,

EFFECT OF HIGH ENERGY FOCUSED ELECTROMAGNETIC FIELD VERSUS ELECTRICAL MUSCLE STIMULATION ON PREMENOPAUSAL BODY COMPOSITION AND ABDOMINAL STRENGTH: A RANDOMIZED CONTROLLED TRIAL

Hala Mohamed Hanafy Emara[1], Osama MOHAMAD ELSAYED DEIF [2], Rola Mahmoud Mostafa Kamel[3]*

[1]Professor of Physical Therapy for Women's Health, Faculty of Physical Therapy, Cairo University.
[2]Assistant professor of obstetrics and gynecology, Faculty of Medicine for Boys, Al Azhar University.
[3]Physical Therapist, Egypt.
*Corresponding author: Rola Mahmoud Mostafa Kamel. Email address: rolazzzkamel94@gmail.com.

Abstract

Background: Obesity is a chronic, complex, progressive, and relapsing disease rather than a decision. Increased visceral adiposity in premenopausal period is caused by hormonal and body composition changes, which worsen women's physical, mental, and cardio-metabolic health.

Aim: To detect the effectiveness of High Energy Focused Electromagnetic (HIEMF) field versus Electrical muscle stimulation (EMS) on premenopausal abdominal muscle strength.

Subjects and methods: Forty-six Premenopausal women with abdominal muscle weakness were selected from the outpatient clinic of Misr International Hospital, aged from 45to 50 years; their body mass index (BMI) was 30-35 kg/m^2. They were excluded if they had Cardiac disease, cardiac peacemaker, Mental implantation, and Epileptic fits. The participants divided randomly into two equal groups in number 23 each: **Group A** received HIEMF, and **Group B** received EMS both applied on the abdominal region 30 minutes per session, three times per week for four weeks. All outcome measures were used before and after the treatment, body composition was assessed by using Inbody Body-coder analysis, Waist hip ratio (WHR) with tape measurement, and Muscle strength by manual muscle testing. **Results:** There was significant difference across both groups in all body compositions variables and WHR in the favor of HEIMF group. However, there was no significant difference across both groups in abdominal muscle toning.

Conclusions: The study found that both HIEMF and EMS improved abdominal muscle strength and body composition in premenopausal women, with HIEMF showing greater effectiveness in reducing waist-hip ratio and enhancing overall body composition.

Key words: Menopause ,High Energy Focused Electromagnetic, Electrical muscle stimulation, Abdominal Muscle Strength.

INTRODUCTION

A woman's menopause is a significant life shift, including a number of physical and psychological alternations. A major factor that raises the likelihood of menopausal symptoms and metabolic problems is an increase in body weight and a change in the distribution of fat (1).

Premenopausal obese women can expect to live with the combined burden of menopausal symptoms and obesity-related metabolic problems for the remainder of their lives. This stage of weight gain can be partially explained by middle-aged women's lacking awareness of their health-related problems as they put their family's wellbeing first (2).

High-Intensity Focused electromagnetic (HIFEM) makes use of magnetic stimulation. It works by applying a rapidly shifting magnetic field, which causes electrical currents to flow through the underlying tissue. This depolarizes motor neurons, resulting in muscle contractions that can't be achieved voluntary (3).

Electrical muscle stimulation (EMS) is the process of artificially stimulating or superimposing training innervated muscles using a range of electrical wave patterns. In various rehabilitation situations, EMS has been used to maintain muscle size and strength during extended immobility, facilitate muscular contraction and motor control, and strengthen muscles. Furthermore, EMS programs are utilized to enhance athletes' muscle performance and strength in healthy persons (4).

Electrical stimulation, which involves placing electrodes on the skin's surface and delivering an electric current straight into the tissue, is frequently contrasted with magnetic stimulation (MS). Such a configuration invariably results in a high current density beneath the electrode perimeter, which is linked to a preponderance of skin receptor activation and an uncomfortable sensation of discomfort and itching, which restricts the intensity that can be applied. Burns and warming of the skin tissue can also result from unchecked current accumulations. Due to the absence of a localized high current density at the skin surface underneath the stimulation coil, magnetic stimulation offers a significant benefit over electrical stimulation in terms of sensation-free experience during application (5).

The study aimed to explore the effectiveness of High Energy Focused Electromagnetic field versus Electrical muscle stimulation on premenopausal abdominal muscle lifting.

MATERIALS AND METHODS

Study design: An experimental randomized controlled trial was conducted from April 10, 2023, to October 15, 2024.

