Effects of Microwave Technology on the Subcutaneous Abdominal Fat and Anthropometric Indices of Overweight Adults: A Clinical Trial

Article *in* Journal of Cosmetic Dermatology · May 2021

DOI: 10.1111/jocd.14245

11 authors, including:

Naseh Pahlavani
Mashhad University of Medical Sciences
54 PUBLICATIONS **171** CITATIONS

Elyas Nattagh-Eshtivani
Mashhad University of Medical Sciences
17 PUBLICATIONS **57** CITATIONS

Alireza Amanollahi
Shahid Beheshti University of Medical Sciences
14 PUBLICATIONS **54** CITATIONS

Golnaz Ranjbar
University of Hertfordshire
27 PUBLICATIONS **37** CITATIONS

Received: 4 March 2021 | Revised: 20 April 2021 | Accepted: 17 May 2021
DOI: 10.1111/jocd.14245

ORIGINAL CONTRIBUTIONS

JCD Journal of Cosmetic Dermatology WILEY

Effects of microwave technology on the subcutaneous abdominal fat and anthropometric indices of overweight adults: A clinical trial

Naseh Pahlavani PhD[1,2] | Elyas Nattagh-Eshtivani PhD candidate[3] | Alireza Amanollahi PhD candidate[4] | Golnaz Ranjbar PhD[3] | Hamid Asadzadeh Aghdaei MD[5] | Jamshid Gholizadeh Navashenaq PhD[6] | Zeinab Shabaninezhad MS[7] | Najibeh Razgardani Sharahi MS student[7] | Moona Maleki BS[7] | Mahsa Malekahmadi PhD[5] | Abdolreza Norouzy MD, PhD[3]

[1]Social Development and Health Promotion Research Center, Gonabad University of Medical Sciences, Gonabad, Iran
[2]Cellular and Molecular Research Center, Research Institute for Health Development, Kurdistan University of Medical Sciences, Sanandaj, Iran
[3]Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran
[4]Department of Epidemiology, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[5]Research Center for Gastroenterology and Liver Disease, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[6]Noncommunicable Diseases Research center, Bam University of Medical Sciences, Bam, Iran
[7]Behbood Research Center for Gastroenterology and Liver Diseases, Tehran, Iran

Correspondence
Abdolreza Norouzy, Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.
Email: NorouzyA@mums.ac.ir

Mahsa Malekahmadi, Research Center for Gastroenterology and Liver Disease, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
Email: Malekahmadimahsa@gmail.com

Funding information
This study was supported by the Artiman company

Abstract

Background and Objective: Non-invasive body contouring devices have fewer side effects and are the new techniques for the treatment of obesity. The present study aimed to evaluate the effects of microwave technology on the abdominal obesity and anthropometric indices of overweight adults.

Materials and Methods: This clinical trial was conducted on 53 overweight adults aged 18–65 years who referred to Behbood Clinic in Tehran, Iran. The participants were exposed to microwave technology (radiofrequency: 2.5 GHz) based on a standard treatment protocol at three intervals (0, 20, and 40 days). Abdominal obesity, body mass index, waist-to-hip ratio, body fat mass, and fat thickness were measured at the beginning and 20, 40, and 60 days after the study. In addition, three-day dietary records were collected at intervals.

Results: In total, 77.6% of the subjects were female and 22.4% were male. The mean calorie intake of the participants was 2245.14 ± 1981.16 kcal/day. Microwave shock significantly reduced fat thickness in four abdominal areas ($p < 0.001$). Moreover, waist circumference ($p < 0.001$) and total fat thickness of the abdomen decreased ($p = 0.003$ and $p = 0.002$, respectively).

Conclusion: According to the results, microwave technology and radiofrequency could effectively reduce anthropometric indices. In general, the reduction of these indicators and weight may be more significant in men compared to women.

