

# *Body shaping with high-intensity focused electromagnetic technology*

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# Body shaping with high-intensity focused electromagnetic technology

## Introduction

Current surgical as well as noninvasive body shaping procedures are effective for fat elimination, but require patients with well-defined bulges for successful and safe treatment. Many patients, especially those with lower BMI, are not considered suitable candidates for established body shaping procedures such as cryoadipolysis (membrane defect to subcutaneous white adipose tissue, sWAT), radiofrequency (heat = apoptosis in sWAT), or high-intensity focused ultrasound (HIFU) [1] (“cooking” of sWAT).

Furthermore, while there are many ways of targeting subcutaneous fat, none of the established procedures deals with the underlying musculature. However, it is the shape, volume, and firmness of the underlying muscles that is highly responsible for a toned and aesthetically pleasing visual appearance. Physical exercise has long been the only option for muscle toning. Although various electrical stimulation-based modalities have been introduced for muscle strengthening [2, 3], their efficacy has been considered controversial. The electric current induced by electrical stimulation depolarizes motor neurons, which results in muscle contraction [4]. However, during electrical stimulation, most of the energy is concentrated superficially, which leads to skin overheating and the risk of burns [5, 6]. Moreover, nociceptors are activated, making the procedure highly painful at higher intensities [7] and thus limiting the use of efficient settings. When using

low intensities, the stimuli are not strong enough to trigger any muscle structure changes or growth.

A true advancement for aesthetic use came with the introduction of the high-intensity focused electromagnetic (HIFEM) procedure based on electromagnetic field technology, which overcomes the disadvantages of electrical stimulation. Without any risk of burns or pain [7], the HIFEM procedure can induce supramaximal involuntary contractions that have been found to result in muscle growth and even in a reduction of subcutaneous fat in (but not limited to) lower-BMI patients. With dual effects of this kind, the procedure complements the fat reducing set of tools for practitioners to cover the entire patient spectrum and offers a completely new approach to body shaping by targeting muscle tissue.

## HIFEM technology

— HIFEM technology utilizes low frequency magnetic waves (3–5 kHz), which propagate through the tissue without being absorbed. Thus, an interaction between the wave and human tissue occurs according to the principles of electromagnetic induction first described by Michael Faraday in 1831.

A distinction is made between the following frequencies:

**430–750 THz** (between infrared/ultraviolet <laser>)

= light spectrum visible to the human eye

— **1–30 MHz** (high frequency)

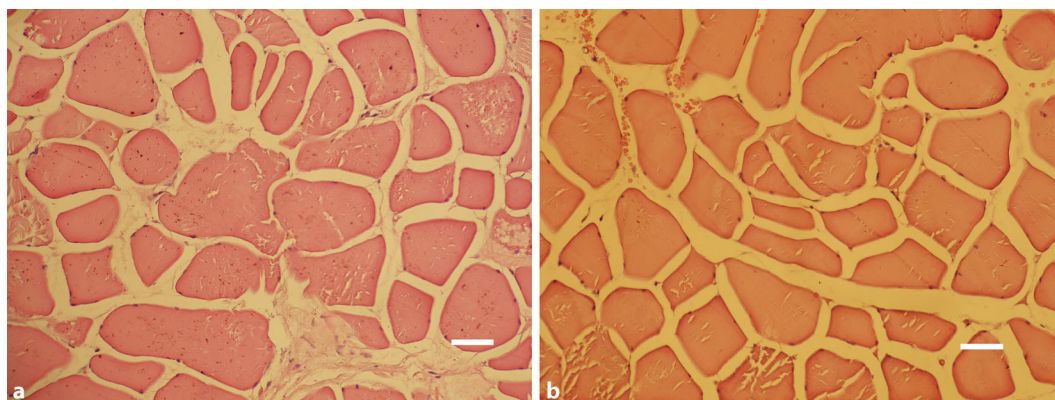
= most non-invasive radiofrequency-based devices for skin/fat

— **3–30 kHz** (very low frequency)