Ethical consideration

In conformity with the Helsinki Declaration (World Medical Association Code of Ethics). Cairo University's Faculty of Physical Therapy's Ethical Committee gave its approval to the study protocol (No.P.T.REC/012/004724). Prior to beginning the study procedures, women's participation was approved by a signed written consent form.

Subjects:

Forty-six premenopausal women with abdominal muscle weakness, who were selected from the outpatient clinic of Misr International Hospital. The computer-generated block randomization tool, available at http://www.randomization.com/, was used to perform the randomization. With a 1:1:1 allocation ratio, the participants were randomized into block sizes of 6 and 9. Using opaque envelopes that were sealed and sequentially numbered, concealed allocation was carried out. The randomization conducted by a blinded researcher who was not included in recruiting, data collection or treatment. The participants were split into two equal groups at random: Group A (study group): Comprised 23 women who were receive HIEMF on the abdominal region, 30 min/ session, trice weekly for four weeks. Group B (control group): Comprised 23 women and were receive EMS on the abdominal region, 30 min/ session, trice weekly for four weeks.

Sample size calculation: Based on Porcari et al. (6), the sample size was calculated utilizing BMI, with 80% power at the α = 0.05 level, two measurements for two groups, and an effect size of 0.44 using the F-test MANOVA within and between interaction effects. With 4 (10%) people added as dropouts, the minimum appropriate sample size is 42 subjects, for a sample size of 46 subjects totally, 23 in each group. The G*Power software (version 3.0.10) was applied to compute the sample size. Figure 1 displays the study's flow chart.

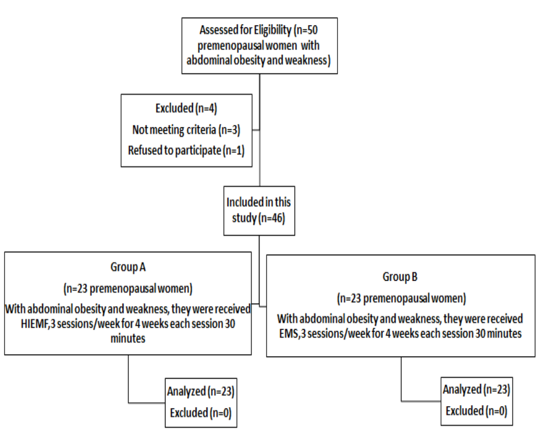

Figure 1: Flow chart for recruitment of the participants.

Inclusion criteria: Patients were examined by a gynecologist before the study and were selected based on the following criteria: all participants were in the premenopausal stage, aged between 45 and 50 years, with abdominal obesity and weakness of the abdominal muscles their grade ranged from 1-2 grade of manual muscle testing without following any type of dietary program and any form of physical exercises, and their Body Mass Index (BMI) ranged from 30 to 35 kg/m².

Exclusion criteria: Cardiac disease ,present cardiac peacemaker, metal implantation and epileptic fits.

Interventions:

High intensity electromagnetic field (HIEMF): (AU-27 Industries, with serial NO. JKL-1901125004 made in China). Electrical muscle stimulation (EMS) (TGBODY-4CH (serial number 612001 ~ 612030, 612061 ~ 612090) developed by NS-Medicom (Gimhae, South Korea)**.** Each participant in Group A received HIEMF treatment for 30 minutes, three times per week for two weeks, with at least two days of rest between sessions. While lying supine, a magnetic coil was positioned over the abdominal area to stimulate the muscles, starting at 15% intensity and adjusted based on participant tolerance (Figure 2). Treatment continued for four weeks, after which BMI, BMR, visceral fat, abdominal fat, and muscle strength were reassessed. Improvements in abdominal appearance were observed even three months post-treatment **(7).**

Figure 2: Application of HIEMF

Electrical muscle stimulation (EMS) (TGBODY-4CH (serial number 612001 ~ 612030, 612061 ~ 612090) developed by NS-Medicom (Gimhae, South Korea). All participants in Group B received EMS treatment for 30 minutes, three times per week. While lying supine, silicone electrodes were placed over the abdominal muscles, and intensity was gradually increased based on individual tolerance, ensuring strong but painless contractions (Figure 3). Participants were instructed to center the device over the umbilicus and avoid voluntary contractions during stimulation **(8)**. After four weeks, BMI, BMR, visceral fat, abdominal fat, and muscle strength were reassessed and compared to baseline data **(9).**

Figure 3: Application of EMS.

