THE JOURNAL OF ALTERNATIVE AND COMPLEMENTARY MEDICINE
Volume 21, Number 4, 2015, pp. 229–236

DOI: 10.1089/acm.2014.0114

Effects of Aerobic Exercise Associated with Abdominal Microcurrent: A Preliminary Study

Andreia Noites, PT, MSc,[1,2] Rita Nunes, PT,[1] Ana Isabel Gouveia, PT,[1] Alexandra Mota, PT,[1]
Cristina Melo, PT, PhD,[1] Ágata Viera, PT,[1] Nuno Adubeiro, MSc,[3] and José Mesquita Bastos, MD, PhD[2]

Abstract

Objective: To analyze the short- and long-term effects of microcurrent used with aerobic exercise on abdominal fat (visceral and subcutaneous).

Methods: Forty-two female students from a university population were randomly assigned into five group: intervention group (IG) 1 ($n=9$), IG2 ($n=9$), IG3 ($n=7$), IG4 ($n=8$), and placebo group (PG) ($n=9$). An intervention program of 10 sessions encompassing microcurrent and aerobic exercise (performed with a cycloergometer) was applied in all groups, with slightly differences between them. In IG1 and IG2, microcurrent with transcutaneous electrodes was applied, with different frequency values; 30-minute exercise on the cycloergometer was subsequently performed. IG3 used the same protocol as IG1 but with different electrodes (percutaneous), while in IG4 the microcurrent was applied simultaneously with the cycloergometer exercise. Finally, the PG used the IG1 protocol but with the microcurrent device switched off. All groups were evaluated through ultrasound and abdominal perimeter measurement for visceral and subcutaneous abdominal fat assessment; through calipers for skinfolds measurement; through bioimpedance to evaluate weight, fat mass percentage, and muscular mass; and through blood analyses to measure cholesterol, triglyceride, and glucose levels.

Results: After intervention sessions, visceral fat decreased significantly in IG1 compared with the PG. Subcutaneous fat was reduced significantly in all groups compared with the PG. After 4 weeks, almost all results were maintained.

Conclusion: The addition of microcurrent to aerobic exercise may reduce fat more than does aerobic exercise alone.

Introduction

Continuous habits of decreased physical activity performance, along with eating behaviors characterized by excess consumption of sugar and saturated fats, has led to increased body fat in the general population.[1] There is a well-established relationship between excessive total body fat, cardiometabolic diseases, and increased mortality. It also established that abdominal fat (android pattern) additionally influences health risks.[2,3] Indeed, women with abdominal adipocytes (visceral fat) showed an increased lipolytic activity that releases free fatty acids (FFAs) to the systemic and portal circulations; this, in turn, leads to the metabolic syndrome, which increases the risk of cardiovascular diseases.[2,4–6]

Performing aerobic exercise (prolonged and moderate exercise for a minimum of 30 minutes) induces fat reduction by stimulating lipolysis through an increase in catecholamine levels resulting from greater sympathetic nervous system activity.[7–9] The increased catecholamine levels activate lipolysis via β_1, β_2-adrenergic receptors and inhibit lipolysis via α_2-adrenergic receptors.[7] The simultaneous activation of both receptors modulates the intracellular cyclic adenosine monophosphate (cAMP) concentration, which activates cAMP-dependent protein kinase; this then leads to the phosphorylation and activation of the hormone-sensitive lipase, which hydrolyzes triglycerides.[7] Because aerobic exercise–induced reduction in lipidic sources is global,[10] electrolipolysis using microcurrent is thought to be an effective way to reduce abdominal fat locally. In fact, this

[1]Department of Physiotherapy, School of Allied Health Technologies, Polytechnic Institute of Porto, Vila Nova de Gaia, Portugal.
[2]Health Sciences Department, University of Aveiro, Aveiro, Portugal.
[3]Department of Radiology, School of Allied Health Technologies, Polytechnic Institute of Porto, Vila Nova de Gaia, Portugal.

