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INVITED REVIEW

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An overview of HIFEM technology in body contouring

Bruce E. Katz[1,2]

[1]Juva Skin and Laser Center – Dermatology, New York City, New York

[2]Mt Sinai Medical Center – Dermatology, New York City, New York

Correspondence
Bruce E. Katz, Juva Skin and Laser Center – Dermatology, 60 East 56 Street, New York City, NY 10022.
Email: brukatz@gmail.com

Abstract

Background

This review comprises a technology overview, clinical background, and applications of high-intensity focused electromagnetic technology (HIFEM).

Methods

The physiology, mechanism of action, and dynamics of HIFEM will be discussed and its action on muscle fibers and fat elucidated.

Results

Clinical applications, body areas treated, and treatment parameters will be reviewed.

Conclusion

Efficacy and safety results from multiple studies will be included.

KEYWORDS

body contouring, emsculpt, HIFEM, muscle building

1 | INTRODUCTION

It has been evident that muscles are inherently associated with athletic, toned, and esthetically pleasing body appearance. Still, many established noninvasive and surgical body contouring procedures have been unable to modify the shape and structure of the muscles, which could impact the body contour positively. A few injectable-based solutions were introduced for such purposes, but they put patients' life to a high risk.[1] There are a few surgical procedures that could affect muscles esthetically, such as abdominoplasty or subdermal radiofrequency. However, these procedures do not result in muscle growth or muscle toning.[2] So far, long-term exercise programs requiring a high physical effort have been the only option for muscle toning.

Fortunately, muscle tissue is neurogenic and, therefore, electrically excitable.[3] Muscles can thus be stimulated externally and under special circumstances to an even larger extent than voluntarily.[4] This principle has been extensively used for rehabilitation since the 1960s.[5] However, except for several home-based electrical stimulators of limited power and vague clinical evidence, this principle was not widely applied in esthetic medicine until 2018.

In 2018, high-intensity focused electromagnetic technology (HIFEM) was introduced for noninvasive body contouring.[6,7] Since then, it rapidly became one of the most popular noninvasive procedures in esthetic medicine and gained a lot of positive feedback.[8] Besides efficacy, the popularity can be attributed mainly to HIFEM's unique ability to complement other noninvasive as well as surgical body contouring procedures. Although HIFEM technology was found to affect fat tissue, the main benefit of the HIFEM procedure is its effect on muscles. Due to the versatile nature of this procedure, it can be used as a standalone body shaping tool or in combination with other established fat-reducing technologies.

This article aims to explain the technological background of HIFEM; to provide an overview of the clinical application and associated clinical evidence and to collaborate on proper patient selection and result expectation.

2 | WHAT IS HIFEM TECHNOLOGY AND HOW IT WORKS?

HIFEM procedure is based on magnetic stimulation of muscle innervating motor neurons, which results in the contraction of these muscles.[9] The concept of magnetic stimulation of the nervous system was first used by d'Arsonval in 1896.[10] Since then, the method has been widely investigated, and nowadays, magnetic stimulation is being used in diagnostics, research, and rehabilitation. It has become an established tool in neurology where it is used not only in diagnostics and research[11] but also as a clinical tool for the treatment of depression[12] (repetitive transcranial magnetic stimulation [rTMS]) or reducing the symptoms of Parkinson's disease[13] (deep rTMS). Magnetic stimulation has also been used for the treatment of incontinence,[14] cough restoration,[15] or treatment of dysphagia.[16] In physiotherapy, it has been used for muscle relaxation and pain management.[17,18]

Although many of these applications are based on muscle stimulation, the use for medical purposes does not require as high power output and intensity of contractions as would be needed for muscle toning. HIFEM technology was thus developed expressly for the body contouring purposes to be able to deliver a high number of stimuli of high intensity in a short period of time. The applicators of the HIFEM-utilizing device contain a circular coil that is powered by an alternating electric current of high amplitude. These large currents heat the coil, which thus needs to be cooled during the application. According to the law of electromagnetic induction, the alternating electric field generates alternating magnetic pulses with a frequency of 3 to 5 kHz, which propagate through the underlying tissue. In response to the alternating magnetic field, a changing electric current is induced within the tissue where it can cause depolarization of excitable tissue. Due to the differences in electrical properties between different types of neurons, predominantly motor neurons are activated, while sensory neurons and nociceptors are largely unaffected. Action potential induced in motor neurons carries the electrical signal to neuromuscular junction, where muscle is depolarized and contracted.[19] The properties of HIFEM stimulation pulse such as pulse width, duration, frequency, or intensity were designed to induce tetanic supramaximal contractions. Delivering the individual pulses fast enough does not allow the muscles to relax in between, which leads to exponential recruitment of all motor units in the treated area. When all motor units are recruited, a maximal contraction force is reached, which is not possible to achieve voluntarily. Then, the muscle is left to relax and another set of pulses is delivered to repeat the process over and over.

