OVERVIEW OF PRINCIPLES IN NEUROMUSCULAR STIMULATION BY ELECTROMAGNETIC FIELDS: CURRENT STATE ANALYSIS WITH EMPHASIS ON MAGNETIC SIMULATION TECHNOLOGY IN PHYSIOTHERAPY AND AESTHETICS

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ABSTRACT

The application of electric currents on human body has been intensively studied in the past and today, its neurostimulative effects are well understood. However, the utilization of induced currents by rapidly changing magnetic fields has recently raised an attention in the clinical practice as a complementary and possibly more advanced modality for muscle stimulation. The overall goal of this study is to review the essential technical parameters and principles of electromagnetic stimulation devices while focusing on the interaction of the electromagnetic fields with excitable biological tissues. The study discusses key differences between the electrical and magnetic stimulation and aims to summarize the current knowledge about magnetic stimulation of muscle tissue in physiotherapy and consequently its pioneering use in aesthetic.

1 INTRODUCTION

1.1 Anatomy of striated muscle

Striated skeletal muscle is one of three major muscle types in the body (besides the cardiac and smooth muscle) and it is under voluntary control by the somatic nervous system. The basic building units of all striated muscles are various types of muscle fibers, composed of cylindrical elongated cells that provide muscles with electrical and contractile properties. From the structural perspective, skeletal muscles are composed of type IIB (fast-twitch, fatigable), type IIA (fast-twitch, fatigue-resistant), and type I fibers (slow-twitch, resistant to fatigue). The actual representation of each fiber type in muscle tissue, as well as, the overall muscle fiber mix varies among different muscle groups due to genetic and phenotypic expression, physical conditioning and a number of other factors. Muscle fibers are activated by a stimulus in the form of action potential conducted by nerve fibers – motor neurons. Each motor neuron innervates a limited group of fibers together referred to as a motor unit. One motor unit may encompass as many as 1000 fibers. As the action potentials propagate along motor nerves to the muscles, the fibers become depolarized and contract. The greater the number of fibers is recruited, the greater the force is produced[1].

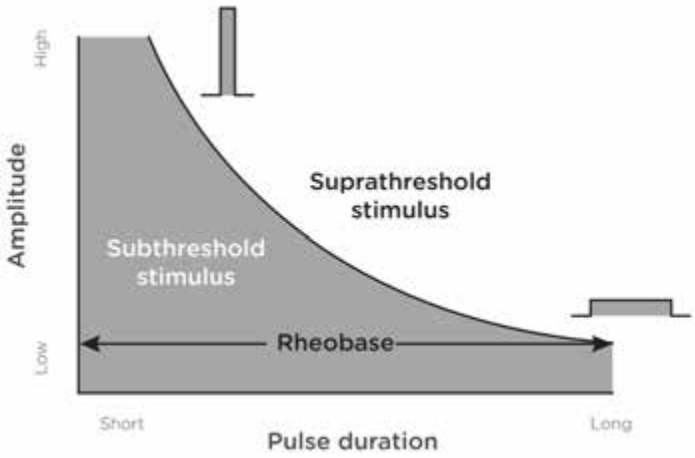

Figure 1. The strength-duration curve of excitable tissue. The area under the curve corresponds to the subthreshold stimulus. When the stimulus reaches sufficient pulse duration and amplitude, an action potential is induced[1].

1.2 External stimulation of neuromuscular tissue

Application of electric fields within the human body can induce action potentials in the nervous and muscle tissues. Such a stimulus is essentially indistinguishable from those evoked by the central nervous system

(CNS). Therefore there has been an increasing focus on non-invasive neuromuscular stimulation over these last decades, especially for rehabilitation[2], re-education[3], and strengthening[4]. Today, two popular modalities are used to elicit a response of excitable neural tissue, while bypassing the brain activity – electromyostimulation (EMS) and peripheral magnetic stimulation (MS). Historically, EMS was introduced for clinical applications much earlier than MS, resulting in its extensive usage and standardization of treatment protocols in rehabilitation. Contrarily the use of MS for peripheral stimulation is a relatively novel approach. It was first documented by Kolin et al. roughly half a century ago[5,6] in an animal model, and the first report of developing a magnetic stimulator for human patients was reported 1982[7].

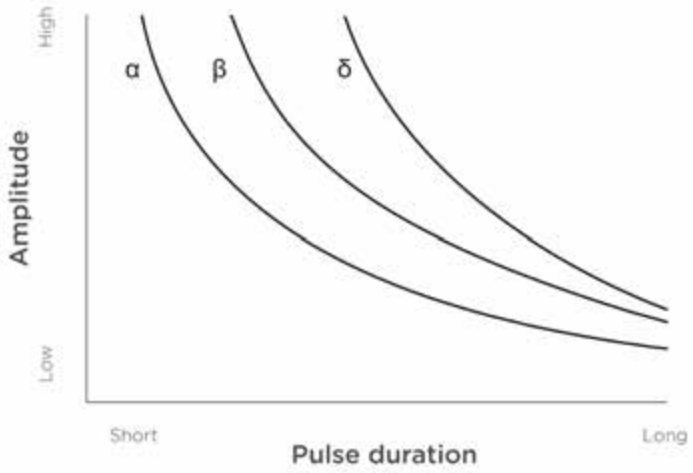

Figure 2. Strength duration curve for different types of peripheral nerve fibers (α = contraction, β = sensory, δ = pain receptors)[1].