KEYWORDS
microwave technology, radiofrequency, overweight, abdominal fat, anthropometry indices

1 | INTRODUCTION

Obesity and overweight are often caused by high-calorie intake (particularly through fatty and sugary foods) and are defined as the excessive and abnormal accumulation of fat in the body, which is associated with severe health risks. Overweight and obesity are also confirmed with the body mass index (BMI) of more than 25 and 30 kg/m^2, respectively.[1] Obesity is currently a major global health concern and is considered to be a chronic disease with a growing prevalence.[1,2] A study in this regard indicated that the prevalence of obesity among adults in the United States was 39% in 2016.[3] Although obesity used to be a health concern only in Western countries, lifestyle changes and diet modifications have increased its prevalence in other regions of the world, including Asia.[2] In the Iranian population, the prevalence of overweight and obesity was, respectively, 39.6% and 24%, and the obesity rate has been reported to be higher in women compared to men.[4]

Untreated obesity may lead to severe and potentially life-threatening disorders, such as coronary artery disease, stroke, and type II diabetes mellitus.[5-8] To date, several methods have been used for the prevention and treatment of obesity, such as increasing physical activity, dietary modification, behavioral therapy, pharmacotherapy (BMI of ≥27 kg/m^2 with comorbidities, BMI of >30 kg/m^2), and bariatric surgery (BMI of 35 kg/m^2 with comorbidities, BMI of >40 kg/m^2).[9,10] Increased localized fat in the abdomen and flanks is a form of obesity, which is caused by excessive calorie intake and a sedentary lifestyle and requires topical methods of obesity control.[11]

Today, the adoption of non-invasive methods with fewer side effects for obesity treatment and control has resulted in a new generation of non-invasive technologies to eliminate or decrease the accumulation of fat in the abdomen, thighs, and flanks.[12,13] Non-invasive body contouring devices are a popular area of cosmetic medicine and play a key role in the removal of the localized fat that cannot be eliminated by exercise and diet.[14]

Radiofrequency (RF) refers to the electromagnetic waves within the range of 3 kHz–10 GHz, which cause thermal energy and increase the cell temperature in the adipose tissue, thereby stimulating the process of apoptosis in the adipocytes. According to the literature, the increased temperature of the adipose cells to 50 degrees in vitro leads to the loss of 80% of the fat cells. A new RF technology used for lipolysis involves the use of microwave electromagnetic waves (2.5 GHz) as this wavelength is highly absorbable in the adipocytes owing to its dielectric properties.[15,16]

To the best of our knowledge, this study is the first research aimed at evaluating the effects of microwave technology on the abdominal obesity and anthropometric indices of overweight adults.

2 | MATERIALS AND METHODS

2.1 | Study design

This clinical trial has been registered in the Iranian Registry of Clinical Trials (No: IRCT20181010041303N1) and approved by the Ethics Committee. Written informed consent was obtained from the participants before enrollment.

2.2 | Subjects

In total, 53 overweight adults were selected via convenience sampling. The subjects were aged 18–65 years and referred to Behbood Nutrition Clinic in Tehran, Iran, during October-December 2020. The subjects were invited to the trial by a public ad and verbally informed on the research procedures and objectives at the clinic.

The inclusion criteria of the study were as follows: (a) BMI of <30 kg/m^2; (b) intra-abdominal fat volume of <12 kg; (c) no active cancers (chemotherapy/radiotherapy) within the past six months; (d) no non-invasive lipolysis of the abdomen or other parts of the body within the past three months; (e) no abdominal surgeries within the past six months; and (f) no history of liver cirrhosis and acute heart disease within the past six months.

2.3 | Measurements

Collected data included age, dietary intakes, anthropometric indices, medical history, education level, occupation status, and medication and supplement use. In addition, anthropometric data were collected on weight, height, waist-to-hip ratio (WHR), BMI, waist circumference, fat thickness, and body fat mass (BFM) at the beginning and 20, 40, and 60 days after the study.

