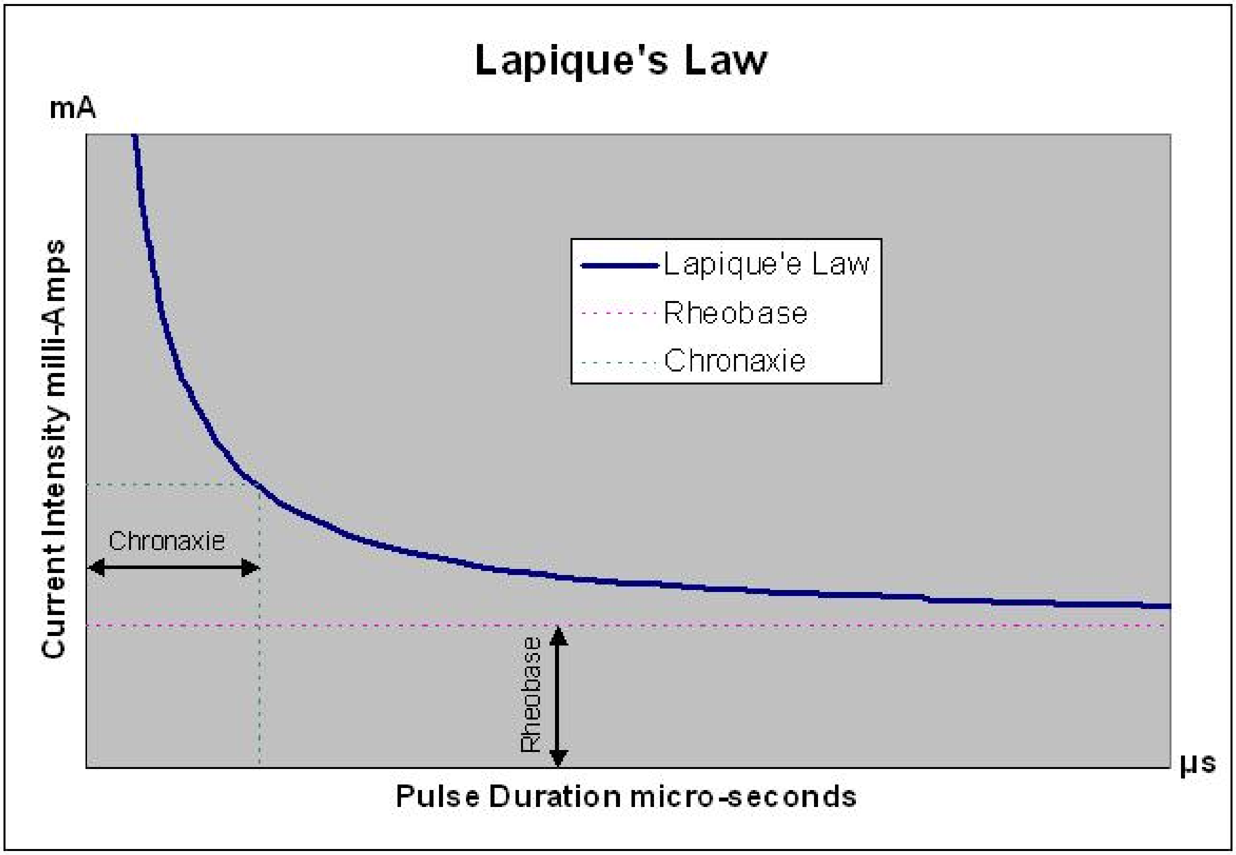
To excite the nervous tissue the following conditions are necessary

- Enough current through the targeted tissue
- Adequate duration of the stimulus for the muscle group

The next figure shows the relationship between current intensity and duration, which also changes for different muscle groups.

Chronaxie and Rheobase

The relationship between current intensity and duration has been determined by Lapique. As duration increases, the current intensity necessary to trigger a contraction decreases.



Another characteristic of body tissue is that of accomodation, which means that any tissue gets used to a particular stimulus and consequently needs next time a stronger stimulus to trigger a reaction. Lapique defined two parameters as reference points to characterize and compare the effects of electrical stimuli: rheobase and chronaxie.
Rheobase is defined as the minimum current intensity necessary to trigger an excitation (action potential), no matter how long the duration of the stimulus is.
Chronaxie is defined as the duration necessary to trigger a reaction, when current intensity is twice the rheobase. This value is an excellent compromise to trigger a good contraction in a reasonably short time, without generating any accommodation, and without causing any of the negative side effects.

Chronaxie in Various Muscular Groups

Chronaxie is an important parameter for electrostimulation, because it determines the duration of each impulse. Therefore the duration of each impulse has to change depending on the muscular group. Generally there are 6 different areas to stimulate, with 6 different chronaxie values and therefore 6 different impulse durations. Average values are the following.

- Lower Leg, 430 microseconds;
- Upper Leg, 380 microseconds;

- Lower Torso, 330 microseconds;
- Upper Torso, 280 microseconds;
- Arm, 200 microseconds;
- Forearm, 230 microseconds.

Characteristics of Waveforms Utilized by Electrostimulators

Modern e-stim machines utilize a biphasic, rectangular, symmetric waveform, which favor stimulation and keep a good comfort.

Biphasic Waveform

A biphasic current will transport ions first in one direction then it will reverse this direction. The alternated current will excite the tissue with the impulse that first goes in one direction, and at the same time it will minimize the net movement of ions, thus avoiding chemical burns and other irritations.

The Waveform

Body tissue tends to accommodate to stimulation that is gradual, and elevate the threshold potential. However, it will not accommodate if the stimulus is sudden. Comfort will also be greater. The chronaxie has to be adequate too. The waveform that better responds to these characteristics is rectangular.

MUSCLE FIBERS AND STIMULATION FREQUENCIES

Fibers and Stimulation Frequencies

Classification of Muscular Fibers

Voluntary muscles are formed by muscle fibers, all of which can shorten on command, contributing to a muscle contraction. However, they may have different characteristics, and they have been classified accordingly into:

- Slow twitch, or slow fibers of type “I”
- Fast twitch, or fast fibers of type “II”, which can be subdivided in
    - Fast twitch, or intermediate fibers of type “IIa”
    - Fast twitch, or very fast fibers of type “IIx” or “IIb”;
      what used to be called IIb is called IIx by more recent research, and is the accepted correct denomination.

The following table (courtesy of Wikipedia) shows the main functional aspects. From it, it can be understood how, depending on the goal it’s useful to train certain types of fiber. For instance for endurance goals it is useful to train slow fibers. To increase maximum force it’ll be useful to train Type IIx fibers; it will not be useful to train type I fibers which are not capable to develop a high level of force.

Fiber Type	**Type 1**	**Type 2a**	**Type 2x** (formerly 2b)
Contraction time	Slow	Fast	Very Fast
Motor neuron size	Small	Medium	Large
Fatigue resistance	High	Intermediate	Low
Activity	Aerobic	Long-term anaerobic	Anaerobic
Maximum duration	Hours	< 30 minutes	< 5-1 minutes
Force production	Low	Medium	High
Mitochondrial density	High	Medium	Low
Capillary density	High	Intermediate	Low
Oxidative capacity	High	Intermediate	Low
Glycolitic capacity	Low	High	High

To correctly organize an electrostimulation session, it will be useful to select the type of program in line with the goals listed by this table.

Twitch and Tetany

To understand EMS contraction it is important to distinguish between muscle twitch and muscle tetany. When we apply a current stimulus the muscle contracts for a short period of time: this is called a twitch, the force developed is not very strong and lasts for a short period of time. After this the muscle becomes insensitive to the stimulation (it accommodates) and relaxes. However, if we apply several current stimuli in a short period of time, each twitch builds upon the peak of the previous twitch, and the strength of the contraction grows to a significant amount: this is called tetany, or tetanic contraction, and it is the basis of EMS.

The frequency at which the stimuli start building on top of each other, resulting into tetany, depends on the characteristic of the muscle fibers according to the table above. For example, slow-twitch fibers contract more slowly than fast-twitch fibers, their peak force taking place at a later time than in fast-twitch fibers. Therefore the next impulse does not need to take place as quickly as in a fast-twitch fiber, to build up into tetany. Therefore to cause strong training contraction in different fiber types we'll need to employ different EMS frequencies, depending on the muscle fiber we want to train, and on the training effect that we want to obtain.

Stimulation Frequencies

The choice of stimulation frequency is very important for several reasons:

- Different fiber types respond differently to different stimulation frequencies. A particular frequency will stimulate more fully fibers of a particular type.
- The proportion of each type of muscle fiber “I”, “IIa” and “IIx” present in each muscle varies, depending on the function of the muscle.
- The use of a particular stimulation frequency will tweak the muscle fibers of one type to adapt and work similarly to muscle fibers of another type that work well at that frequency.

Therefore stimulation frequency is selective for the type of training that we want to obtain. It is measured in Hz, which means the number of stimulation impulses sent to the muscle in one second.

The frequency ranges to recruit prevalently different muscle fiber types are as follows.

- 1 Hz. 15 Hz.
- 15 Hz. 20 Hz.
- 20 Hz. 50 Hz.
- 50 Hz. 90 Hz.
- 90 Hz. 120 Hz.

Stimulation between 1Hz and 15 Hz

At these low frequencies there isn’t a real contraction but only a series of twitches. The force developed by each muscle fiber at each twitch is slight, approximately 1/3 of what can be developed with a full contraction by the same fiber. As the frequency increases the twitches start to overlap.

Stimulation between 15 Hz and 20 Hz

As the frequency increases the twitches overlap ever more fully, and somewhere between 15 Hz and 20 Hz they become one strong contraction, the so called tetanic contraction. Stronger athletes will experience the tetanic contraction at slightly higher frequency.

Stimulation between 20 Hz and 50 Hz

Stimulation between 20 Hz and 50 Hz causes full contraction of slow fibers of type “I” which therefore are trained. With this selection it is possible to improve fatigue resistance, i.e. endurance characteristics, of these fibers.

Stimulation between 50Hz and 90 Hz

Stimulating between 50 Hz and 90 Hz, it is possible to work on intermediate fibers of type “IIa”, which have intermediate characteristics between slow type “I” fibers and fast type “IIx” fibers. This training will improve strength and a moderately help fatigue resistance.

Stimulation between 90Hz and 120 Hz

Stimulating between 90 Hz and 120 Hz, muscle fibers of type “IIx” will be trained with strength and speed characteristics, but scarce fatigue resistance.

Stimulation of Slow fibers - slow-twitch type “I”

To train these fibers one has to utilize frequencies between 20 Hz and 50 Hz.

Stimulation of fast fibers – fast-twitch type “II a”

To train these fibers one has to utilize frequencies between 50 Hz and 90 Hz.

Stimulation of fast fibers – fast-twitch type “II x”

To train these fibers one has to utilize frequencies between 90 Hz and 120 Hz.

Plasticity of Muscle Fiber Types

Earlier fiber-type research indicated that muscle fiber composition is very much genetically determined (i.e. the percentage of the various muscle fiber types in a certain athlete will not change with training). However, very recent research has shown that muscles trained with EMS exhibit a significant plasticity, depending on the frequency employed.

- For a comprehensive explanation of muscle plasticity, see Vrbova, Hudlicka, Schaefer-Centofanti, *Application of Muscle/Nerve Stimulation in Health and Disease* , Springer 2008.
- For a study on plasticity relating to endurance athletes, see Nuhr et al., *Functional and biochemical properties of chronically stimulated human skeletal muscle* , 2003 European Journal of Applied Physiology.
- For a study on plasticity relating to force training, see Maffiuletti et al., *Neuromuscular Adaptations to Electrostimulation Resistance Training*, 2006 American Journal of Physical Medicine & Rehabilitation.

ELECTRODE PLACEMENT

The electrodes have to be positioned to allow to the electrical impulse to arrive to the neuromuscular plate, which will then deliver the signal to contract to the muscle. To do this they have to:

- Be positioned entirely on the muscle;
- Be aligned with the muscle fibers;
- The negative electrode has to be close to the muscle origin;
- The positive electrode has to be positioned at the center of the muscle mass
- The negative electrode has to be twice the size of the positive electrode, if possible.

Because we are utilizing a rectangular symmetrical waveform, it doesn't make sense to distinguish between a positive and a negative electrode: both electrodes will be both positive and negative, depending on the instant considered during the waveform.

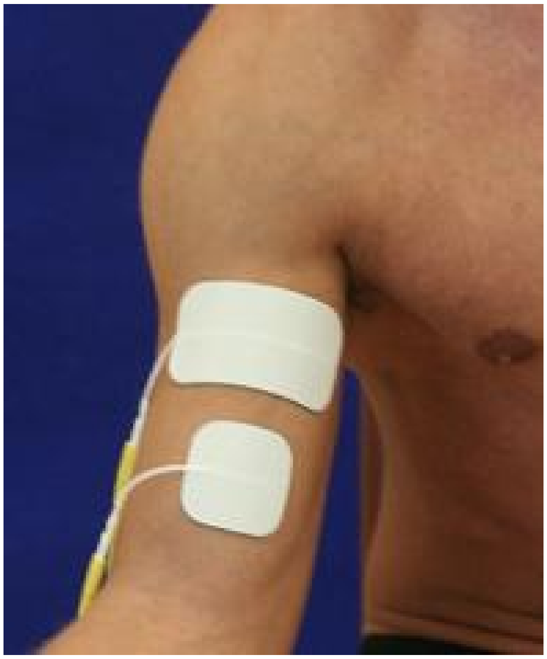
Mos illustrations found in books and on-line (link to the site with the original pictures) depicting electrode pads, mark positive and negative pads. This is done because some illustration may also be used for medical therapy applications, in which asymmetrical waveforms are based on polarity of the pads. However, for Muscle Training there is no difference. The convention is used along the terms *active pad* (positive) and *inactive pad* (negative) to discuss the pads relative sizes. It's useful to have a smaller positive electrode, to concentrate the current to get deeper into the muscle structure.

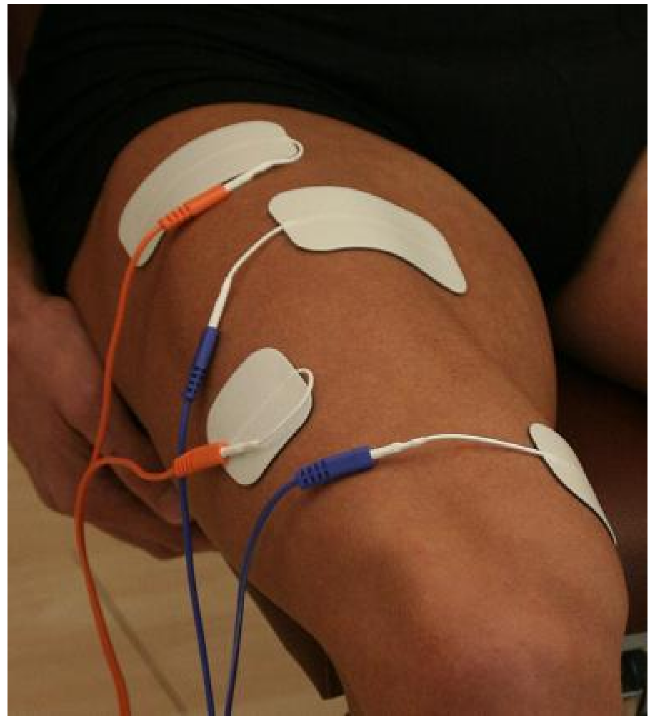
When to utilize two electrode pads of the same size

Some muscle groups are stimulated with electrodes of the same dimension for ease of use. This is the case of muscles of smaller dimensions like the biceps (but if possible one large and one small pad may give better results).