The mechanism of stimulation at the neural level is essentially identical for both technologies. In general, the current passes across a nerve membrane into its axon and results in depolarization, which is required to trigger the opening of voltage-gated sodium and potassium ion channels. The action potential is initiated in response to a threshold and suprathreshold stimulus[1], and it is further propagated by the physiological mechanisms of nerve conduction, evoking a contraction of muscle fibers when reaching the neuromuscular junction[1,7].

The transmembrane stimulus must have sufficient amplitude (strength), as well as duration to overcome the resting membrane potential trigger depolarization and then evoke an action potential. The relation between the time and the strength of a stimulus is generally expressed by the strength-duration (S-D) curve. This curve shows that excitable tissue may be stimulated either by short but intense pulses or by longer pulses of at least minimum amplitude referred to as rheobase[1] (see Fig. 1).

The excitable neuromuscular tissues, including peripheral nerves and muscles, are stimulated during an application of sufficient stimulus. Peripheral nerves contain different fibers of various diameter and internal resistance. Fibers with the largest diameter and the lowest internal resistance are depolarized predominantly. This means that A_{α} motor neurons which are directly responsible for the initiation of muscle contractions tend to be activated first[1] (see Fig. 2).

1.3 EMS

EMS applies currents to the human body directly through attachable electrodes. The electric charge carried by electrons translates into an ion flow at the electrode-tissue surface. Unfortunately, only a fraction of these ions flow into axons of nerve fibers, and in order to reach satisfactory muscle contraction, the intensity of stimuli must often be enhanced.

Figure 3. Example of an adverse event caused by the uncontrolled heating effects stemming from high current densities beneath the stimulation electrodes. The skin suffered severe burns in areas which were in direct contact with the electrodes.

However, increasing the intensity of the electrical current may cause localized spots with high current densities under the electrodes resulting into undesirable side effects such as severe cutaneous erythema, burns (see Fig. 3), and activation of cutaneous nociceptors (sensation of pain) or sensory nerves, which makes it impossible to achieve maximal muscle activation[7–9].

