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Transcutaneous Electrical Nerve Stimulation for Pain Relief After Liposuction: A Randomized Controlled Trial

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Abstract

Background Liposuction is a common cosmetic surgical procedure, which requires analgesia for postoperative pain. Transcutaneous electrical nerve stimulation (TENS) has been used for postoperative pain relief; however, there is no evidence of its effectiveness in liposuction patients and this is the focus of this paper.

Methods A prospective, randomized, double-blind, controlled trial was conducted with 42 adult patients who underwent liposuction. Patients were randomly allocated to either the TENS group (active TENS) or control group (sham TENS). All patients received morphine (0.1 mg/kg) and dipyrone 1 g immediately after surgery; TENS was delivered 2 h later. The primary outcome was pain intensity. Secondary outcomes were analgesic requirement, number and types of adverse effects of TENS, quality of pain, treatment success, and patient satisfaction. Postoperative pain was measured using a visual analog scale (VAS) and the Brazilian version of the McGill Pain Questionnaire (Br-MPQ).

Results Patients in the TENS group reported significantly lower pain intensity ($P < 0.001$, effect size = 0.92) compared with those in the control group. TENS significantly decreased the consumption of analgesics in the postoperative period ($P < 0.001$). No withdrawals or adverse effects were observed in the TENS group, but 33.3 % of patients in the control group reported drowsiness and nausea. About 95 and 38 % of patients in the TENS and control groups, respectively, were satisfied with the analgesic treatment.

Conclusion The results indicate that TENS is effective as an adjunct to analgesics for pain relief after liposuction.

Level of Evidence I This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keywords Plastic surgery · Liposuction · Postoperative pain · TENS · Analgesia · Electrotherapy

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Introduction

Liposuction is an invasive technique performed to remove subcutaneous fat using suction cannulas [1, 2]. This technique can be utilized to esthetically improve body contouring and harvest fat grafts to be used in reconstructive surgery to repair body deformities resulting from lipodystrophy, burns, trauma, and tumor resection [2, 3]. Postoperative complications may occur, including inflammation and fibrosis formation in the treated area [4, 5]. Postoperative pain after liposuction may be acute and interfere with

recovery, increasing hospital length of stay [6–9]. Therefore, appropriate and effective postoperative analgesia, preferably without significant adverse effects, should be incorporated into the patient's rehabilitation plan [10–12].

Modern advances in liposuction techniques have focused on reducing postoperative pain [6, 13–15]. Transcutaneous electrical nerve stimulation (TENS) is an inexpensive non-invasive analgesic technique. TENS uses low-voltage electrical current applied to the skin through self-adhesive electrodes to control acute and chronic pain [12, 15, 16]. Electrotherapy involves sensory stimulation that increases afferent input, changing the perception of pain and operating via the pain gate concept. TENS, especially at high frequencies, inhibits the response of C-fiber nociceptors in the dorsal horn of the spinal cord [17]. Evidence of the analgesic effect of TENS associated with the release of endogenous opioids can be found in the literature [18–20]. TENS at high frequencies (>50 Hz) activates δ-opioid receptors in the spinal cord and rostral ventral medulla, reducing glutamate release, and activates gamma-aminobutyric acid type A ($GABA_A$) receptors in the spinal cord [18, 19].

The combined use of electrical stimulation and pharmacological analgesics can provide great pain relief after abdominal, thoracic, and gynecological surgeries [12, 21–27]. The use of TENS has also been associated with significant decrease in analgesic consumption for postoperative pain [12]. However, no evidence was found that TENS can be used as adjunct therapy for pain relief after liposuction.

Thus, the aim of this study was to evaluate the effectiveness of TENS as an adjunct analgesic therapy for postoperative pain in liposuction patients.

Patients and Methods

This prospective, randomized, double-blind, controlled trial was approved by an Institutional Research Ethics Committee (approval number 1251/10), and registered at the Brazilian Clinical Trials Registry (ReBec; ensaiosclinicos.gov.br), registration code RBR-8ftzft. It was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its subsequent revisions. Written informed consent was obtained from all patients prior to their inclusion in the study. Patient anonymity was assured.

Women between 18 and 40 years of age were recruited from a waiting list for liposuction in a plastic surgery outpatient clinic of a university hospital.