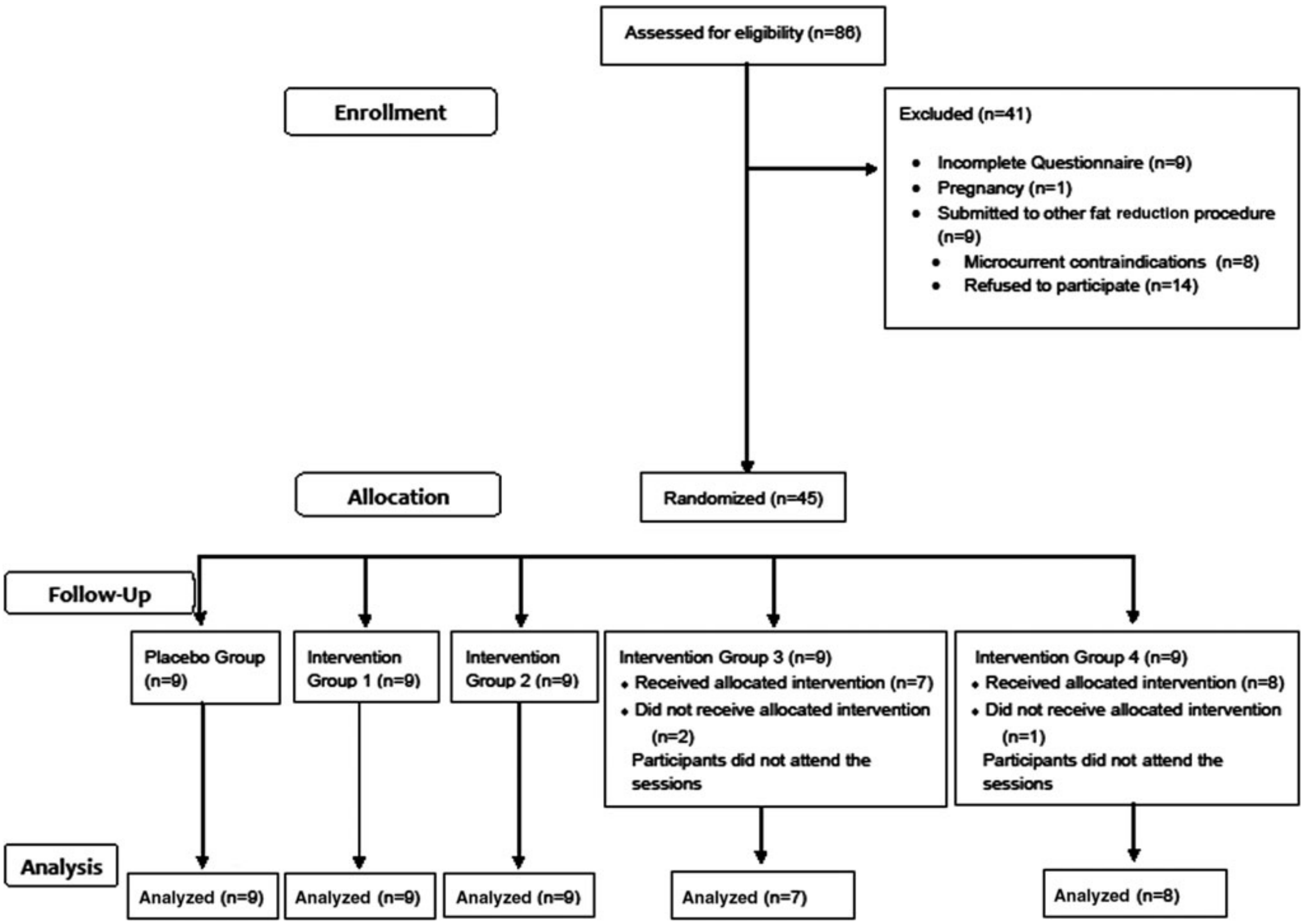

FIG. 1. Study flow diagram.

technique has been widely used in clinical practice in such countries as Portugal and Brazil.

The use of electrical current is based on the fact that the human body expends a certain amount of its energy generating electricity; all cells maintain a voltage, either across the external membranes or across the membranes of the organelles.[11,12] This is possible because of the transport of the active ions (in particular sodium and potassium) against their concentration gradients.[12] Therefore, some *in vitro* studies have revealed that the application of electric fields and currents similar to those generated within the body can substantially change cell structure and behavior. In fact, the application of microcurrent increases the number of organelles responsible for cellular activities and increases concentrations of adenosine triphosphate (ATP),[11,12] amino acid transport, protein synthesis,[13] and activating hormone-sensitive lipase[14] which can increase lipolysis. Lipase is responsible for triglyceride breakdown, which does not permit FFA oxidation. As a result, it is necessary to perform aerobic exercise in order to avoid the negative effects of FFA in the systemic circulation. However, the most suitable time at which to introduce aerobic exercise after application of microcurrent is not well established. In addition, the selection of the microcurrent frequencies still lacks evidence. Only the report by Melo and colleagues suggests using frequencies of 10 and 25 Hz (15 minutes each, to prevent desensitization of adipocytes); those authors emphasize these frequencies as the most adequate for stimulating lipolysis.[14]

McMakin and Oschman state that microcurrent uses low-frequency, low-level micro-amperage currents and is based on the principles of biologic resonance.[15] This technique can be applied transcutaneously or percutaneously; the former is not as effective because the skin can be an obstacle to the current's effect on visceral and subcutaneous fat.

The aim of this study was to analyze the short- and long-term effects of microcurrent used with aerobic exercise on

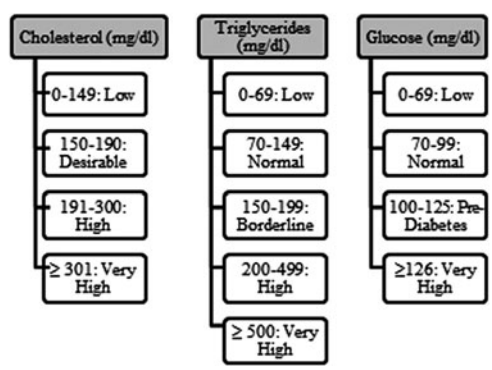

FIG. 2. Classification of cholesterol, triglyceride, and glucose levels (mg/dL) (Source: Accutrend Plus, Roche; 2008).

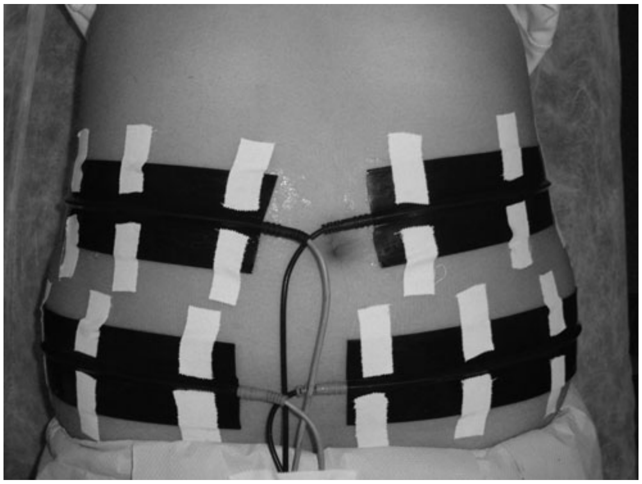

FIG. 3. Electrode position in transcutaneous application.

abdominal fat. The study also analyzed the most suitable moment at which to introduce aerobic exercise (during or just after microcurrent application), the most appropriate microcurrent frequencies, and the most effective type of application (transcutaneous or percutaneous).