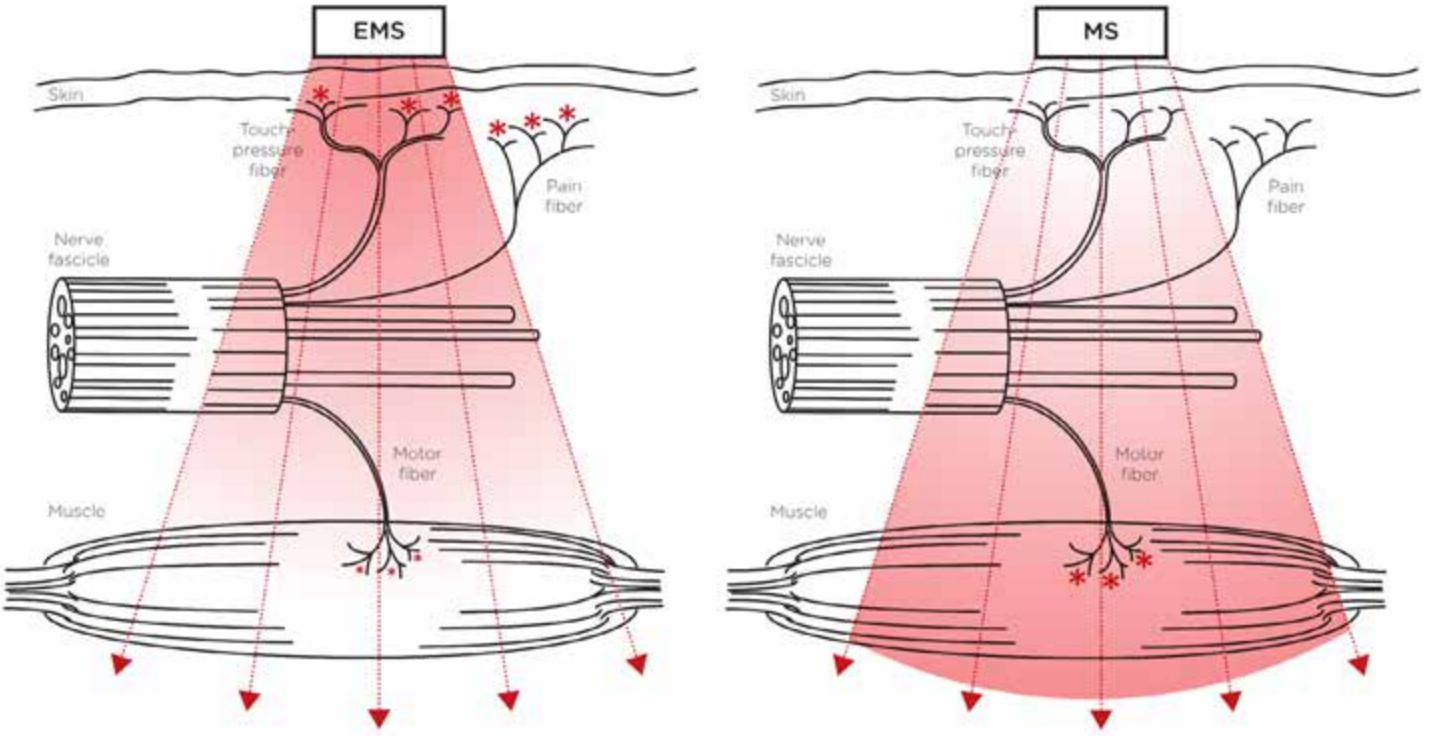

Figure 4. Differences in nervous tissue excitation (red asterisks) depending on the type of stimulator used. The pain and sensory fibers are located closer to the surface, which limits the use of EMS 1. The dotted lines schematically show the direction of electromagnetic field penetration, and red hatching depicts the intensity of EMS/MS generated fields. As shown, MS more selectively affects the excitable neuromuscular tissue and allows greater depth of stimulation.

1.4 Peripheral Magnetic Stimulation (MS)

MS achieves muscle stimulation differently. The muscles are stimulated using a pulsed magnetic field. A time-varying electric currents flow through a stimulation coil while generating a high intensity pulsed magnetic field[7]. As described by Faraday in 1832[10], pulsed magnetic fields induce electric currents in conductive volume (for instance biological tissues) depending on the electrical conductivity of that volume. Thus, as the pulses of a magnetic field pass through the body, the electrical current is predominantly generated in highly conductive tissues (nerves, muscles) and the effect is proportional to their conductivity levels. Due to this principle the magnetic field provides some fortunate advantages.

1.5 Differences between EMS and MS in neuromuscular tissue activation

The main differences between electric and magnetic stimulation are the selectivity of MS and its effective delivery of electromagnetic fields into targeted tissues. First, MS produces a stimulus at deeper levels, since the magnetic field can pass through biological tissues without attenuation of energy. Second, the strength of an induced electric field decreases much less rapidly with distance when compared to the fields produced by surface electrodes[7]. More importantly, there is minimal risk of a painful sensation since an insignificant portion of the currents flow through the skin surface, so activation of nociceptors, sensory nerves and the risk of cutaneous burns is avoided[8,9] (see Fig. 4). For these reasons, MS is currently recognized as the ideal solution in clinical use[8,11].

Recently many different names have emerged to promote magnetic stimulation technology such as HIFEM, rPMS, HIMMS, MMS, HI-EMT, and many others. While HIFEM is developed explicitly for use in aesthetics, many others are innovative or trade names for physiotherapy devices. Even though these technologies are based on the same basic principles of muscle stimulation they often claim to provide superior outcomes compared to competing devices. The true clinical efficiency of any magnetic stimulation technology depends on various parameters such as magnetic field strength, pulse pattern, frequency, the shape of the magnetic field, and the ability to sustain these parameters for a sufficient duration of time. These parameters depend on the level of technical sophistication of the technology.

2 PARAMETERS OF MAGNETIC STIMULATION

Although somewhat limited by the lack of data regarding the exact MS settings needed to stimulate muscle for different devices, we do understand that different parameters cause different preferential activation. When contraction is induced, its performance can be modulated by the proper configuration of various parameters including duty cycle, intensity of stimulus, total number of stimuli, frequency, time of therapy, pulse patterns and others.

2.1 Intensity

The recruitment of motor neurons and activation of muscle fibers is controlled by the intensity of electromagnetic fields. This intensity is defined by magnetic induction and magnetic flux, which are influenced by the characteristics of the current pulse applied to the coil. The distribution of the magnetic field also highly depends on the geometry of the stimulation coil itself.

2.1.1 Magnetic induction

MS intensity is often expressed in Tesla (T), the derived unit of magnetic induction. The absolute strength of the magnetic field alone does not indicate the efficacy of muscle stimulation. For instance, there are conventional MRI systems in use which generate homogenous magnetic fields of intensities 1.5 T and more (some experimental applications even achieved fields of up to 12 T[14–16]) while no stimulation of muscle is triggered. To induce action potential and thus initiate muscle contractions, it is essential to create a time-varying magnetic field which generates the current in a conductive volume according to the law of electromagnetic induction[10].