Eligibility criteria were being healthy, with body mass index (BMI) between 20 and 24.9 kg/m^2, no previous TENS treatment, and be referred by the plastic surgery outpatient clinic of a university hospital with indication for liposuction due to excess of adiposity in the abdomen, back and flanks, after being evaluated by a plastic surgeon.

Exclusion criteria were low back pain lasting for more than 6 months, use of illicit psychotropic drugs for more than one year; continuous use of analgesics; presence of cardiac pacemaker, systemic diseases, presence of keloid in the region of liposuction, known allergy to any drug used in the study (including morphine, dipyrone, remifentanil, propofol, cephalothin, lidocaine), pregnancy, previous laparotomy (including cesarean section because denervation could influence pain perception), presence of abdominal wall hernia, and previous liposuction.

Forty-two eligible patients were included in the study and randomized in a 1:1 ratio to receive either active TENS (TENS group; $n = 21$) or sham TENS (control group; $n = 21$). The allocation sequence was generated using a computer-generated randomization chart, and group allocation was concealed in sealed opaque envelopes, which were opened by a physiotherapist after the liposuction procedure.

Patients were told before TENS treatment that the stimuli could be imperceptible.

Two investigators were trained to administer the questionnaires.

Liposuction Procedure

The patients received general anesthesia with propofol (2.0 mg/kg), remifentanil hydrochloride (50 μg/kg/min), and pancuronium (0.04 mg/kg). Infiltration was performed with Klein solution, consisting of 1 ml of adrenaline and 50 ml of 1 % lidocaine diluted in 1,000 ml of normal saline (0.9 % NaCl). During liposuction, 500 ml of Klein solution was infiltrated for every 1,000 ml of aspirated fat (1:2 ratio). Conventional liposuction (suction-assisted lipoplasty) was performed 10 min after infiltration using 3- and 4-mm blunt cannulas (Mercedes, MD Engineering, Foster City, CA, USA) connected to a suction device.

Intervention

All patients received intramuscular morphine sulfate (0.1 mg/kg) and intravenous dipyrone 1 g for postoperative analgesia, an injectable solution containing 5 mg/ml of metoclopramide hydrochloride (0.5 mg/kg) administered intravenously for antiemetic treatment, and cephalothin sodium 1 g for antibiotic prophylaxis.

Rescue analgesia consisting of 2.5 mg of intravenous morphine sulfate and oral dipyrone 500 mg was provided based on measures of pain intensity (VAS). Dipyrone was offered for mild pain (VAS pain scores up to 30/100 mm), and morphine sulfate was provided for moderate pain (VAS pain scores ≥50/100 mm).

Two hours after liposuction, two pairs of 5 × 5-cm self-adhesive rubber or silicone electrodes were placed on dermatomes located in the surgical region at four different points in all patients. Two electrodes were placed 2 cm from the adjacent spinal processes of the 11th and 12th thoracic vertebrae, and two electrodes were positioned 2 cm from the adjacent spinal processes of 5th lumbar vertebra, parallel to the above-mentioned electrodes (Fig. 1).

The TENS device (Neurodyn II, Ibramed, São Paulo, Brazil) was set at a frequency of 100 Hz and pulse duration of 100 μs. The stimulus intensity was adjusted to produce a strong but comfortable tingling sensation. Active TENS was delivered for 30 min to patients in the TENS group. Patients in the control group (sham TENS) received the same handling and electrode placement, but no current was applied.

A digital oscilloscope (DPO 7000, Tektronix Inc., Beaverton, OR, USA) was used for calibration of the TENS device.

Outcome Measures

The primary outcome was pain intensity, which was measured using a visual analog scale (VAS) immediately before stimulation (baseline), immediately after stimulation, and 6, 12, and 24 h postoperatively. Secondary outcomes were analgesic requirement, number and types of adverse effects of TENS, quality of pain, treatment success, and patient satisfaction after TENS application.