In a single HIFEM session, the muscles are stimulated for 30 minutes and are forced to contract more than 20 000 times. Such a high overload on the muscle triggers compensatory hypertrophic effect that can be quantified by increased muscle mass. During any high-load contractions, as well as during HIFEM contractions, muscle fibers suffer microinjuries, which are crucial for the hypertrophic response of the muscle.[20] During the microinjury, signaling molecules are sent to trigger muscle protein synthesis and to activate skeletal muscle satellite cells, which in the end, results in muscle growth.[21,22] Besides muscular adaptations, stimulation of motor neurons may also trigger neural adaptation such as increased motor unit synchronization,[23] increased motor unit firing rate,[24] or decrease in the stimulation threshold.[25] However, neural changes in response to HIFEM have not yet been investigated to support these claims.

Similar changes also occur during resistance exercise; however, due to the supramaximal nature of the HIFEM-induced contractions, the compensatory processes leading to hypertrophy are activated to a large extent only in four sessions. In-vivo animal study by Duncan et al[26] found a 20.56% increase in the cross-sectional muscle area. In addition, the results, although not statistically significant, showed indications of an increased number of muscle fibers in the tissue—muscle fiber hyperplasia.[26]

Although HIFEM stimulation directly affects muscles, the effect on fat tissue has also been documented. Initial trials showed that patients lost a significant amount of fat in the subcutaneous layer after the treatment, and a consequent histological study performed by Weiss et al[7] showed that HIFEM treatment induces fat cell apoptosis. Until then, fat apoptosis in noninvasive body shaping had always been associated with direct exposure to thermal stress, such as cooling with cryolipolysis or heating with radiofrequency.[27] The study by Weiss et al[7] proposed a theory that apoptosis may be related to the high energy demand of the contracting muscles, and since glycogen is quickly depleted, a fat breakdown into free fatty acids (FFAs) and glycerol is initiated. However, the release of FFAs is exaggerated to such a degree that the fat cells are unable to dispose of the FFAs into the bloodstream quickly enough and the concentration of FFAs inside the cells becomes toxic. In response to the toxicity, the fat cell enters apoptosis—programmed cell death. This phenomenon has been previously observed in cancer research before.[28,29] In regard to HIFEM, the proposed hypothesis of a rapid release of FFA has been tested by Halaas et al,[30] who indeed showed steep elevation of FFA levels by 134.1% in the fat tissue accompanied by a decrease in pH as the tissue acidity increased. These findings, together with magnetic resonance imaging (MRI),[6] computed tomography (CT),[31] and ultrasound (US)[32] evidence of reduced fat thickness, suggest this hypothesis as valid, although further research is necessary to provide more evidence.

Magnetic stimulation is often compared with electrical stimulation where electrodes are placed on the skin surface, and electric current is directly delivered into the tissue. Such setup inevitably leads to high current density under the electrode perimeter and is thus associated with a predominant stimulation of skin receptors and an uncomfortable feeling of itches and pain, which limits the level of used intensity.[9] Uncontrolled current accumulation may also lead to overheating of the skin tissue and its burns. Unlike electrical stimulation, magnetic stimulation yields a considerable advantage of sensation-free feeling during the application because there is no localized high current density at the skin surface under the stimulation coil.[33]

3 | CLINICAL APPLICATION

3.1 | Body areas and patient selection

The HIFEM device now includes two types of applicators. Large applicators are intended for use on abdomen, buttocks, and front and back thighs. Small applicators were designed for use on smaller body parts—arms and calves. Small applicators may also be convenient for off-label use in other body parts, such as inner thighs, saddlebags, or oblique muscles.

During patient selection, it is necessary to take the thickness of patient's fat layer into account. Ideal patients are both males and females, with fat thickness not exceeding 3 cm.

Due to the penetration depth of about 7 cm (large applicator) and the quadratic attenuation of intensity with distance, large fat deposits may result in none or very mild muscle contractions. For such patients, it would be beneficial to schedule a fat-reducing procedure at first and then apply the HIFEM procedure. Special attention should be given to contraindications. Due to the electromagnetic nature of the procedure, patients with any metallic and electronic implants close to the treatment area should not be treated. Contraindicated is also pregnancy, breastfeeding, heart disorders, unhealed wound in the treatment area, and any medical condition contraindicating the use of electromagnetic field.