2.1.2 Stimulation pulse

To produce muscle contraction in an innervated muscle, the pulse duration should be optimally between 150-350 μs to stimulate the motor nerves[12]. Magnetic stimulators are inherently unable to produce monophasic pulses; therefore, the induced electric field is biphasic/sinusoidal and proportional to the rate of change of the magnetic field[7]. According to patient preferences, biphasic stimulation tends to be more comfortable[13].

2.1.3 Magnetic flux

The total amount of the magnetic field (T), which passes through a given area (m^2) is called the magnetic flux and is measured in Webers (Wb or T/m^2). Magnetic flux is a quantity which can directly explain the relationship between a magnetic and electric field, as the change of the magnetic flux over time generates electric currents. When a higher magnetic flux flows through the tissue or when it is changing more rapidly, a stronger electric field is generated. Therefore, it is not only the intensity of the magnetic field but also the length of the stimulation pulse passing through the coil that determines the magnitude of generated current and tissue response (e.g., the strength of muscle contraction).

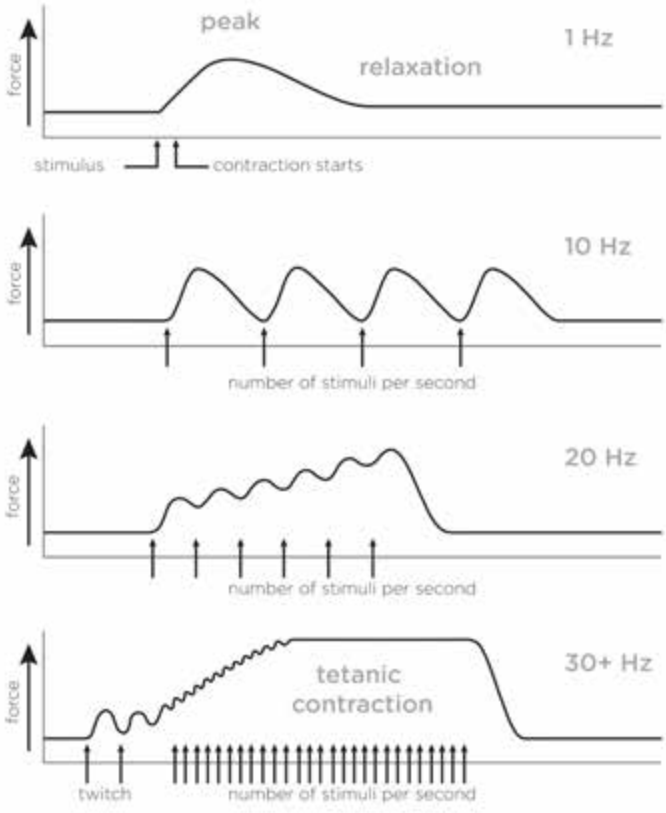

Figure 5: The muscle contractile response according to the frequency of the applied stimulus. A frequency of more than 30 Hz is needed to induce sustained, complete and rigid muscle contractions may be referred to as tetanic.

2.1.4 Coil design

The strength and shape of a magnetic field may also be influenced by the design of the electromagnetic coil while the induced electric field changes with its geometry[17,18]. The design of the coil and winding architecture plays an essential role in its ability to achieve sufficient flux of the magnetic field in the tissue, and ensuring the effective spot size is large enough to depolarize all the excitable structures in full. The shape of the coil logically influences the area

through which the magnetic flux is passing, and thus limits the extent of the induced electric field[30].

2.2 Frequency

Pulse repetition frequency is a major efficiency parameter of MS stimulation, as it determines the type of tissue response and directly affects the strength of muscle contractions. Each separate pulse may induce muscle contraction referred to as a twitch. As the frequency of muscle activation increases, the force produced by the muscle rises as well. With the increased frequency of pulses, the twitch-like contractions will occur closer together, eventually summating to produce a smooth complete and maximal contraction. Maximum fused rigid contractions are better indicators of muscle's contractile capabilities than twitch-like contractions often induced by nerves. To achieve a rigid contraction, rapid delivery of the stimuli is required – at least 30-40 stimuli per second (equivalent to a frequency of 30-40 Hz, see Figure 5). Further increase in frequency is not as beneficial for the muscle due to its rapid fatigue[1,12].

2.3 Pulse patterns

Individual pulses are merged into the waveforms referred to as trains. The waveforms differ in shape, and overall duration called duty cycle, which defines a rest-pause (On/Off) duration of stimulation. Both of these parameters - shape and duty cycle - significantly affect the performance of muscle contraction.