How to position electrode pads on a muscular group

To position the electrodes correctly on a muscular group, the inactive (negative) electrode is positioned proximally (i.e. closer to the vertical spine from which all nerves irradiate). Then the active (positive) electrode is positioned on the center of the muscle belly.





Biceps Brachii example.
- Inactive (negative) large pad with proximal position;
- Active (positive) small pad on the belly of the biceps brachii.

Quadriceps example.
- Two inactive (negative) large pads with proximal position;
- Active (positive) small pad on the belly of the vastus medialis;
- Active (positive) small pad on the belly of the vastus lateralis.

Verify the correct position before starting the stimulation

Before starting the real stimulation training, verify the correct position of the electrodes, with a warm up program, i.e. lower intensity and reduced parameters. It's useful to have a muscle anatomy chart handy, to help with electrode positioning.

Commercially Available Electrode Pads

On the market there are electrodes made with different materials for different uses. Most are for for muscle stimulation, but there also pads for pain therapy (TENS) made out of different plastic material.

Plastic Electrode Pads

Plastic electrode pads also known as gel, are made of a conducting plastic material. They are flexible, and need gel to be spread on the surface to improve conductivity and eliminate areas where the current would concentrate.

This type of pads also need a means to keep them in place. Medical tape is suggested rather than an elastic band, to avoid blood vessel constriction. They are recommended when there is a lot of hair or if the electrostimulation training is combined with movements.

Self-Adhesive Electrode Pads

Self –adhesive electrodes are made of a conductive mesh end of a conductive layer that acts both as a gel and as the adhesive. The gel improves conduction eliminating irregularities of the skin as a conduction obstacle. It's easy to use, even though adhesiveness deteriorates with the number of uses, especially in presence of sweat. Duration varies a lot also depending on the quality of the pad. Skin lotions are detrimental to adhesiveness and duration.

Self-Sticking Film

Another recent product is a solid gel film that can be used jointly with plastic pads, to replace only the adhesive part, when this wear out.

THE TRAINING SESSION

To obtain good training results, it's important to select the correct program. This means first of all the stimulation frequency to pursue the training goals intended. Once selected the stimulation protocol, it's important to plan the training session in detail. The principles are the same as in a traditional training session.

Integrating Stimulation with Traditional Methods

It is important to consider that electrostimulation training contracts muscle fibers without the intervention of the Central Nervous System (CNS). Later on the CNS will have to reap the benefits of electrostimulation training without electrostimulation itself.
Therefore electrostimulation cannot replace traditional training, but has to be integrated with the other methods. It's therefore very important to plan and schedule correctly the various activities. With a correct integration of the various methods, both muscular properties and functional properties will improve together.

The Training Session

Before starting an electrostimulation session it is recommended to warm up.

Warm-Up

A warm up prepares the muscles to completely receive the benefits of the stimulation, and to limit delayed onset of muscle soreness (the day after soreness). In addition the muscle uses up energy and the rest of the body needs to get ready to the change.

Systemic Warm-Up

For an adequate electrostimulation training session, especially if demanding, both muscles and cardiovascular system have to be activated to start them toward an intense training for the muscle fibers. For cardiovascular activity, a bike, a step machine or a treadmill can be utilized for 8' – 10' minutes.
The warm up of the whole system is important especially for large muscle groups like quadriceps, calves, gluteus, abdominals or pectorals.

Specific Warm-Up

Although a systemic warm-up can be skipped, if the stimulation doesn't require a big muscular commitment, or if the muscles are small, a specific warm up is always recommended. The choice of training warm-up is extremely dependent on the muscular group that has to be stimulated, and on the individual. Quadriceps, biceps, abdominals, pectorals and dorsals can for instance all be warmed up. During warm-up the muscles should not be fatigued nor stressed, but just prepared to be ready to capture the advantages of an electrostimulation session.

Electrostimulation Warm-Up

Once the physical warm up is completed, the electrode pads will be positioned on the muscles to be stimulated. The chronaxie utilized has to be the correct one for the muscular group to be trained. Warm up programs do not need to fully contract the muscle as in a training program. Modern electrostimulation programs are normally supplied with a range of stimulation frequencies that cover all needs.

Amyotrophic Warm-Up

In case of stimulation of amyotrophic (atrophied) and hypotonic muscles, the programs to be utilized will have not to stress the musculature. A program of this type will have a frequency between 5 Hz and 10 Hz, will not cause a tetanic contraction, and will stimulate continuously without pauses.

Force Warm-Up

For warm up before strength programs, it may be convenient to use a more demanding warm up, with tetany of the muscle, but without fatiguing the muscle. Slow fibers of type “I”, stimulated between 20 and 35 Hz, will effectively increase blood flow to the muscle to be warmed up. Current intensity has to be high enough to cause a contraction, but has to stay low so that the muscle does not get fatigued. Contraction has to be alternated with rest to avoid contraction pains or cramps.

Work

After warm up, the muscle is in the best condition to train. The program has to be selected as a function of the result that has to be obtained, with frequency targeting the fiber types that have to be trained.

Know the Stimulation Objectives

Analyze what the needs of the athlete are, as a function of the sport, or of the functional athletic gaps that the individual has.

Define the Muscular Characteristics to Train

Define what muscular qualities have to be trained.

Know the Relationship between Muscular Characteristics and the Muscle Fibers to Stimulate

As a function of the muscle qualities that have to be improved, decide if they are slow-twitch fibers type “I”or intermediate fast-twitch fibers of type “IIa” or fast-twitch fibers of type “IIx”.

Chose the Stimulation Frequency

Pick a frequency as a function of the objectives to be pursued.

Choice of the Stimulation Frequency

Once decided which muscle fiber types have to be stimulated, chose the stimulation frequency that best recruits the fibers. The following table gives a good indication

20 Hz 50 Hz	Slow fibers of type “I”
50 Hz 90 Hz	intermediate fibers of type “IIa”
90 Hz 120 Hz	Fast fibers of type “IIx”

Work Positions and Methods

The position to assume during stimulation must have the following characteristics:

- Most comfortable;
- Must give the least joint problems;
- Must allow the highest stimulation intensity;
- Contracts the muscle in a way similar to that of the sport event.

It must be decided whether to further load the muscle, with voluntary contraction and with or without loads.

Electrostimulation Alone

Electrostimulation alone is effective only for functional recovery, but is extremely limiting for training purposes.
To utilize the electrostimulator at intensities adequate for training it is important to limit the movement of the part of the body to which the muscle is attached. This has to be avoided because it could cause either muscular or joint pain. This is easily solved by using fixed resistance.

Combined Methods

By combining training methods, electrical stimulation increment its ability to train the individual. Not only artificial loads but just natural are enough to obtain this result. In addition stimulation comfort increases and the athlete is therefore able to use higher stimulation intensities, which favor a better recruiting.

Natural Loading

It is useful and practical to stimulate the muscle during a training session, utilizing only the weight of the body, because it can be done anywhere. It is also the base stimulation training adopted by personal trainers, and it is useful for competing athletes who are continuously traveling to competitions.
However, it may not be to the best training session. Not all muscular groups are well suited to natural loading. All extending muscles of the the legs can be trained well with stimulation and natural loads because of their natural way of working against gravity during a concentric action. Abdominal muscles too, can be stimulated without overloads, limiting the range of motion of the joint.
However, it is difficult to utilize this working method on muscular groups that normally do not work against gravity. For instance the biceps brachii, or the flexing muscles of the leg (like the hamstring or the calf).

Additional Loads

Utilizing overloads and electrostimulation together, resolve many of the problems of electrostimulation either alone, or with natural loads. In fact the presence of an overload reduces the risk that the stimulated muscle shortens too much with pain and possible risk of cramps.
By using additional loads, it's also possible to train an individual affected by muscle, tendon or joint pathologies. This can be done by selecting and fine tuning the method that works best, avoiding at the same time to worsen the pathology. Gym machines in addition can limit the range of motion during the exercise.

Quadriceps

Extensory muscles of the lower limbs are the most trained. To train the quadriceps it's possible to utilize with stimulation a series of exercises with overloads, like the leg extension or leg-press. All of these exercises are good to increase strength, depending also on the stimulation frequency used during the session.

Biceps Brachii

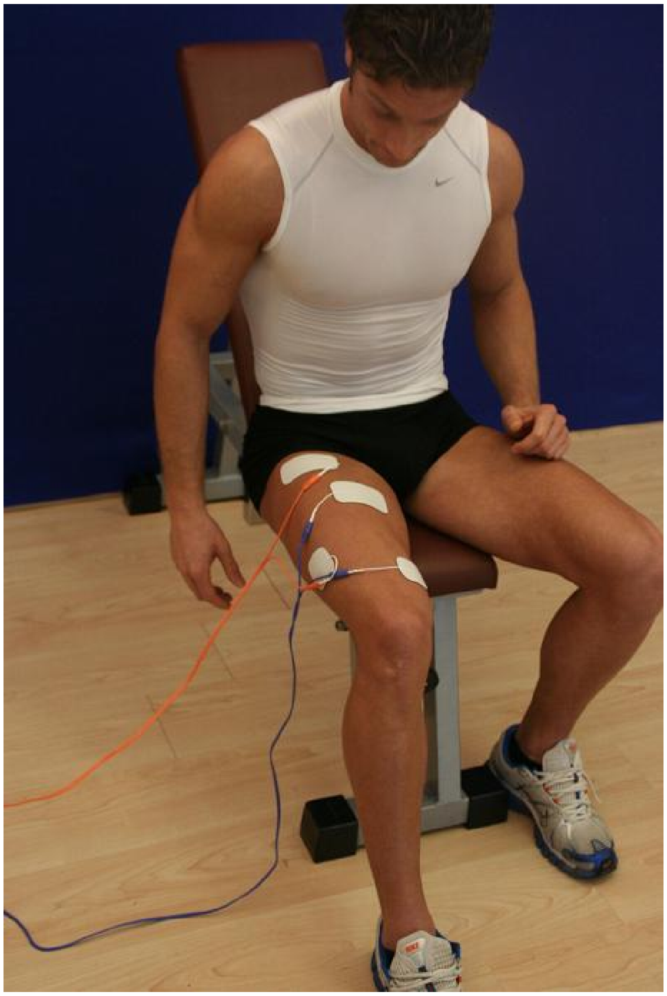
To stimulate the biceps it's best to use the electrostimulator with free weights or on a bench.

Leg Flexor

To stimulate the leg flexors, the most convenient solution is to use a leg-curl machine.

Abdominals

Abdominals are best stimulated without performing a crunch exercise or without any overload. Stimulation solely with the natural load gives best results, both for muscular tone and strength, without overloading the back. This limits muscle aches or joint problems on the vertebrae.



Recommendations

When performing dynamic exercises, either with natural load or with overload, it is recommended to be with a person expert in the training method to avoid problems. It's safer also to use electrostimulation with ROM (range of motion) machines to keep the motion within a safe range.
The muscle shall never be stimulated when in its shortest position, to avoid contractures and pain.

Defatigueing

After stimulation it's useful to spend 5' or 10' minutes defatigueing the muscle. The most effective recovery is not just rest, but a bland activity defined as *Active Recovery* in which the muscles are stimulated at a frequency between 1 Hz and 10 Hz, and must be performed in a position in which the muscle can be relaxed and almost completely at rest (see picture).

Transformation

Once the stimulation session is over, it's useful to add some dynamic voluntary exercises which increase the effectiveness of the stimulation. This phase, called *transformation,* has the athlete select the exercises and work methods most useful to reach the training objectives. For this it is important to know whether one wants to act on strength or if one wants to have a lighter end of the training and work on coordination.

Force

If one wants to complete the training by working on strength development, one has to utilize overloads, managed with specific methods as a function of short, medium and long term objectives desired.

Coordination

If one wants to improve the sport technique, it is convenient to utilize reduced or no overloads, and concentrate on precision and speed of movement, exploiting the muscle fatigue induced by stimulation. In this way it is possible to make the athlete repeat competition movements, but in more difficult muscle conditions. For a high level of coordination, after stimulation a technical training could follow, even though with moderate intensity.

Stimulation Duration

The best duration for a stimulation session cannot be standardized, even though a range of duration can be considered for the most typical needs.

Warm-Up

Electrostimulation warm-up is generally done with a duration of 5' minutes, both for a session of functional recovery and for a toning session for aesthetics.

Work Phase

The real section of the stimulation session (i.e. after warm-up), can last even just 10' or 15' minutes, if the individual is not yet used to this training method, and his/her musculature is hypotonic (weak) and hypotrophic (underdeveloped). Training sessions for individuals who are already used to stimulation can last even 40' or 50' minutes, obviously with programs tailored to the need and the type of session wanted. General prescriptions cannot be done, and it's best to adapt the general concept to the needs of the individual to train.

Defatigueing

Defatigueing or active recovery is useful if it lasts for at least 5' minutes, but could last much longer depending on the degree of fatigue of the individual being stimulated.

ELECTRICAL PARAMETERS PROGRAMMING

Programming

The market for electrostimulators has opened to devices that within consumer reach can offer good performance to professionals. Programmable stimulators allow coaches, strength-and-conditioning trainers and athletes to customize stimulation programs by adjusting the electrical parameters. Customization, if done correctly by knowledgeable people, adapts stimulation training exactly to the need of a particular athlete. It takes advantage of the physical characteristics of the individual and adapts them to the goals of the sport targeted.
In other words customization produces better results. The converse is true. Incorrect programming not only is not going to give the hoped for results, but it may be detrimental to the goals.

The Best Choice

Although commercially available devices allow one to program training sessions, it is better to adjust electrical stimulation parameters with a professional who know how to proceed.

When to Program

Some stimulators allow for an adjustment of electrical parameters for total customization. This has to be done with caution. The departure from standard parameters has to be done with a complete understanding of their effectiveness, and the effects of change on the results of training. The following questions will help:

- What's the stimulation objective?
- Is it possible to reach the same goal by using one of the program offered as standard by the device?
- Is it really necessary to customize the stimulation?
- Am I able to make the best selection of stimulation parameters for the goals pursued?