Outcome measures:

History taking: a detailed recording data sheet was completed at the initial visit that included: name, age, menstrual date, any previous illness.

Muscle strength assessment: It was assessed using manual muscle testing (MMT), the most widely used method for determining muscular strength. MMT uses a five-point grading system (**10**):

- 0: The participant hadn’t the ability to perform any noticeable contraction in the tested muscle.
- 1: Muscle contraction was observed but no motion occurs.
- 2: Muscle could contract; full muscle activation with gravity elimination, but it could not move the body part fully against gravity.
- 3: Muscle activation against gravity complete range of motion (ROM).
- 4: Muscle activation against some resistance, complete ROM.
- 5: Muscle activation against examiner's full resistance, complete ROM.

All participants in both group were asked to lay in crock line position with pared skin on the abdominal region and the test procedures were explained for each woman, they were asked to contract the abdominal muscles as possible as they can then the muscle grades were given according to the degree of muscle contraction as shown in **(Figure 4).**

Figure 4: Assessment of abdominal muscle strength

Body composition: It was assessed using InBody (Bodecoder)device (CHL-818, China) with software version 2.2.1 apk and tape measure for waist and hip circumference measurements. It was used to determine the subjects' height and weight to calculate the BMI, Muscle mass, Body Fat, Body percentage of fat, abdominal Fat, visceral fats, body water, water burnet rate, basal metabolic rate, body minerals, muscle to fat ratio-biological age, body balance overall results and overall score) for all women of both groups before and after the treatment programs **(11)**.

Assessment of waist hip ratio (WHR): For both groups, the waist circumference (WC) was taken using a tape measure at a level halfway between the crista iliaca superior and the lowest rib before and after therapy. The measurement was taken when the subject was standing erect, feet together, arms swinging loosely at the sides, at the end of a normal expiration. The hip circumference (HC) was taken without applying pressure on the skin at the maximal point below the waist. The WC was divided by the HC to determine the WHR. **(Figure 5) (12).**

Figure 5: Waist hip ratio measurement

Data analysis and statistical design

Unpaired t-test was used to compare between subjects characteristics of the two groups. Shapiro-Wilk test was used for testing normality of data distribution. MANOVA was performed to compare within and between groups' effects for parametric variables (weight, BMI, W/H ratio, BMR, Visceral fat, total body fat and abdominal muscle strength), while Wilcoxon and Mann-Whitney tests were used to compare within and between groups' effects for abdominal muscle strength varaible. Statistical package for the social sciences computer program (version 20 for Windows; SPSS Inc., Chicago, Illinois, USA) was used for data analysis. P less than or equal to 0.05 was considered significant.

RESULTS

There were no significant changes in the mean value of women age and height of both groups (p=0.896 and 0.780) respectively (Table 1).

Comparison between groups regarding the measured variables, mixed design MANOVA revealed that, there was no statistically significant change in the mean values of weight before treatment between both groups (p=0.920), While there was significant difference observed after treatment in favor of group A (p=0.048). The same result was found for BMI (p=0.391 before treatment, p=0.001 after treatment in favor of group A), W/H ratio (p=0.057 before treatment, p=0.001 after treatment in favor of group A), BMR (p=0.862 before treatment, p=0.001 after treatment in favor of group A), VF (p=0.245 before treatment, p=0.001 after treatment in favor of group A), and TBF (p=0.210 before treatment, p=0.004 after treatment in favor of group A). Mann-Whitney test was used for comparison of abdominal muscle strength between both groups revealed that, there was no significant change before (p=0.511) or after treatment (p=0.776) (Table 2).

Table (1): Subjects' demographic data of both groups

Demographic data	Group A	Group B	t-value	p-value
Age (years)	47.4±1.8	47.5±1.8	-0.2	0.869
Height (cm)	164.7±4	164.4±3.5	0.3	0.780

Data was expressed as mean ± standard deviation, p-value: significance

Table (2): Comparison of measured variables pre- and post-treatment within and between groups.