2.3.1 Shape of the pulse train

The train of stimuli may follow either the shape of a rectangle or a trapezoid with a gradual ramp up and ramp down time. During the trapezoidal pattern, the electrical current at the coil gradually builds up to the desired level, holds there for the programmed time and then slowly dissipates. The biggest advantage of a trapezoidal pulse train is that they mimic the natural course of muscle contraction by the gradual recruitment of particular motor units and then gradually returning back to the resting position[12,20,21]. This also makes the stimulation comfortable and much easier to tolerate. It also allows patients to achieve stronger muscular contractions (see Fig. 6). When rectangularly shaped pulse trains are applied, patients are not able to tolerate sudden high intensities of stimulation[22]. If depolarization and consequent muscle contraction follow a sudden excitation caused by rectangular pulses of high intensity, it can evoke an uncomfortable shock sensation. It has also been documented that stimulators which are capable of ramping the pulse train maximize the neuromuscular benefits of the therapy and reduce risks of stressing the tissue[12,21]. Overall, the perception of stimulation intensity might be misleading as slightly uncomfortable contractions may not be directly linked with higher therapeutic efficacy. Instead, it might be a sign of an aggressively set up train of pulses of rectangular shape. It is therefore recommended that when high levels of magnetic field flux are applied to tissue, such types of pulse trains should be avoided.

2.3.2 Length of the pulse train

The time of each pulse train may vary significantly. Shorter pulses can more likely be of subthreshold nature, i.e., they do not necessarily trigger muscle contractions, or the contractions are very short. Contrary to that, longer pulses of several seconds or more can mimic voluntary resistance training. Besides, longer pulses generally require more energy from the body.

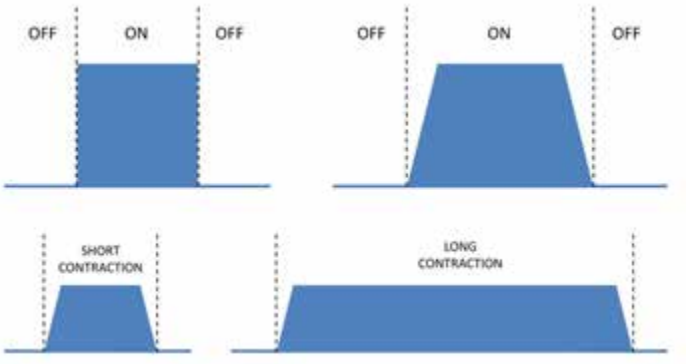

Figure 6: Example of the stimulation waveforms. The rectangular pulse train on the left, trapezoidal on the right. The endurance of contraction increases with the duration of the applied pulse train.

The generation of longer pulses may become challenging based on the apparatus used to induce electromagnetic fields. In general, former technologies are not able to continuously generate electromagnetic pulses of longer durations due to issues with cooling of the heated coil[7,17].

2.3.3 Duty cycle

Muscles must be allowed time to relax during the treatment, as the application of uninterrupted pulse trains would rapidly induce muscle fatigue. The optimal ratio of on and off periods for intermittent protocol differs according to the application of MS while ranging from 1:1 (50% duty cycle) to 1:10[11,19].

2.4 Total effective time

The overall duration of stimulation and the number of stimuli is highly variable across the literature and depends on the application of MS. Longer treatment procedures may have less effective time due to more extended pause period between individual trains of pulses. From the patient's perspective, the ideal technology should offer the right amount of stimulation (depending on the treated indication etc.) in the shortest possible treatment time. This again poses high requirements for the stimulation technology[11,23].

3 USE IN PHYSIOTHERAPY

3.1 Applications

MS of muscle tissue has been used intensively for a wide range of applications in physiotherapy and is recognized as a standard of physical therapy modality. It has been found that repetitive trains of stimuli can be used to improve motor functions and to reduce pain, which is affecting the neuromuscular system[11,24]. MS is also often used as a possible option for rehabilitation in conjunction with conventional muscle training or reconstructive surgical procedures to improve achieved results as it may speed up muscle healing[8,25]. Furthermore, MS might be used to reduce muscle degradation or to increase blood circulation locally[26].

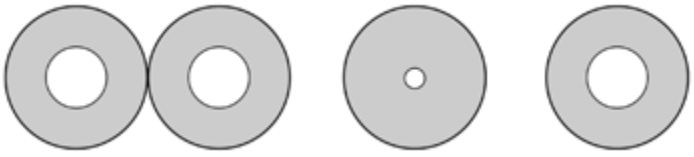

Figure 7: Schematic illustration of the stimulation coils. The Fof8 coil (primarily used for transcranial MS) on the left, round coil with a small-sized internal diameter generating concentrated field in the middle and round coil with big internal diameter for stimulation of large muscle areas on the right.

The applications of MS in physiotherapy usually require a highly selective stimulation, with electromagnetic coils that are specifically designed to concentrate magnetic energy to a small spot size. Predominantly round coils with small-sized internal diameters or occasionally figure-of-eight (Fof8) symmetrical coils are used for neuromuscular stimulation[11,30]. Due to its geometry, a magnetic field of Fof8 coil has the highest intensity right at the applicator's center. In case of a round coil, the maximal strength of magnetic field occurs around the edges of the inner circle. The bigger the internal diameter is, the broader is the distribution of the field (see Fig. 7).