If after this analysis one decides to pursue programming, it is necessary to learn in depth the meaning of all the parameters.

Electrical Parameters and their Meaning

- Type of current
- Session duration
- Chronaxie
- Increase Ramp
- Contraction Time
- Decrease Ramp
- Rest Time

- Contraction Frequency
- Rest Frequency

Type of Current

The choice of the type of current is normally limited to either TENS or EMS.
TENS (Transcutaneous Electro Neuro Stimulation), allows the programming of program with analgesic (pain therapy) effects. EMS (Electro Muscle Stimulation) supposedly is for strengthening goals.

Treatment Duration

Session duration depends on the needs of the individual. Minimum or maximum duration cannot be prescribed. However, normal durations go from 30' to 60' minutes. Often it's possible to combine together different programs that together determine the total duration.

Chronaxie

Chronaxie is the duration of the single impulse or waveform phase, and depends on the muscular group. Adjustment of this parameter may improve or worsen the stimulation effect and cannot be changed on a whim. It has to follow an indicative table of values depending on the muscle. Different individuals may have different chronaxie values. The utilization of chronaxie values much higher than normal would stress the muscle without obtaining a training benefit. Chronaxie values below optimal there will be no stress, but the effectiveness of the training will be lower. Most fibers will not reach the stimulation threshold and some fibers will get into accommodation. Chronaxie lower than suggested may be used for individuals who are weak or recovering from muscle injury.

Muscular Contractions

The work phase is made of three different segments which affect both comfort and fatigue:

- Increase ramp
- Contraction time
- Decrease ramp

Ramp-Up

Ramp up is the time it takes to go from 0 to the current intensity wanted during the work portion. Too-short ramps do not give the athlete time to get ready to the contraction, and the sudden change will be uncomfortable. Too-long ramps will fatigue the muscle before it reaches the contraction needed for training. Most sport training programs ramp-up in 0.5" to 2" seconds.

Contraction Time

During contraction time muscle fibers will perform their training work. The muscle will use up energy. This is a delicate phase, because surpassing maximum resistance of the muscle fibers could cause contractures and cramps.
The duration of this phase doesn't have a fixed standardized value, but must be evaluated as a function of the type of fiber. The following table shows reference values.

Frequency	Fiber Type	Charactteristics	Work Time	Rest Time
35 Hz	1	Slow Twitch	8" sec	6" sec
55 Hz	2a	Intermediate	6" - 8" sec	7" sec
85 Hz	2a - 2x	Intermediate - Fast	4" sec	25" sec
100 Hz	2x	Fast Twitch	3" - 4" sec	30" sec

In general, contraction and rest times are not too different from values used for voluntary resistance or dynamic training; remember that the muscles are contracted in the same physiological way and for the are still valid the same metabolic and adaptation mechanisms. If the individual whose advice you are following is knowledgeable about EMS, this person may have particular goals in mind that would differ from the examples given.

Ramp-Down

This parameter is less important than ramp-up for comfort. However, a too sudden decrease of contraction force may be unpleasant. If it is too long, it will contribute to fatigue.

Rest Phase

Rest time between contractions has to be long enough to allow catabolite flushing from the muscle fibers. A very low frequency between 1 Hz and 4 Hz will cause the muscle to pump blood through the fibers and facilitate flushing of the byproducts of contraction. Slow-twitch type "I" fibers do not need a rest time as long as fast-twitch type "IIx" fibers.

Frequency During Contraction

Stimulation frequency allows selecting the type of fiber being trained. It will be between 20 and 120 Hz depending on the fiber.

Frequency During Rest

Between two contractions it is necessary to have a short rest time to allow blood to refuel the muscle, and to take away waste products of the previous contraction. A low frequency that massages the muscle increases blood flow. During active recovery the can be utilized a frequency between 1 Hz and 6 Hz.

Who Needs Customized Stimulation Parameters?

Standard programs found in electrostimulators on the market are good for most individual, and program customization should be done only when needed.

Are We Able to Program?

Knowing the meaning of electrical parameter is not enough to be able to program, and a lot of practical experience is necessary. The first step is to analyze the parameters of the programs already available. To gain an understanding of the protocols and to change them it is necessary to discuss them with an expert.

A Different Interpretation of Stimulation

Only a minority of athletes will need a modification of the electrical parameters. It is important instead to customize for the need of each athlete the protocol of the training program.
For instance the sequence of the programs and their duration will have to be modified obtaining a precise duration of the entire training session. In this way the goals of the athlete can be reached even though the electrical parameters are the same.

ANATOMY AND ELECTRODE PAD PLACEMENT

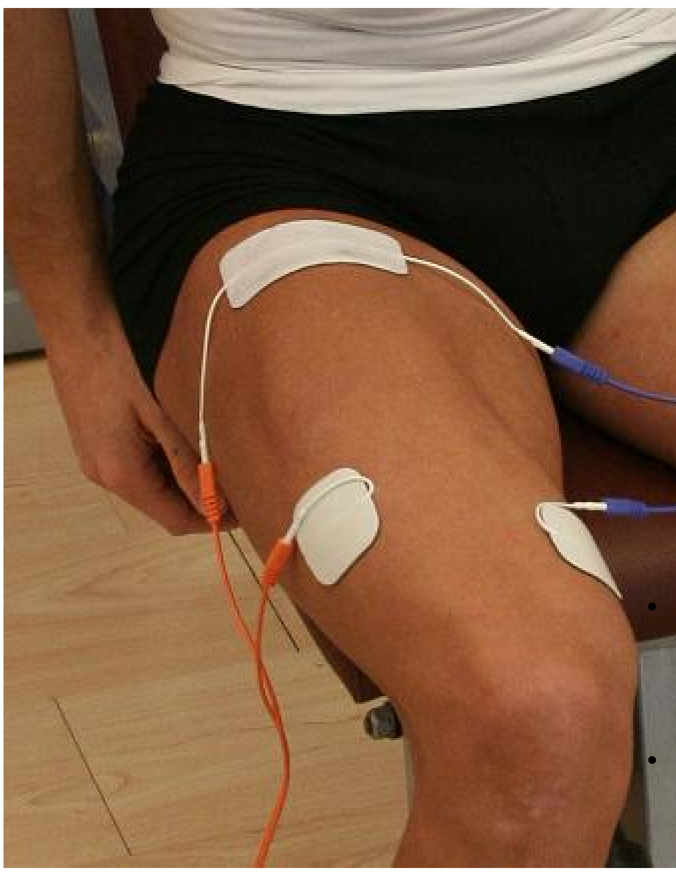
Practical examples and videos of pad placement can be found at
www.globuscorporation.com/eng/catalogo.asp?cat=0&idcat=1&sottocat=3&idsottocat=39

FEMORAL QUADRICEPS

The quadriceps is the main extending muscle of the lower leg with respect to the upper leg. Its various sections start from the hip and femur, and converge on one common tendon attached to the tibia. It also elevates the thigh with respect to the hip. It contrasts gravity, keeping an individual
standing. It's of utmost importance in all sports using the legs, from running to jumping, biking etc.

When to train it

Given its function to contrast gravity, it's important in all sports in which the trunk has



to be moved vertically: volleyball, basketball, high jump, long jump, soccer, football, rugby, skiing, gymnastic.
It's equally important in running sports in which explosive force or resistance of the quadriceps are needed. The type of stimulation program needed depends then on the sport, and the choice of frequency is consequential.

Pad Placement

The electrode pads can be positioned in a few different manners, depending on the goal. The most simple is:

- Inactive (*Negative*) Electrode:
centrally in position close the hip so as to be on top of vastus medialis, vastus lateralis, and rectus femoris.
- Active (*Positive*) Electrodes:
on the muscle belly of the vastus medialis, at its center;
on the muscle belly of the vastus lateralis at its center.

GASTROCNEMIUS calf

Similarly to what said for the Quadriceps, the extensory musculature of the lower leg has an important role counteracting gravity. It is very important for all running and jumping activities. The origin of the muscle group is on the femur, and the soleus on the tibia, converging on achille's
heel attached to the calcaneous bone.

This muscular group gets activated together with the
quadriceps and the gluteus. Because the quadriceps is larger, individuals have a tendency to underestimate its importance in dynamic situations, and in training.

When to train it

When power and explosive force are needed. For example in volleyball, basketball, and other athletic disciplines with similar motor demands. It is of utmost importance in all disciplines like fast running and and middle distance running, in which the movement of the ankle is important. In downhill skiing it is used very much. In cycling it is also very important both in its static and endurance action.

Pad placement

Passive electrode:
position the pad at its beginning, totally placed on the muscle; do not place it too close to the cavus popliteus, which could impair the movement of the knee.
Active electrodes (two):
They must be placed distally, at the center of both muscle bellies that make the gastocnemius.

GLUTEUS MAXIMUS

It is considered the third and last of the extensor apparatus of the the lower limbs. Its origin is in the ridge going from the ilius to the sacrum and coxis, and its insertion is on the femur. It's mainly responsible to maintain an erect position, since it abducts the thigh with respect to the trunk. Therefore with the quadriceps and the calf is responsible to counteract gravity. It is thus important in training finalized to running and jumps.

When to train it

It can be trained for all the situations already considered for quadriceps and calf. Because of its anatomical position it is particularly important in extensions starting from a position in which the angle between trunk and leg is small.

Training of the gluteus is particularly important in sports like skiing and carving. In general the gluteus is important in all sports that require explosive strength and power to be developed by the lower limbs. Therefore volleyball, basketball, soccer, ski, athletic, skating etc. will benefit from its training.

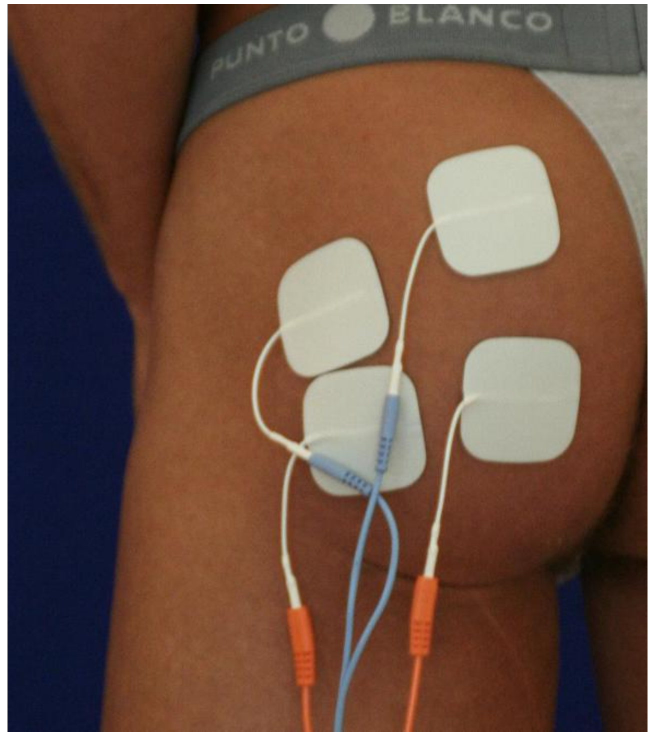
Pad placement

- Inactive electrode:
  In proximity of the great trochanter, slightly higher and closer to the center line, and perpendicular to the direction of the gluteus maximus fibers.
- Active electrode:
  At the center of the muscle. Some trainers prefer a smaller electrode for stimulation of deeper muscle fibers (it's debatable).

GLUTEUS Medius and Minimus

The small and middle gluteus participate to the extensory movements of the lower limbs, specifically in the outward rotation and abduction of the thigh.

These muscles are deeper than the gluteus maximus. They originate just below the crest of the ilium, and have their insertion on the
great trochanter (protuberance) of the femur.



When to train it

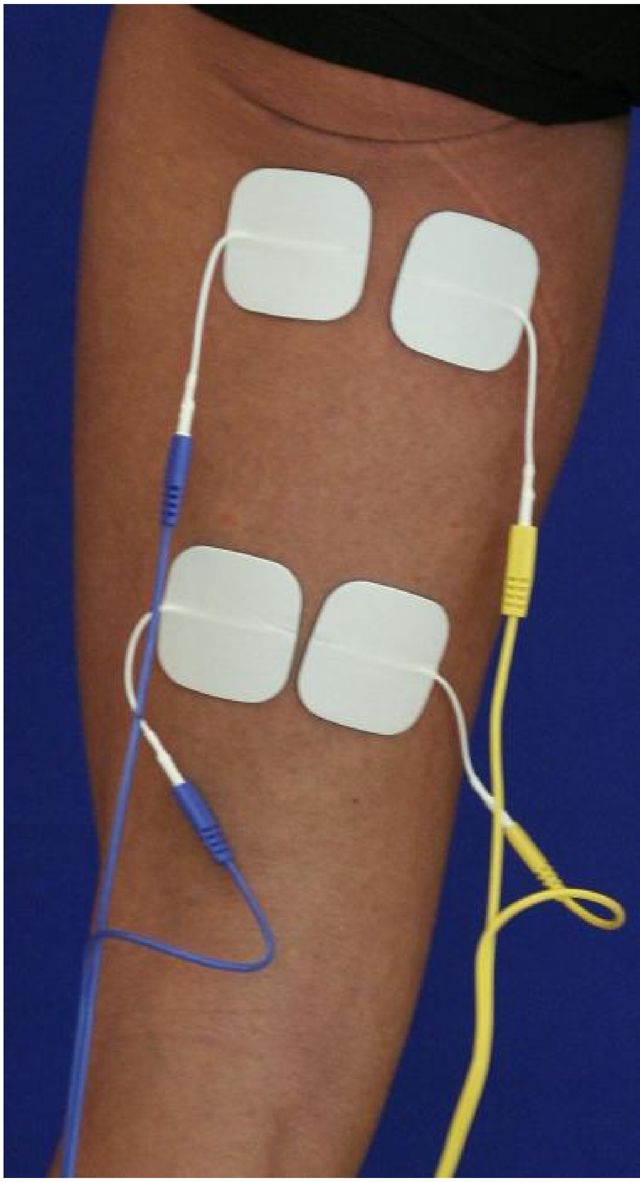
To be effective the stimulation of these muscles has to be done with that of the gluteus maximus. It is mostly doen to obtain aesthetic results. From a sport point of view it does not give particular advantages over a stimulation of the gluteus maximus only.

Pad placement

- Inactive electrode:
  Close to the great trochanter,
  parallel to the gluteus rim, slightly on the internal side.
- Active electrode:
  At the center of gluteus.
    - The picture's top two pads (blue connectors) are for the Gluteus Medius. However, it may be preferable to use larger pads (4" long) in a slightly higher position.

HAMSTRINGS

In the back of the thigh there are three muscles that flex the lower leg on the upper leg: biceps femori, semitendinosus and semimembranosus. They originate at the ischium and insert at the Condyle of the tibia and the head of the fibula.
They flex the lower leg on the upper leg, and in a limited way in collaboration with the gluteus they help the extension of the leg from the trunk.
The flexing muscle controls the knee joint in antagonism with the quadriceps.