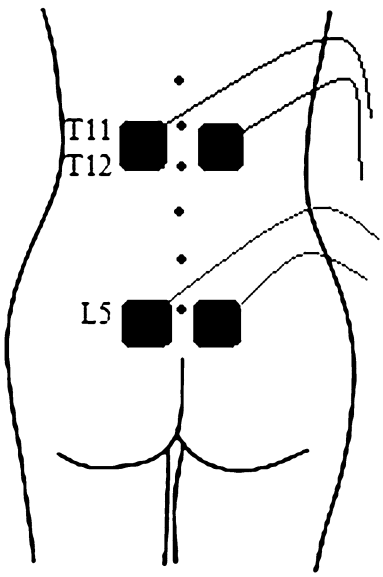

Fig. 1 Electrodes placed on dermatomes in the surgical region. One pair of 5 × 5-cm self-adhesive rubber or silicone electrodes was placed 2 cm from the adjacent spinal processes of the 11th and 12th thoracic vertebrae, and the other pair of electrodes was placed 2 cm from the adjacent spinal processes of 5th lumbar vertebra, parallel to the above-mentioned pair

Quality of pain was measured using the Brazilian version of the McGill Pain Questionnaire (Br-MPQ) [28–30].

The treatment would be considered successful if ≥50 % of patients reported pain reduction. Reduction in pain intensity in 30–49 % and ≥50 % of patients would be considered moderate and substantial, respectively [31].

To assess patient satisfaction with TENS application, all patients were asked the following question after the stimulation: "Did you like the treatment, yes or no?" Answers such as "a little bit," "more or less," and "I don't know" were not used in this study.

Sample Size Estimation

Setting the power of the sample at 85 % and significance level at 5 % using the Mann–Whitney test, the sample size of 20 patients in each group (TENS group and control group) would be required to detect a difference of 2.0 points in pain intensity (VAS) between pre- and post-stimulation measurements within and between groups. Therefore, 21 patients were randomly allocated to each group.

Statistical Analysis

The Mann–Whitney test was used to compare the VAS pain intensity scores and Br-MPQ scores between groups and between different time points within groups. Friedman's test was used to evaluate overall differences and period effects. If differences were found, individual comparisons were made with the Wilcoxon rank-sum test.

All statistical tests were performed at a significance level of 0.05 ($P < 0.05$). Data are expressed as median (interquartile range [IQR]).

Results

Forty-two patients were included in the study and randomized to double-blind treatment. No patient was lost to follow-up. The flow chart of the study is shown in Fig. 2.

Median values for age, BMI, and total aspirated fat volume in the control and TENS groups were 27 (25–25) years and 25 (24–28) years; 23.0 (23.0–23.7) kg/m^2 and 23.0 (22.4–23.4) kg/m^2; 2,400 (2,300–2,500) ml and 2,200 (2,000–2,500) ml, respectively. The characteristics of the study population are listed in Table 1.

No significance differences were found in median VAS pain scores between groups at baseline (control group, 6.0 (6.0–6.0); TENS group, 6.0 (6.0–6.5); $P = 0.291$, effect size (ES) = 0.16). However, there was a significant reduction in