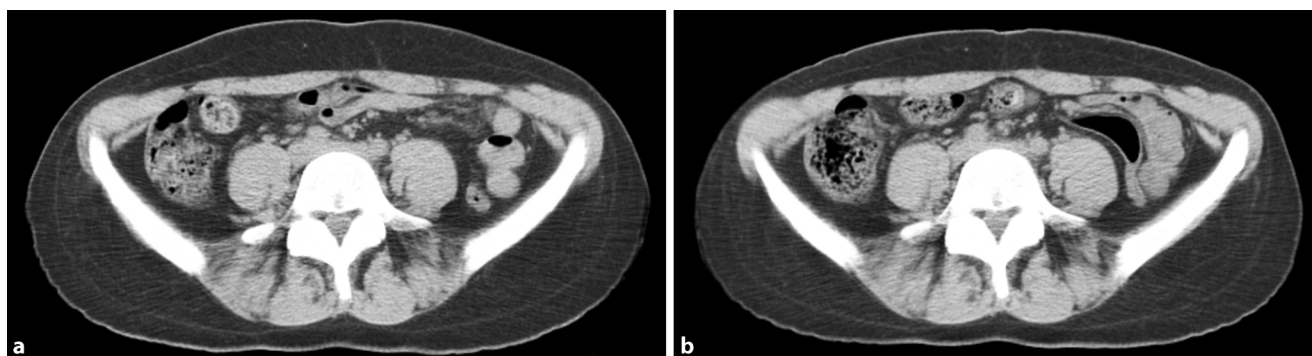
= HIFEM

Thus we are looking at the very low frequencies. The law of electromagnetic induction says that any change in a magnetic field induces an electric current and vice versa. The HIFEM device comprises a circular coil located in the applicator, which is placed over the treatment area. During the treatment, an alternating electric current is passed through the wire of the circular coil. The alternations in the electric current induce rapidly changing magnetic waves, which propagate into the underlying tissue, where they induce a secondary electric current. These electric currents within the tissue depolarize the muscle-innervating motor neurons and induce muscle contractions [8].

Several studies have shown that humans are unable to fully activate muscles voluntarily, since the power of muscle contraction is limited by the firing rates and conductivity of neural pathways [9, 10]. The application of HIFEM bypasses the central nervous system and directly stimulates the muscles, thereby allowing their full contraction. In addition, the frequency of delivered pulses does not allow the muscle to relax between two consecutive stimuli, which results in supramaximal tension within the muscle and thus supramaximal muscle contraction.



**Fig. 1** ◀ Examples of histological images of slices taken at baseline (a) and 2 weeks post treatment (b). The baseline image shows the normal structure of muscle fibers, while the post-treatment image shows hypertrophy of muscle fibers with the muscle cell diameter being noticeably larger. (With permission from © BTL Medical Technologies s.r.o. All rights reserved)



**Fig. 2** ▲ Computed tomography scans taken at baseline (a) and 1 month post treatment. The measurements showed a 30.3% reduction in thickness of subcutaneous fat, a thickening of abdominal muscle by 8.4%, and a reduction in waist circumference by 2.0 cm. (With permission from © BTL Medical Technologies s.r.o. All rights reserved)

The HIFEM field directly targets the fibers of peripheral motor nerves in the stimulated area and thus leads to a contraction of the whole muscle group innervated by the specific nerve or nerve plexus.

## Mechanism of action

### Effect on muscle

The intensity of muscle contractions has a very powerful impact on deep muscle remodeling and firm toning of the muscles. The muscle structure is directly modified through the specific conditions to which the muscles need to adapt. HIFEM technology utilizes a unique combination of various field intensities, frequencies, and contraction lengths to induce optimum changes in muscle tissue. The supramaximal nature of the HIFEM-induced contractions puts a high load on the muscle tissue, which results in muscle fiber micro-damage, much like during resistance exercise

[11], but to a greater extent. This triggers biochemical processes aimed at strengthening the muscle in order to adapt to such high-load stimuli. Physiologically, the adaptation response manifests as a highly efficient growth of myofibrils—muscle fiber hypertrophy, creation of new protein strands, and possibly new muscle fibers—muscle fiber hyperplasia [12, 13]. ◀ **Fig. 1** provides an example of a histological image. According to previous research, the first results of muscle structural improvements can be seen as early as 14 days after the last systematic muscle contractions, when tissue growth, thickening, and regeneration are fully completed [14].

### Effect on subcutaneous fat

HIFEM-induced supramaximal muscle contractions create a high demand for energy supplies, which cannot be provided solely from glycogen storage. Lipolysis is thus initiated by an intracellular cascade reaction, which is activated by

catecholamine epinephrine (adrenaline) to supply the muscle with the energy stored in fat. During the process, triglycerides are broken down into free fatty acids (FFA) and glycerol [15, 16]. Released molecules normally act as the primary energy source for muscle and body metabolism. However, when the amount of released FFAs exceeds a certain level, they start accumulating intracellularly in adipocytes, and eventually cause their dysfunction [17, 18].

Lipolysis starts primarily in the area around the muscles undergoing contractions. This is due to increased adipose tissue blood flow (ATBF) and paracrine substances released from contracting muscles, which diffuse to the adipose tissue and stimulate blood flow and adipose tissue lipolysis [15].