Measured variables	Group A	Group B	Mean difference	P-value	η2
Weight (kg)					
Pre-treatment	83.4 ± 4	83.3± 3.7	0.1	0.920	0.001
Post-treatment	80 ± 4.2	82.4 ± 3.7	-2.4	0.048*	0.09
% of change	4%	1%			
P-value	0.001*	0.001*			
BMI (kg/m2)					
Pre-treatment	30.7 ± 0.6	30.9 ± 0.6	-0.2	0.391	0.02
Post-treatment	29.4 ± 0.8	30.5 ± 0.6	-1.1	0.001*	0.37
% of change	4%	1%			
P-value	0.001*	0.001*			
W/H ratio					
Pre-treatment	0.93 ± 0.04	0.9 ± 0.04	0.03	0.057	0.08
Post-treatment	0.7 ± 0.06	0.83 ± 0.04	-0.13	0.001*	0.64
% of change	25%	8%			
P-value	0.001*	0.001*			

BMR (Kcal)					
Pre-treatment	1547.2 ± 42.8	1544 ± 75.5	3.2	0.862	0.001
Post-treatment	1965.3±101.6	1769±105.1	196.3	0.001*	0.49
% of change	27%	15%			
P-value	0.001*	0.001*			
Visceral fat index					
Pre-treatment	14.9 ± 2.8	15.9 ± 2.7	-1	0.245	0.03
Post-treatment	10.4 ± 2.3	14.3 ± 2.8	-3.9	0.001*	0.37
% of change	30%	10%			
P-value	0.001*	0.001*			
Total body fat (%)					
Pre-treatment	34.8 ± 6	32.5 ± 5.5	2.2	0.210	0.04
Post-treatment	25.2 ± 6.5	30.8 ± 5.6	-5.6	0.004*	0.18
% of change	28%	5%			
P-value	0.001*	0.001*			
Abdominal muscle strength			**z-value**		
Pre-treatment	2.9 ± 0.7	3 ± 0.7	-0.1	0.511	
Post-treatment	3.9 ± 0.6	3.8 ± 0.7	-0.1	0.776	
% of change	34%	27%			
P-value	0.001*	0.001*			

SD: standard deviation, *: significant, p value: Probability value, η2: partial eta square, z-value: of Wilcoxon test

DISCUSSION

A woman's risk of gaining weight is most during the menopause. As ovarian function gradually declines, decreased circulating estrogen levels result, which leads to weight gain associated with menopause. Additionally, aging, hormonal changes, a decrease in physical activities combined with a westernized diet, and frequent eating disorder linked to psychological discomfort all contribute to the rise in waist circumference and overall body fat **(13).**

The current findings indicated statistically significant change of weight after treatment between both groups in favor of group A. Also, there was statistically significant difference after treatment between both groups regarding the mean values of BMI in favor of group A. That might be HIEMF was a body contouring tool that so as by decreasing the fat percentages in the body the weight and then BMI might decrease on the other hand EMS due to the contractions that undergoing for the fate cells in breakdown its linkage thus these might decrease the body weight and then BMI so both of them were effective in decreasing body weight.

The results of our study revealed that both HIEMF and EMS have good effect in weight reduction However, HIEMF produces higher weight loss results, which may be because the HIFEM method, which is based on electromagnetic induction principles, has been shown to be an effective body shaping technique for multiple body regions **(14).**

However, the current results contradict the research conducted by Martinez et al. **(15)**, as the authors did not observe any noteworthy alterations in body weight and BMI following their HIEMF intervention in schoolchildren. This discrepancy may be because the studies' programs were designed for school-age children, whereas our sample consisted of premenopausal women. It is possible that 12 weeks is insufficient to observe a change in children's weight and BMI.

The present study indicated statistically significant change in the mean values of W/H ratio after treatment across both groups in favor of group A. A probable explanation decreasing WHR might be as a result of the thermal effect of HIEMF that by its role it breakdown the subcutaneous fate then it decrease the WHR on the other hand EMS cause electric construction on the abdominal muscle and by working the muscle it improve circulation, metabolism around the abdominal region so it deceased the waist circumference then decreased the WHR.

This is corroborated with **Choi et al. (16)**, which indicated that at week 12, the EMS group had a somewhat higher drop in WC than the control group. Additionally, the EMS group's percentage of participants who observed a WC reduction of greater than 4 cm was double that of the control group, which received transcutaneous nerve stimulation (TENS).

The present results indicated statistically significant change in the mean values of BMR after treatment across both groups in favor of group A. Similar findings were made by **Eijsbouts et al. (17),** who investigated if oxygen intake could be promoted in healthy adults (N = 11) through arm-cranking exercise with EMS on legs at the highest possible intensity. They found that both the oxygen consumption during exercise and the NMES at baseline increased by approximately 0.08 L/min.

The present study indicated a statistically significant change in the mean values of VF after treatment for both VF and TBF in favor of group A. As mentioned previously both EMS and HIEMF improved circulation and thus improve metabolic rate. While EMS has received a lot of attention for its ability to support exercise, its effects on physiological responses while at rest, such as its ability to promote fat burning, have received less attention.