Materials and Methods

Sample

The sample consisted of 45 university students who volunteered for this prospective, randomized, double-blind study. Inclusion criteria were white women age 18–30 years with a normal to preobese body–mass index (BMI) (18.5–29.9 kg/m^2) and a moderate physical activity level (600–3000 metabolic min/wk [MET-min/wk] scored by the International Physical Activity Questionnaire (IPAQ).[8,9,16–19] Exclusion criteria were involvement in other fat reduction procedures/programs, cardiovascular risk factors or diseases or any physical condition limiting aerobic exercise, contraindications to microcurrent application (pacemaker, tumor areas, osteosynthesis material, open wounds, or skin inflammation) or aerobic exercise, use of medication that influences metabolism, and pregnancy.[9,18,20]

Participants were randomly allocated to one of four intervention groups (IGs)—IG1, IG2, IG3, and IG4—or the placebo group (PG). Allocation sequences were computer-generated. Three participants did not attended the sessions and were excluded. The sample was composed of 42 participants (9 in the PG, IG1, and IG2; 7 in IG3; and 8 in IG4) (Fig. 1).

Instruments

A pilot study was performed to analyze intra-rater reliability using an intraclass correlation coefficient (ICC). Bioimpedance BC-545 InnerScan™ (Tanita, Arlington Heights, Illinois) was used to calculate total and abdominal fat percentage, weight, and muscle mass through a hand-to-foot electrical current. When compared with dual-energy x-ray absorptiometry, bioimpedance has excellent correlation coefficient of 0.96 ($p<0.001$) for muscle mass and 0.87 ($p<0.001$) for fat percentage.[21] Echograph (Viamo™ Toshiba Medical Systems, Tustin, California) with a 7.5-MHz probe was used to measure subcutaneous and visceral abdominal fat (ICC, 0.89).[22] Subcutaneous adipose tissue thickness at the abdomen measured with ultrasonography was compared with thickness measured by using dual-energy x-ray absorptiometry; the two showed very good correlations ($r=0.905$; $p<0.01$).[23] Strong correlations were also found between ultrasonographic and computed tomographic measurements of visceral adipose tissue ($r=0.85$–0.87).[22,24]

A rigid tape was used to measure height; this has an excellent correlation ($r=0.98$) with height measured radiographically.[25] Intrarater reliability was analyzed in a pilot study, m km resulting in an ICC$_{(3,1)}$ of 0.98 for body perimeters of 0.88 for skinfold measurements (performed by using Harpenden® analog caliper [Baty International, West Sussex, United Kingdom]).

Cholesterol, triglyceride, and glucose levels were measured by using Accutrend® Plus (Roche Diagnostics, Rotkreuz, Switzerland). Compared with the enzymatic colorimetric method, this diagnostic method showed an excellent correlation ($r=0.97$) to lipid measurements as well as to glucose laboratory tests ($r=0.96$).[26,27]

A food-frequency questionnaire (FFQs) and IPAQ were used to monitor lifestyle behaviors. FFQ responses showed moderate and higher correlations for the comparison between FFQ and 7-day diet records, and IPAQ measured physical activity in the preceding week.[17,28] During cycloergometer sessions, aerobic exercise intensity was controlled through the use of heart monitors (Polar®, Lake Success, New York) and Borg scale, which is correlated with maximal oxygen consumption ($r=0.64$).[29]

Percutaneous and transcutaneous microcurrent was administered by using a current device (Sonopuls 692® [Enraf Nonius, Rotterdam, the Netherlands]). This current is characterized by a pulsating stream of electrons in a relatively low concentration that mimic the endogenous electric energy of the human body.[30]

Procedures

All groups were evaluated initially (moment 0 [M0]), at the end of the protocol (moment 1 [M1]), and 4 weeks after

Table 1. Characteristics of Study Sample

Characteristic	*PG* (n=9)	*IG1* (n=9)	*IG2* (n=9)	*IG3* (n=7)	*IG4* (n=8)
Age (y)	20 ± 1	21 ± 1	20 ± 1.5	20 ± 2.5	21 ± 0.5
BMI (kg/m^2)	21.1 ± 1.9	23.2 ± 1.5	23.9 ± 2.1	24.9 ± 3.2	22 ± 0.9
FFQ score (kcal/d)	1758.92 ± 823.65	2183.73 ± 643.12	2679.24 ± 699.09	1787.83 ± 331.86	2169.78 ± 320.58
IPAQ (MET-min/wk)	1188 ± 579.13	1386 ± 547.05	1626 ± 788.5	1902 ± 516	1279.5 ± 497.5

Values are expressed as the median ± interquartile deviation.

BMI, body mass index; FFQ, food-frequency questionnaire; IG, intervention group; IPAQ, International Physical Activity Questionnaire; MET, metabolic equivalent (min/wk); PG, placebo group.

Table 2. Ultrasonographic Values in Placebo and Intervention Groups 1 at Moments 0 and 1 Compared with Values in Intervention Groups 2, 3, and 4 at Moment 1

Anatomic location	*Time*	*Ultrasonographic measure (mm)*					p-*Value (M1–M0)*		
		PG	*IG1*	*IG2*	*IG3*	*IG4*	*PG-IG1-IG2*	*PG-IG1-IG3*	*PG-IG1-IG4*
Between xiphoid apophysis and navel	M0	13.8 ± 7.3	12.9 ± 6.2	13.3 ± 5.6	20.9 ± 4.3	11.7 ± 5.5	NS	0.01	NS
	M1	13.7 ± 7.2	12.5 ± 6.9	12.1 ± 6.6	17.8 ± 5	12 ± 5.6			
Below navel	M0	21.3 ± 8.2	25.6 ± 10.5	23.7 ± 6.8	31.3 ± 6.7	21.4 ± 2.1	0.010	0.035	0.025
	M1	20 ± 7	21.1 ± 9.3	20.6 ± 7.8	25.1 ± 8.3	17.6 ± 5.2			
Right ASIS	M0	9 ± 2.6	8.5 ± 1.4	10.7 ± 3.3	11.4 ± 4.7	8.3 ± 2.1	NS	NS	NS
	M1	7.6 ± 2	7.6 ± 2.6	8.8 ± 3.1	10 ± 2.7	5.2 ± 2.6			
Left ASIS	M0	8.5 ± 2.4	9 ± 3.9	11 ± 3.3	11.3 ± 4.1	8.3 ± 2.3	0.002	0.006	0.002
	M1	7.5 ± 2.2	7.1 ± 2.5	8.8 ± 2.7	10.1 ± 2.5	8 ± 1.9			