Bodyweight was measured with no shoes and minimal clothing to the nearest 500 grams, and height was measured using a non-stretched tape measure without shoes. BMI was determined as weight (kg) divided by height (meters squared), and BFM was measured using the BC-418 Segmental Body Composition Analyzer (Tanita, Tokyo, Japan). In addition, the food frequency questionnaire (FFQ) was completed by the participants at baseline, the reliability and validity of which have been confirmed for the Iranian population.[17]

During the intervention, the participants adhered to an isocaloric diet based on their body weight. Subcutaneous abdominal fat was measured by ultrasound using a probe (7 MHz) in four areas, including the right upper quadrant (RUQ), right lower quadrant (RLQ), left lower quadrant (LLQ), and left upper quadrant (LUQ). Fat thickness was also measured in the abdominal area using the same device.

2.4 | Intervention

The participants received treatment based on a standard protocol of microwave technology (RF: 2.5 GHz) using an Onda device (Onda, DEKA Technology, Florence, Italy) in two sessions at 20-day intervals, including the beginning of the study, and 20 and 40 days after the study.

2.5 | Sample size

The sample size was determined based on the leptin level as proposed in the study by Arabpour et al.[18] In addition, we used the formula for estimating the mean quantitative trait in a population considering the test power of 80% and type I error of 5% (α = 0.05). The final sample size was calculated to be 45 subjects.

2.6 | Statistical analysis

Data analysis was performed in SPSS version 21 (SPSS, Inc.) using the Kolmogorov-Smirnov test to assess the normal distribution of the variables. To describe the participants, mean and standard deviation (SD) were applied for the continuous variables, while number and percentage were used for the qualitative variables. In addition, repeated measures analysis of variance (ANOVA) was employed to determine the effects of the intervention at different intervals on the participants with and without adjusted covariates.

3 | RESULTS

In total, 74 subjects were screened in the present study, and 53 subjects were selected based on the inclusion and exclusion criteria. At baseline, four subjects were excluded due to non-referral, and 49 subjects completed the trial. The mean age of the participants was 39.92 ± 7.06 years. Table 1 shows the demographic and baseline data of the subjects, including age, gender, education level, occupation status, calorie intake (2245.14 ± 1981.16 kcal/day), carbohydrate intake (262.55 ± 140.37 g/day), fat intake (99.21 ± 59.97 g/day), and protein intake (77.82 ± 51.65).

Table 2 shows the crude (unadjusted) and adjusted mean difference in the abdominal fat quadrants on days zero, 20, 40, and 60 of the study. Accordingly, the mean fat thickness in the four abdominal areas decreased during the four follow-up periods, which was considered significant in all the abdominal quadrants without and with adjustment (adjusted for age, gender, and calorie, carbohydrate, fat, and protein intake variables), confirming the effectiveness of the intervention.

The RUQ was significant before adjusting age (p > 0.001). Also after adjustment, it remains significant (p = 0.02). Decreasing in fat thickness during the study varied with the mean age of the subjects, while the reduced mean LUQ was not affected by other variables in this regard. Therefore, it could be inferred that the intervention and other variables had no significant effects on these data. After the adjustment of the variables for the RLQ, protein intake (p = 0.04) was considered significant as protein intake affected the fat thickness reduction in this area. After adjusting the differences in the LLQ area, the variables of age (p = 0.02) and protein intake (p = 0.03) remained significant (Table 2).

In the present study, the effects of microwave technology/RF were assessed on the anthropometric indices of the subjects, including fat thickness, weight, BFM, BMI, WHR, and waist circumference. According to the findings, RF significantly reduced the crude values of the anthropometric indices, while after adjustment for the effects of the confounding variables (age, gender, and calorie, carbohydrate, fat, and protein intake), the effects on weight, BFM, WHR, and BMI

TABLE 1 Demographic and baseline data of participants

Variable	Mean ± SD/N (%)
Age (year)	35.92 ± 7.06
Calorie Intake (kcal/day)	2245.14 ± 1981.16
Carbohydrate Intake (g/day)	262.55 ± 140.37
Fat Intake (g/day)	99.21 ± 59.97
Protein Intake (g/day)	77.82 ± 51.65
Gender	
Female	38 (77.6)
Male	11 (22.4)
Education Level (%)	
High School	14 (28.6)
Bachelor's Degree	23 (46.9)
Master's Degree (or higher)	12 (24.5)
Occupation Status (%)	
Unemployed	3 (6.1)
Employed	21 (42.9)
Self-employed	12 (24.5)
Housewife	13 (26.5)

were not considered significant. Therefore, it was concluded that the significant changes in the crude values were affected by the changes in the other variables, while with the adjusted effects of the covariates, the reduced values of fat thickness and waist circumference remained significant (Table 3).