A good equilibrium between flexor and extensor muscles of the leg will help prevent problems on the knee.

When to train them

It's rare to have to train the hamstring muscles selectively, because it's rarely in deficit with respect to to the other extensors muscles.
It could be useful to train the flexory muscles in those sports, like soccer, skiing and crosscountry skiing, in which it is important to train the extension of the thigh on the trunk. It is also useful to train these muscles when the risk of knee and ACL traumas is high.

Note
When stimulating the flexor muscles it is important to look after a balance between these muscles and the extensors muscles, because an imbalance would cause instability of the knee.

Pad placement

It is convenient to utilize only two large electrodes, because of the anatomy of the back of the thigh.

- Passive electrode:
  At the center of the thigh just below the gluteus
- Active electrode:
  At the level of the third distal , in the center of the belly of the muscle.

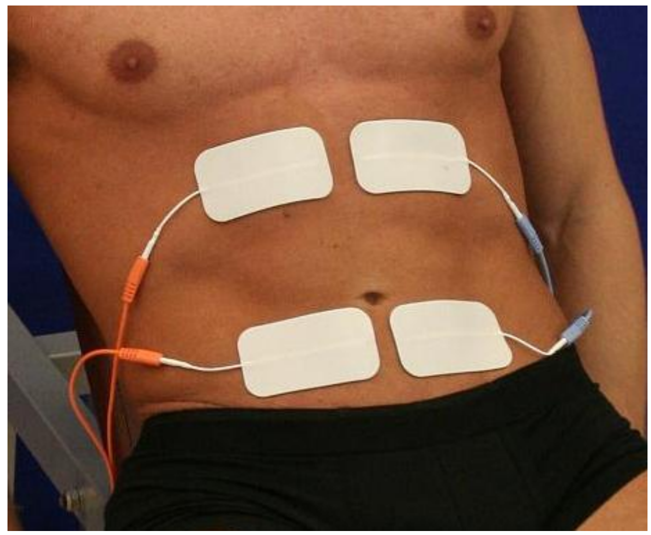
RECTUS ABDOMINIS

The rectus abdominis is a long and thick muscular ribbon, interrupted by connective tissue strips; it originates from the pubic crest and inserts into the last ribs. In its respiratory function lowers the ribs, and in its dynamic function flexes the spinal column forward.

The rectus abdominis, conjointly with the transverse abdominis, and the obliques stabilizes the spinal column giving solidity to the trunk. Because of this stabilization function it has an important role in almost all dynamic movements, and it maintains the posture.

When to train it

Among all muscles that can be trained with an electrostimulator, the rectus abdominis is the winner.

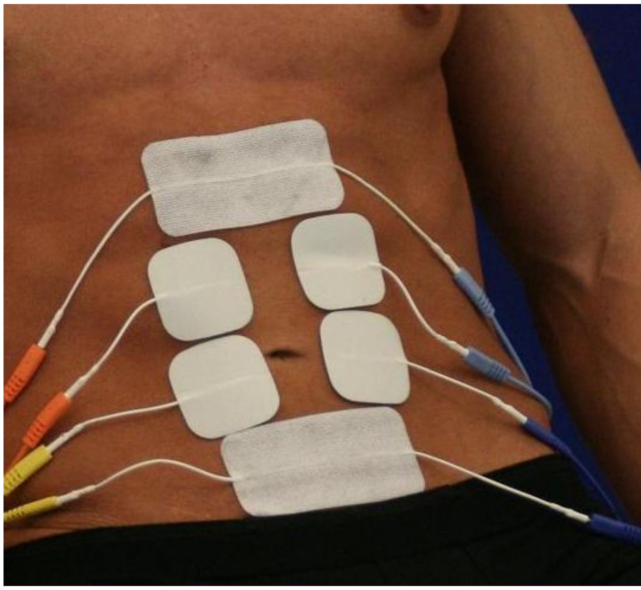


Because of its role in stabilizing the spinal column and the hips, it is important in all sports in which it has to develop either force or speed of the lower limbs.
Its tone is also important in all sports that use the arms, which need a good supporting base.
Therefore any sport benefits from a selective training of the abdominals.

Pad placement

It's possible to utilize four large electrodes (or two, each across the abdominal wall), but there are also other possibilities.

- Inactive electrode:
  Between the iliac crests and the navel.
- Active electrode:
  at the level of the rib arc such that the electrode stay on the abdomen and not on the ribs, to avoid that the stimulation act on the intercostal muscles.



RECTUS ABDOMINIS – Six Electrode Pads

To stimulates the abdominals, instead than 2 large electrodes one can also use 2 large electrodes and 4 small. Six electrodes allow to optimize the location of the stimulation and to utilize more channels. The two arrangements give the same results, and only depend on preference.

Pad placement

The two large pads are the passive electrodes, and are placed in the same location as for the 2-electrode arrangement, but more apart from each other.

- Passive electrode (lower): at the iliac crest, between the navel and the pubic area in the center.
- Passive electrode (upper): At about the rib arc, above the navel, such that the electrode remains completely on the abdomen, to avoid inter-costal muscle stimulation.
- Active electrode: Around the navel, two above, in the area included between the upper passive pad and the navel; two in the area between the lower passive electrode and the navel.

TRAVERSUS ABDOMINALIS – two pads

Origin laterally from the last two ribs. It's perpendicular to the other abdominals and it stabilizes the spinal column without participating much to dynamic movements.

When to train it

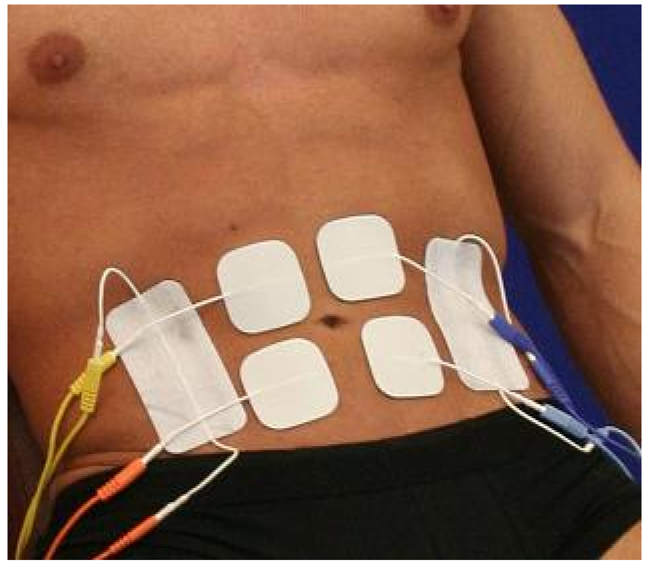
It's important in sports in which both lower and upper limbs are used. It helps protect the spinal column. It can be stimulated for aesthetic goals.

Pad placement

Similarly to what said for for the other abdominals, there are different arrangements to position the electrodes, the simplest being with two large pads. Active and passive electrodes are completely interchangeable.With reference to the picture for six pads, only the two outer pads are employed (if using double input pads, connect only one input to each terminal of the same channel)

- Passive electrode:
  Laterally with respect to the abdomen, but below the ribs so that the intra-costal muscles are not activated.
- Active Electrode:
  at the opposite side of the passive electrode with respect to the abdomen.

TRAVERSUS ABDOMINALIS – six pads



With two large and four small electrode pads. Use either arrangement depending how the athlete is responding to the stimulation.

When to train it

This arrangement is used especially for aesthetic reasons. Because this muscle contains the abdomen, its toning favors a better look, but it doesn't help with losing fat layers.

Pad placement

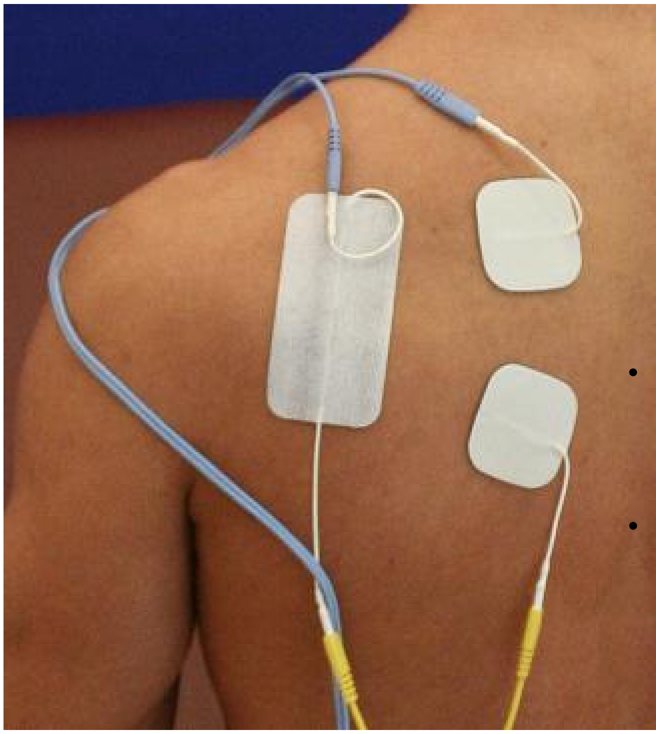
- Inactive electrode (right):
  Vertical position in proximity of the point where the ribs are almost parallel to the iliac crest. Do not position on the ribs, to avoid contractions of the inter costal muscles.
- Inactive electrode (left):
  On the opposite side of the abdomen.
- Active electrodes:
  The four small electrodes are in proximity of the navel, parallel to the inactive electrodes.

TRAPEZIUS

The trapezius has a very wide origin on the spine, and inserts on the clavicle and scapula. It's divided in three main sections, with different functions.
The upper fibers, starting from the cervical vertebrae, elevate the scapula and rotate it outward.
The middle fibers originating from the dorsal vertebrae adduct the scapula toward the spinal column. The lower fibers lower the scapula rotating it inward.
Overall it stabilizes and controls the scapula, which is important in sports that utilize the arms to throw or to lift the body.

When to train it

Electro stimulation of this muscle has to be combined with training of the other muscles that participate to the movement.



It can be useful in climbing, tennis, volleyball, swimming.

Pad placement

The electrodes have to be placed depending on which section of the trapezius needs to be trained. Placement for the middle section follows.

- Inactive electrode:
The large pad must be positioned at the third medial of the scapula, with the long side parallel to the spinal column.
- Active electrode:
Two small electrodes are placed in proximity of the spinal column, approximately one inch from the spinous processes, and parallel to the inactive electrode.
- The upper pad at the same height of the large pad, and the second small pad a little lower.

BICEPS BRACHII

The biceps is made of a long and a shorter head, originating from the scapula and humerus and insertion in the radius. The main function is to flex the forearm on the arm, and helps to elevate the arm, or to lift the trunk (climbing).

When to train it

Stimulation is recommended for climbers, for rowing, swimming, tennis and all sports using the upper limbs.

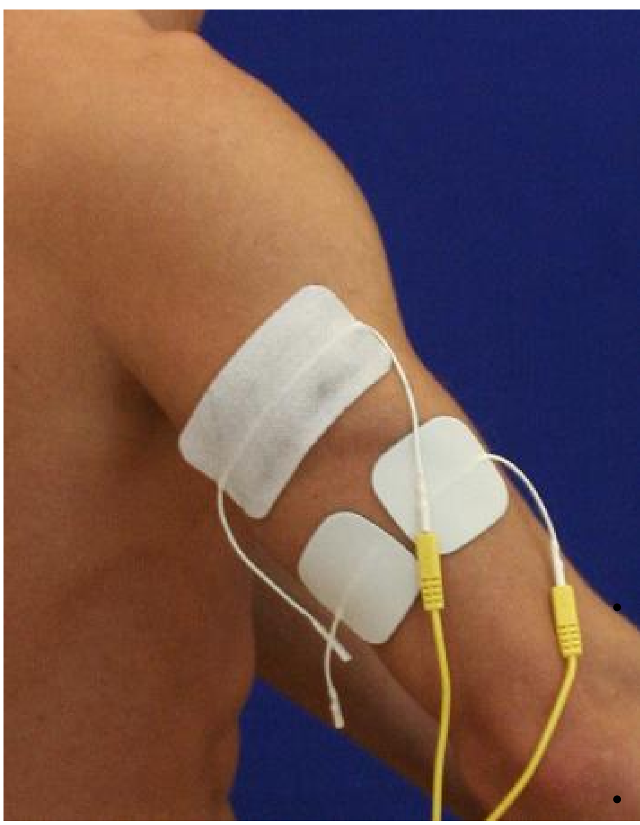
Pad placement

Positioning is simple. It’s possible to use two small electrodes or one large/ one small compatibly with the absolute size of the muscle.

- Inactive electrode:
  Positioned just before the deltoid covers the biceps, aligned at the armpit.
- Active electrode:
  On the muscle belly of the muscle; just flex the muscle, it’s the point where the muscle bulges the most.

TRICEPS BRACHII

Origin with three tendons: from the infraglenoid tubercule of the scapula, and above and below the radial groove of the humerus; all three inserts into the ulna. It extends the forearm with respect to the arm, and it’s the antagonist of the biceps.



When to train it

It’s useful to stimulate this muscle to train throw and push of the upper limbs. Main sports that benefit from it are volleyball, crosscountry skiing and all disciplines in which it is necessary to throw an object. It is also trained for aesthetic reasons.

Pad placement

Positioning is not difficult, depending on the individual (only one channel has been connected in the picture, the other one is similarly connected)

- Inactive electrode:
  On the posterior face of the arm at the height of the armpit where the tricpes can be felt, that is below the lower margin of the deltoid.
- Active electrode:
  because the are two muscle bellies, it is

necessary to place one active electrode for each. These can be determined with a voluntary muscular contraction

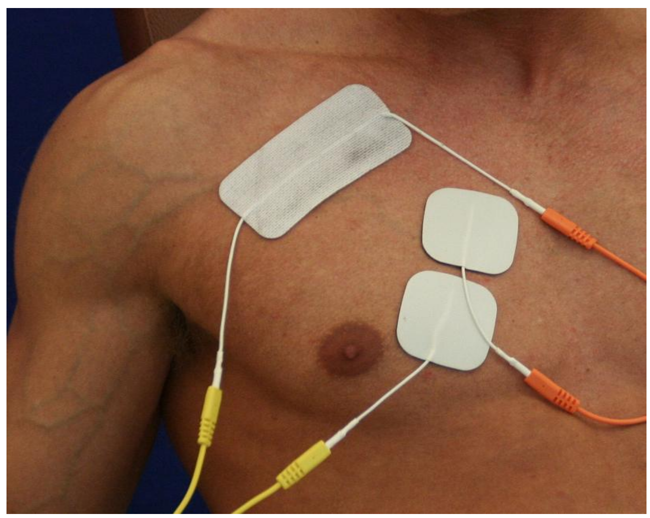
PECTORALIS MAJOR

The pectoralis major originates from the clavicule, from the sternum and from the costal rib cartilage; the three origins converge on the insertion on the humerus.
It adducts and rotates inward the arm; if the latter is kept fix, it helps elevating the trunk. It also helps deep inspiration.