Our study's findings are consistent with those of Kent and Kinney's **(18)** investigation, which found that HIFEM significantly reduced visceral fat, improving the abdomen's aesthetic look.

The present results indicated a significant increase in abdominal muscle strength in group A post-treatment by 28% compared with that of pre-treatment, significant increase in abdominal muscle strength in group B post-treatment by 5% in comparison to that of pre-treatment, while there was no statistical significant change in the mean values of abdominal muscle strength between post-treatment both groups. A probable explanation for that EMS has been a mainstay of physical therapy practice for many years as a method to rehabilitate muscles after an injury or surgery, also HIEMF based on application of rapidly changing magnetic field that generate electrical currents in the underlying tissue where it depolarizes motor neurons and causes muscle contraction.

Since the HIFEM technology immediately stimulates muscles, it may be utilized to strengthen and tone muscles like the buttocks. The gluteus maximus is a large muscle, and patients may benefit from its stimulation. As more people want to tone and reshape their buttocks, the number of buttocks shaping treatments is rising annually **(19).**

Additionally, HIFEM can raise the muscle tissue's metabolic level in the treated area, which can lead to compensatory muscular growth. Muscle fiber density and muscle mass density both increased following HIFEM treatment, according to animal trials. By combining fiber hypertrophy and hyperplasia, it may be concluded that HIFEM may promote muscle growth **(20; 21).**

On the other hand, the potential benefits of EMS have been marketed to the general public as another ‘‘get-fitquick’’ gimmick. ‘‘Building rock-hard abs’’ or ‘‘firming the flab on your buttocks and thighs’’ while working at your computer or watching TV, without having to exercise, is an attractive lure for many people **(22).**
Electric muscle stimulation can recruit deep muscle fibers at lower training intensities, because the nerves stimulated by the NMES are distributed throughout the muscle. Further, muscle contractions induced by electrical stimulation activate a larger proportion of type II muscle fibers than does voluntary exercise at a comparable intensity **(23).**

Strengths and limitations:

The study uses in body analysis, a reliable method for determining body composition, but has limitations such as a small sample size, primarily involving patients with BMI between 30 and 35 kg/m2, and not investigating the precise process of body fat and visceral fat reduction, its health benefits, and longevity. Further research is needed to offer a more thorough explanation of the observed results.

Recommendations for further studies

The recommendations include further research on the impact of HIEMF on BMR, including its combination with other modalities, further examination of the effect of high intensity electromagnetic field on BMR, comparison of HIEMF's effects on different BMI and sexes, and the need for new studies to detect the effect of EMS on body composition. Additional research should be done to identify the long-term impact of HIEMF on abdominal obesity and weakness.

CONCLUSION

The study’s findings concluded that both HIEMF and EMS improved abdominal muscle strength and body composition in premenopausal women, with HIEMF showing greater effectiveness in reducing waist-hip ratio and enhancing overall body composition. So, it would be better in adding HIEMF in the treatment of abdominal muscle weakness and obesity. Overall, these results showed that EMS and HIFEM improved the abdominal area's aesthetic appearance and body composition improvement. In addition, they were easy to administer, had long-lasting efficacy without adverse reactions, high patient ratings, and good security and tolerability.

References

1. Koo S, Ahn Y, Lim JY, Cho J, Park HY. Obesity associates with vasomotor symptoms in postmenopause but with physical symptoms in perimenopause: a cross-sectional study. BMC women's health. 2017 Dec;17:1-8.
2. Rathnayake N, Lenora J, Alwis G, Lekamwasam S. Prevalence and severity of menopausal symptoms and the quality of life in middle-aged women: A study from Sri Lanka. Nurs Res Pract. 2019;2019(1):2081507.
3. Busso M, Denkova R. High-intensity focused electromagnetic (HIFEM)

field therapy used for non-invasive buttock augmentation and lifting: feasibility study. J Aesthet Reconstr Surg. 2019;5(1):2.