Unless otherwise noted, values are expressed as the median ± interquartile deviation. *p*-Value (M1–M0) of the Kruskal-Wallis test. ASIS, anterior superior iliac spine; M, moment; NS, not significant ($p > 0.05$).

the end of the protocol (moment 2 [M2]). All groups attended a total of 10 sessions (2 sessions per week).

The evaluation began with blood analysis. The volunteers had been fasting (12 hours), and a finger blood sample was collected. The results were recorded according to the instrument rules (Fig. 2).

BMI was calculated by dividing the body weight in kilograms (bioimpedance) by height in meters squared.[31,32] For bioimpedance evaluation, volunteers were instructed to not drink alcohol and perform vigorous physical exercise during 24 hours, avoid heavy meals, and empty the bladder before the measure.

Ultrasonography was performed at the end of expiration to measure subcutaneous abdominal fat between the xiphoid apophysis and the navel, below the navel, and above the left and right anterior superior iliac spine. Visceral abdominal fat was measured between xiphoid apophysis and the navel.[33,34]

The perimeter measurements were done at the end of expiration, at waist level (below the last rib), at navel level, at the point immediately above the iliac crests, and at the trochanter level.[35] The waist-to-hip ratio was calculated by using the waist-level perimeter divided by the trochanter-level perimeter.[31,36] Suprailiac, vertical, and horizontal abdominal skinfold measurements were performed three times and the mean was calculated.[35,36]

All groups were assessed by bioimpedance, ultrasonography, body perimeters, skinfold measurements, and IPAQ 4 weeks after the end of the protocol.

The intervention protocol included 30 minutes of monophasic and rectangular microcurrent with polarity changes every second and 30 minutes of aerobic moderate-intensity exercise performed on a cycloergometer (50% maximal oxygen consumption using Karvonen formula). The Borg scale (score, 12–13) and Polar® heart monitors were used to measure heart rate.

IG1 and IG2 performed the aerobic exercise just after application of microcurrent to the abdominal region using four transcutaneous electrodes (55 cm × 5.5 cm) in a parallel position (Fig. 3). An intensity below the sensitivity threshold was used with a maximum of 1 mA. After 15 minutes, IG1 changed from 25 to 10 Hz and IG2 changed from 25 to 50 Hz. In IG3, the same microcurrent intensity and frequencies as IG1 were applied but with percutaneous electrodes (4 in the anterior abdominal region and 2 in the right and left suprailiac region with acupuncture needles 40 mm × 0.25 mm), followed by 30 minutes of exercise on the cycloergometer. In IG4, the same microcurrent parameters as in IG1 were applied, but the cycloergometer exercise was performed simultaneously. Finally, in the PG, the same protocol as IG1 was applied but the microcurrent device was switched off.

Ethics

This study is registered at ClinicalTrials.gov (NCT01853761) and was approved by the ethical committee of the higher education institution. Participants in the PG were invited to participate in the intervention protocol at the end of the study. All volunteers provided written informed consent according to the Declaration of Helsinki.

Statistical analysis

Statistical analysis were performed by using Predictive Analytics Software (PASW® Statistics), version 18 (IBM, Armonk, NY), with a significance level of 5% ($p < 0.05$). Given the small sample size, nonparametric tests were applied. Difference variables were compared between groups

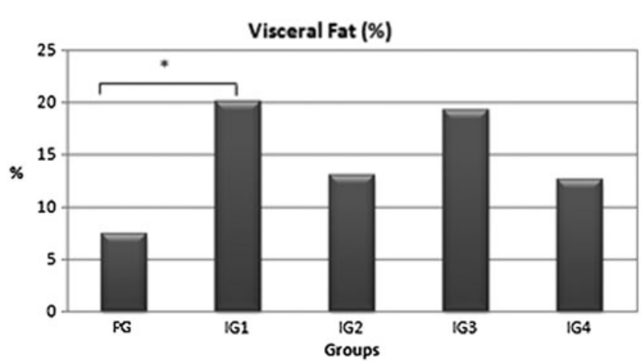

FIG. 4. Percentage change of visceral fat values in moment 1 to moment 0, measured by ultrasonography in the placebo group (PG) and intervention groups (IGs) 1, 2, 3, and 4. $*p = 0.01$.

Table 3. Bioimpedance Values in Placebo and Intervention Groups 1 at Moments 0 and 1 Compared with Values in Intervention Groups 2, 3, and 4 at Moment 1

		Bioimpedance value					p-*Value (M1–M0)*		
Variable	*Moment*	*PG*	*IG1*	*IG2*	*IG3*	*IG4*	*PG-IG1-IG2*	*PG-IG1-IG3*	*PG-IG1-IG4*
BMI (kg/m^2)	M0	21.1 ± 1.9	23.2 ± 1.5	23.9 ± 2.1	24.9 ± 3.2	22 ± 0.9	NS	NS	NS
	M1	20.6 ± 1.8	22.9 ± 1.3	23.4 ± 2	24.5 ± 3.1	21.7 ± 0.9			
Total fat (%)	M0	23.9 ± 5	28.1 ± 4.5	28.9 ± 4.3	30.3 ± 4	29.8 ± 3.3	0.040	NS	NS
	M1	22.5 ± 4.6	26.8 ± 4.3	26 ± 5	28.7 ± 3.9	27.6 ± 2.6			
Muscle mass (kg)	M0	40.3 ± 2	41.4 ± 2.6	42.1 ± 1.5	40.8 ± 3.5	40.3 ± 2.0	0.012	NS	NS
	M1	39.2 ± 2.3	42.1 ± 1.8	42.1 ± 1.3	42.4 ± 2.3	40.6 ± 2.5			

Unless otherwise noted, values are expressed as the median ± interquartile deviation. *p*-Value (M1–M0) of the Kruskal-Wallis test.

with Kruskal-Wallis tests followed by Dunn test as a *post hoc* test. The Wilcoxon test was used to compare M0 versus M1 and M1 versus M2 in each group.[37]

Results

Table 1 shows characteristics of the 42 participants, including age, BMI, FFQ response, and IPAQ score. The groups did not differ at M0.