3.2 | Treatment procedure

The usual treatment protocol with large applicators for abdominal, buttock, and thigh treatments includes four 30-minute procedures delivered twice a week. Each calf and arm treatment with small applicators usually lasts for 20 minutes. The treatment protocol may be adjusted individually upon patients' discussion with the physicians to fulfill the patient's needs and goals better. Additional treatments on top of the four treatment protocols may bring additional improvement. However, as seen in clinical studies, additional treatments may not provide as significant improvement as after the first four treatments.[31]

Before each treatment, the patient is asked to remove all jewelry and metallic objects. Then, applicators are placed over the treatment area. A fixation belt is used to affix the applicators to avoid any applicator movements during the treatment. In regard to abdominal treatment, one or two applicators may be used depending on patient size. Two applicators are recommended for everyone who can fit them. Upon initiation of the treatment with low intensity, the muscle response should be monitored. If the contractions are not strong enough or homogenously distributed, the position of the applicator should be adjusted to ensure full contractions of the entire muscle group. The intensity should be increased during the treatment to achieve the maximum response while taking the patient's threshold into consideration. The response should not be painful; however, it may be slightly uncomfortable.

4 | EXPECTED RESULTS

Although the outcomes may vary from patient to patient depending on the initial fitness, the results of published clinical studies may give an overview of the results that can be expected

TABLE 1 Summary of HIFEM studies

Author	Body part	No. of subjects	Evaluation method	Outcome
Kinney et al[6]	Abdomen	22	MRI, tape measures	Fat thickness: −18.6%; muscle thickness: +15.4%; abdominal separation: −10.4%; waist circumference: −3.8 cm; no adverse events
Jacob et al[34]	Abdomen	19	Tape measures, satisfaction	Waist circumference: −4.37 cm; satisfaction: 92%; no adverse events
Kent et al[31]	Abdomen	22	CT, tape measures	Fat thickness: −17.5%; muscle thickness: +14.8%; abdominal separation: −9.5%; waist circumference: −3.9 cm; no adverse events
Katz et al[32]	Abdomen	33	US	Fat thickness: −19.0%/−23.3% (1/3 mo); satisfaction: 91%; no adverse events
Kinney et al[35]	Abdomen	21	MRI, CT	At 1 y: fat thickness: −14.6%; muscle thickness: +19%; abdominal separation: −10.5%; no adverse events
Jacob et al[36]	Buttocks	75	Satisfaction, photo evaluation	Improved patient's self-evaluation; 85% satisfaction; no adverse events
Busso et al[37]	Buttocks	21	Satisfaction, photo evaluation	Recorded esthetic improvement; high satisfaction, no discomfort and adverse events
Katz et al[38]	Arms, calves	2	MRI	Cross-sectional muscle area: biceps +17.1%, triceps +10.2%, gastrocnemius +14.6%; fat thickness: arm −12.8%, calf: −9.9%; no adverse events
Weiss et al[7]	Animal in-vivo study	2	Fat histology, apoptotic index	Apoptotic index: +91.7%; increased levels of proapoptotic markers; no adverse events
Duncan et al[26]	Animal in-vivo study	4	Muscle histology	Cross-sectional area: +20.56%; muscle fiber size: +12.15%; number of muscle fibers: +8.0%; no adverse events
Halaas et al[30]	Animal in-vivo study	2	Fat biochemistry, pH	FFA concentration: +134.1%; pH: −0.6; increased levels of proapoptotic markers; no adverse events

Abbreviations: CT, computed tomogaphy; FFA, free fatty acid; HIFEM, high-intensity focused electromagnetic technology; MRI, magnetic resonance imaging; US, ultrasound.

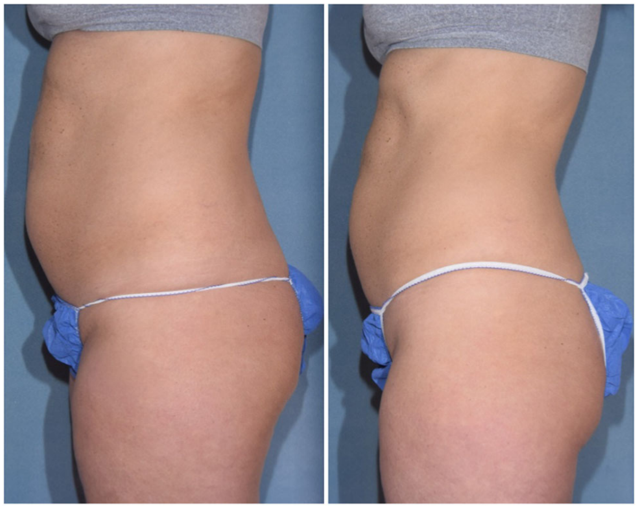

FIGURE 1 Photographs of a patient before and 1 month after four high-intensity focused electromagnetic technology (HIFEM) treatments showing visible toning of the abdominal area along with reduced fat layer

after the HIFEM procedure. A summary of studies investigating HIFEM can be found in Table 1.