According to our findings, gender had significant effects on the BFM, BMI, and WHR after adjustment. Table 4 shows the differences in the BFM, BMI, and WHR during the study based on the gender variables. As can be seen, the mean reduction in these variables in the male subjects was more significant compared to the women, so that the BFM in men was 24.95 at baseline and 21.32 at the end of the study, while it was estimated at 29.12 and 28.31, respectively, in women, indicating the more significant difference in the male subjects (3.63) compared to the females (0.81). In addition, BMI and WHR decreased in men more significantly than in women. At baseline and at the end of the follow-up, the differences in the BMI of men were determined to be 29.08 versus 27.01 and 0.96 versus 0.92 for the WHR. In women, the values were calculated to be 27.89 versus 27.47 for the BMI and 0.93 versus 0.91 for the WHR (Table 4). Therefore, it could be concluded that the reductive effects of RF were more significant in men compared to women.

4 | DISCUSSION

Microwave technology and RF are reliable and safe treatment approaches for fat removal. Non-invasive body contouring procedures have also attracted attention in this regard.[19-21] With an upward trend, non-invasive body contouring methods (especially among women) are frequently performed to enhance the physical shape and decrease local fat tissues.[22] These methods are based on various procedures, such as liposuction, RF waves, ultrasound wave

TABLE 2 Microwave technology/radiofrequency effects on abdominal quadrants (RUQ, LUQ, RLQ, and LLQ) during Study

Variables	Unadjusted (crude)			Adjusted	
		Mean ± SD	*p*-value	Covariate	*p*-value
RUQ (mm)	Day 0	30.51 ± 11.33	<0.001	Gender	0.38
	Day 20	24.24 ± 8.78		Age	0.02
	Day 40	20.54 ± 8.1		Calorie Intake	0.13
	Day 60	17.4 ± 6.19		Carbohydrate Intake	0.58
				Fat Intake	0.17
				Protein Intake	0.12
				RUQ	<0.001
LUQ (mm)	Day 0	29.79 ± 11.95	<0.001	Gender	0.21
	Day 20	24.22 ± 9.19		Age	0.19
	Day 40	20.98 ± 8.52		Calorie Intake	0.17
	Day 60	17.96 ± 6.77		Carbohydrate Intake	0.41
				Fat Intake	0.23
				Protein Intake	0.12
				LUQ	0.007
RLQ (mm)	Day 0	31.33 ± 11.56	<0.001	Gender	0.07
	Day 20	24.93 ± 8.73		Age	0.37
	Day 40	20.42 ± 6.95		Calorie Intake	0.26
	Day 60	17.79 ± 6.35		Carbohydrate Intake	0.32
				Fat Intake	0.18
				Protein Intake	0.04
				RLQ	0.003
LLQ (mm)	Day 0	32.09 ± 13.05	<0.001	Gender	0.61
	Day 20	24.84 ± 9.01		Age	0.02
	Day 40	20.51 ± 6.64		Calorie Intake	0.2
	Day 60	17.57 ± 5.35		Carbohydrate Intake	0.41
				Fat Intake	0.17
				Protein Intake	0.03
				LLQ	<0.001

Abbreviations: LLQ, left lower quadrant; LUQ, left upper quadrant; RLQ, right lower quadrant; RUQ, right upper quadrant.

cryogenic methods, and laser treatment.[23,24] In the current research, the microwave technology/RF had a significant reductive effect on the crude values of the anthropometric indices (fat thickness, weight, BFM, BMI, WHR, and waist circumference).