A significant decrease in subcutaneous fat between the xiphoid apophysis and the navel was observed in IG3 ($p \leq 0.01$), below the navel in IG1 ($p < 0.05$) and IG2 ($p < 0.01$), and on the left anterior superior iliac spine in IG1 ($p < 0.01$) compared with the PG (Table 2).

Participants in IG1 also showed a significant decrease in visceral fat ($p = 0.01$) when compared with the PG (Fig. 4).

Total fat decreased significantly after 10 intervention sessions ($p < 0.05$) and muscle mass increased significantly ($p \leq 0.01$) in IG2 versus the PG (Table 3). Abdominal fat decreased significantly in IG1 ($p = 0.01$), IG2 ($p = 0.001$), and IG4 ($p = 0.013$) compared with the PG (Fig. 5).

Any type of microcurrent applied before or simultaneously with the performance of aerobic exercise was associated with a significant decrease in vertical and horizontal abdominal skinfold among the four IGs compared with the PG ($p \leq 0.01$) (Table 4). The application of microcurrent before aerobic exercise was associated with a significant decrease below the last rib and above the iliac crest perimeters in IG1, IG2, and IG3 ($p < 0.05$), as well as a waist-to-hip ratio that decreased significantly in IG1 and IG2 ($p < 0.05$), compared with the PG (Table 5).

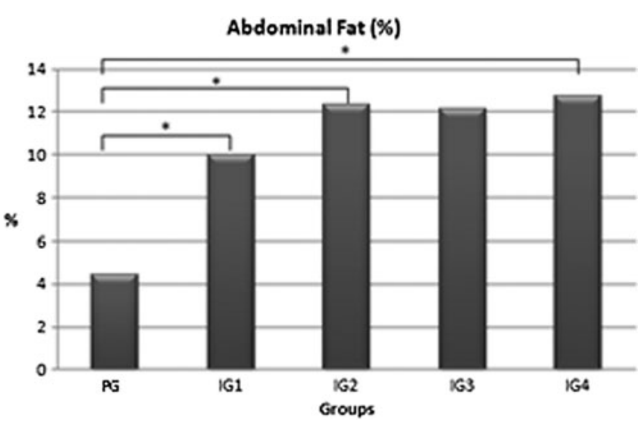

FIG. 5. Percentage change in abdominal fat values in moment 1 to moment 0, measured by bioimpedance, in the placebo group and intervention groups 1, 2, 3, and 4. *$p < 0.01$.

There were no significant differences on blood analyses between the four IGs and the PG. Nevertheless, in IG1 triglycerides significantly increased ($p = 0.016$) after the 10 sessions of the intervention (Fig. 6).

IPAQ and FFQ scores did not significantly at any moment. Four weeks after the end of the intervention protocol (M2), most of the positive results remained in the IGs. In addition, IG1 showed a statistically significant decrease in total fat ($p = 0.031$) and vertical abdominal skinfold ($p = 0.03$), a significant decrease muscle mass ($p = 0.031$), and a significant increase in the perimeter above the iliac crest ($p = 0.031$).

Discussion

The results of this study show that microcurrent application using transcutaneous as well as percutaneous electrodes with a frequency of 25–10 Hz and 25–50Hz, combined with aerobic exercise, led to a significant decrease in subcutaneous abdominal fat thickness as measured by ultrasonography. Indeed, according to Ramírez-Ponce et al., fat cells are sensitive to electric currents, demonstrating that human adipose cells have voltage-dependent potassium currents.[38] Moreover, according to Hamida et al., microcurrents can induce cell membrane depolarization of the adipocyte, which can be cAMP dependent and contribute to increase lipolysis. These findings explain the use of microcurrent to stimulate lipolysis.[39]

Despite these positive results in relation to subcutaneous abdominal fat, microcurrent stimulation using a frequency of 25 and 10 Hz before aerobic exercise with transcutaneous electrodes was the only procedure that significantly decreased visceral fat. This change was measured by ultrasonography, which revealed the influence of the frequency on this type of fat. The studies also suggested that the frequencies used had a deeper effect and were more effective in β-adrenergic receptors stimulation compared with 25 and 50 Hz.

IG3, whose intervention used the same microcurrent frequencies as that used in IG1, followed by aerobic exercise, did not have a significant decrease in visceral fat, which can probably be explained by the selection of different electrodes (i.e., percutaneous). In fact, transcutaneous electrodes have a larger area of contact with the abdominal

Table 4. Skinfold Values in Placebo and Intervention Groups 1 at Moments 0 and 1 Compared with Values in Intervention Groups 2, 3, and 4 at Moment 1