Abdominal studies on HIFEM used different evaluation techniques to assess treatment outcomes. A CT imaging study[31] showed a 17.5% fat thickness reduction and a 14.8% increase in muscle thickness. These results were in correlation with an MRI study[6] which found an 18.6% reduction in fat and 15.4% muscle growth. In addition, both CT and MRI studies found reduced abdominal separation by 9.5% and 10.4%, respectively. Consistent were also the results of waist circumference reduction, which was seen in both of these studies: 3.8 cm[6] and 3.9 cm.[31] Waist circumference was also a subject of a study by Jacob et al[34] who found a reduction of 4.37 cm.

Also, the results in fat reduction were further confirmed in a study by Katz et al[32] who used US imaging as an evaluation method. The study found a 19.0% reduction in fat thickness at 1 month after treatment. Example of patient results can be seen in Figure 1.

Published studies investigating the effect of HIFEM on buttocks[36,37] did not yet present any quantitative data, but did show high patient satisfaction and pronounced buttock lifting effect contributing to esthetic improvement in the buttock appearance seen in digital photographs. In regard to arms and calves, a case study has been published by Katz et al.[38] The study used MRI imaging and found a 17.1% increase in biceps muscle mass, 10.2% in triceps muscle mass, and 14.6% in gastrocnemius muscle mass accompanied by a significant reduction in arm and calf fat thickness (see Figure 2 for an example of HIFEM effect on arms).

In regard to the longevity of the results, a study by Kinney et al[35] did show that although some decline is present at 1 year after treatment, both muscle and fat improvement was still maintained highly above the baseline levels. Long-term results, however, are highly dependent on patient lifestyle as any lifestyle or dietary changes may affect the results. Nevertheless, the results indicate that in patients who follow a healthy and active lifestyle, the results may be preserved up to a level even 1 year after the treatment, although additional maintenance treatment would be beneficial to prevent declines.

5 | SUMMARY AND CONCLUSION

HIFEM technology evolved from therapeutic magnetic stimulation for use in esthetic medicine, where it has started to be used for body shaping with application to abdomen, buttocks, thighs, arms, and calves. The outcomes of clinical studies indicate that high-intensity muscle contractions promote muscle strengthening and growth and suggest that the contractions may result in breakdown

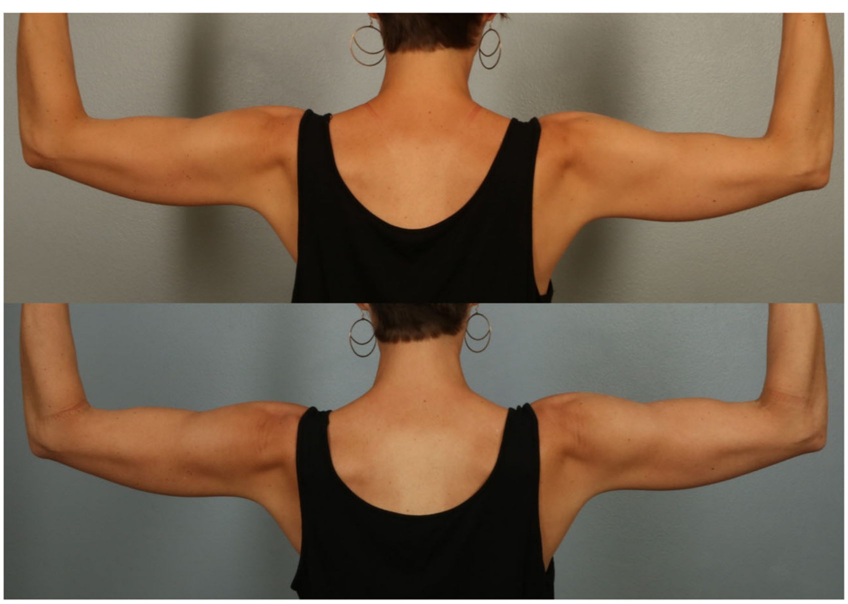

FIGURE 2 Patient photograph at baseline (upper image) and after four HIFEM sessions (lower image). Courtesy of Diane Duncan, MD. HIFEM, high-intensity focused electromagnetic technology

of fat possibly through increased metabolic activity. Although multiple studies were performed, the technology is still new and studies on greater number of patients are required to establish its efficacy.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest. Informed consent was obtained from the patients.

ORCID

Bruce E. Katz http://orcid.org/0000-0001-8255-6552

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