When to train it

The pectoralis covers a main role in all athletic-throw sports, and intervenes during play in volleyball, tennis. It stabilizes the dynamic movement of the shoulder. It is also important in climbing, swimming and wind-surf.
Because of these multiple functions its training is recommended in any sport utilizing the upper limbs.

Pad placement



Electrode positioning is finalized to the functionality of this muscle during execution of a movement.

- Inactive electrode:
  Use a large rectangular pad, placed proximally to the armpit, just before the point where the pectoralis buries under the deltoid.
- Active electrode:
  Both acive electrodes are placed at the center of the muscular mass of the pactoralis. The lower pad is placed above the nipple, slightly toward the sternum. The upper pad is positioned above the latter, and closer to the sternum.

DELTOID

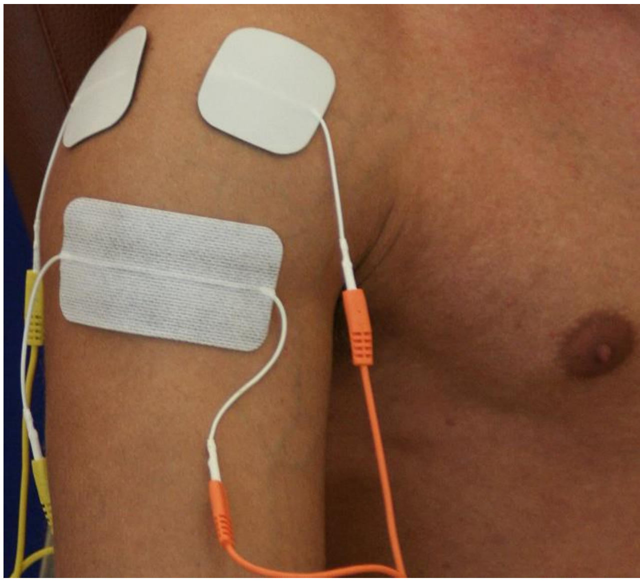
The deltoid is made of three sections, anterior, lateral and posterior. The anterior section originates from the clavicle, the lateral originates from the acromion, and the posterior from the scapula. All three sections insert in the humerus, but because of their orientation they are functionally different.

- The anterior moves the arm forward, rotating it inward.
- The lateral abducts laterally and lifts the arm.

- The posterior moves the arm backwards in extension.

It stabilizes all shoulder movements, collaborating with deeper muscles.

When to train it



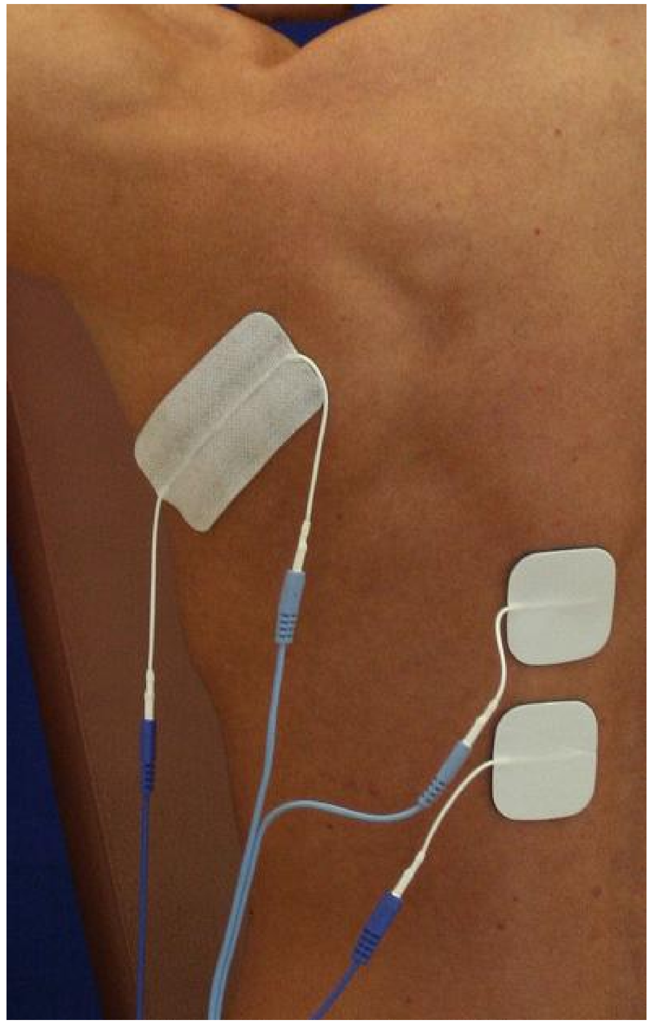
Because of its stabilization effect, this muscle should be trained for all sports that considerably load the upper limbs. In throwing sports there is also a collaborative effect. It is therefore useful to train in for volleyball, basketball, swimming, ski, carving, throwing sports, canoeing, kayaking and climbing.

Pad placement

Correct positioning of the electrodes on the deltoid takes into consideration the three sections. It is therefore convenient to use a rectangular inactive electrode, and two active smaller electrode pads on the anterior and posterior sections. It is not convenient to place electrodes above the shoulder to avoid bothersome compression feelings on the shoulder joint.

- Active electrode:
  positioned on the humerus, just above the insertion of the deltoid on the humerus; this place is recognizable by the fact that the muscle tends to reduce its width.
- Inactive *anterior* electrode:
  on the belly of the anterior section of the shoulder.
- Inactive *posterior* electrode:
  The posterior inactive electrode is placed similarly on the belly of the posterior section of the muscle

LATISSIMUS DORSI



The Latissimus Dorsi originates from the spinal column (L1-5, T7-12), the posterior ribs, the ilium and the sacrum; it inserts into the humerus. Its function depends on what is kept fixed: it rotates inwards, moves back and adducts the arm; or it elevates the trunk.

When to train it

The Latissimus Dorsi participates to throw movements and is advantageous to train for swimming, volleyball, climbing and in general athletes who use the upper limbs.

Pad placement

To stimulate the Latissimus Dorsi the electrodes have to be placed to recruit a good portion of the muscle fibers. The active lectrode is a large rectangular one, the inactive electrodes are two square ones.

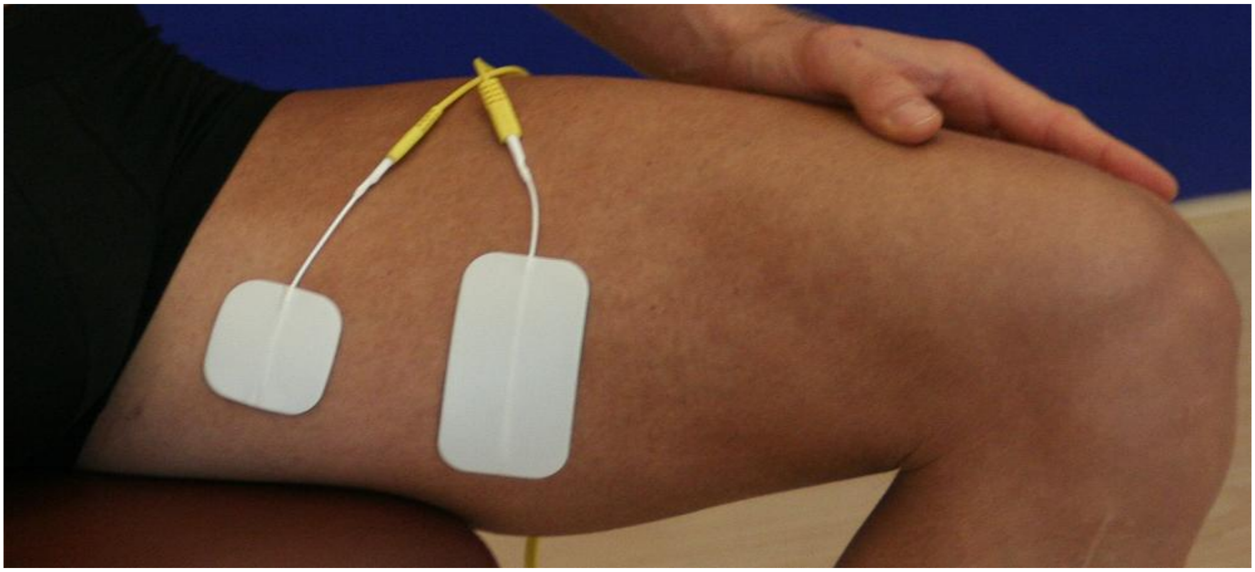
- Inactive electrode:
  below the armpit; the upper side should almost touch the lateral side of the scapula.
- Active Electrodes:
  they must be positioned, one above the other, at the level of the last dorsal vertebrae and the first lumbar vertebrae.

ADDUCTORS

The adductor group is composed of 4 muscles contributing to the same functional movement: adductor brevis, adductor longus, adductor magnus and pectineus. Origin is on the pubis and ischium. The insertion is on the femur at different points. The main function is the adduction of the leg toward the other leg.

When to train it

The adductors are important in all flexion-extension movements of the thigh, and therefore are important for dance and gymnastic. Riding sports also use these muscles. They are also important aesthetically, since their tone determines the shape of the inside of the upper leg.



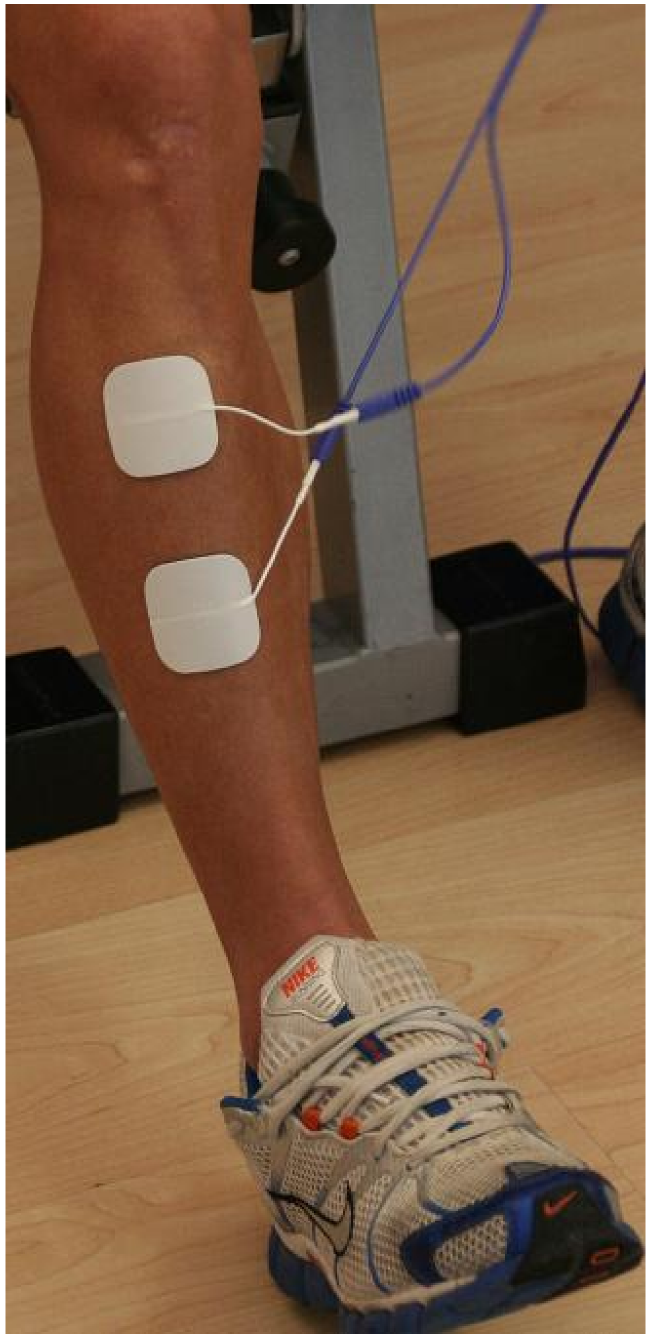
Pad placement

- Active electrode:
  below the pubic origin of the adductors, at the center of the inner side.
- Inactive electrode:
  at about one third of the length of the thigh, starting from the pubis origin.