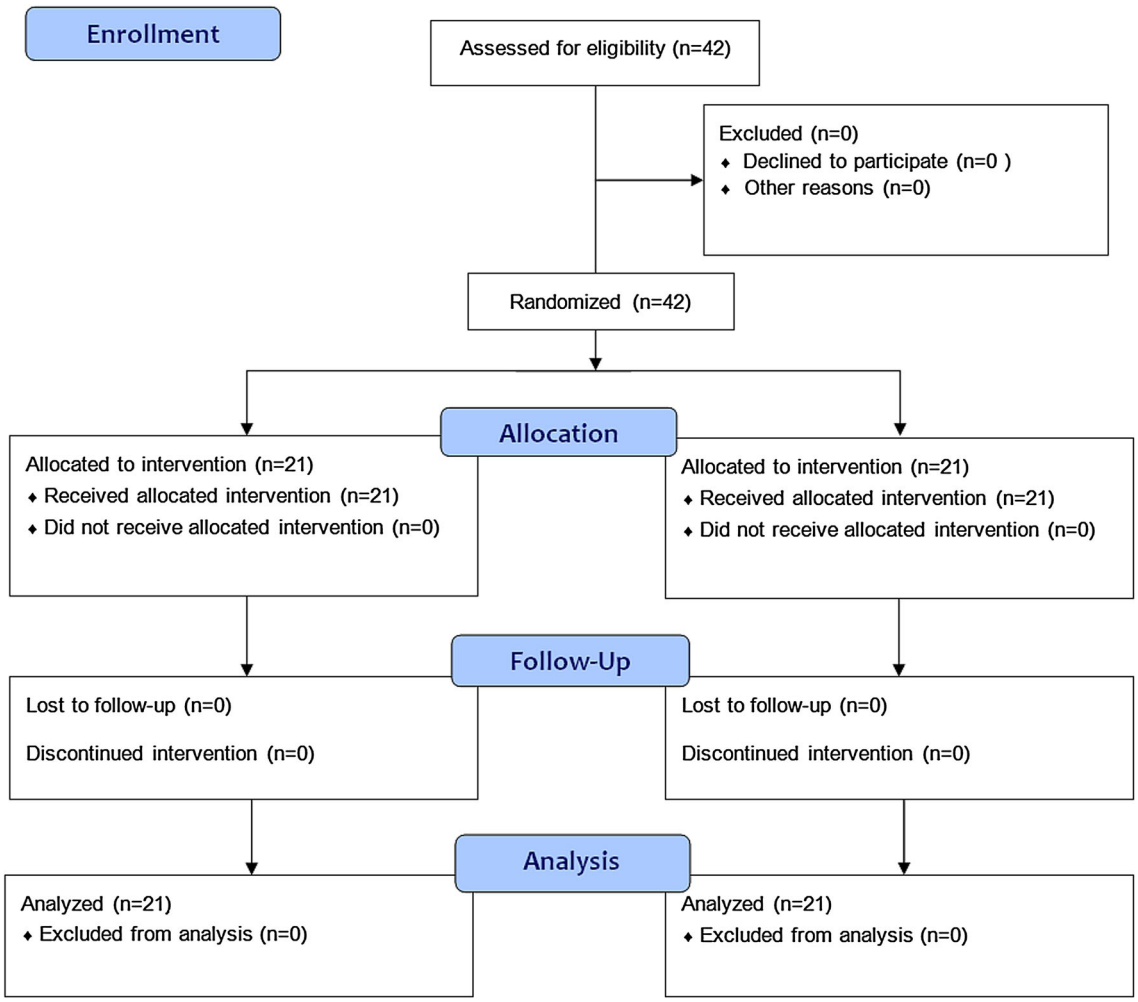

Fig. 2 Study flow chart

median VAS pain scores from baseline in the TENS group, and significant differences between groups immediately after the stimulation ($P = 0.001$, ES $= 0.92$) and at all post-stimulation time points ($P = 0.001$). No significant differences in median VAS pain scores were found in the control group among time points (Table 2; Fig. 3). There was no significant between-group difference in the number of patients who required analgesics immediately after stimulation ($P = 0.488$). At other post-stimulation time points (6 h, 12 h, and 24 h after liposuction), the consumption of analgesics was significantly greater ($P < 0.001$) among patients in the control group (sham TENS) than among those in the TENS group (active TENS), as shown in Table 3.

In both groups, no patient reported severe pain intensity (VAS pain scores ≥80/100 mm) after stimulation. No adverse effects were observed in the TENS group, but 33.3 % of patients in the control group reported drowsiness and nausea.

There were no significant differences in median Br-MPQ scores between groups at baseline. However, the TENS group showed significant differences from baseline in the pain rating index (PRI), number of words chosen (NWC), and present pain intensity (PPI) immediately after stimulation ($P < 0.001$) (Table 4). Significant differences in quality of pain, evaluated by the sensory, affective, evaluative, and miscellaneous Br-MPQ domains, were observed between the TENS and control groups after stimulation ($P < 0.001$), as seen in Table 5. No significant differences were found in Br-MPQ domain scores in the control group ($P = 0.105$, Friedman's test) between baseline and the immediate post-stimulation assessment;

Table 1 Characteristics of the participants

Characteristics	Control group $N = 21$ Median (IQR)	TENS group $N = 21$ Median (IQR)
Age (years)	27.0 (25.0–25.0)	25.0 (24.0–28.0)
BMI (kg/m^2)	23.0 (23.0–23.7)	23.0 (22.4–23.4)
Volume of fat aspirated (ml)	2,400 (2,300–2,500)	2,200 (2,000–2,500)

Table 2 Median VAS pain scores measured immediately before and after stimulation at the different time points

Time points	Control group $N = 21$ Median (IQR)	TENS group $N = 21$ Median (IQR)	*P* value	ES
Immediately before stimulation	6.0 (6.0–6.0)	6.0 (6.0–6.5)	0.291	0.16
Immediately after stimulation	4.0 (4.0–4.0)	1.0 (1.0–1.0)	0.001*	0.92
6 h postoperatively	4.0 (4.0–4.0)	0 (0–1.0)	0.001*	0.92
12 h postoperatively	3.0 (3.0–5.0)	0 (0–0)	0.001*	0.68
24 h postoperatively	2.0 (2.0–3.0)	0 (0–0)	0.001*	0.65

