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RESEARCH ARTICLE

Effects of microcurrent therapy combined with High-Intensity Interval Training on the reduction of localized abdominal adiposity: a randomized clinical trial

Raciele I. G. Korelo, Aline Pesaski, Nandara L. dos Santos, Natalia de P. da Silva, Rubia Alana S. dos Anjos, Ana Carolina B. de Macedo, Rubneide B. S. Gallo, Audrin S. Vojciechowski.

Center for Studies in Physiotherapy and Advanced Technological Innovations (CEFITA); Department of Prevention and Rehabilitation in Physiotherapy, Federal University of Paraná (UFPR), Paraná, Brazil.

ABSTRACT:

Background: The combination of aerobic exercise and transcutaneous microcurrent application (Microcurrent Electrical Stimulation - MES) was shown to have a positive effect on localized abdominal adiposity(LAA) reduction. However, the effect of the combination of MES and high-intensity interval training (HIIT) is still unknown. **Objective:** This study aimed to evaluate the effect combination of MES and HIIT on LAA reduction. **Methods:** 39 sedentary women with LAA, distributed in a Control Group (CG), an Exercise Group (EG), and a Microcurrent plus Exercise Group (MEG) participated in this randomized clinical trial. The CG was not submitted to intervention. The EG was submitted to a HIIT protocol (80% of Heart Rate max in a functional circuit) and MEG was submitted to abdominal transcutaneous application of MES prior to HIIT, 2x/week, during 5 weeks. The outcomes were collected by a blind evaluator and measured in three moments (before the 1st intervention, and after the 5th and 10th intervention), based on body composition parameters, anthropometric data, physical activity level (PAL), body satisfaction, quality of life (QoL), and lumbar functionality. **Results:** After 10 interventions, MEG showed significant improvement in skinfolds, QoL, and body satisfaction, but no significant difference compared to EG or CG. Regarding PAL, MEG differed significantly in relation to CG, but not in relation to EG. **Conclusion:** The combination of MES and HIIT in 10 interventions did not show satisfactory results for LAA reduction compared to HIIT, but the increase in PAL and the improvement in lumbar functionality may provide positive effects in the medium-term, although further studies are required.

Keywords: Abdominal fat; high intensity interval training; electrical stimulation therapy; randomized controlled trial.

Corresponding author: Raciele Ivandra Guarda Korelo
E-mail: raciele@ufpr.br

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BACKGROUND

Women's search for aesthetic treatments, as a means to fit into society's beauty standards, has become increasingly more common. Localized abdominal adiposity (LAA) is one of the most frequent complaints in dermato-functional physiotherapy clinics[1]. Repercussions of LAA transcend aesthetical aspects since it represents a health risk factor for cardiovascular diseases, diabetes, and metabolic syndrome[2].

Liposuction is an effective procedure to reduce LAA. However, patients are reluctant to undergo this procedure due to postoperative complications, such as pain and long recovery. This has motivated researchers to develop non-invasive alternatives for this situation, such as cryolipolysis, radiofrequency (RF), non-invasive lasers, high-intensity focused ultrasound (HIFU), and even excitatory currents that perform electrical lipolysis[3]. Microcurrent (MES - Microcurrent Electrical Stimulation) is a electrostimulation current that can be used transcutaneously in order to provide electrolysis, using low frequency parameters and an intensity in the range of

microamperes that acts directly on the adipocytes, breaking them and favoring their subsequent eliminatio[4].

Due to its low current intensity, the increase in temperature provided by the passage of the current in biological tissues (Joule effect) does not reach the organic tissue, yet it is enough to cause vasodilation and increase the blood flow in the region. This stimulates local cellular metabolism, favors metabolic exchanges, and facilitates calorie burning.[4] Stimulation of the sympathetic nervous system also activates lipolysis through triglyceride lipase, breaking triglycerides into fatty acids and glycerol. These fatty acids are then released into the blood and can be used as an energy substrate.[5] However, the elimination of fatty acids occurs through negative energy balance, that is, it is necessary to consume these energy-rich substrates through physical exercise performed after the current application. Otherwise, these fatty acids are recaptured and recombined with glycerol, re-forming triacylglycerols that accumulate again into fat[5].

HIIT is a short-term training method consisting of brief periods of intense activity, with active or less vigorous rest intervals. This method is an effective alternative when compared to other physical exercises due to high adherence rates and its lower volume and duration, saving time and bringing equal or better results[6]. Both HIIT and lipolysis are powerful resources to reduce local fat, but, as described and justified in the protocol previously published by our study group[7], the possible advantage of incorporating MES before a session of HIIT would be to promote a cumulative effect on the mobilization of the adipose panicle, increasing its bioavailability as an energy source, in a protocol that includes a shorter time of physical exercise practice. However, the lack of research on the use of MES for electrolipolysis hinders the establishment of an adequate protocol and implies uncertainty on which electrical parameters must be used. Although the relationship between MES and HIIT has yet to be studied, previous studies have demonstrated that moderate intensity aerobic exercise combined with MES has an effect in cardiopathic[8] and overweight individuals[9], which has been shown to be beneficial in reducing LAA.

Thus, the main objective of this randomized clinical trial was to evaluate the effect of the combination of MES and HIIT on the reduction of LAA in sedentary adult women. In addition, we intended to verify whether there was an improvement in quality of life (QoL), body satisfaction, and pelvic-lumbar compound muscle function. The hypothesis of this study was that the combined use of MES and HIIT for 5 weeks, twice a week, would be sufficient to reduce LAA and its related body measurements.

MATERIALS AND METHODS

Study Design and research methods

The study consisted of a randomized clinical trial, approved by the Research Ethics Committee of the Faculty of Health Sciences of the Federal University of Paraná (CAAE: 55963816.2.0000.0102) and registered in the Brazilian Registry of Clinical Trials (RBR-96sw76). All participants signed a Free and Informed Consent Form (FICF) and an authorization for image use. Data collection was performed in the Physical Therapy Laboratory of the Federal University of Paraná (UFPR) and was based and was based on the study protocol published by Korelo et al.[7].

Participants

We used an electronic brochure published on social networks for the recruitment of participants. The inclusion criteria were sedentary women, aged between 18 and 40 years old, with LAA (subcutaneous adipose tissue thickness of the abdominal wall greater than 15 mm[10] measured by adipometry, using as a reference point 2 cm from the right side of the umbilical scar)[11].