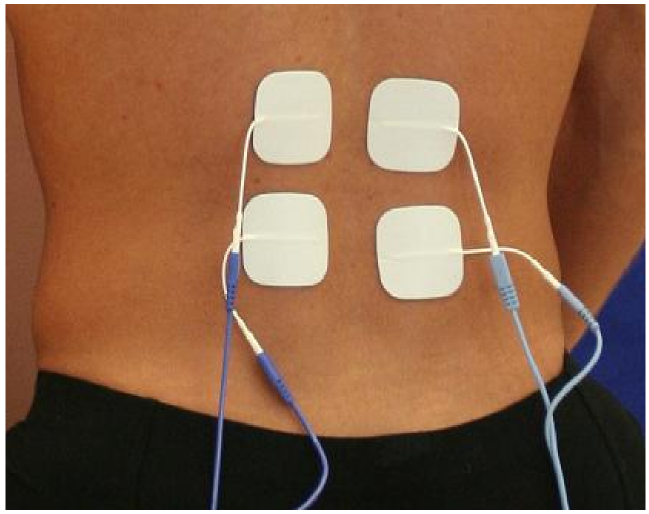
Additional Body Parts Pad Placement

Forearm

Tibialis Anterioris



Lower Back



Appendix 1: Russian Currents

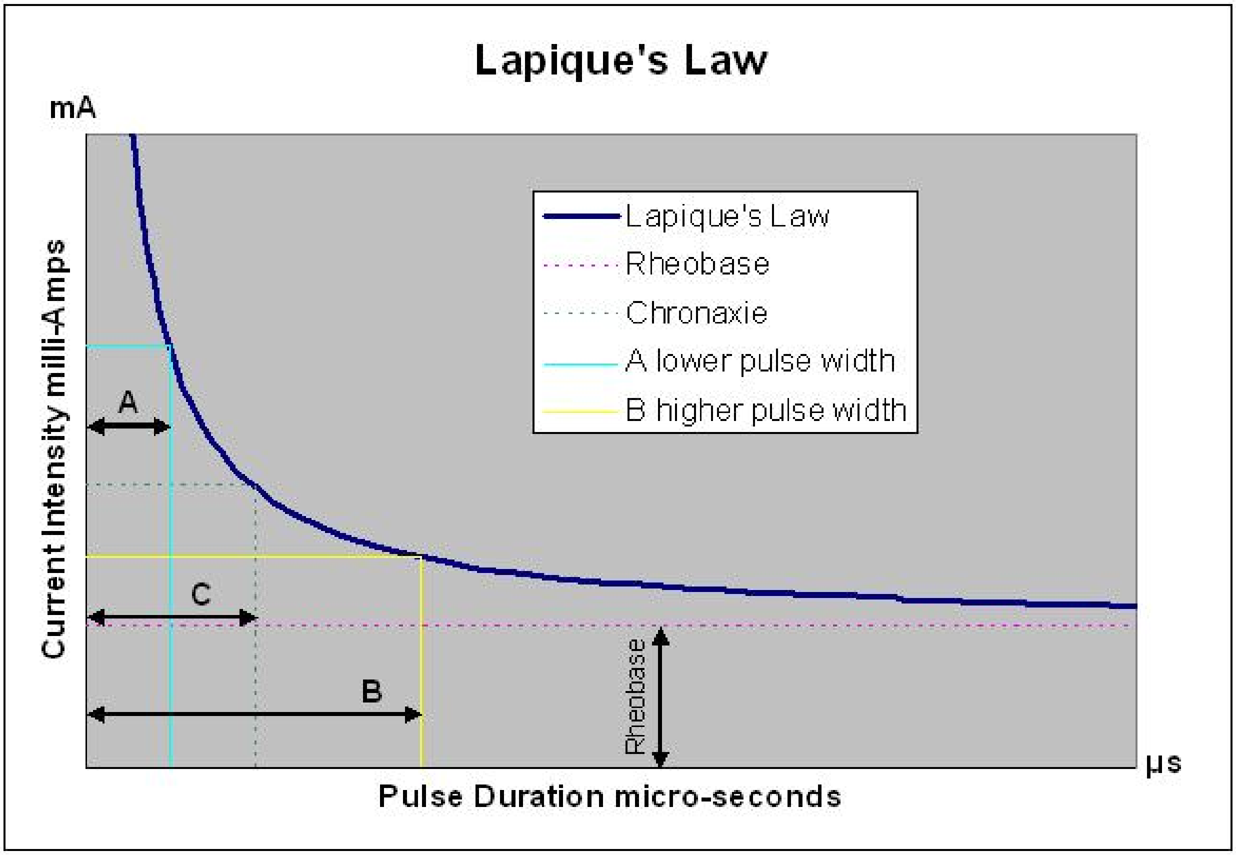
Improvement of Square-Wave Currents over Russian Currents.

Russian currents encounter the sympathies of many practitioners, and many are still using them. The reasons are historical: Russian currents were the first to succeed at professional sport training. Although modern training currents have evolved toward square wave currents, old habits get entrenched and are culturally difficult to change, because they are transmitted from early users to newer users.

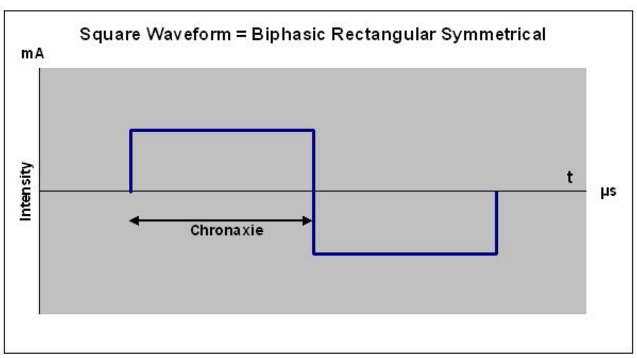
I will explain using the principles of EMS theory presented, why Russian stimulation works, how a square wave compares with it, and why the latter is more performing. I will interchangeably use the term Russian current, Russian program or Russian stimulation for the same protocol introduced by Russian scientist Yakov Kots. I will also use interchangeably use the term rectangular current, square wave, or Biphasic Rectangular Symmetrical waveform for the electrostimulation current we have considered so far.

Back to Lapique's law. We have seen that there is a direct relationship between current intensity and pulse width to excite a nerve cell. This is true for nerve cells innervating muscles, also known as motor neuron (measured in microseconds, that is millionth of a second, and for short µs). Keep in mind that we are exciting a motor neuron and not a muscle fiber. The motor neuron then triggers the muscle fiber in a physiologically-natural way.

With reference to the diagram shown, we can see that if we use a pulse width equal to the chronaxie of the muscle, we strike an intuitively sweet spot in the muscle: the intensity doesn't need to be too high, and we don't need to stimulate the muscle for too long.

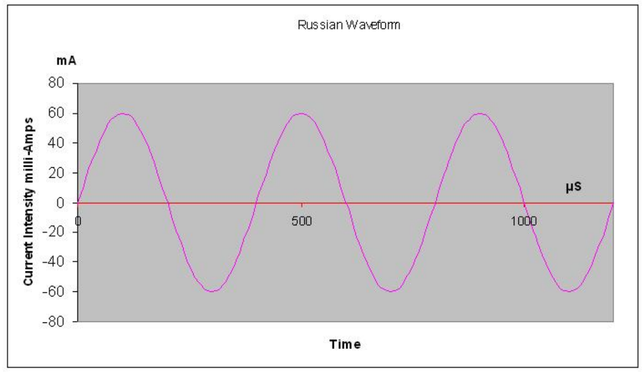


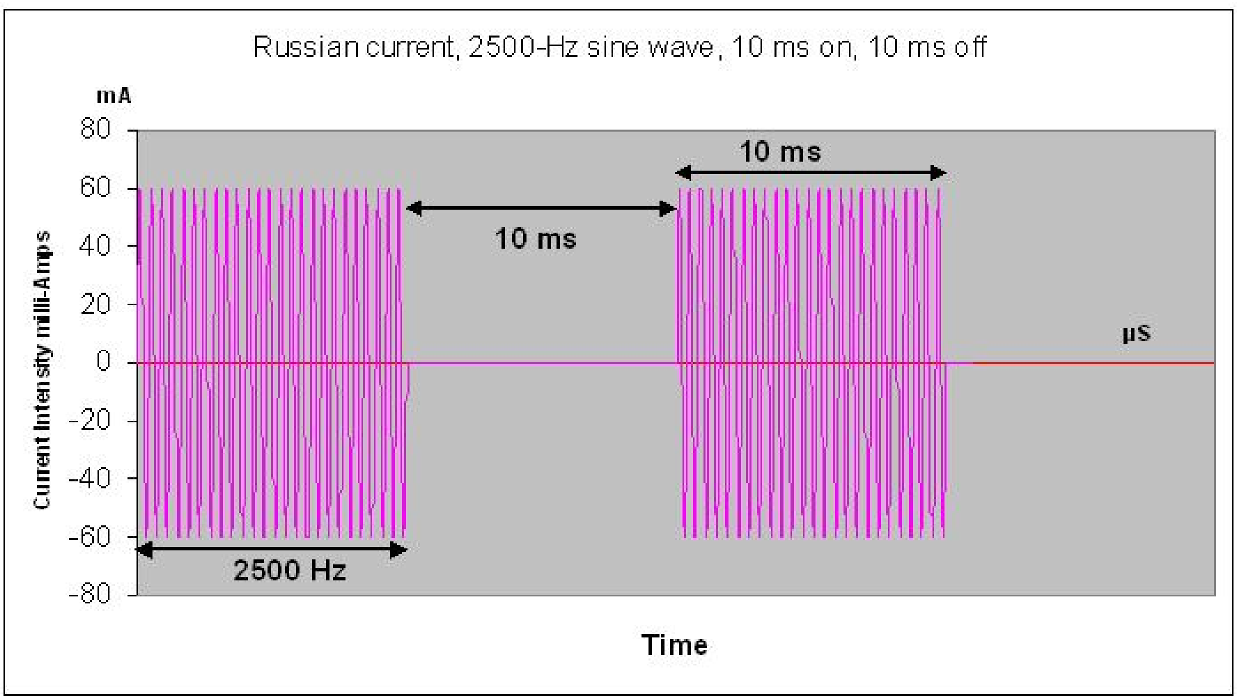
With reference to the alternatives: square wave A excites the motor neuron for a shorter time, but requires percentage wise a much higher intensity; square wave B excites the motor neuron for a longer time, thus requiring lower intensity; the gain in lower intensity though has to be compensated percentage wise by a much longer stimulus which stresses the nerve cell. We are left with curve C which uses pulse width equal to chronaxie, the best compromise in terms of energy expensed to excite the nerve (an in turn the muscle it innervates). (Minimal energy expenditure can be demonstrated with high-school calculus starting from Lapique's law I=Rheobase + Rehobase*Chronaxie/T). We utilize this chronaxie to generate the proper square wave.

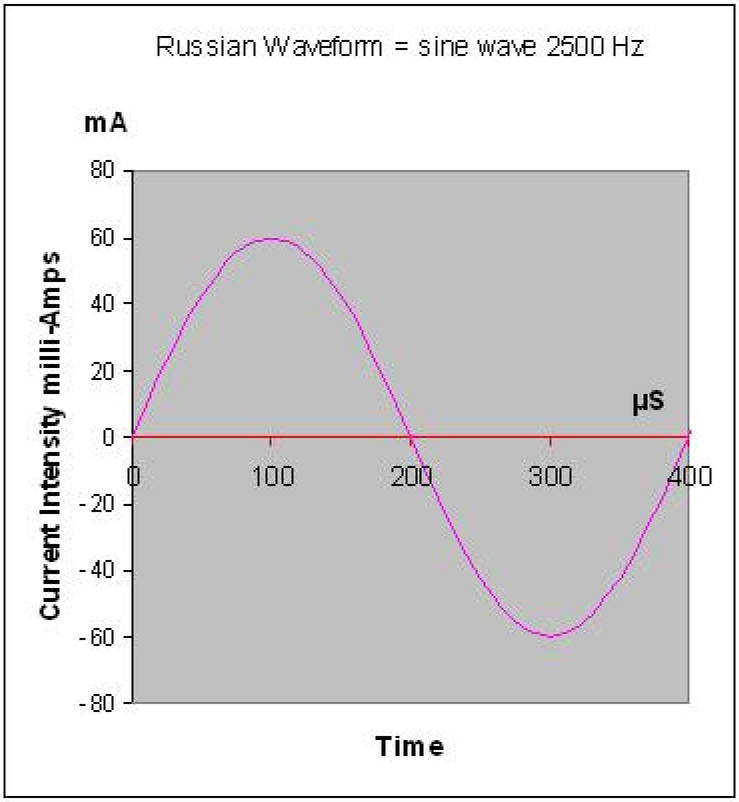


Although Lapique's law dates from the early 20th century, its full implications for training and measurement of parameters involved were not fully understood until much later. Many researchers were therefore experimenting with a wide range of many parameters: different waveforms, different frequencies, different pulse widths, different current intensities, as well as on/off times, duration of the training, repetitions, sessions per week etc. One can understand that to try all the possible combinations, and having to wait a few weeks for each experiment, to measure results, would take too long. Science advances by both understanding of the phenomenon, intuition of possible implications, and trial and error. Then somebody has a better intuition, or hits a lucky attempt. The better results obtained are studied, more light is shed on why it works, and from the new knowledge more experiments are tried to advance even further.

This is what happened to Russian scientist Yakov Kots: guided by profound understanding, and experimenting with various combinations of parameters that made sense to him, in the '60s he started hitting on a combination that produced results. You have to remember than in the 60's solid-state electronic was at the beginning and miniaturization was not available (it was just being invented to put a man on the moon with NASA's Apollo program). It was far simpler for a researcher to generate an electric pulse with readily available electronic tubes rather than to experiment with transistors. Therefore the waveforms that Kots had at his disposal were so called sine-wave pulses as in this picture. Experimenting with various frequencies, he refined his results and consolidated the findings in a training current at 2500 Hz, on for 10 ms (milliseconds) and of for 10 ms.

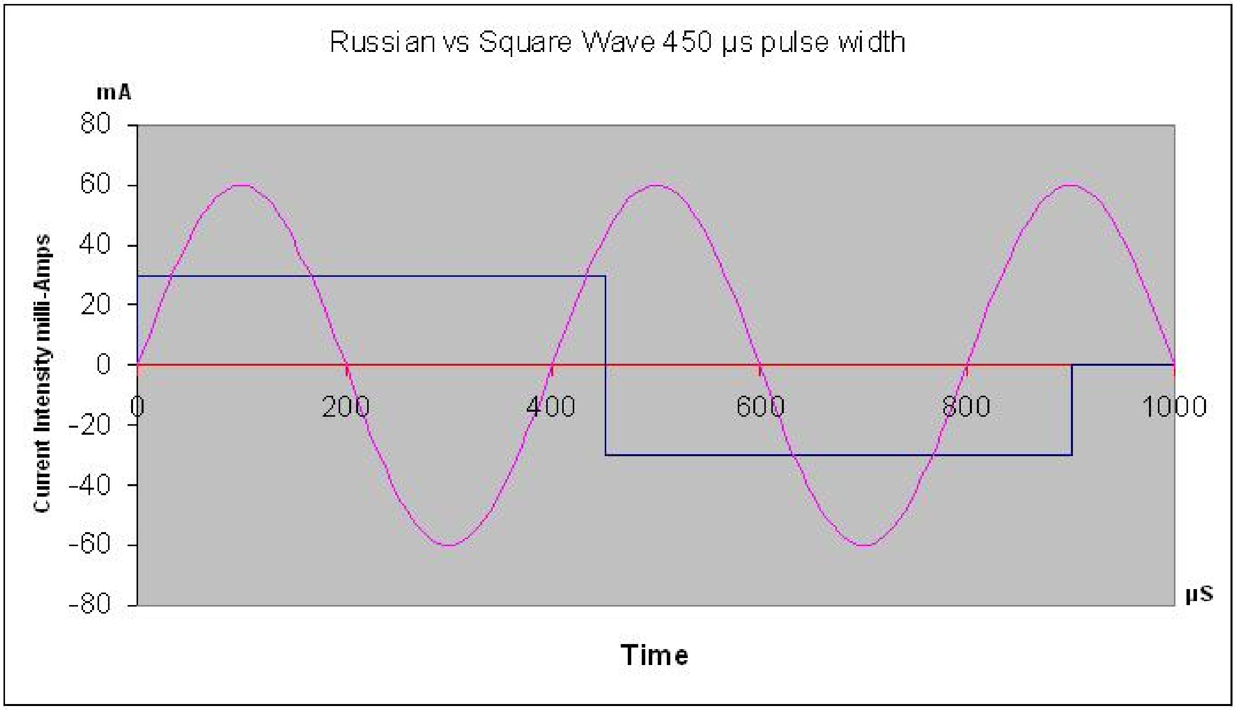






Let's take a look at a single 2500-Hz wave, we obtain the following curve (sine wave). Looking at its shape one can see that 2500 Hz translates into one full wave every 400 µs: 2500 Hz means that the wave repeats itself 2500 times every second, therefore 1/ 2500 = 0.0004 s = 0.4 ms = 400 µs. That also means that the positive half of the sine-wave pulse, which triggers the motor neuron, concludes itself within 200 µs.