4. Cho HK, Jung GS, Kim EH, Cho YW, Kim SW, Ahn SH. The effects of neuromuscular electrical stimulation at different frequencies on the activations of deep abdominal stabilizing muscles. J Back Musculoskele Rehabil. 2016 Feb;29(1):183-9.
5. Jacob CI, Paskova K. Safety and efficacy of a novel high-intensity focused electromagnetic technology device for noninvasive abdominal body shaping. J Cosmet Dermatol. 2018 Oct;17(5):783-7.
6. Porcari JP, Miller J, Cornwell K, Foster C, Gibson M, McLean K, Kernozek T. The effects of neuromuscular electrical stimulation training on abdominal strength, endurance, and selected anthropometric measures. J Sports Sci Med. 2005 Mar 1;4(1):66.
7. Busso M, Denkova R. High-intensity focused electromagnetic (HIFEM) field therapy used for non-invasive buttock augmentation and lifting: feasibility study. J Aesthet Reconstr Surg. 2019;5(1):2.
8. Hwang UJ, Jung SH, Kim HA, Kim JH, Kwon OY. Effect of abdominal electrical muscle stimulation training with and without superimposed voluntary muscular contraction on lumbopelvic control. J Sport Rehabil. 2020 Jan 7;29(8):1137-44.
9. Lalingkar RA, Gosavi PM, Jagtap VK, Yadav TS. Effect of electrical stimulation followed by exercises in postnatal diastasis recti abdominis. Int J Health Sci Res. 2019 Mar;9(3):88-92.
10. Naqvi U, Margetis K, Sherman AL. Muscle Strength Grading. In: StatPearls. Treasure Island (FL): StatPearls Publishing; April 27, 2025.
11. McLester CN, Nickerson BS, KlisZczewicz BM and McLester JR. Reliability and agreement of various Inbody body composition analyzers as compared to Dual- energy X-ray absorptiometry in healthy men and women. PubMed. 2018; 23(3):443-450.
12. Millar SR, Perry IJ, Broeck JVD, Phillips CM. Optimal Central Obesity Measurement Site for Assessing Cardiometabolic and Type 2 Diabetes Risk in Middle-Aged Adults. PLoS

One.2015; 10(6): e0129088.

13. Dakanalis A, Mentzelou M, Papadopoulou SK, Papandreou D, Spanoudaki M, Vasios GK, Pavlidou E, Mantzorou M, Giaginis C. The association of emotional eating with overweight/obesity, depression, anxiety/stress, and dietary patterns: a review of the current clinical evidence. Nutrients. 2023 Feb 26;15(5):1173.
14. Katz BE. An overview of HIFEM technology in body contouring" Dermatol Rev. 2020;1(3):91-96.
15. Martínez SR, Ríos LJC, Tamayo IM, Almeida LG, López-Gomez MA, Jara CC. An After-School, high-intensity, electromagnetic therapy, and interval impoves health-related fitness in children. Mot. Rev. Educ. Física, 2016;22: 359–367.
16. Choi EJ, Kim YJ, Lee SY. Effects of electrical muscle stimulation on waist circumference in adults with abdominal obesity: A randomized, double-blind, sham-controlled trial. JNMA.2018 Dec 31;56(214):904.
17. Eijsbouts XH, Hopman MT, Skinner JS. Effect of electrical stimulation of leg muscles on physiological responses during arm-cranking exercise in healthy men. Eur J Appl Physiol Occup Physiol.1997 Jan;75(2):177-81.
18. Kinney BM, and Kent DE. MRI and CT assessment of abdominal tissue composition in patients after high-intensity focused electromagnetic therapy treatments: one-year follow-up. Aesthetic Surg J. 2020;40(12):NP686–NP693.
19. Heidekrueger PI, Juran S, Patel A, Tanna N, Broer PN. Plastic surgery statistics in the US: evidence and implications. Aesthetic Plast Surg. 2016 Apr;40:293-300.
20. Duncan D, Dinev I. Noninvasive induction of muscle fiber hypertrophy and hyperplasia: effects of high-intensity focused electromagnetic field evaluated in an in-vivo porcine model: a pilot study. Aesthetic Surg J. 2020 Apr 14;40(5):568-74.
21. Kinney BM, Lozanova P. High intensity focused electromagnetic therapy evaluated by magnetic resonance imaging: Safety and efficacy study of a dual tissue effect based non-invasive abdominal body shaping. Lasers Surg Med. 2019

Jan;51(1):40-6.

22. Porcari JP, Miller J, Cornwell K, Foster C, Gibson M, McLean K, Kernozek T. The effects of neuromuscular electrical stimulation training on abdominal strength, endurance, and selected anthropometric measures. J Sports Sci Med. 2005, 4(1):66-75.
23. Stevens-Lapsley JE, Balter JE, Wolfe P, Eckhoff DG, Kohrt WM. Early neuromuscular electrical stimulation to improve quadriceps muscle strength after total knee arthroplasty: a randomized controlled trial. Phys Ther. 2012, 92:210-26.