The exclusion criteria were being on a diet; smoking and alcoholism; use of medication for weight loss, corticoids, progesterone and diuretics; being pregnant or puerperal for less than one year; having electronic monitoring or metallic implants in the pelvic region; being under dermato-functional treatment for the abdominal region; having undergone surgery or radiotherapy less than 6 months ago in the abdominal/pelvic region; carriers of lymphatic or cardiovascular system diseases, thrombophlebitis, acute infection, central nervous system diseases, tumors, and diabetes.

Measurements

Primary outcomes

The primary analyzed outcomes and their respective instruments were 1) body composition, measured by bioimpedance and adipometry; 2) anthropometric measures, measured by perimetry.

Secondary outcomes

The secondary analyzed outcomes and their respective instruments were 1) physical activity level (PAL), measured by the short version of the International Physical Activity Questionnaire (IPAQ)[12]; 2) effects of weight on quality of life (QoL), estimated by the IWQoL-Lite questionnaire (short version); 3) body satisfaction, measured by the Pulver's Figure Rating Scale[13]; 4) evaluation of lumbar functionality of trunk flexors and extensors, lateral trunk flexors, and lumbar pelvic conditioning as proposed by Peña et al.[14]; 5) and degree of satisfaction with the performance of the adapted intervention.

Changes in outcomes

Over the course of the study, changes in outcomes translated into an adaptation of methodology, taking into account the number of active participants in each study group, due to difficulties related to the time required for intervention and re-evaluation. Thus, randomization by convenience had to be performed for data analysis, which diverges from the initial block randomization proposed in the protocol[7].

Interventions

The evaluations were conducted at 3 moments by a blind evaluator, using a pre-structured form: before the 1st intervention (T0), after the 5th intervention (T1), and after the 10th intervention (T2). After T0, the participants were randomized by convenience into 3 groups and were instructed not to modify their daily routine during the course of the study. The participants allocated to the Exercise Group (EG) and Microcurrent + Exercise Group (MEG) were submitted to interventions twice a week, with a minimum interval of 48 hours, during a 5-week treatment period, totaling 10 interventions.

Exercise protocol (HIIT circuit)

The EG was submitted to a HIIT protocol of 30 minutes. Exercise intensity was monitored using a Polar heart rate monitor (above 80% of HRmax).

MES application protocol

Parameters were used in this study frequency of 25Hz in the first 15 minutes, changing to 10Hz in the remaining 15 minutes, with maximum intensity (500μA) or sub sensorial level, before the realization of the same HIIT circuit performed by the EG[7].

Control

Control Group (CG) did not receive any intervention and participated only in the 3 evaluations (T0, T1, and T2).

Sample Calculation and Statistical Analysis

The sample calculation considered the lean mass measured by bioimpedance and was based on the study published by Noites et al.[8], which found an increased lean mass in female participants aged 18-30 years after transcutaneous application of MES. The sample size was calculated using the G*Power 3.1.9 software, with an effect size of 0.2; significance level of 0.05 (type I error); and sample power of 0.80. According to this calculation, 54 participants would be required, 18 in each group. However, considering possible sample losses, this number was increased by 10% of the total to maximize effect size, resulting in 60 participants, 20 in each group.

Statistical analyses were performed by a blind evaluator, using the Statistical Package for the Social Sciences (SPSS) software, version 22.0 for Windows®. Numerical data were described by mean ± standard deviation, and categorical data in frequency and percentage. The normality of the participants' clinical and demographic characteristics was tested by the Kolmogorov-Smirnov or Chi-square test. Variable analysis followed intention-to-treat principles. Categorical data were submitted to Pearson's chi-square test to analyze differences between groups. The effect size was determined by Cramer's V, with values smaller than 0.10 considered as a negligible effect, between 0.10 to 0.20 as a weak effect, between 0.20 and 0.40 as a moderate effect, between 0.40 and 0.50 as a relatively strong effect, between 0.60 and 0.80 as a strong effect, and values between 0.80 and 1.0 as a very strong effect[15].

Numerical data were submitted to analysis of variance sphericity and homogeneity, using Mauchly and Levene's test, respectively. The difference between groups was calculated using a mixed ANOVA test, with repeated measures, with a 3 (treatment group: control vs. exercise vs. MES and exercise) x 3 (pre-intervention outcome variables vs. 5 applications vs. 10 applications) design. Bonferroni post-hoc were used for comparisons in the interaction model between groups vs. time.

The confidence interval was set at 95% for all analyses. Values of $p<0.05$ indicate statistical significance. The effect size was determined by Hedges'g[16], which considers a value less than 0.19 as a insignificant effect, between 0.20 and 0.49 as a small effect, between 0.50 and 0.79 as a moderate effect, between 0.80 and 1.29 as a large effect, and above 1.30 as a very large effect.

RESULTS

A total of 167 women with LAA were recruited and 150 underwent T0. Sixty nine of these had exclusion factors, so only 81 were randomized by convenience into the three study groups. Despite the initial number of participants, only 39 completed the intervention protocol, with a higher percentage of discontinuation in the EG. The process of identifying studies was presented in Figure 1.