Variable	Moment	Skinfold value (mm)					p-Value (M1–M0)		
		PG	IG1	IG2	IG3	IG4	PG-IG1-IG2	PG-IG1-IG3	PG-IG1-IG4
Suprailiac	M0	18.5 ± 2.7	19.1 ± 1.4	18.1 ± 2.9	19.5 ± 1.8	18.4 ± 0.7	NS	NS	0.01
	M1	17.4 ± 1.9	17.1 ± 1.1	16.1 ± 1	16.9 ± 0.5	15.7 ± 1.0			
Vertical abdominal	M0	15.5 ± 2.2	15.9 ± 1.4	15.6 ± 1.1	17.1 ± 1.1	16.4 ± 0.7	0.01	0.002	0.002
	M1	16.1 ± 2.2	15.7 ± 1.1	13.7 ± 1.8	15.3 ± 0.7	14.4 ± 1.4			
Horizontal abdominal	M0	17.7 ± 2.8	19.1 ± 0.8	17.8 ± 2.2	19.1 ± 0.37	17.3 ± 0.7	0.001	< 0.001	0.001
	M1	16.9 ± 2.7	16.3 ± 0.9	15.4 ± 1.8	17.4 ± 1.1	15.5 ± 1.4			

Unless otherwise noted, values are expressed as the median ± interquartile deviation. *p*-Value (M1–M0) of the Kruskal-Wallis test.

region and consequently had wider β-adrenergic receptors stimulation.

In IG2, after the intervention protocol, a significant increase in muscle mass was associated with the 25 and 50 Hz frequencies. Evidence suggests that frequencies in this range (20–50 Hz) influence the muscular layer; through stimulation of muscle fibers muscle mass and strength increase.[40]

Analysis of the results for the simultaneous performance of aerobic exercise with the application of microcurrent (the IG4 protocol), showed significantly decreased abdominal fat, measured by bioimpedance, as well as vertical and horizontal abdominal skinfolds. Indeed, some studies have shown that aerobic exercise stimulates lipolysis through an increase in catecholamine levels resulting from a higher sympathetic nervous system activity.[7,41] Despite this, the groups that performed aerobic exercise after microcurrent application (IG1, IG2, and IG3) had even better results, with a significant decrease in almost all variables. This finding indicates that when microcurrent was applied before exercise, triglyceride breakdown was stimulated during microcurrent use and increased further with aerobic exercise.

Bioimpedance used as an assessment too showed that abdominal fat percentage decreased significantly with transcutaneous electrodes, despite the frequency and the sequence of aerobic exercise/microcurrent application. This finding suggested a local electrolipolysis effect on abdominal fat decrease. Only IG3, which used percutaneous electrodes, showed no significant influence on abdominal fat percentage; this may have occurred because of the number of available channels, which restricted the abdominal area for microcurrent application.

BMI did not differ between groups; a possible reason could be an increase muscle mass despite a total fat percentage decrease. This finding suggests that BMI may be a limited evaluation indicator because it does not discriminate between fat and lean mass in total weigh.[32]

Skinfolds measurement decreased significantly when microcurrent was used, reveling that it can contribute to lipolysis stimulation and subcutaneous fat decrease. The significant reduction in abdominal skinfold after 10 sessions of microcurrent application was correlated with a significant decrease in below-last-rib and above-iliac-crest perimeters in all groups that performed aerobic exercise after microcurrent application.[36] This finding reinforced the theory that abdominal fat decrease is higher when aerobic exercise is performed after microcurrent application.

Although perimeters cannot discriminate fat types, the literature shows a significant correlation between waist-to-hip ratio and visceral fat.[31] Therefore, the significant decrease in waist-to-hip ratio in IG1 and IG2 reinforce the idea that microcurrent can influence visceral fat. It also supports the idea that aerobic exercise after microcurrent application extends lipolysis time and that transcutaneous electrodes stimulate more β-adrenergic receptors and stimulate the mitochondria to produce ATP.[30] In that way cAMP levels

Table 5. Perimeter Values in Placebo and Intervention Groups 1 at Moments 0 and 1 Compared with Values in Intervention Groups 2, 3, and 4 at Moment 1

Variable	Moment	Perimeter value (cm)					p-Value (M1–M0)		
		PG	IG1	IG2	IG3	IG4	PG-IG1-IG2	PG-IG1-IG3	PG-IG1-IG4
Below last rib	M0	67.8 ± 4.3	70.4 ± 4.9	72.7 ± 3.5	72.7 ± 5.3	71. 7 ± 3.0	0.004	0.006	0.011
	M1	68 ± 4.3	69.5 ± 4.9	69.7 ± 4.1	71.6 ± 3.7	69.2 ± 2.1			
Navel label	M0	80.3 ± 4.4	81.8 ± 5.7	83.2 ± 4.4	81.1 ± 5.8	79.6 ± 2.8	0.026	NS	NS
	M1	79.4 ± 4.4	80.8 ± 0.5	81.8 ± 4.1	79 ± 4.3	79.4 ± 4.4			
Above iliac crest	M0	76.3 ± 4.3	81.3 ± 5.1	80.5 ± 4.6	80.6 ± 5.9	76.6 ± 2.0	0.009	0.015	0.022
	M1	75.1 ± 4.7	79.8 ± 5	78 ± 3.8	78.8 ± 5	76.5 ± 2.9			
Waist-to-hip ratio	M0	0.731 ± 0.011	0.758 ± 0.03	0.726 ± 0.025	0.711 ± 0.047	0.721 ± 0.024	0.024	NS	0.046
	M1	0.728 ± 0.014	0.747 ± 0.029	0.709 ± 0.023	0.695 ± 0.042	0.709 ± 0.023			

Unless otherwise noted, values are expressed as the median ± interquartile deviation. *p*-Value (M1–M0) of the Kruskal-Wallis test.