3.2 Mechanism of action

It is assumed that the mechanism responsible for the restoration of muscle functions after MS might be the neuromodulation of cortical networks. Repeated magnetic stimulation of the muscle can directly activate type I and type II afferent nerve fibers by creating rhythmic contraction and relaxation-like vibration[27]. It is thought that properly administered physiotherapy can increase motor cortical excitability by facilitating and reorganization of CNS through the activation of the afferent sensory pathway and eventually improving the strength and performance of treated muscle[28]. In simple terms, this means that the effects of MS in physical therapy are primarily based on affecting the nervous system and improving or restoring its qualities and pathways. However, the functional impact of MS is hard to summarize, since it is often combined with other modalities, and treatment options and the outcomes are assessed under different parameters of stimulation.

3.3 Methodological limitations

Physiotherapy magnetic stimulators are designed with very specific functions in mind and face certain constraints which can limit their range of usage. First, there are limited standardized protocols for MS treatments, forcing therapists to adjust the settings of the stimulator according to their specific needs and hypotheses. From the literature[11], various applications and settings of MS therapy can be found, as an example, the applied penetration depth and intensities varied between deeper (muscle regeneration) and more superficial indications (anything in proximity to bones and spine)[24,29]. Modulation of intensity may also relate to the so-called movement threshold, meaning the lowest intensity of MS stimulus, which is able to induce a contraction. Depending on the type of therapeutic application, the applied stimulus is either sub-threshold or more frequently supra-threshold (Fig. 1) while the intensity of stimulation is defined as a percentage of the movement threshold[11]. Physical therapy with MS usually involves pulses delivered at lower repetition rate and intensities resulting in less than complete and rigid contractions[23,24].

3.4 Technical limitations

Besides the lack of methodological uniformity, certain technical disadvantages are also present when using physiotherapy devices at their technical limits. The thermal performance of the stimulation coil becomes a severe issue when higher