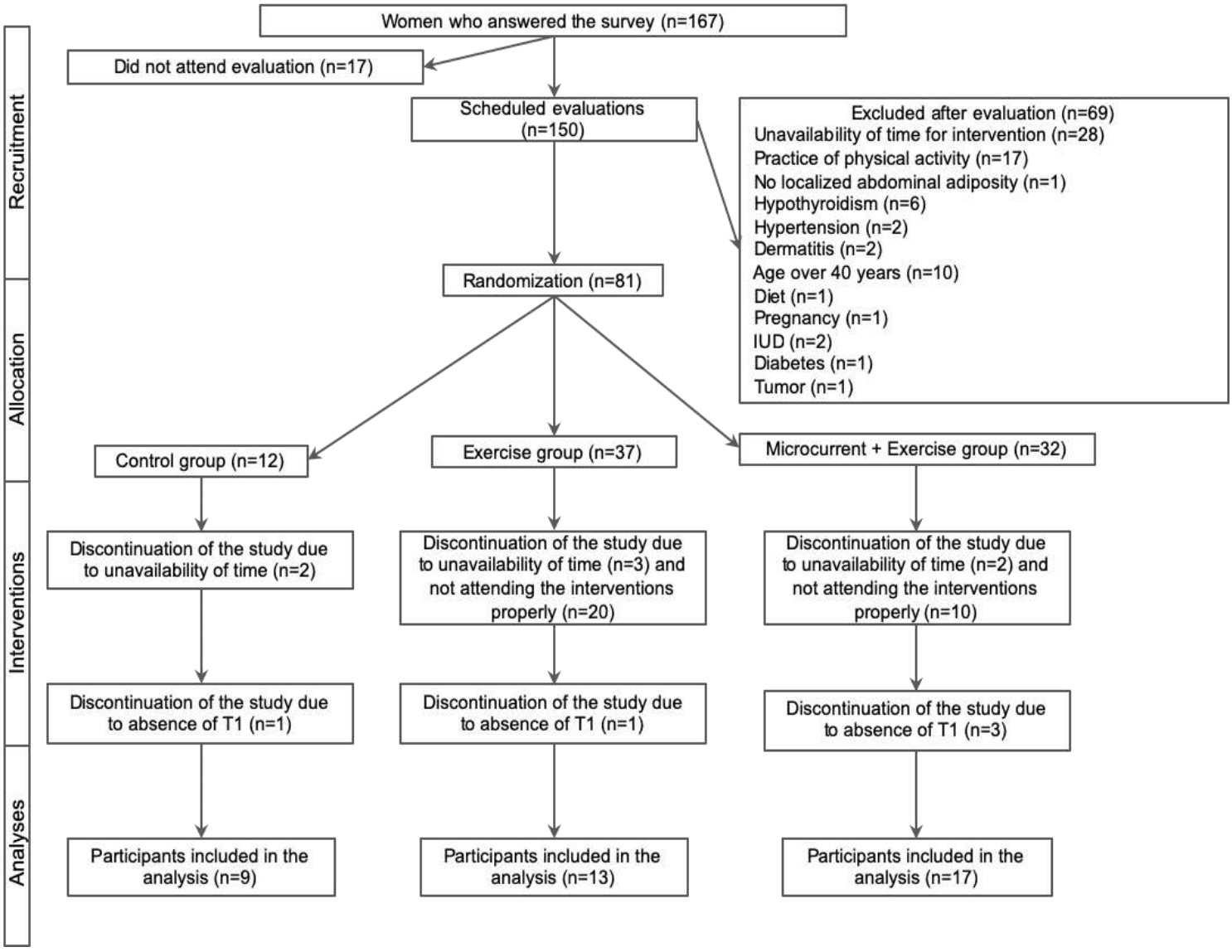

Figure 1. CONSORT flowchart

On average, the intervention protocol was not able to modify body composition or anthropometric measurements. However, as displayed in Table 1, MEG showed, at T2, a decrease of the skinfolds in the axillary line (p=0.041, 95%CI [3.1:0.1;6.2]), suprailiac (p=0.047, 95%CI [4.6:0.04;9.3]) and especially in the abdominal area (p=0.001, 95%CI [6.0:2.2;9.7]); an increase in lean mass (p=0.025, 95%CI [1.5:0.1;2.9]), and a decrease in excess fat (p=0.002, 95%CI [2.2:0.7;3.7]) and fat percentage, calculated according to Faulkner (p=0.05, 95%CI [2.2:0.5;3.9]). These differences, however, were not statistically significant (p>0.05) when compared to CG or EG.

Table 1. Adipometry and fat percentage (mean ± SD) of the study participants, measured before intervention, after 5, and after 10 interventions, and adjusted by the difference of means between groups.