Several studies have shown the effects of RF on the reduction of local fat deposits.[25,26] Pumperla et al. investigated the effects of RF treatment on metabolic parameters and anthropometric indices, reporting significant associations with the reduction of the abdominal circumference after four sessions of RF treatment.[26] Furthermore, Mohammadzade et al. conducted a clinical trial to evaluate the combined effects of RF and ultrasound technology along with a low-calorie diet compared to a low-calorie diet alone on the measures of adiposity. According to the results of the mentioned study, adiposity decreased significantly in the women receiving a combination of the low-calorie diet, RF, and ultrasound cavitation.[25] In another study, Winter performed a prospective self-controlled study and observed a reduction in circumference, and skin laxity improvement could also be effectively achieved using a combination of RF, infrared, and mechanical manipulation.[27] Our findings are consistent with the results obtained by Qin et al., which indicated that non-invasive and contactless selective RF methods were effective and safe in the reduction of fat, BMI, and abdominal circumference.[28]

Fajkošová et al. reported that a selective RF system is a painless, safe, and effective treatment for body contouring and circumferential fat.[29] Several other studies have also confirmed the effectiveness of RF as a non-invasive technique in the reduction of subcutaneous fat in the thighs and buttocks.[15,21,30,31] The proposed mechanism for the therapeutic effects of RF involves an increment in the local blood flow supply to the adipose tissue.[32] Moreover, it seems that elevated tissue temperature activates the autonomic nervous system, thereby leading to the release of catecholamines. These hormones trigger the activation of lipolysis. Simultaneously, the heated adipose tissue directly causes the vasodilatation phenomenon, which increases perfusion and tissue oxygenation.[33] With improved blood perfusion, the flow of catecholamines affects lipolysis more significantly.[26,34] Therefore, oxidation and lipid turnover improve, and the adipocyte cell volume decreases.[35]

Clinical evidence attests to the significant increase of the apoptotic index in the adipose tissue, which could be justified by the use of non-invasive RF device treatments.[36,37] Apoptosis is defined as programmed cell death,[38] which leads to cell corruption and removal. RF may decrease the adipocytes in number rather than size.[39] Due to the higher production of estrogen in women, it could also increase the

TABLE 3 Microwave technology/radiofrequency effects on anthropometric indices during study

	Unadjusted (Crude)			Adjusted	
		Mean±SD	*p*-value	Covariate	*p*-value
Waist Circumference (cm)	Day 0	98.55 ± 8.54	<0.001	Gender	0.27
	Day 20	95.46 ± 7.78		Age	0.38
	Day 40	93.37 ± 7.65		Calorie Intake	0.75
	Day 60	92.04 ± 7.59		Carbohydrate Intake	0.11
				Fat Intake	0.85
				Protein Intake	0.5
				Waist Circumference	0.003
Fat Thickness (mm)	Day 0	37.63 ± 9.35	<0.001	Gender	0.43
	Day 20	31.99 ± 7.7		Age	0.49
	Day 40	28.49 ± 7.21		Calorie Intake	0.66
	Day 606	25.54 ± 7.63		Carbohydrate Intake	0.86
				Fat Intake	0.71
				Protein Intake	0.66
				Fat Thickness	0.002
Weight (kg)	Day 0	78.13 ± 11.37	0.001	Gender	0.13
	Day 20	76.98 ± 10.7		Age	0.57
	Day 40	76.33 ± 10.55		Calorie Intake	0.21
	Day 60	75.68 ± 10.07		Carbohydrate Intake	0.67
				Fat Intake	0.21
				Protein Intake	0.63
				Weight	0.31
BFM (%)	Day 0	28.2 ± 6.36	<0.001	Gender	0.009
	Day 20	27.14 ± 6.23		Age	0.8
	Day 40	26.63 ± 6.31		Calorie Intake	0.29
	Day 60	26.78 ± 6.78		Carbohydrate Intake	0.34
				Fat Intake	0.42
				Protein Intake	0.65
				BFM	0.65
BMI (kg/m^2)	Day 0	28.07 ± 2.15	0.001	Gender	0.001
	Day 20	27.67 ± 2.09		Age	0.56
	Day 40	27.32 ± 2.32		Calorie Intake	0.005
	Day 60	27.28 ± 2.23		Carbohydrate Intake	0.09
				Fat Intake	0.01
				Protein Intake	0.59
				BMI	0.24
WHR	Day 0	0.95 ± 0.06	<0.001	Gender	0.01
	Day 20	0.93 ± 0.05		Age	0.6
	Day 40	0.92 ± 0.05		Calorie Intake	0.37
	Day 60	0.91 ± 0.05		Carbohydrate Intake	0.64
				Fat Intake	0.6
				Protein Intake	0.58
				WHR	0.63