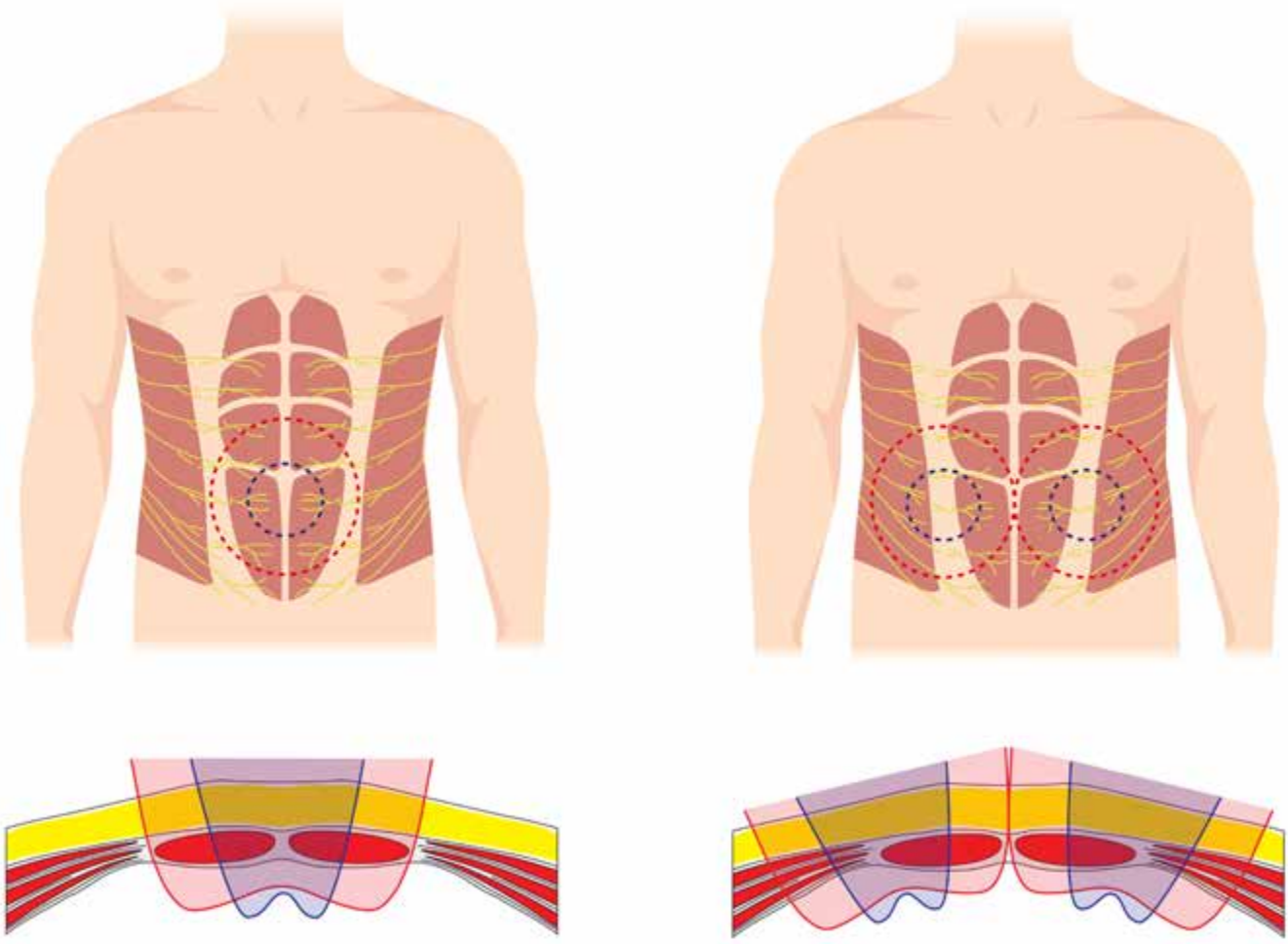

Figure 8. Illustration of a spot size covering rectus abdominis on the tighter and thicker patient when using a small spot size (blue line) and a more broadly distributed magnetic field (red line). Front view on the top, the cross-section view on the bottom. The hatching shows the hypothetical area of activated nervous/muscle tissue.

intensities and repetition rates of pulses are sustained for longer periods than intended. This especially holds true in cases where higher intensities of up to 1-1.5 T are used. It is known that a certain portion of the energy is not delivered to the patient, but creates heat within the coil itself. In order to comply with safety standards defining temperature limits of applied parts of a medical device that are in direct contact with patients (e.g. IEC 60601-1:2015+AMD1:2012), the time of therapy may be limited. Also, the number of pulses plays a role, and in that case, it is often reduced to only several tens or hundreds, which leads to suboptimal response by the muscle being treated.

In conclusion, to allow the sustained application of these higher intensities, compromises will be made in terms of the stimulator settings. Additional cooling may be necessary to prevent overheating of the active coils. The negative impact of adding such a cooling system is that the weight of the applicator may significantly increase. This may influence patient comfort during the therapy and can make the placement of the applicator difficult[7].

4 MAGNETIC STIMULATION FOR AESTHETICS

Until recently, the potential of muscle strengthening by MS had been omitted in aesthetic practice; this was primarily due to the absence of technology that would meet the criteria for application in aesthetics.

4.1 Required advancements of MS technology

Contrary to physiotherapy, which focuses on healing, mobilization, pain reduction, and other indications, in aesthetic medicine, it is essential to look at the application of MS from a total body approach. In aesthetics, it is ideal to involve larger muscle groups/volumes (for instance abdominal and gluteal muscles) to such an extent that the delivered load would induce muscle growth, which then projects into a visible change of body contours[31]. In addition, with respect to the natural pattern of muscle strengthening, the MS-induced contractions should be of maximum possible intensity since higher loads provide a greater stimulus for muscle hypertrophy[33]. To maximize the benefits of therapy, sections with the contraction frequency of more than 30 Hz must be achieved and maintained through the entire treatment time. Considering the great fluxes and intensities applied to the muscle tissue, the stimulation paradigm requires the utilization of trapezoidal shaped trains to ensure the patient's safety and comfort. The duty cycle plays an important role, as well. Finding specific pause duration and pause-stimulation times is essential for supporting the beneficial effect of the rest-pause approach, which avoids unnecessarily decreasing the muscle activity and minimizing muscle fatigue[44]. The ideally balanced pauses between contractions increase contraction volume and elicit greater mechanical stress on the muscle.

4.2 Spot size

The ability to target large muscle groups is strongly influenced by the specific design of the coil, and the coil geometry (see Fig. 7). Parameter considerations such as coil inner and outer diameter, its height/thickness, the winding architecture, as well as, the material used can all affect the shape of the resulting magnetic field. Even though magnetic fields don't have a clearly defined spot size similar to what is typical for lasers, the shape of the fields significantly define the area in which the high intensity of induced currents is achieved. Existing devices intended for physiotherapy often use single core coils which are purposely designed to stimulate only a smaller region (such as one specific joint or tender) and thus concentrate most of the intensity to a smaller spot size. The importance of spot size cannot be understated; it helps determine the number of nerve fibers which are effectively recruited (affected by the induced currents). The larger the spot, the more motor neurons are recruited. In some instances, the fields concentrated into smaller spots may suffice as long as they hit the superior motoric nerve and the action potential then spreads across all subordinate motor neurons. This is, however, usually not the case, since it would take a highly skilled technician with a thorough understanding of muscle anatomy. As an example, the rectus abdominis is the large vertically oriented muscle of the anterior abdominal wall, and it is innervated by multiple anterior rami of the spinal T6-T12 nerves. This means that all of the major branches and adjacent motor units should be activated to perform the most effective muscle contraction (see Fig. 8).