Variables	CG (n=9)	EG (n=13)	MEG (n=17)	CG x EG (95% CI)	CG x MEG (95% CI)	EG x MEG (95% CI)
Triceps (mm)						
Pre-intervention	30.6 (3.1)	28.6 (2.6)	30.7 (2.3)	2.0 (-8.3 to 12.3)	0.1 (-9.7 to 9.8)	2.0 (-6.6 to 10.8)
5 interventions	29.7 (2.9)	25.4 (2.4)	30.5 (2.1)	4.2 (-5.3 to 13.7)	0.8 (-8.2 to 9.9)	5.0 (-3.0 to 13.1)
10 interventions	28.7 (3.0)	26.1 (2.5)	29.5 (2.2)	2.5 (-7.5 to 12.7)	0.7 (-8.8 to 10.3)	3.3 (-5.1 to 11.9)
Axillary line (mm)						
Pre-intervention	26.5 (3.4)	22.8 (2.8)	29.2 (2.4)	3.6 (-7.5 to 14.7)	2.7 (-7.8 to 13.3)	6.3 (-3.1 to 15.8)
5 interventions	26.2 (3.4)	21.7 (2.8)	27.9 (2.4)	4.4 (-6.6 to 15.5)	1.7 (-8.8 to 12.3)	6.2 (-3.2 to 15.6)
10 interventions	26.4 (2.9)	21.3 (2.4)	26.0 (2.1)*	5.1 (-4.4 to 14.6)	0.3 (-8.6 to 9.4)	4.7 (-3.3 to 12.8)
Suprailiac (mm)						
Pre-intervention	37.2 (3.5)	33.4 (2.9)	40.8 (2.5)	3.8 (-7.8 to 15.4)	3.6 (-7.3 to 14.6)	7.4 (-2.4 to 17.3)
5 interventions	36.2 (3.4)	32.2 (2.8)	36.5 (2.5)*	4.0 (-7.2 to 15.3)	0.3 (-10.4 to 11.0)	4.3 (-5.2 to 13.9)
10 interventions	37.1 (3.3)	32.6 (2.7)	36.1 (2.4)*	4.4 (-6.4 to 15.3)	0.9 (-9.3 to 11.3)	3.4 (-5.7 to 12.7)
Abdominal (mm)						
Pre-intervention	40.7 (3.7)	39.4 (3.3)	44.7 (2.8)	2.4 (-10.5 to 15.3)	2.8 (-9.4 to 15.2)	5.2 (-5.7 for 16.3)
5 interventions	41.8 (3.6)	38.7 (3.0)	42.7 (2.6)	2.1 (-9.9 to 14.1)	1.8 (-9.5 to 13.3)	3.9 (-6.2 to 14.2)
10 interventions	40.4 (3.2)	37.0 (2.5)	38.7 (2.3)*	1.2 (-8.9 to 11.4)	0.3 (-9.3 to 10.0)	1.6 (-7.0 to 10.3)
Thigh (mm)						
Pre-intervention	42.8 (3.7)	49.6 (3.1)	51.4 (2.7)	6.7 (-5.6 to 19.0)	8.5 (-3.1 to 20.2)	1.8 (-8.6 to 12.3)
5 interventions	39.4 (3.2)	48.5 (2.7)	48.7 (2.3)	9.1 (-1.5 to 19.8)	9.3 (-0.8 to 19.5)	0.2 (-8.8 to 9.3)
10 interventions	40.5 (3.6)	43.3 (3.0)*	47.5 (2.6)	2.8 (-8.9 to 14.6)	7.0 (-4.1 to 18.2)	4.1 (-5.8 to 14.1)
Faulkner % fat						
Pre-intervention	27.7 (2.0)	26.5 (1.6)	29.5 (1.4)	1.1 (-5.5 to 7.8)	1.7 (-4.5 to 8.1)	2.9 (-2.7 to 8.5)
5 interventions	26.9 (1.9)	25.7 (1.6)	28.3 (1.4)	1.1 (-5.2 to 7.6)	1.4 (-4.7 to 7.5)	2.5 (-2.9 to 8.0)
10 interventions	26.7 (1.8)	24.3 (1.5)*	27.2 (1.3)*	2.3 (-3.6 to 8.3)	0.5 (-5.1 to 6.2)	2.8 (-2.2 to 7.9)
% fat surplus						
Pre-intervention	11.8 (2.0)	10.8 (1.6)	13.6 (1.4)	1.0 (-5.5 to 7.5)	1.7 (-4.4 to 8.0	2.7 (-2.7 to 8.3)
5 interventions	10.9 (1.9)	10.0 (1.5)	12.3 (1.3)	0.8 (-5.3 to 7.1)	1.3 (-4.5 to 7.3)	2.2 (-3.0 to 7.5)
10 interventions	10.8 (1.7)	9.0 (1.4)*	11.3 (1.2)*	1.7 (-4.0 to 7.5)	0.5 (-4.9 to 6.0)	2.2 (-2.6 to 7.1)
Weight of fat						
Pre-intervention	19.8 (2.9)	19.6 (2.4)	23.4 (2.1)	0.2 (-9.1 to 9.6)	3.5 (-5.4 to 12.5)	3.7 (-4.2 to 11.8)
5 interventions	19.1 (2.8)	19.3 (2.3)	22.8 (2.0)	0.2 (-8.9 to 9.3)	3.2 (-5.4 to 11.9)	3.0 (-4.7 to 10.8)
10 interventions	19.1 (2.9)	16.7 (2.4)	23.5 (2.1)	2.3 (-7.3 to 12.0)	4.4 (-4.8 to 13.6)	6.7 (-1.4 to 15.0)
Weight of lean mass						
Pre-intervention	47.9 (2.7)	52.2 (2.2)	54.0 (1.9)	4.2 (-4.6 to 13.1)	6.1 (-2.3 to 14.5)	1.8 (-5.6 to 9.4)
5 interventions	48.8 (2.7)	53.2 (2.2)	54.9 (2.0)	4.3 (-4.6 to 13.3)	6.1 (-2.4 to 14.6)	1.7 (-5.8 to 9.4)
10 interventions	48.9 (2.8)	54.2 (2.3)*	55.6 (2.0)*	5.2 (-3.8 to 14.4)	6.7 (-1.9 to 15.4)	1.4 (-6.3 to 9.2)
Jackson %fat						
Pre-intervention	36.8 (2.5)	36.2 (2.1)	39.2 (1.8)	0.6 (-7.7 to 8.9)	2.3 (-5.5 to 10.2)	2.9 (-4.1 to 10.0)
5 interventions	35.8 (2.4)	34.9 (2.0)	37.9 (1.7)	0.9 (-7.1 to 9.0)	2.1 (-5.5 to 9.7)	3.0 (-3.7 to 9.9)
10 interventions	36.1 (2.4)	33.0 (2.0)*	37.4 (1.8)	3.1 (-5.0 to 11.2)	1.2 (-6.4 to 8.9)	4.3 (-2.5 to 11.2)

Notes*: CG - Control Group; EG - Exercise Group; MEG - Microcurrent and Exercise Group; * - Significant difference ($p<0.05$) between the subjects in relation to the time of intervention.

Regarding the PAL, EG and MEG did not present a statistically significant difference in the time spent in physical activities (minutes/week) for both moderate activity and sitting time when compared to CG. When compared to CG, MEG showed, at T2, an increased time spent walking in minutes/week (p=0.041, 95%CI [4.6;277.0], g of Hedges=3.76). Both EG (p=0.000, 95%CI [6.4;37.1], g of Hedges=5.00) and MEG (p=0.000, 95%CI [15.8;44.9], g of Hedges=7.66) also showed, at T2, an increase in time spent in vigorous activities, as shown in Table 2.

Table 2- Time spent on physical activity in minutes/week of the study participants, according to the IPAQ activity types, measured before the intervention, after 5, and after 10 interventions, and adjusted by the difference of means between the groups.