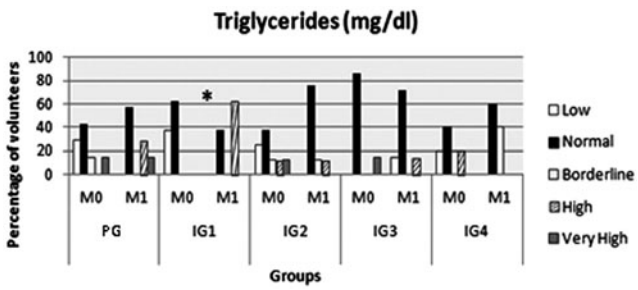

FIG. 6. Percentage of volunteers who had decreased, maintained, or increased triglyceride results in the placebo group ($n=7$) and intervention groups 1 ($n=8$), 2 ($n=8$), 3 ($n=7$), and 4 ($n=5$). M, moment. $^{*}p=0.016$.

are elevated and lipolysis is activated through protein kinase A–mediated phosphorylation of hormone-sensitive lipase.[42]

Despite the significant results found on the application of microcurrent followed by the aerobic exercise, triglycerides levels increased significantly with use of microcurrent frequencies of 10 Hz and 25 Hz (IG1). In fact, these frequencies induce lipolysis mainly in visceral fat. A high lipolytic rate characteristic of visceral fat may have contributed to greater FFA release than those that were consumed, leading to an FFA plasmatic and liver increase, which promotes triglyceride-rich lipoproteins synthesis.[16,42] Microcurrent promotes lipolysis through a catecholamine (epinephrine and norepinephrine) release by the adrenal gland. This stimulates adenyl cyclase enzyme, which catalyzes ATP conversion in intracellular cAMP. Thus, hormone-sensitive lipase is excited, promoting fat tissue triglyceride breakdown in glycerol and FFA, which serve as a source of energy or remain in systemic circulation, returning subsequently to triglycerides form.[9,19,39,42,43] Given what was explained before, it seems that the duration of aerobic exercise was too short to oxidate all FFAs released by microcurrent with frequencies 10 and 25 Hz.

Although aerobic exercise features were selected on the basis of studies reporting that prolonged exercise (more than 30 minutes) with moderate intensity (between 47% and 52% of maximal oxygen consumption) stimulate effectively FFA oxidation, more studies with different aerobic exercise characteristics to increase FFA oxidation (such as room temperature control, increased duration, or another exercise modality) are needed.[8,9,20,44,45]

Participants' physical activity and food habits had no influence on the reported results; IPAQ and QFA didn't reveal any statistically significant differences between M0 and M1, at the end of the 10 sessions.

Intervention effects were maintained after 4 weeks of the end of the procedures. Nevertheless, IG1 revealed a significant decrease in total fat percentage and vertical abdominal skinfold, suggesting that the positive effects of microcurrent application with transcutaneous electrodes with 25- and 10-Hz frequencies may have been prolonged even after the end of protocol. However, this group showed a muscle mass decrease and increase in perimeter above the iliac crest, supporting the need for an ongoing aerobic exercise program to maintain results over time.[46]

In addition, studying the intervention effects in a larger sample and on a weekly basis is needed to more accurately determine when these effects are improved and they start to attenuate.

This study has provided some answers to guide future clinical practice. In the future, it would be important to check the applicability in obese individuals and individuals with specific metabolic diseases.

In conclusion, the results of this study suggest that microcurrent application induces lipolysis and provides effects additive to aerobic exercise on fat tissue decrease. Aerobic exercise performed after microcurrent application seems to be more effective in reducing visceral and subcutaneous fat. Both sets of frequencies were effective, but only 25-Hz and 10-Hz frequencies seem to be able to influence visceral fat. Transcutaneous application appears to be more effective than percutaneous application. The results of aerobic exercise with microcurrent were maintained over time.

Acknowledgments

The authors are grateful to the participants and to physiotherapy experts Paulo Carvalho, Miriam Couto, and Claudia Silva.

Author Disclosure Statement

No competing financial relationships exist. All authors have reviewed the manuscript and take responsibility for its content. The experiments of this study comply with the current laws of Portugal.

References

1. Shaw K, Gennat H, O'Rourke P, Del Mar C. Exercise for overweight or obesity. Cochrane Database Syst Rev. 2006(4):CD003817.
2. Després JP, Lemieux I. Abdominal obesity and metabolic syndrome. Nature 2006;444:881–887.
3. Shea JL, King MT, Yi Y, et al. Body fat percentage is associated with cardiometabolic dysregulation in BMI-defined normal weight subjects. Nutr Metab Cardiovasc Dis. 2012;22:741–747.
4. Ahmadian M, Duncan RE, Sul HS. The skinny on fat: lipolysis and fatty acid utilization in adipocytes. Trends Endocrinol Metab. 2009;20:424–428.
5. Sadikot S, Hermans M. Here we go again…The metabolic syndrome revisited! Diabetes Metabol Syndr Clin Res Rev 2010;4:111–120.
6. Tchernof A, Bélanger C, Morisset AS, et al. Regional differences in adipose tissue metabolism in women: minor effect of obesity and body fat distribution. Diabetes. 2006;55:1353–1360.
7. de Glisezinski I, Larrouy D, Bajzova M, et al. Adrenaline but not noradrenaline is a determinant of exercise-induced lipid mobilization in human subcutaneous adipose tissue. J Physiol. 2009;587(Pt 13):3393–3404.
8. Achten J, Jeukendrup AE. Optimizing fat oxidation through exercise and diet. Nutrition. 2004;20:716–727.
9. McMurray RG, Hackney AC. Interactions of metabolic hormones, adipose tissue and exercise. Sports Med. 2005;35:393–412.
10. Powers SK, Howley ET. Exercise Physiology: Theory and Application to Fitness and Performance. New York: McGraw-Hill, 2012.