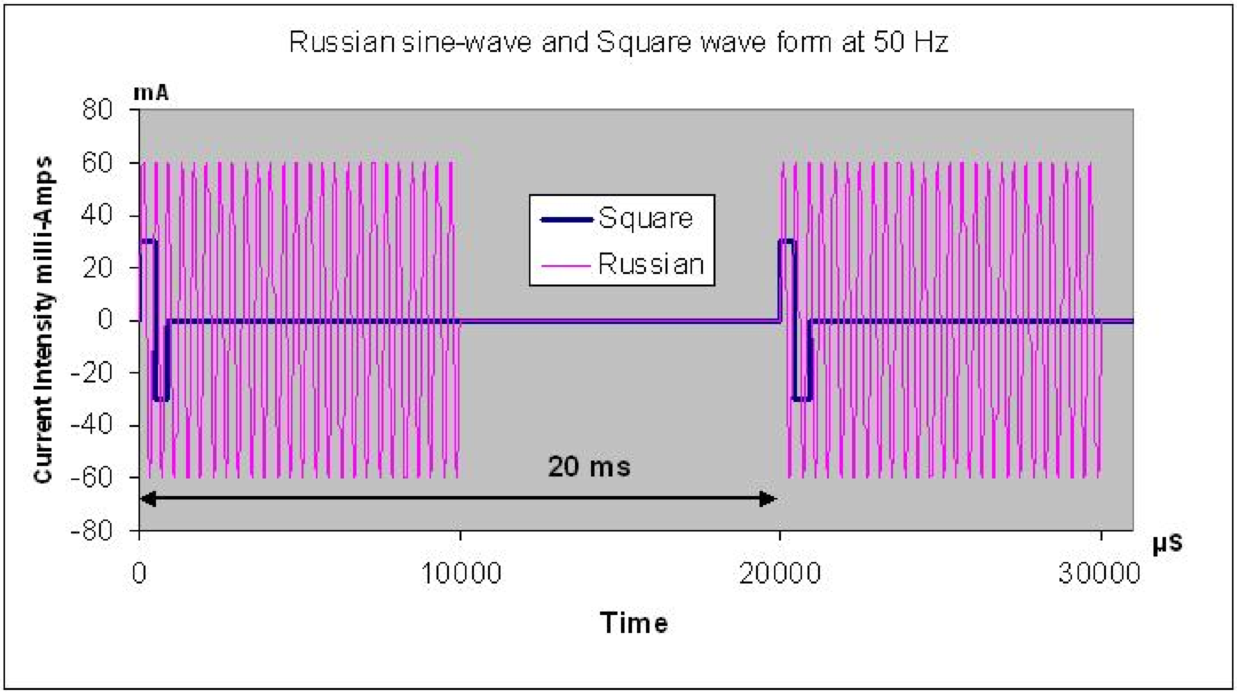
Let's superimpose it on a square wave. The excitation roughly correlates with the area under the curve. If you look at the area enclosed under the Russian wave, you can easily see why to get the same excitation, the peak of the Russian has to be turned to much higher intensity (i.e. more uncomfortable or painful) than a square wave to obtain the same excitation.



In other words a square wave gets more bang for the buck than a sine wave. However, sine wave was the best technology available at the time, and electronic was not sophisticated enough to produce a good square wave.

Another comparison factor is that Russian stimulation is fixed, whereas square wave stimulation is more flexible. We have seen in previous sections explaining the theory of EMS, that the chronaxie of different muscle group may vary between 200 µs and 450 µs. Russian stimulation has always the characteristics of approximating 200 µs pulse width duration. This value is just too low for certain muscle groups like the legs, whereas the pulse width of a square wave can be changed at leisure, adapting it to the muscle group.

The last parameter of Russian current to understand is its on/off time of 10 ms. For Kots, it was presumably easy to interrupt his 2500 Hz sine wave every 10 ms, because in Europe AC current from an outlet is available at 50 Hz, and this was used as the triggering signal to turn it on and off. Thus Kots obtained a train of sine-wave pulses at 50 Hz as shown in the following picture. The sequence of pulses is called a pulse train; you can fit 25 of these sine waves within the first 10 ms of the Russian wave; then there is an interval of another 10 ms during which there is no current, and the whole sequence restarts: all this takes place in 20 ms, which results in the 50 Hz frequency. Thus it is directly comparable to a square wave at 50 Hz and pulse width 200 µs.



But what happens after the first sine wave in the Russian train of pulses excites the motor neuron? There is another physiological phenomenon called refractory time, according to which, once a neuron has been excited, it's impossible to excite it again until some time later. Refractory time lasts a few milliseconds, which renders the next few sine pulses of the Russian pulse train useless. This is one more reason why Russian currents are not as effective: much of the energy injected in the motor neuron goes wasted.

To summarize, Russian currents compared to square wave currents have the following shortcomings:

- Require much higher current intensity, which is much less comfortable;
- Do not offer pulse width flexibility for different muscle groups;
- Do not offer different frequencies for different stimulation goals;
- Waste a lot of unneeded energy in the muscle tissue, triggering several possible issues,
    - skin irritation,
    - tissue heating,
    - shorter battery lifespan.

Appendix 2:
PERIODIZATION - SPECIFIC-SPORTS TRAINING

This section contains suggestions regarding EMS training routines and schdules for specific sports. It will be updated as contributions from professional sport trainers and suggestions from readers become available.

You may be adhering to a set weekly schedule or a varied weekly training schedule. Many different weekly schedules can offer a successful approach to training. The various weekly schedules shown here are meant to suggest approaches that are likely similar to the schedule you choose. Use these examples to illustrate patterns that will successfully combine Globus strength training and active recovery with sport specific training plans. The combination of Globus strength with the multi-paced sport specific workout types aims to fit training sessions into a week while maximizing the amount of recovery between more intense or longer sport specific workouts.

Cyclist's Training Plan Incorporating EMS

by Jim Bruskewitz

Weekly training schedule varies

RPE = (Borg Rating of Perceived Exertion scale and training zone)
FTP = Functional Threshold Power

Power Zone		RPE	%FTP	HR zone % max HR	Description
1	Recovery	6		AR <70%	
1	Recovery	7		AR <70%	very,very light
1	Recovery	8<55%		AR <70%	
2	Extensive endurance	9	56%	OD <75%	very light
2	Extensive endurance	10to		OD <75%	
2	Extensive endurance	11	75%	OD <75%	fairly light

3	Intensive endurance	12	76%	EXT AT 83% - 86%	
3	Intensive endurance	13to		EXT AT 83%-86%	somewhat hard
3	Intensive endurance	14	90%	EXT AT 83% - 86%	
4	Threshold	15	91%	INT AT 88% - 92%	hard
5a	Threshold	16	105%	INT AT 88% - 92%	
5b	Anaerobic endurance	17	106%	VO_2 max >93%	very hard
5b	Anaerobic endurance	18	120%	VO_2 max + >93%	
5c	Power	19>120%		MAX >93%	very, very hard
5c	Power	20		MAX >93%	

Example of one or two times per week Globus strength training regimen

Week 1

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Active Recovery	Power!	Medium Endurance	Lactate Threshold	Active Recovery	Tempo	Extensive endurance
	Globus				Globus	
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 2

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
REST	Sub-lactate threshold	Power!	Active Recovery	Tempo	Tempo	Extensive endurance
		Globus			Globus	
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 3

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
REST	Active Recovery	Sub-lactate threshold	Tempo	Active Recovery	Extensive endurance	Extensive endurance
		Globus				Globus
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 4 **rest week**

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
REST	Active Recovery	Active Recovery	Active Recovery	REST	Tempo	REST
		Globus			Globus	
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 5

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Power!	Lactate Threshold	Active Recovery	Power!	Active Recovery	Extensive endurance	Extensive endurance
	Globus			Globus		
Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 6

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
REST	Tempo	Power!	15min @60-65% FTP	REST	3.5 hours hilly	Active Recovery
		Globus			Globus	
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 7

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
REST	Lactate Threshold	Tempo	Active Recovery	Power!	Extensive endurance	Active Recovery
		Globus			Globus	
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 8

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
REST	Active Recovery	REST	Active Recovery	REST	Tempo	REST
	Globus				Globus	
	Active rec.		Active rec.		Active rec.	

Example of a three Globus training day split. The Globus denotes muscle groups with a primary training emphasis
while the Globus/split denotes muscle groups that are trained with a secondary emphasis.
Most commonly athletes will train for strength using electro muscular stimulation three times per week foregoing the split routine

Week 1

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Active Recovery	Power!	Medium Endurance	Lactate Threshold	Active Recovery	Tempo	Extensive endurance
	Globus		Globus		Globus	
		Globus/split		Globus/split		Globus/ split
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 2

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

REST	Sub-lactate threshold	Power!	Active Recovery	Tempo	Tempo	Extensive endurance
		Globus		Globus		Globus
	Globus/split		Globus/split		Globus/split	
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 3

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
REST	Active Recovery	Sub-lactate threshold	Tempo	Active Recovery	Extensive endurance	Extensive endurance
	Globus		Globus		Globus	
		Globus/split		Globus/split		Globus/ split
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 4 **rest week**

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
REST	Active Recovery	Active Recovery	Active Recovery	REST	Tempo	REST
	Globus		Globus		Globus	
		Globus/split		Globus/split		Globus/ split
	Activ rec.	Activ rec.	Activ rec.	Activ rec.	Activ rec.	Activ rec.

Week 5

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Power!	Lactate Threshold	Active Recovery	Power!	Active Recovery	Extensive endurance	Extensive endurance
	Globus		Globus		Globus	
		Globus/split		Globus/split		Globus/ split
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 6

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
REST	Tempo	Power!	15min @60-65% FTP	REST	3.5 hours hilly	Active Recovery
		Globus		Globus		Globus
	Globus/split		Globus/split		Globus/split	
	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Week 7

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
REST	Lactate Threshold	Tempo	Active Recovery	Power!	Extensive endurance	Active Recovery
		Globus		Globus		Globus
	Globus/split		Globus/split		Globus/split	
	Activ rec.	Activ rec.	Activ rec.	Activ rec.	Activ rec.	Activ rec.

Week 8

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
REST	Active Recovery	REST	Active Recovery	REST	Tempo	REST
	Globus		Globus		Globus	
		Globus/split		Globus/split		Globus/ split
	Activ rec.	Activ rec.	Activ rec.	Activ rec.	Activ rec.	Activ rec.

Suggested periodized strength training plan for the Globus Premium Sport model

Program	Frequency	duration
max strength 1	2 to 3 times weekly	2 to 3 weeks
max strength 2	2 to 3 times weekly	2 to 3 weeks
max strength 3	2 to 3 times weekly	2 weeks
	max strength	6 to-9weeks total

	t r a n s i t i o n w e e k	
resistance strength 1	1 time weekly	
max strength 3	1 to 2 times weekly	1week
Resistance 1	2 to 3 times weekly	2 to 3 weeks
Resistance 2	2 to 3 times weekly	2 to 3 weeks
Resistance 3	2 to 3 times weekly	2 to 3 weeks
	resistance strength	6 to-9weeks total
	t r a n s i t i o n w e e k	
Endurance 1	1 time weekly	
Resistance strength 3	1 to 2 times weekly	1week
Endurance 1	2 to 3 times weekly	4 to 6 weeks
	t r a n s i t i o n w e e k s	
Endurance 1	1 time weekly	
Endurance 2	1 to 2 times weekly	2 to 3 weeks
Endurance 2	1 to 2 times weekly	4 to 6 weeks
	Endurance	10 to 15 weeks total

Example of Run Training Plan Incorporating EMS

by Jim Bruskewitz

Run Training: Weekly training schedule varies -
RPE = (Borg Rating of Perceived Exertion scale and training zone)
FTP = Functional Threshold Power

	RPE	HR zone	% max HR	Description
Recovery	6	AR		
Recovery	7	AR		very,very light
Recovery	8	AR	<75%	
Extensive endurance	9	OD	75%	very light
Extensive endurance	10	OD	to	
Extensive endurance	11	OD	80%	fairly light
Intensive endurance	12	EXT AT	86%	
Intensive endurance	13	EXT AT	to	somewhat hard
Intensive endurance	14	EXT AT	88%	
Threshold	15	INT AT	89%	hard
Threshold	16	INT AT	92%	
Anaerobic endurance	17	VO_2 max	95%	very hard
Anaerobic endurance	18	VO_2 max +	>95%	
Power	19	MAX		very, very hard
Power	20	MAX		

Example of one or two times per week (1st and 2nd session), Globus strength training regimen.
V stands for **Voluntary** or Volitional training, **E** stands for **EMS** training.

	Week 1						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	Power-VO2	Active Recovery	Medium Endurance	Lactate Threshold	Active Recovery	Extensive endurance	Active Recovery
E	Globus			Globus			
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 2

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	Power-VO2	Medium Endurance	REST	Medium Endurance	Active Recovery	Extensive endurance	REST
E	Globus			Globus			
E	Active rec.	Active rec.		Active rec.	Active rec.	Active rec.	

	Week 3						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	Lactate Threshold	Active Recovery	Active Recovery	Medium Endurance	REST	Extensive endurance	REST
E	Globus			Globus			
E	Active rec.	Active rec.	Active rec.	Active rec.		Active rec.	

	Week 4						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	Active Recovery	Power-VO2	REST	Medium Endurance	Active Recovery	Extensive endurance	REST
E		Globus			Globus		
E	Active rec.	Active rec.		Active rec.	Active rec.	Active rec.	

	Week 5						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	Medium Endurance	Active Recovery	Power-VO2	Medium Endurance	REST	Active Recovery	Extensive endurance
E	Globus			Globus			
E	Active rec.	Active rec.	Active rec.	Active rec.		Active rec.	Active rec.

	Week 6						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	REST	Medium Endurance	REST	Medium Endurance	Active Recovery	Extensive endurance	Power-VO2
E		Globus			Globus		
E		Active rec.		Active rec.	Active rec.	Active rec.	Active rec.

	Week 7						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	Medium Endurance	Active Recovery	Lactate Threshold	REST	Active Recovery	Extensive endurance	Extensive endurance
E	Globus			Globus			
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 8						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	Medium Endurance	Power-VO2	Medium Endurance	Lactate Threshold	REST	Extensive endurance	REST
E	Globus			Globus			
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 9						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	Medium Endurance	Active Recovery	Medium Endurance	REST	Lactate Threshold	Active Recovery	Medium Endurance
E	Globus			Globus			
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 10						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	REST	Active Recovery	Extensive endurance	Active Recovery	REST	Active Recovery	Lactate Threshold
E			Globus		Globus		
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 11						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	REST	Active Recovery	Power-VO2	Active Recovery	REST	Medium Endurance	Extensive endurance
E			Globus		Globus		

E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 12						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	REST	Active Recovery	Lactate Threshold	REST	Extensive endurance	Active Recovery	Extensive endurance
E			Globus		Globus		
E		Active rec.	Active rec.		Active rec.	Active rec.	Active rec.