During HIFEM therapy, the mechanism that leads to adipocytes' death is endoplasmic reticulum (ER) stress-induced apoptosis [17, 18]. This reaction is triggered by an increased intracellular concentration of FFA due to an exag-



gerated lipolytic reaction to the supra-maximal contractions. The ER is central for protein folding, secretions, calcium homeostasis, and lipid synthesis. With regard to adipocytes, the ER is directly involved in lipid droplet (LD; reservoir for cholesterol and triglycerides) formation and maintenance of lipid homeostasis [19].

The cell reacts to the FFA overflow by initiating an ER stress response to restore homeostasis. However, one of the additional cell responses to the ER stress is lipolysis itself, creating a continuous flow of FFA through lipolysis caused by the supramaximal muscle contractions and lipolysis triggered by the ER stress [20, 21].

At some point, the cell can no longer regulate homeostasis and enters apoptosis—programmed cell death. The apoptotic response to the fatty acid treatments has been confirmed by the measurement of cytoplasmic histone-associated DNA fragments. The results confirmed that the ER stress contributes to apoptosis induced by increased intracellular levels of FFA [22]. The fat cell apoptosis following a HIFEM procedure was proven in an animal study [23], where the apoptotic index increased by 91.7%.

The best aesthetic improvement after non-invasive fat reduction treatments has been widely claimed to appear between 1 and 3 months after the actual treatment [24], when the body fully processes and clears the cell debris and other metabolic waste. The visible fat reduction captured by computed tomography (CT) can be seen in **Fig. 2**.

## Clinical application

The HIFEM procedure is currently used for strengthening and toning the entire abdominal area, for lifting and toning buttocks and thighs, as well as for toning arms and calves. Ideal patients for the HIFEM procedure are males and females with a fat layer of up to 2–3 cm. Exclusion criteria include pregnancy, breastfeeding, heart disorders, unhealed wounds in the treatment area, and any medical condition contraindicating the application of an electromagnetic field.

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## Body shaping with high-intensity focused electromagnetic technology

### Abstract

The field of non-invasive body shaping has long been represented solely by fat reducing technologies, and the condition of the underlying muscles could be altered only by physical exercise. In 2018, high-intensity focused electromagnetic (HIFEM) technology was introduced to simultaneously tone and strengthen muscle and reduce fat. The technology is based on delivering focused electromagnetic fields into the treatment area, causing supramaximal muscle contractions. Clinical studies showed a significant reduction in subcutaneous white adipose tissue (sWAT) and an increase in

muscle thickness (e.g., abdominal muscle) after a series of HIFEM treatments. The effect on both types of tissue was also confirmed by histological studies and was present in all imaging techniques (ultrasonography, magnetic resonance imaging, computed tomography). With an effect of this kind, HIFEM technology has opened up a completely new segment in body contouring.

### Keywords

HIFEM · Electromagnetic stimulation · Muscle building · Fat removal · Muscle atrophy

## Körperformung mit hochintensivem fokussiertem elektromagnetischem Feld

### Zusammenfassung

Das Fachgebiet der nichtinvasiven Körperformung beinhaltete lange Zeit nur fettreduzierende Techniken. Der Zustand der darunter liegenden Muskeln konnte ausschließlich durch körperliches Training beeinflusst werden. Im Jahr 2018 wurde die sogenannte High-intensity-focused-electromagnetic(HIFEM)-Technik eingeführt, um zugleich eine Formung und Kräftigung der Muskulatur sowie eine Fettreduktion zu erreichen. Die Technik basiert auf der Erzeugung fokussierter elektromagnetischer Felder im zu behandelnden Gebiet, wodurch supramaximale Muskelkontraktionen ausgelöst werden. Klinische Studien zeigten eine signifikante Reduktion von weißem Unterhautfettgewebe und eine

Zunahme der Muskeldicke (beispielsweise des M. rectus abdominis) nach einer Serie von HIFEM-Anwendungen. Der Effekt auf beide Gewebetypen wurde in histologischen Studien bestätigt und ließ sich mit sämtlichen bildgebenden Verfahren darstellen (Sonographie, Magnetresonanztomographie, Computertomographie). Mit einer derartigen Wirkung eröffnet die HIFEM-Technik ein vollkommen neues Arbeitsfeld im Bereich der Körperformung.

### Schlüsselwörter

HIFEM · Elektromagnetische Stimulation · Muskelaufbau · Fettentfernung · Muskelatrophie

The recommended treatment protocol for the abdominal, thigh, and buttock HIFEM procedure consists of four treatments, each lasting 30 min, while the individual treatments should be spaced at 2–3 days. For arm and calf procedures, 20-min treatments are recommended due to the smaller volume of these muscle groups.