11. McCaig CD, Rajnicek AM, Song B, Zhao M. Controlling cell behavior electrically: current views and future potential. Physiol Rev 2005;85:943–978.
12. Poltawski L, Watson T. Bioelectricity and microcurrent therapy for tissue healing: a narrative review. Phys Ther Rev 2009;14:104–114.
13. Curtis D, Fallows S, Morris M, McMakin C. The efficacy of frequency specific microcurrent therapy on delayed onset muscle soreness. J Bodyw Mov Ther 2010;14:272–279.
14. Melo ASC, Moreira JS, Noites A, et al. Clay body wrap with microcurrent: effects in central adiposity. Appl Clay Sci 2013;80–81:140–146.
15. McMakin CR, Oschman JL. Visceral and somatic disorders: tissue softening with frequency-specific microcurrent. J Altern Complement Med 2013;19:170–177.
16. Large V, Peroni O, Letexier D, et al. Metabolism of lipids in human white adipocyte. Diabetes Metab 2004;30:294–309.
17. Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35:1381–1395.
18. Melzer K. Carbohydrate and fat utilization during rest and physical activity. e-SPEN J 2011;6:e45–e52.
19. AbouRjaili G, Shtaynberg N, Wetz R, et al. Current concepts in triglyceride metabolism, pathophysiology, and treatment. Metabolism 2010;59:1210–1220.
20. Jakicic JM, Marcus BH, Gallagher KI, et al. Effect of exercise duration and intensity on weight loss in overweight, sedentary women: a randomized trial. JAMA 2003;290:1323–1330.
21. Pietrobelli A, Rubiano F, St-Onge MP, Heymsfield SB. New bioimpedance analysis system: improved phenotyping with whole-body analysis. Eur J Clin Nutr 2004;58:1479–1484.
22. Bazzocchi A, Filonzi G, Ponti F, et al. Accuracy, reproducibility and repeatability of ultrasonography in the assessment of abdominal adiposity. Acad Radiol 2011;18:1133–1143.
23. Leahy S, Toomey C, McCreesh K, et al. Ultrasound measurement of subcutaneous adipose tissue thickness accurately predicts total and segmental body fat of young adults. Ultrasound Med Biol 2012;38:28–34.
24. Wagner DR. Ultrasound as a tool to assess body fat. J Obes 2013;2013:280713.
25. Gogia PP, Braatz JH. Validity and reliability of leg length measurements. J Orthop Sports Phys Ther 1986;8:185–188.
26. Fermann GJ, Suyama J. Point of care testing in the emergency department. J Emerg Med 2002;22:393–404.
27. Ng WY, Tiong CC, Jacob E. Maltose interference-free test strips for blood glucose testing at point-of-care: a laboratory performance evaluation. Diabetes Technol Ther 2010;12:889–893.
28. Lopes C, Aro A, Azevedo A, et al. Intake and adipose tissue composition of fatty acids and risk of myocardial infarction in a male Portuguese community sample. J Am Diet Assoc 2007;107:10.
29. Chen MJ, Fan X, Moe ST. Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. J Sports Sci 2002;20:873–899.
30. Lee BY, Al-Waili N, Stubbs D, et al. Ultra-low microcurrent in the management of diabetes mellitus, hypertension and chronic wounds: report of twelve cases and discussion of mechanism of action. Int J Med Sci 2009;7:29–35.
31. Noble RE. Waist-to-hip ratio versus BMI as predictors of cardiac risk in obese adult women. West J Med 2001;174:240–241.
32. Kyle UG, Schutz Y, Dupertuis YM, Pichard C. Body composition interpretation. Contributions of the fat-free mass index and the body fat mass index. Nutrition 2003; 19:597–604.
33. Holzhauer S, Zwijsen RM, Jaddoe VW, et al. Sonographic assessment of abdominal fat distribution in infancy. Eur J Epidemiol 2009;24:521–529.
34. Tadokoro N, Shinomiya M, Yoshinaga M, et al. Visceral fat accumulation in Japanese high school students and related atherosclerotic risk factors. J Atheroscler Thromb 2010;17: 546–557.
35. Goh LG, Dhaliwal SS, Welborn TA, et al. Anthropometric measurements of general and central obesity and the prediction of cardiovascular disease risk in women: a cross-sectional study. BMJ Open 2014;4:e004138.
36. Minghelli B, Nunes C, Oliveira R. Prevalence of overweight and obesity in portuguese adolescents: comparison of different anthropometric methods. N Am J Med Sci 2013;5:653–659.
37. Rosner BA. Fundamentals of Biostatistics. Boston: Thomson-Brooks/Cole, 2006.
38. Ramírez-Ponce MP, Mateos JC, Bellido JA. Human adipose cells have voltage-dependent potassium currents. J Membr Biol 2003;196:129–134.
39. Hamida ZH, Comtois AS, Portmann M, et al. Effect of electrical stimulation on lipolysis of human white adipocytes. Appl Physiol Nutr Metab 2011;36:271–275.
40. Hopkins PM. Skeletal muscle physiology. Contin Educ Anaesth Crit Care Pain 2006;6:1–6.
41. Kwon HR, Min KW, Ahn HJ, et al. Effects of aerobic exercise on abdominal fat, thigh muscle mass and muscle strength in type 2 diabetic subject. Korean Diabetes J 2010;34:23–31.
42. Ahmadian M, Wang Y, Sul HS. Lipolysis in adipocytes. Int J Biochem Cell Biol 2010;42:555–559.
43. Henderson GC, Krauss RM, Fattor JA, et al. Plasma triglyceride concentrations are rapidly reduced following individual bouts of endurance exercise in women. Eur J Appl Physiol 2010;109:721–730.
44. Katzmarzyk PT, Leon AS, Rankinen T, et al. Changes in blood lipids consequent to aerobic exercise training related to changes in body fatness and aerobic fitness. Metabolism 2001;50:841–848.
45. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007;39:1423–1434.
46. Achten J, Venables MC, Jeukendrup AE. Fat oxidation rates are higher during running compared with cycling over a wide range of intensities. Metabolism 2003;52:747–752.

Address correspondence to:
Andreia Noites, PT, MSc
Department of Physiotherapy
School of Allied Health Technologies
Polytechnic Institute of Porto
Rua Valente Perfeito, 322
4400-330 - Vila Nova de Gaia
Portugal

E-mail: arn@estsp.ipp.pt or andreianoites@gmail.com