Activity (min./wk.)	CG (n=9)	EG (n=13)	MEG (n=17)	CG x EG (95% CI)	CG x MEG (95% CI)	EG x MEG (95% CI)
Walk						
Pre-intervention	93.8 (24.7)	91.5 (20.5)	117.8 (18.0)	2.3 (-78.5 to 83.2)	23.9 (-52.8 to 100.8)	26.3 (-42.3 to 95.0)
5 interventions	143.3 (78.8)	206.9 (65.5)	180.0 (57.3)	63.5 (-193.8 to 321.0)	36.6 (-208.1 to 281.4)	26.9 (-191.8 to 245.6)
10 interventions	74.4 (43.8)	145.3 (36.4)	215.2 (31.9)*	70.9 (-72.3 to -214.2)	140.8 (4.6 to 277.0)#	69.9 (-51.8 to 191.6)
Moderate						
Pre-intervention	10.0 (16.9)	16.5 (14.0)	39.4 (12.3)	6.5 (-48.7 to 61.8)	29.4 (-23.1 to 82.0)	22.8 (-24.1 to 69.8)
5 interventions	26.6 (67.4)	49.2 (56.1)	89.1 (49.0)	22.5 (-197.8 to 242.9)	62.4 (-147.0 to 271.9)	39.8 (-147.3 to 227.1)
10 interventions	36.6 (22.5)	27.6 (18.7)	59.1 (16.4)	8.9 (-64.7 to 82.7)	22.4 (-47.6 to 92.5)	31.4 (-31.2 to 94.1)
Vigorous						
Pre-intervention	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.0)
5 interventions	1.0 (3.2)	35.3 (2.6)*	40.0 (2.3)*	35.3 (24.9 to 45.8)#	40.0 (30.0 to 49.9)#	4.6 (-4.2 to 13.5)
10 interventions	6.6 (4.6)	28.4 (3.9)*	37.0 (3.4)*	21.7 (6.4 to 37.1)#	30.3 (15.8 to 44.9)#	8.5 (-4.4 to 21.6)
Sitting						
Pre-intervention	957.7 (112.4)	973.8 (93.5)	1032 (81.8)	16.0 (-351.3 to 383.5)	75.1 (-274.1 to 424.4)	59.0 (-253.1 to 371.3)
5 interventions	806.6 (106.9)	941.5 (89.0)	969.4 (77.8)	134.8 (-214.6 to 484.3)	162.7 (-169.5 to 495.0)	27.8 (-269.0 to 324.8)
10 interventions	826.6 (115.3)	1056 (95.9)	840.0 (83.8)	230.2 (-146.4 to 606.9)	13.3 (-344.7 to 371.4)	216.9 (-103.1 to 536.9)

Notes*: CG - Control Group; EG - Exercise Group; MEG - Microcurrent and Exercise Group; * - Significant difference (p<0.05) between the subjects in relation to the time of intervention; # - Significant difference (p<0.05) between the different interventions.

Regarding the effect of weight on QOL (Table 3), MEG showed a significant improvement in self-esteem (p=0.014, 95%CI [-15.1:-27.7;-2.5]), sexual life (p=0.045, 95%CI [10.2:0.16;20.4]), and in total score (p=0.024, 95%CI [6.8:0.7;13.0;]) at T2. Regarding body satisfaction, on average, MEG perceived the current silhouette as thinner at T2 (p=0.000, 95%CI [0.8:0.4;1.2]), as show in Table 3.

As for the functionality of the lower trunk muscles, when compared to the CG, MEG, on average, increased the contraction time for trunk extensors (p=0.026, 95%CI [0.8;16.6], g of Hedges=4.09), trunk lateral (p=0.010, 95%CI [1.1;10.3], g of Hedges=4.89), and lumbar pelvic conditioning (p=0.032, 95%CI [0.4;11.3], g of Hedges=4.12) at T2. However, there was no statistically significant difference (p>0.05) in relation to EG, as shown in Table 4.

Table 3. Effect of weight on quality of life measured by IWQOL-Lite© Short Form of the study participants, according to domains and total score, measured before the intervention, after 5, and after 10 interventions, and adjusted by the difference of means between groups.

Domains of the *IWQOL-Lite*© (mean ± SD)	**CG (n=9)**	**EG (n=13)**	**MEG (n=17)**	**CG x EG (95% CI)**	**CG x MEG (95% CI)**	**EG x MEG (95% CI)**
Physical function						
Pre-intervention	80.3 (5.5)	85.8 (4.6)	78.4 (4.0)	5.5 (-12.6 to 23.6)	1.8 (-15.4 to 19.0)	7.3 (-8.0 to 22.7)
5 interventions	78.5 (5.3)	87.7 (4.4)	79.9 (3.8)	9.2 (-8.1 to 26.6)	1.4 (-15.1 to 17.9)	7.8 (-6.9 to 22.6)
10 interventions	81.3 (6.0)	87.0 (5.0)	80.2 (4.4)	5.7 (-14.1 to 25.6)	1.0 (-17.8 to 20.0)	6.8 (-10.0 to 23.7)
Self-esteem						
Pre-intervention	62.3 (7.6)	65.1 (6.3)	58.4 (5.5)	2.8 (-21.2 to 27.7)	3.8 (-10.8 to 27.6)	6.7 (-14.5 to 27.9)
5 interventions	66.2 (7.0)	69.5 (5.8)	66.5 (5.1)	3.2 (-19.8 to 26.2)	0.3 (-21.5 to 22.2)	2.9 (-22.4 to 16.6)
10 interventions	75.7 (7.2)	68.1 (6.0)	73.5 (5.2)*	7.6 (-16.0 to 31.3)	2.2 (-10.2 to 24.7)	5.3 (-14.7 to 25.5)
Sex life						
Pre-intervention	81.2 (7.2)	94.2 (6.0)	77.5 (5.2)	12.9 (-10.6 to 36.6)	3.6 (-18.8 to 26.1)	16.6 (-3.4 to 36.7)
5 interventions	82.6 (5.2)	96.1 (4.3)	81.9 (3.7)	13.5 (-3.4 to 30.5)	0.6 (-15.4 to 16.8)	14.1 (-0.1 to 28.6)
10 interventions	89.5 (5.4)	90.3 (4.5)	87.8 (3.9)*	0.8 (-17.1 to 18.7)	1.7 (-15.3 to 18.7)	2.5 (-12.7 to 17.7)
Difficulties in public places						
Pre-intervention	92.7 (5.7)	95.0 (4.8)	82.3 (4.2)	2.2 (-16.6 to 21.1)	10.4 (-7.5 to 28.4)	12.6 (-3.4 to 28.7)
5 interventions	92.2 (5.3)	95.0 (4.4)	85.8 (3.9)	2.7 (-14.7 to 20.2)	6.3 (-10.3 to 22.9)	9.1 (-5.7 to 24.0)
10 interventions	91.6 (4.7)	95.7 (3.9)	88.2 (3.4)	4.1 (-11.4 to 19.6)	3.4 (-11.3 to 18.2)	7.5 (-5.6 to 20.7)
Work						
Pre-intervention	93.7 (4.0)	92.7 (3.3)	88.9 (2.9)	0.9 (-12.3 to 14.2)	4.7 (-7.8 to 17.3)	3.8 (-7.4 to 15.0)
5 interventions	91.6 (4.0)	96.1 (3.3)	87.8 (2.9)	4.4 (-8.6 to 17.6)	3.7 (-8.6 to 16.2)	8.2 (-2.8 to 19.4)
10 interventions	94.4 (2.9)	94.2 (2.4)	93.3 (2.1)	0.2 (-9.3 to 9.7)	1.0 (-8.0 to 10.1)	0.8 (-7.2 to 8.9)
Total score						
Pre-intervention	80.1 (5.0)	84.6 (4.2)	75.8 (3.7)	4.5 (-12.1 to 21.1)	4.3 (-11.5 to 20.1)	8.8 (-5.3 to 22.9)
5 interventions	80.1 (4.5)	86.9 (3.7)	79.1 (3.3)*	6.7 (-8.0 to 21.5)	1.0 (-13.0 to 15.1)	7.7 (-4.7 to 20.3)
10 interventions	84.4 (4.7)	85.5 (3.9)	82.6 (3.4)*	1.0 (-14.6 to 16.6)	1.8 (-13.0 to 16.6)	2.8 (-10.4 to 16.1)
Scale of Pulvers Figures						
Current body silhouette						
Pre-intervention	4.3 (0.4)	4.5 (0.3)	5.3 (0.3)	0.2 (-1.3 to 1.7)	1.0 (0.4 to 2.4)	0.8 (-0.4 to 2.1)
5 interventions	4.2 (0.4)	4.5 (0.3)	4.9 (0.3)*	0.3 (-1.0 to 1.7)	0.7 (-0.6 to 2.0)	0.4 (-0.7 to 1.5)
10 interventions	4.6 (0.4)	4.1 (0.3)	4.5 (0.3)*	0.5 (-0.9 to 1.9)	0.1 (-1.2 to 1.5)	0.3 (-0.8 to 1.6)
Silhouette you would like						
Pre-intervention	2.8 (0.2)	3.0 (0.2)	3.2 (0.1)	0.1 (-0.7 to 0.9)	0.4 (-0.4 to 1.2)	0.2 (-0.4 to 1.0)
5 interventions	3.0 (0.2)	2.7 (0.2)	3.1 (0.1)	0.2 (-0.5 to 1.0)	0.1 (-0.5 to 0.9)	0.4 (-0.2 to 1.0)
10 interventions	3.2 (0.2)	2.8 (0.1)	3.1 (0.1)	0.3 (-0.3 to 1.1)	0.1 (-0.6 to 0.8)	0.2 (-0.3 to 0.9)
Ideal silhouette						
Pre-intervention	3.0 (0.2)	3.0 (0.2)	3.2 (0.1)	0.0 (-0.8 to 0.8)	0.2 (-0.5 to 1.0)	0.2 (-0.4 to 1.0)
5 interventions	3.0 (0.2)	3.0 (0.2)	3.1 (0.1)	0.0 (-0.8 to 0.8)	0.1 (-0.6 to 0.8)	0.1 (-0.5 to 0.8)
10 interventions	3.2 (0.2)	3.0 (0.1)	2.9 (0.1)	0.1 (-0.5 to 0.8)	0.2 (-0.3 to 0.9)	0.1 (-0.4 to 0.7)