A highly concentrated field would inherently be able to activate only a smaller portion of the neuromuscular structure. With the use of a coil with larger diameter and thus greater field distribution, the total affected area would be substantially larger. This would allow targeting the entire large muscle group with the supra-threshold stimulus, thus recruiting a much higher number of muscle fibers. This results in a complex response of stimulated tissue and muscle enhancement[32].

4.3 Clinical evidence

Since the first muscle stimulator was introduced almost four decades ago, a lot of published evidence has become available that describes the efficacy of MS technologies for blood flow increase, pain management, fatigue recovery, bone healing, as well as many other indications. However, no study has been able to highlight any clinical results that would suggest potential use of MS in aesthetic medicine.

The first MS procedure with clinically proven results in aesthetics was HIFEM. It uses magnetic fields of very high intensities over a large area to induce strong muscle load referred to as supramaximal muscle contractions, and it is reported to be widely used for improving the aesthetic appearance of the abdomen[34–47] and buttocks[38,39]. As a result of the intensive stimulation, multiple studies have appeared that described an increased volume of striated muscles which was predominantly attributed to the hypertrophic effects as well as possible formation of new muscle fibers[35,37,38]. As a secondary effect, several studies also mentioned a significant reduction of the abdominal fat layer, which oscillates around the 20% bar depending on the source. In contrast with devices which affect fat by temperature stress[40], the mechanism of non-thermal fat reduction by HIFEM has been shown to have a hypermetabolic effect on the localized tissues in the body. Induced supramaximal contractions increase metabolic activity in the stimulated region to such an extent that the lipids (triglycerides) break into free fatty acids (FFA) and glycerol[41] and this lipid breakdown leads to an overflow of FFA in the intracellular space and consequently initiates adipocyte dysfunction by the mechanism of endoplasmic reticulum stress (ER-stress) apoptosis[42,43].

HIFEM procedure was specifically developed for use in aesthetics to combine several distinct characteristics of the magnetic technology. As such, it uses large-spot magnetic fields and also has much improved overall energetic balance, which allows it to maintain unique and very energy hungry treatment protocols.

4.4 HIFEM

HIFEM procedure uses unique and patented pulse configurations which offer high amplitudes, high intensities, and long durations. In order to do so, the procedure is based on uniquely designed treatment protocols with intense trapezoidal sequences intended to mimic an intensive muscle workout, interrupted with resting periods to prevent muscle fatigue (see Fig. 6). During the therapy, several thousands of stimuli are delivered to the muscle tissue at varying high frequencies and intensities to achieve tetanic contraction, and the procedure has a very high total effective stimulation time. The appropriate handling of these variables (duration of the pulse, pause-stimulation times, frequency and intensity) is crucial as overstimulation may lead to excessively long periods of complete tetanus and decrease in blood circulation, nutrient/waste exchange and insufficient outcomes. On the other hand, setting parameters too low may not be enough to induce desired effects[45,46].

The patented air-cooling system is one of the factors that enable to deliver full therapy even when the maximal possible settings are applied. Also, due to the double winding architecture of the coil the procedure allows to induce wide electromagnetic field which is more broadly distributed and covers much larger areas with high magnetic flux when compared to other technologies. In addition, the device is able to perform active bilateral treatment with two of its applicators simultaneously, which allows covering even larger body area at the same time.

5 CONCLUSION

Even though physiotherapy magnetic stimulators have been around for decades, there have been no reported studies highlighting the aesthetic benefits or an ability to affect fat. This can be easily explained by the fact that physiotherapy devices were not designed for such use in the first place and they are unable to mimic resistance training.

HIFEM seems to be the only MS-based procedure with peer-reviewed evidence suggesting hypertrophic effects of the treated muscle tissue that is accompanied with a localized reduction in subcutaneous fat. As such, HIFEM represents the logical evolution of electromagnetic technology that now can be used in the field of aesthetic medicine. Patient response, correlated with animal histological data, was observed clinically by MRI, CT and ultrasound, not only at the level of muscle tissue (hypertrophy), but also in subcutaneous fat (apoptosis of adipocytes). Therefore, the pioneering use of magnetic stimulation in aesthetics provides patients with a dual effect of both fat reduction and the enhancement of muscles which results in improved visual appearance. HIFEM is unique in that multiple studies demonstrate high patient satisfaction rates[34,36,37,39]. HIFEM represents a new class of MS technology that has been specifically designed for aesthetic procedures, and addresses specific previously unmet needs for muscle contouring. It offers a unique combination of technical features such as double winding architecture with high energy, high flux and large spot size, dual applicators, a trapezoidal ramp up for greater patient comfort and tolerability and safety in terms of remaining cool during the treatment cycles. This leads to superior patient outcomes and satisfaction. Multiple peer-reviewed studies have confirmed HIFEM technology results.

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