	Week 13						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	REST	Power-VO2	Medium Endurance	REST	Lactate Threshold	Active Recovery	Extensive endurance
E			Globus		Globus		
E		Active rec.	Active rec.		Active rec.	Active rec.	Active rec.

	Week 14						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	REST	Power-VO2	REST	Medium Endurance	Active Recovery	Power-VO2	Extensive endurance
E		Globus		Globus			
E		Active rec.		Active rec.	Active rec.	Active rec.	Active rec.

	Week 15						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	REST	Active Recovery	Power-VO2	REST	Medium Endurance	Active Recovery	Extensive endurance
E			Globus		Globus		
E		Active rec.	Active rec.		Active rec.	Active rec.	Active rec.

	Week 16						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	REST	Power-VO2	Active Recovery	REST	Active Recovery	Power-VO2	Extensive endurance

E		Globus		Globus			
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Example of a three Globus training day split. The Globus denotes muscle groups with a primary training emphasis while the Globus/split denotes muscle groups that are trained with a secondary emphasis. Most commonly athletes will train for strength using electro muscular stimulation three times per week foregoing the split routine.

	Week 1						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	Power-VO2	Active Recovery	Medium Endurance	Lactate Threshold	Active Recovery	Extensive endurance	Active Recovery
E	Globus		Globus		Globus		
E		Globus/split		Globus/split		Globus/split	
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 2						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	Power-VO2	Medium Endurance	REST	Medium Endurance	Active Recovery	Extensive endurance	REST
E	Globus		Globus		Globus		
E		Globus/split		Globus/split		Globus/split	
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	

	Week 3						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	Lactate Threshold	Active Recovery	Active Recovery	Medium Endurance	REST	Extensive endurance	REST
E	Globus		Globus		Globus		
E		Globus/split		Globus/split		Globus/split	
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	

	Week 4						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	Active Recovery	Power-VO2	REST	Medium Endurance	Active Recovery	Extensive endurance	REST

E		Globus		Globus		Globus	
E			Globus/split		Globus/split		Globus/split
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 5						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	Medium Endurance	Active Recovery	Power-VO2	Medium Endurance	REST	Active Recovery	Extensive endurance
E	Globus		Globus		Globus		
E		Globus/split		Globus/split		Globus/split	
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 6						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	REST	Medium Endurance	REST	Medium Endurance	Active Recovery	Extensive endurance	Power-VO2
E		Globus		Globus		Globus	
E			Globus/split		Globus/split		Globus/split
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 7						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	Medium Endurance	Active Recovery	Lactate Threshold	REST	Active Recovery	Extensive endurance	Extensive endurance
E	Globus		Globus		Globus		
E		Globus/split		Globus/split		Globus/split	
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 8						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	Medium Endurance	Power-VO2	Medium Endurance	Lactate Threshold	REST	Extensive endurance	REST
E		Globus		Globus		Globus	
E	Globus/split		Globus/split		Globus/split		

E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	

	Week 9						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	Medium Endurance	Active Recovery	Medium Endurance	REST	Lactate Threshold	Active Recovery	Medium Endurance
E	Globus		Globus		Globus		
E		Globus/split		Globus/split		Globus/split	
E	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 10						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	REST	Active Recovery	Extensive endurance	Active Recovery	REST	Active Recovery	Lactate Threshold
E		Globus		Globus		Globus	
E			Globus/split		Globus/split		Globus/split
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 11						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	REST	Active Recovery	Power-VO2	Active Recovery	REST	Medium Endurance	Extensive endurance
E		Globus		Globus		Globus	
E			Globus/split		Globus/split		Globus/split
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 12						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	REST	Active Recovery	Lactate Threshold	REST	Extensive endurance	Active Recovery	Extensive endurance
E			Globus		Globus		Globus
E		Globus/split		Globus/split		Globus/split	
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 13

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
V	REST	Power-VO2	Medium Endurance	REST	Lactate Threshold	Active Recovery	Extensive endurance
E		Globus		Globus		Globus	
E			Globus/split		Globus/split		Globus/split
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 14						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	REST	Power-VO2	REST	Medium Endurance	Active Recovery	Power-VO2	Extensive endurance
E		Globus		Globus		Globus	
E			Globus/split		Globus/split		Globus/split
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 15						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	REST	Active Recovery	Power-VO2	REST	Medium Endurance	Active Recovery	Extensive endurance
E			Globus		Globus		Globus
E		Globus/split		Globus/split		Globus/split	
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

	Week 16						
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
V	REST	Power-VO2	Active Recovery	REST	Active Recovery	Power-VO2	Extensive endurance
E		Globus		Globus		Globus	
E			Globus/split		Globus/split		Globus/split
E		Active rec.	Active rec.	Active rec.	Active rec.	Active rec.	Active rec.

Suggested periodized strength training plan for the Globus Premium Sport.

Program	Frequency	Duration
maximum strength		**6-9 weeks total**
max strength 1	2 to 3 times weekly	2 to 3 weeks
max strength 2	2 to 3 times weekly	2 to 3 weeks
max strength 3	2 to 3 times weekly	2 to 3 weeks
transition week		
resistance strength 1	1 time weekly	1week
max strength 3	1 to 2 times weekly	
resistance strength		**6 to-9weeks total**
Resistance 1	2 to 3 times weekly	2 to 3 weeks
Resistance 2	2 to 3 times weekly	2 to 3 weeks
Resistance 3	2 to 3 times weekly	2 to 3 weeks
transition week		
Endurance 1	1 time weekly	1week
Resistance strength 3	1 to 2 times weekly	
Endurance		**10 to 15 weeks total**
Endurance 1	2 to 3 times weekly	4 to 6 weeks
Endurance 1	1 time weekly	2 to 3 weeks
Endurance 2	1 to 2 times weekly	
Endurance 2	1 to 2 times weekly	4 to 6 weeks

To be continued ...

Triathlon

Borg RPE (rating of perceived exertion) scale and training zones

Power Zone		RPE	Functional Threshold Power %FTP	HR zone	Description
1	**Recovery**	6		AR	
1	**Recovery**	7		AR	very,very light
1	**Recovery**	8	<55%	AR	
2	**Extensive endurance**	9	56%	OD	very light
2	**Extensive endurance**	10	to	OD	
2	**Extensive endurance**	11	75%	OD	fairly light
3	**Intensive endurance**	12	76%	EXT AT	
3	**Intensive endurance**	13	to	EXT AT	somewhat hard
3	**Intensive endurance**	14	90%	EXT AT	
4	**Threshold**	15	91%	INT AT	hard
5a	**Threshold**	16	105%	INT AT	
5b	**Anaerobic endurance**	17	106%	VO_2 max	very hard
5b	**Anaerobic endurance**	18	120%	VO_2 max +	
5c	Power	19	>120%	**MAX**	very, very hard
5c	Power	20		**MAX**	

Basic one workout/day schedule with one day off per week.

Example of one or two times per week Globus strength training regimen

Note: Voluntary refers to training sessions that are specific to the sport (e.g. bicycling)

EMS refers to electromuscular stimulation training with Globus

More to be added soon.

Appendix 3 - Recruitment

It's important for those who need to deeply understand the mechanisms of EMS, i.e. coaches who need to customize a training program to target specific goals, to highlight a very important and misunderstood feature of EMS: recruitment.

Voluntary muscle activation activates muscle fibers in a very specific order, from smallest Slow-Twitch (ST) fibers, to largest Fast-Twitch (FT) fibers. Early research seemed to point out that this was reversed in EMS exercise: FT fibers were activated more easily than ST fibers. However, very recent research has demonstrates that EMS does not reverse the natural recruitment order, and it rather activates fibers indiscriminately, and onlywhich based on position relative to the electrode pads.

Voluntary recruitment order, as quoted from Zatsiorsky's & Kraemer's - Science and Practice of Strength Training; Human Kinetics, Champaign, IL:

- The orderly recruitment of MUs (Motor Units) is controlled by the size of motorneurons (Hennemann's size principle): Small motorneurons are recruited first, and requirements for higher forces are met by the activation of the large motoneurones that innerfate fast MUs.

Early studies that experimented on single fibers in a lab setting, found that FT larger fibers were easier to excite: see Gorman and Mortimer, The effect of stimulus parameters on the recruitment characteristics of direct nerve stimulation. However, those studies were performed on anesthetized animals, attaching electrodes directly to muscle fibers by cutting through the skin. Since this were the only available findings at the time, the literature on EMS started using this as a self fulfilling benchmark, which gained acceptance.

Clinical Electrophysiology by Robinson and Snyder-Mackler, a sacred reference textbook on EMS writes:

- For isolated motor nerve situation, the pattern of recruitment tends to be in order from largest-diameter to smallest-diameter fiber…
  Stimulated contraction occurs by an activation of type FF (fast-twitch, fatigable) motor units first, followed by type FR (fast-twitch, fatigue-resistant) and ending with type S (slow-twitch, fatigue-resistant) units. **This reversed order of motor unit recruitment in electrically induced contractions is not stable** as that for voluntary contraction. For example, if the axons of fatigue-resistant units are located significantly closer to the stimulating electrodes than axons for type FF units, these units may be recruited before the fatigable type.

It's noticeable in the above quote that some exception arise to the, until then, complete belief in the reversed-recruitment-order principle. More recent research has actually confirmed that **there isn't actually an order, but rather an indiscriminate recruitment**: the peer-reviewed article, Recruitment Patterns in Human Skeletal Muscle During Electrical Stimulation , by Gregory and Bickel, says:

- Previous studies as well as some commonly used textbooks, presume the reversal of recruitment pattern based on studies of lower mammals. However, factors that affect current flow, and therefore muscle activation in vivo (ie, skin impedance, subcutaneous fat, peripheral nerve orientation, and so on), result in a different physiological environment relative to the animal studies. Thus, although the neurophysiological principles commonly used to support a reversal of recruitment order are based on well designed studies, these principles do not strictly apply during typical EMS applications to humans.

Jubeau et al. verified this hypothesis in the peer-reviewed published research, Random Motor Unit Activation by Electrostimulation , concluding:

- The present findings confirm the suggestions made by Gregory and Bickel, that MU recruitment pattern during NMES is random and nonselective. Over-the-muscle electrostimulation would neither result in motor unit recruitment according to Henneman's size principle nor would it result in a reversal in voluntary recruitment order. During electrostimulation, muscle fibres are activated without obvious sequencing related to fiber type.

Understanding recruitment correctly is very important. The consequence is enormous: recruitment percentage is dictated by the depth of the electric field (which increases with increasing current intensity). ST and FT fibers are normally mixed in a muscle bundle, i.e. equally distant from the pads. Therefore stimulation frequency becomes the most important factor in deciding what type of work we are going to do with EMS training.

BIBLIOGRAPHY

- Vrbova, Hudlicka, Schaefer-Centofanti - *Application of Muscle/Nerve Stimulation in Health and Disease* - Springer 2008
- Fox, E., Bowers, R., & Foss, M. - *The physiological basis for exercise and sport. -* (1993) Madison, WI: Brown & Benchmark.
- Ganong W.F - *Review of Medical Physiology* - 1979 Lange Medical Publications
- Harre D. - *Principles of Sports Training. -* (1982) Sportverlag, Berlin
- Hatfield, F.C. - *Bodybuilding a Scientific Approach* - Contemporary, 1984.
- Clayton, E. - *Clayton's electrotherapy* - W B Saunders Co
- Kubiak, RJ - *Changes in quadriceps femoris muscle strength using isometric exercise versus electrical stimulation* - J. Orthop. Sports Phys. Therapy – 8:537-541 1987
- Whitman KM, Johnston RM - Muscle strength using isometric exercise versus electrical stimulation - Phis. Ther. 63: 494-499 1983
- Laughman RK, Youdas JW, et al. - Strength changes in the normal quadriceps femoris muscle as a result of electrical stimulation – Phys.Ther. 4/1983.
- Mc Miken DF Todd-Smith M., Thompson C.,- Strengthening of human quadriceps femoris by cutaneus electrostimulation – Scand.J. Rehabil.Med. 15:25-28 1983
- Nuhr et al., *Functional and biochemical properties of chronically stimulated human skeletal muscle*, 2003 European Journal of Applied Physiology.
- Maffiuletti et al., *Neuromuscular Adaptations to Electrostimulation Resistance Training,* 2006 American Journal of Physical Medicine & Rehabilitation.

GLOSSARY

- Actin A filament-like protein that paired to Myosin generates muscular movement.
- Aerobic generating muscular energy with contribution of oxygen
- Agonist a muscle that contracts while another relaxes
- Anaerobic generating muscular energy without contribution of oxygen
- Antagonist a muscle that opposes the action of another
- Biphasic symmetrical rectangular Waveform: the shape of an electric impulse having two identical phases, one positive the other negative, and rectangular shape.
- Chronaxie: the minimum impulse duration to excite a muscle, when using a current intensity double the rheobase.
- CNS (Central Nervous System): part of the nervous system consisting of the brain and of the spinal cord.
- Concentric muscular contractions during which the muscle shortens.
- Eccentric muscular contractions during which the muscle elongates.
- Electrostimulation :stimulation of a body part with an electric current.
- Genotype group of organisms sharing a specific genetic constitution
- Hertz abbreviation Hz, number of times per second that an electric impulse is repeated
- Hypertrophy enlargement of a muscle well above the average range
- Isometric contraction or form of exercise in which the muscle doesn't change length.
- mA abbreviation for milli-Ampère, unit of current intensity used in EMS.
- Myosin A filament-like protein with mobile heads that paired to Actin generates muscular movement.
- Motor Neuron a neuron that transmit movement commands to and innervating a muscle fiber.
- Muscle Fiber muscle cell
- Muscle Fiber Types: I, Iia, IIx, Iix main types of muscle fiber which differ mainly in the mechanism they use to produce muscular energy.
- Neuromuscular Plate the main point where nervous fibers coming from the CNS innervate the muscle.
- Neurotransmitters a chemical substance transmitting nerve impulses across a synapse
- Phenotype the constitution of an organism as determined by the interaction of its genetic constitution and the environment.
- Plyometrics type of training designed to produce fast, powerful movements, and improve the functions of the nervous system, generally for the purpose of improving performance in a specific sport
- Rectangular Waveform the shape of an electric impulse of rectangular shape, i.e. increasing intensity instantaneously, maintaining the intensity for a certain duration, and then decreasing intensity instantaneously.
- Rheobase the minimum value of current intensity necessary to trigger a muscular twitch (when the current is maintained for a long time, but practically a few milliseconds will suffice).
- Sarcomere the smallest contractile unit within a myofibril

- Synapse the junction between two neurons (axon-to-dendrite) or between a neuron and a muscle.