For abdominal treatments, one or two applicators are placed over the treatment area according to patient size. Bilateral placement is used for the buttock, thigh, arm, and calf procedures. Prior

to the treatment, the device applicator is positioned over the treatment area and should be secured by a fixation belt to prevent it from shifting with the movements of contracting muscles. Low intensities should be used at the beginning of the treatment, as it is necessary to adjust the applicator position to a location resulting in the strongest and most evenly distributed contractions across the entire muscle group. During the ongoing treatment, the intensity should be continuously increased according to patient



**Fig. 3 ▲** An example of the result of abdominal treatment in a 52-year-old female patient. Photographs taken at baseline (a) and 2 months post four treatments (b). (With permission from © BTL Medical Technologies s.r.o. All rights reserved)



**Fig. 4 ▲** An example of buttock treatment outcome in a 31-year-old female patient. Photographs taken at baseline (a) and 1 month post four treatments (b). (With permission from © BTL Medical Technologies s.r.o. All rights reserved)

feedback to induce challenging but not painful muscle contractions.

Immediately after the treatment, patients experience firming of the treated area, but the results fully manifest approximately 2 weeks to 2 months after the final procedure. For some patients seeing declines in the achieved outcomes, it may be beneficial to perform maintenance treatments 8–12 months post treatment in order to preserve the results.

## Clinical evidence

Numerous clinical studies [13, 23, 25–30] investigating HIFEM technology have

been published to date in peer-reviewed journals. The studies comprising hundreds of test subjects focused on determining the safety and efficacy of HIFEM for abdominal body shaping, buttock shaping, and histological evaluation.

A histological study by Weiss et al. [23] focusing on fat tissue demonstrated levels of apoptosis elevated by 92% through an apoptotic index following HIFEM treatment. The study also found increased levels of pro-apoptotic markers, further indicating the apoptotic response of subcutaneous fat to the treatment. The muscle histology study performed by Duncan et al. [13] confirmed HIFEM-in-

duced muscle hypertrophy on a cellular level. The investigators acquired muscle biopsies prior to and after four HIFEM treatments and found a significant increase in the cross-sectional muscle mass of 20.56%. Individual muscle fibers increased by 12.15% on average and, although not statistically significant, the number of muscle fibers also increased by 8%, indicating that muscle fiber hyperplasia may also play a role in addition to muscle fiber hypertrophy.

Besides histology, the effects of the treatment on the abdomen were assessed using various imaging techniques: CT [29], magnetic resonance imaging (MRI) [27], and ultrasound imaging (US) [28]. The results from the different studies were seen to be consistent in terms of both subcutaneous fat and muscle thickness. The average subcutaneous fat reduction seen in these studies was 19.6% (17.5–23.3%), while muscle thickness was increased by 15.1% (14.8–15.4%) on average. Some of the studies also measured abdominal separation, which was found to be reduced by 9.95% on average due to the muscle thickening effect. In addition, the waist circumference measured in these studies was found to be decreased by 3.85 cm on average. ■ **Fig. 3** provides an example of the abdominal treatment outcome.

The studies [25, 30] investigating the HIFEM procedure for shaping, toning, and lifting of buttocks were based primarily on a satisfaction assessment and an evaluation of digital photographs. In general, the studies found high patient satisfaction and a significant improvement in the aesthetic appearance of the buttocks, as documented by the digital photographs. An example of treatment outcome can be seen in ■ **Fig. 4**.

To summarize, the HIFEM procedure is supported by strong clinical evidence based on a variety of investigating methodologies. The studies found the procedure to be effective for body shaping through fat reduction and muscle thickening while being safe, since none of the studies reported any adverse events or side effects.

## Conclusion

Through its dual effect on fat and muscles, HIFEM technology represents a novel approach in the field of non-invasive body shaping. It should not be confused with electrical muscle stimulation (EMS), in which a current runs over the muscle fascia but does not penetrate the muscle in a comparable way to HIFEM. The procedure is convenient for patients that are not ideal candidates for established technologies and thus extends the target patient pool for practitioners. As muscle laxity is a common problem that has not been targeted as yet, the combination of HIFEM with other modalities complements the set of tools for body shaping to achieve complete non-invasive body reconstruction. Wide clinical evidence provides a strong and clear overview of the outcomes that can be expected and gives the practitioners the confidence to use the technology to achieve high patient satisfaction.

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## Compliance with ethical guidelines

**Conflict of interest.** K. Hoffmann, S. Soemantri, K. Hoffmann, and K.K.P. Hoffmann declare that they have no competing interests. K. Hoffmann recurrently holds lectures for CYNOSURE (Westford, USA), the company distributing the STIMSURE device, as well as for BTL (Prague, Czech Republic), the company distributing the EMSCLPT device. Both devices have been regularly purchased by the university dermatology clinic. The author declares that he has no competing interests.

For this article no studies with human participants or animals were performed by any of the authors. All studies performed were in accordance with the ethical standards indicated in each case.

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