Abbreviations: BFM, body fat mass; BMI, body mass index; WHR, waist-to-hip ratio.

TABLE 4 Differences in BFM, BMI, and WHR during Study Based on Gender

Day	BFM (%)		BMI (kg/m^2)		WHR	
0	Male	24.95 ± 6.73	Male	29.08 ± 1.47	Male	0.96 ± 0.07
	Female	29.12 ± 5.96	Female	27.89 ± 2.20	Female	0.93 ± 0.04
20	Male	22.56 ± 5.57	Male	28.29 ± 1.18	Male	0.94 ± 0.07
	Female	28.45 ± 5.75	Female	27.59 ± 2.19	Female	0.93 ± 0.05
40	Male	21.38 ± 5.13	Male	27.12 ± 2.36	Male	0.93 ± 0.06
	Female	28.06 ± 5.82	Female	27.46 ± 2.31	Female	0.92 ± 0.05
60	Male	21.32 ± 4.94	Male	27.01 ± 2.05	Male	0.92 ± 0.07
	Female	28.31 ± 6.50	Female	27.47 ± 2.25	Female	0.91 ± 0.05

concentrations of alpha-2 adrenergic receptors, thereby complicating the lipolytic process.[40]

4.1 | Limitations of the study

The limitations of our study were the small sample size, lack of extended follow-up evaluations, and lack of proper control groups.

5 | CONCLUSION

According to the results, microwave technology/RF had a significant reductive effect on the crude values of the anthropometric indices. Therefore, RF is considered a safe and effective procedure for the improvement of skin appearance and reduction of subcutaneous fat.

ACKNOWLEDGMENTS

The authors take thankful pleasure in acknowledging the unsparing assistance of all participants.

CONFLICT OF INTEREST

There are no conflicts of interest.

AUTHOR CONTRIBUTIONS

The authors' responsibilities were as follows. MM, HAA, and AN designed the trial; NP and ENE wrote the manuscript; AA analyzed data and designed tables; ZS, NRS, and MM participated in the conducting intervention; JGN, GR, and MM editing of the manuscript. All authors read and approved the final manuscript.

ETHICAL APPROVAL

Central ethical approval has been confirmed from the Research Ethics Committees of the Mashhad University of medical sciences (registration No. IR.MUMS.MEDICAL.REC.1399.444). All study procedures were in accordance with the ethical standards of the Declaration of Helsinki. Informed consent was obtained from all study participants and their guardians.

TRIAL REGISTRATION

This clinical trial has been registered in the Iranian Registry of Clinical Trials (IRCT; www.irct.ir; No. IRCT20181010041303N1).

CONSENT FOR PUBLICATION

Not applicable.