Notes*: CG - Control Group; EG - Exercise Group; MEG - Microcurrent and Exercise Group; * - Significant difference ($p<0.05$) between the participants in relation to the time of intervention.

Table 4. Functionality of trunk muscles of study participants, measured before intervention, after 5, and after 10 interventions, and adjusted by the difference of means between groups.

Functionality of the musculature	CG (n=9)	EG (n=13)	MEG (n=17)	CG x EG (95% CI)	CG x MEG (95% CI)	EG x MEG (95% CI)
Trunk extensors						
Pre-intervention	8.5 (1.3)	9.9 (1.1)	9.8 (0.9)	1.3 (-3.0 to 5.8)	1.3 (-2.8 to 5.6)	0.01 (-3.7 to 3.7)
5 interventions	7.7 (2.7)	11.3 (2.2)	16.3 (2.0)*	3.5 (-5.4 to 12.5)	8.5 (0.02 to 17.1)#	5.0 (-2.6 to 12.6)
10 interventions	8.0 (2.5)	12.3 (2.1)	16.7 (1.8)*	4.3 (-3.9 to 12.7)	8.7 (0.8 for 16.6)#	4.3 (-2.6 to 11.4)
Trunk flexors						
Pre-intervention	11.3 (1.9)	12.6 (1.6)	11.4 (1.4)	1.2 (-5.1 to 7.6)	0.1 (-5.9 to 6.2)	1.1 (-4.3 to 6.5)
5 interventions	11.3 (1.7)	15.5 (1.4)	15.4 (1.2)	4.2 (-1.6 to 10.0)	4.0 (-1.4 to 9.5)	0.1 (-4.8 to 5.0)
10 interventions	12.8 (3.7)	18.3 (3.1)	21.6 (2.7)*	5.5 (-17.7 to 6.6)	8.7 (-2.8 to 20.3)	3.2 (-7.1 to 13.5)
Side of the trunks						
Pre-intervention	4.7 (0.9)	5.8 (0.7)	5.9 (0.6)	1.0 (-1.9 to 4.1)	1.2 (-1.6 for 4.1)	0.1 (-2.4 to 2.7)
5 interventions	4.7 (1.1)	6.2 (0.9)	8.5 (0.8)*	1.4 (-5.2 to 2.3)	3.7 (0.1 to 7.4)#	2.3 (-0.9 to 5.5)
10 interventions	5.3 (1.4)	9.7 (1.2)*	11.1 (1.0)*	4.3 (-0.4 to 9.2)	5.7 (1.1 to 10.3)#	1.3 (-2.7 to 5.4)
Lumbopelvic conditioning						
Pre-intervention	8.2 (1.0)	8.8 (0.8)	8.7 (0.7)	0.6 (-2.8 to 4.0)	0.5 (-2.8 to 3.8)	0.09 (-2.8 to 3.0)
5 interventions	8.4 (1.9)	10.7 (1.5)	14.5 (1.3)*	2.3 (-3.9 to 8.5)	6.0 (0.1 for 12.0)#	3.7 (-1.5 to 9.0)
10 interventions	8.3 (1.7)	12.3 (1.4)	14.2 (1.2)*	3.9 (-1.8 to 9.6)	5.8 (0.4 to 11.3)#	1.9 (-2.9 to 6.8)

Notes*: CG – Control Group; EG – Exercise Group; MEG – Microcurrent and Exercise Group; * - Significant difference ($p<0.05$) between the participants in relation to the time of intervention; # - Significant difference ($p<0.05$) between the different interventions.