DATA AVAILABILITY STATEMENT

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

ORCID

Mahsa Malekahmadi https://orcid.org/0000-0002-6707-6929

REFERENCES

1. Engin A. The definition and prevalence of obesity and metabolic syndrome. Obesity and lipotoxicity: Springer; 2017:1-17.
2. Fan J-G, Kim S-U, Wong VW-S. New trends on obesity and NAFLD in Asia. *J Hepatol*. 2017;67(4):862-873.
3. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity among adults and youth: United States. 2015–2016. 2017.
4. Tabrizi JS, Sadeghi-Bazargani H, Farahbakhsh M, Nikniaz L, Nikniaz Z. Prevalence and associated factors of overweight or obesity and abdominal obesity in Iranian population: a population-based study of northwestern Iran. *Iran J Public Health*. 2018;47(10):1583.
5. Perry RJ, Shulman GI. Mechanistic links between obesity, insulin, and cancer. *Trends Cancer*. 2020;6(2):75-78.
6. Riaz H, Khan MS, Siddiqi TJ, et al. Association between obesity and cardiovascular outcomes: a systematic review and meta-analysis of Mendelian randomization studies. *JAMA Network Open*. 2018;1(7):e183788.
7. Pahlavani N, Sadeghi A, Rasad H, Azizi SF. Relation of inflammation and oxidative stress with blood glucose, lipids and BMI, fat mass and body weight in people with type 2 diabetes. *J Zabol Diabetic Nurs*. 2014;2(2):42-51.
8. Pahlavani N, Sedaghat A, Moghaddam AB, et al. Effects of propolis and melatonin on oxidative stress, inflammation, and clinical status in patients with primary sepsis: Study protocol and review on previous studies. *Clin Nutr ESPEN*. 2019;33:125-131.
9. Schutz DD, Busetto L, Dicker D, et al. European practical and patient-centred guidelines for adult obesity management in primary care. *Obesity Facts*. 2019;12(1):40-66.
10. Wadden TA, Tronieri JS, Butryn ML. Lifestyle modification approaches for the treatment of obesity in adults. *Am Psychologist*. 2020;75(2):235.
11. Branford O. Liposuction and body contouring. *J Aesthet Nurs*. 2018;7(4):208-211.
12. Zendejas GH, Reavie DW, Azabache R, Guerrerosantos J. Lipoplasty combined with percutaneous radiofrequency dermaplasty: a new strategy for body contouring. *Aesthet Plast Surg*. 2020;44(2):455-463.
13. Suh DH, Kim CM, Lee SJ, Kim H, Yeom SK, Ryu HJ. Safety and efficacy of a non-contact radiofrequency device for body contouring in Asians. *J Cosmet Laser Ther*. 2017;19(2):89-92.
14. Mazzoni D, Lin MJ, Dubin DP, Khorasani H. Review of non-invasive body contouring devices for fat reduction, skin tightening and muscle definition. *Australas J Dermatol*. 2019;60(4):278-283.
15. Franco W, Kothare A, Ronan SJ, Grekin RC, McCalmont TH. Hyperthermic injury to adipocyte cells by selective heating of subcutaneous fat with a novel radiofrequency device: feasibility studies. *Lasers Surg Med*. 2010;42(5):361-370.
16. Paul M, Mulholland RS. A new approach for adipose tissue treatment and body contouring using radiofrequency-assisted liposuction. *Aesthet Plast Surg*. 2009;33(5):687-694.
17. Ghazizahedi S, Nouri M, Norouzy A, et al. Scientific: validity and reproducibility of Iranian food frequency questionnaire. 2014.
18. Arabpour-Dahoue M, Mohammadzadeh E, Avan A, et al. Leptin level decreases after treatment with the combination of radiofrequency and ultrasound cavitation in response to the reduction in adiposity. *Diabetes Metabolic Syndrome Clin Res Rev*. 2019;13(2):1137-1140.
19. Caruso-Davis MK, Guillot TS, Podichetty VK, et al. Efficacy of low-level laser therapy for body contouring and spot fat reduction. *Obes Surg*. 2011;21(6):722-729.
20. Mulholland RS, Paul MD, Chalfoun C. Noninvasive body contouring with radiofrequency, ultrasound, cryolipolysis, and low-level laser therapy. *Clin Plast Surg*. 2011;38(3):503-520.
21. Kennedy J, Verne S, Griffith R, Falto-Aizpurua L, Nouri K. Non-invasive subcutaneous fat reduction: a review. *J Eur Acad Dermatol Venereol*. 2015;29(9):1679-1688.

22. Afrooz PN, Pozner JN, DiBernardo BE. Noninvasive and minimally invasive techniques in body contouring. *Clin Plast Surg*. 2014;41(4):789-804.
23. Esteghamati A, Mazaheri T, Rad MV, Noshad S. Complementary and alternative medicine for the treatment of obesity: a critical review. *Int J Endocrinol Metab*. 2015;13(2).
24. Hainer V, Toplak H, Mitrakou A. Treatment modalities of obesity: what fits whom? *Diabetes Care*. 2008;31(Suppl 2):S269-S277.
25. Mohammadzadeh M, Nasrfard S, Nezafati P, et al. Reduction in measures of adiposity using a combination of radio frequency and ultrasound cavitation methods. *Eur J Integrat Med*. 2016;8(3):313-316.
26. Pumprla J, Howorka K, Kolackova Z, Sovova E. Non-contact radiofrequency-induced reduction of subcutaneous abdominal fat correlates with initial cardiovascular autonomic balance and fat tissue hormones: safety analysis. *F1000Res*. 2015;4:49.
27. Winter ML. Post-pregnancy body contouring using a combined radiofrequency, infrared light and tissue manipulation device. *J Cosmet Laser Ther*. 2009;11(4):229-235.
28. Qin J, Me G, Xu XG, et al. A clinical evaluation of noninvasive and contactless radiofrequency technique in the treatment of abdominal fat.
29. Fajkošová K, Machovcová A, Onder M, Fritz K. Selective radiofrequency therapy as a non-invasive approach for contactless body contouring and circumferential reduction. *J Drugs Dermatol*. 2014;13(3):291-296.
30. Manuskiatti W, Wachirakaphan C, Lektrakul N, Varothai S. Circumference reduction and cellulite treatment with a TriPollar radiofrequency device: a pilot study. *J Eur Acad Dermatol Venereol*. 2009;23(7):820-827.
31. del Pino EM, Rosado RH, Azuela A, et al. Effect of controlled volumetric tissue heating with radiofrequency on cellulite and the subcutaneous tissue of the buttocks and thighs. *J Drugs Dermatol*. 2006;5(8):714-722.
32. Sadick NS, Mulholland RS. A prospective clinical study to evaluate the efficacy and safety of cellulite treatment using the combination of optical and RF energies for subcutaneous tissue heating. *J Cosmet Laser Ther*. 2004;6(4):187-190.
33. Vale AL, Pereira AS, Morais A, et al. Effects of radiofrequency on adipose tissue: A systematic review with meta-analysis. *J Cosmet Dermatol*. 2018;17(5):703-711.
34. Belenky I, Margulis A, Elman M, Bar-Yosef U, Paun SD. Exploring channeling optimized radiofrequency energy: a review of radiofrequency history and applications in esthetic fields. *Adv Ther*. 2012;29(3):249-266.
35. Mulholland RS, Paul MD, Chalfoun C. Noninvasive body contouring with radiofrequency, ultrasound, cryolipolysis, and low-level laser therapy. *Clin Plast Surg*. 2011;38(3):503-520.
36. McDaniel D, Lozanova P. Human adipocyte apoptosis immediately following high frequency focused field radio frequency: case study. *J Drugs Dermatol*. 2015;14(6):622-623.
37. Weiss R, Weiss M, Beasley K, Vrba J, Bernardy J. Operator independent focused high frequency ism band for fat reduction: porcine model. *Lasers Surg Med*. 2013;45(4):235-239.
38. Green DR. *Means to an end: Apoptosis and other cell death mechanisms*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press; 2011.
39. Zhang YU, Huang C. Targeting adipocyte apoptosis: A novel strategy for obesity therapy. *Biochem Biophys Res Commun*. 2012;417(1):1-4.
40. McDaniel D, Samková P. Evaluation of the safety and efficacy of a non-contact radiofrequency device for the improvement in contour and circumferential reduction of the inner and outer thigh. *J Drugs Dermatol*. 2015;14(12):1422-1424.

How to cite this article: Pahlavani N, Nattagh-Eshtivani E, Amanollahi A, et al. Effects of microwave technology on the subcutaneous abdominal fat and anthropometric indices of overweight adults: A clinical trial. *J Cosmet Dermatol*. 2021;00:1–7. https://doi.org/10.1111/jocd.14245