Regarding the satisfaction with the intervention, most participants evaluated both forms of intervention positively, with no statistically significant difference ($p<0.05$) between the groups.

DISCUSSION

According to the results of this study, MES combined with HIIT can be effective in reducing LAA, as demonstrated by the skinfolds outcome. Interestingly, even more promising results were found in the secondary outcomes analyzed, such as changes in PAL and functionality of the lumbar spine. The findings for the variable "skinfolds" corroborate Rosa and Campos' study[17], which showed a reduction in abdominal adipometry after 10 electrolipolysis sessions of 1 hour, applied once a week with needles. This reduction, especially in the suprailiac and abdominal area, may be associated with the transcutaneous application of MES, as it is capable of promoting physiological modifications in adipocytes through the Joule effect, inducing a temperature increase that causes vasodilation, an increase in local blood flow and cellular metabolism, and facilitating calorie burning.

Electrolipolysis also causes neurohormonal effects and produces an artificial stimulation of the sympathetic nervous system, provoking the release of catecholamines with an increase of intra-adipocyte cyclic AMP and triglyceride hydrolysis.[18]

Nevertheless, the results obtained in EG can be explained by the mechanism of fatty acids' oxidation induced by HIIT, which promotes a global reduction of body fat.[19] The unusual results found in the participants of MEG, for the parameter "functionality of the lumbar spine", may be related to the capacity of MES to stimulate the intracellular metabolism by supplying protons and electrons, leading to depolarization of the membrane and increasing the levels of adenosine triphosphate (ATP)[20,21] .This ATP, synthesized by specific enzymes, may be used as an energy source for various biological processes in the body, such as muscle contraction[22].

Repeated episodes of muscle contraction performed through physical training are potent stimuli for molecular adaptations, as physical exercise triggers activation of intracellular molecular pathways that regulate skeletal muscle plasticity. Mechanical tension causes changes that activate or inactivate certain cell-signaling pathways, such as ATP renewal, which result in perturbations in the cellular environment, and stimulates muscles to adapt to the exercise[23].Thus, it was hypothesized that MES can act on muscle strengthening by increasing ATP, which is used by skeletal muscles in the process of muscle adaptation.

On the other hand, the results observed in EG may be associated with the protocol of exercises performed that demanded, in some cases, greater effort in the lumbopelvic region. It is worth noting that the gains obtained in this variable may be related to satisfaction and/or success in the performance of the skills required in this type of exercise, being a possible motivator for the performance of other physical activities[24]. Thus, when associated with MES, positive results will be obtained more quickly by applying a protocol with a longer intervention time. Regarding PAL and the effect of weight on QOL, the results observed in MEG may be related to the fact that the participants are indirectly motivated to perform activities, with the aim of reducing LAA and, consequently, affecting QOL.

This study provided some answers to guide future clinical trials. However, it is necessary to consider that the non-significant results can possibly be explained by the limitations found during the study, such as the influence of the menstrual cycle (not considered in the evaluation), since during menstrual cycles some women suffer physiological changes that can influence the anthropometric measurements collected, as well as cause oscillation of body weight. At different times of their cycles, there are hydrostatic changes that can be measured by differences in body density and fat percentage[25,26].

Other important limitations are: the type of randomization used and the lack of a 1-month follow-up. According to Boey and Wasilenchuck[27], the intervention follow-up is used to monitor the results obtained and a possible long-term permanence; this would be a valuable method for the study. In a study published by Campos et al.[28], the association of low intensity laser and HIIT was used to improve the body composition of women, with an intervention protocol of 30 minutes, 3 times a week, during 8 weeks, showing improvement in all evaluated anthropometric parameters.

Thus, the time of intervention used in this study may have been insufficient to produce the expected results, nevertheless our results suggest that this combination of protocols may be useful in reducing LAA.

We also highlight the discrepancy in the number of participants in each group, which may compromise the statistical analyses, as well as the heterogeneity of the sample. This is explained mainly by the lack of adherence of the participants, especially those who did not undergo the MES application, and by the randomization by convenience.

The size of the standardized electrodes used for all participants is another variable that may have influenced the results. Piqueras-Sanchiz et al.[29] demonstrated that the larger the electrode, the lower the wave passage resistance in the area. When the electrode is smaller, energy ends up concentrating more in the area of application, increasing the risk of dermis tissue injury. Finally, the lack of nutritional monitoring also possibly influenced the results. Lopes et al.[30] pointed out the need for a combination of physical exercise and diet to reduce body weight, which is more efficient than any of the two in isolation.

CONCLUSION

The combination of MES and HIIT over a 5-week period in sedentary women showed evidence that it may be useful in reducing LAA. However, it did not present significant results when compared to EG, which may be related to the limitations pointed out in the study. Considering the lack of literature directly proving this effect, an in-depth and isolated analysis of the effect of MES on muscle strengthening is still necessary. We recommend that future studies employ other forms of randomization, whether in block or stratified, to better allocate the participants and achieve a greater conformity of the data; we also recommend a follow-up of 1 month to evaluate the maintenance of the clinical responses observed and to understand the factors involved after the end of treatment, in addition to adjusting the size of electrodes to adapt to the area where treatment will be applied

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REFERENCES

1. Ovelar VME, Simões NDP, Moreira, DVQ. Estudos dos efeitos do ultrassom e ultrassom associado a atividade física na redução do diâmetro abdominal. Rev Bras Terap e Saúde. 2020;11(1):1-6.
2. Park YH, Lee J-H. The effects of abdominal interferential current therapy on waist circumference and visceral fat distance in obese women. J Phys Ther Sci. 2017; 29(9):1680-3.
3. Verner I. A novel nonfocused pulsed ultrasound technology for noninvasive circumference reduction. Dermato Ther. 2021;34(5):e15101.
4. Silva RVM, Basilio FB, Nóbrega MG, Medeiros CRBM. Efeitos da eletrolipólise na adiposidade abdominal. Rev Pesq em Fisiot. 2016;6(1):65-72.
5. Cavalheiro CM, Ferreira AS, Assunção FFDO. O uso da eletrolipólise no tratamento da adiposidade localizada: Revisão integrativa, Ensaios e Ciência: Ciências Biológicas, Agrárias e da Saúde. 2012;16(3):157-65.
6. Oliveira-Silva I, Silva SG, Santana F. HIIT & RT ou RT & HIIT: The order of stimulations alters acute hemodynamic response? Manual Therapy, Posturology & Rehabilitation Journal. 2021;1-5.
7. Korelo RIG, Pesaski A, Santos NL dos, Silva NP da, Anjos RAS dos, Vojciechowski AS, Macedo ACB de, Gallo RBS. Effects of high-intensity interval training associated to microcurrent on localized adiposity: protocol of randomized clinical trial, Manual Therapy, Posturology & Rehabilitation Journal. 2020;18:1-10.
8. Noites A, Pinto J, Freitas CP, Melo C, Albuquerque A, Teixeira M, Ribeiro F, Bastos JM. Effects of microcurrent and physical exercise on the abdominal fat in patients with coronary artery disease. Eur J Integr Med. 2015;7(5):499-507.
9. Noites A, Moreira A, Melo C, Faria F, Vilarinho R, Freitas C, Monteiro PRR, Carvalho P, Adubeiro N, Amorim M, Nogueira L, Santos R. Acute effects of physical exercise with microcurrent in the adipose tissue of the abdominal region: a randomized controlled trial, Eur J Integr Med. 2016;9:79-85.
10. Niwa ABM, Shono M, Mônaco P, Prado G, Osório N. Experiência no uso do ultrassom focado no tratamento da gordura localizada em 120 pacientes, Surg Cosmet Dermatol.2010;2(4):323-5.
11. Jackson AS, Pollock ML. Practical Assessment of Body Composition. Phys Sportsmed. 1985;13(5):76-90.
12. IPAQ Core Group. Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ): Short and Long Forms. International Physical Activity Questionnaire: IPAQ. 2005.
13. Pulvers KM, Lee RE, Kaur H, Mayo MS, Fitzgibbon ML, Jeffries SK, Butler J, Hou Q, Ahluwalia JS. Development of a culturally relevant body image instrument among urban African Americans. Obes Res. 2004;12(10):1641–1651.
14. Elvar JRH, Donate FI, Ordoñez FM, Moral S, Peña G, Revisión de los Métodos de Valoración de la Estabilidad Central (Core). PubliCE. 2012.
15. Lee DK. Alternatives to P value: confidence interval and effect size, Korean J Anesthesiol. 2016; 69(6):555-62.
16. Espírito-Santo H, Daniel F. Calcular e apresentar tamanhos do efeito em trabalhos científicos (1): As limitações do $p < 0,05$ na análise de diferenças de médias de dois grupos, Revista Portuguesa de Investigação Comportamental e Social. 2015;1(1):3-16.
17. Rosa JS, Campos L. Efeitos da eletrolipólise na redução de gordura abdominal em mulheres jovens. Revista Inspirar movimento & Saúde. 2015;6(5):13-17.
18. Melo NR, Monteiro FMDAC, Pontes GAR, Mello SMBD, Eletrolipólise por meio da estimulação nervosa elétrica transcutânea (Tens) na região abdominal em pacientes sedentárias e ativas. Fisioter Mov. 2012;25(1):127-40.

19. Gentil P, Lira CAB de, Cardoso Filho SG, Teixeira CVLS, Steele J, Fisher J, Carneiro JA, Campos MH, High intensity interval training does not impair strength gains in response to resistance training in premenopausal women. Eur J Appl Physiol. 2017;117(6):1257-65.
20. Soares VT, Rodrigues NB, Nowotny JP, Limana MD, Benefícios da microcorrentes no envelhecimento cutâneo. Fisioterapia Brasil. 2012:15(1):29-34.
21. Vilarinho R, Faria SM, Monteiro PRR, Melo C, Santos R, Noites A. Effects of Abdominal Microcurrent in the consumption and proportion of energy substrates during aerobic exercise: a pilot study. Healhcare. 2022;10(5):917.
22. Silva CM, Santos MD. Atuação fisioterapêutica no pós-operatório imediato de abdominoplastia, Rev Visão Universitária. 2015(3):4-6.
23. Abreu P, Leal-Cardoso JH, Ceccatto CM, Adaptação do músculo esquelético ao exercício físico: Considerações moleculares e energéticas. Rev Bras Med Esporte. 2017;23(1):60-65.
24. Mourão AB, Gama DT, Levandoski G. Análise de fatores motivacionais em estudantes universitários que aderem a um programa de exercício físico. Revista Conexão Uepg. 2019;15(3);346-51.
25. Andrade J, Da-Silva A, Amorim F, Lustosa R, Uchoa N, Uchoa F, Análise da adiposidade subcutânea durante o ciclo menstrual. Cinergis. 2017;18(2):83-7.
26. Teixeira A, Fernandes Jr F, Moraes EM, Alves HB, Dias MR. Efeitos das diferentes fases do ciclo menstrual na composição corporal de universitárias. RBPFEX. 2012; 6(35):428-32.
27. Boey GE, Wasilenchuk JL. Enhanced clinical outcome with manual massage following cryolipolysis treatment: A 4‐month study of safety and efficacy, Lasers in surgery and medicine. 2014;46(1):20-6.
28. Campos TYTB, Carbinatto FM, Maffel GBR, Bagnato VS, Aquini Jr AE de, Pode a associação de laser de baixa intensidade e treinamento intervalado de alta intensidade (HIIT) melhorar a composição corporal de mulheres em condição de pós menopausa?, Revista Brasileira de Obesidade, Nutrição e Emagrecimento. 2017;11(65):297-303.
29. Sanchiz FP, Rodríguez SM, Blanco FP, Vegas LB, Fernández JB, Bautista IJ, García ÓG, Mechanomyographic Measures of Muscle Contractile Properties are Influenced by Electrode Size and Stimulation Pulse Duration, Scientific Reports. 2020;10(1):1-9.
30. Lopes JF, Matos MA, Magalhães FC, Esteves EA, Vieira ER, Amorim FT. Efeito de mudanças graduais de exercício físico e dieta sobre a composição corporal de obesos, Arquivos de Ciência da Saúde. 2017;24(1):93-7.