IQR interquartile range, *ES* effect size

Mann–Whitney test; * Statistical significance ($P < 0.05$)

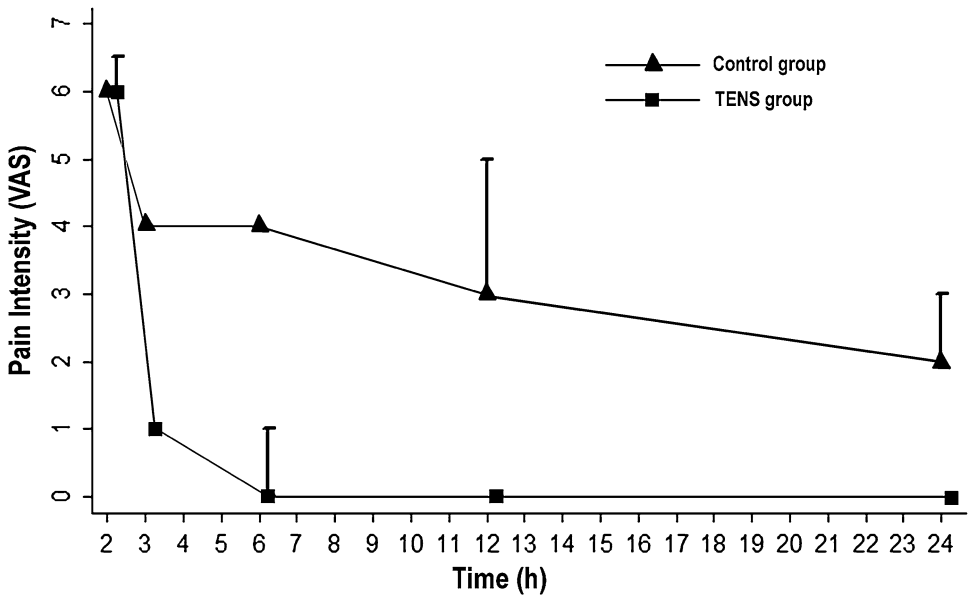

Fig. 3 Pain intensity values measured over the 24-h period after surgery

however, in the TENS group, there were significant differences in score reduction from baseline among the different Br-MPQ domains ($P = 0.048$, ES = 0.48), especially between the sensory and miscellaneous domains ($P = 0.003$, ES = 0.45), with the sensory domain showing greater reduction in scores.

The TENS treatment was considered successful as 95.23 % of patients in the TENS group experienced significant pain reduction. Also, 95 % of patients in the TENS group and 38 % of controls reported being satisfied with the TENS treatment for pain relief, with a significant difference between groups.

Discussion

Postoperative pain associated with different liposuction techniques is an important factor that needs further investigation [3, 6, 13, 14]. For this reason, the primary outcome of this study was pain intensity. Liposuction patients reported moderate postoperative pain, which reduced to mild or no pain after TENS. The use of TENS as adjunct therapy for pain relief provided superior postoperative analgesia compared to drugs alone and led to a significantly smaller consumption of analgesics. Lim et al. [21] obtained similar results and concluded that TENS is effective as an adjunct analgesic therapy for postoperative pain in cholecystectomy patients. Hamza et al. [22] observed that TENS decreased postoperative opioid analgesic requirements and opioid-related side effects when utilized as an adjunct to patient-controlled analgesia (PCA) after lower abdominal surgery. The authors also reported that the use of TENS at mixed frequencies of stimulation resulted in a slightly greater opioid-sparing effect than either low or high frequencies alone. However, Benedetti et al. [32] found that TENS produces analgesic effects after thoracic surgical procedures only when postoperative pain is mild to moderate, and that it is ineffective for severe pain. Other

Table 3 Analgesia request during 24 h after liposuction

Time points/analgesia request	Group				Total	
	Control		TENS			
	N	%	*N*	%	*N*	%
Immediately after stimulation	21	100	21	100	42	100
No	19	90.5	21	100	40	95.2
Yes	2	9.5	0	0	2	4.8
$P = 0.488$						
6 h postoperatively	21	100	21	100	42	100
No	1	4.8	21	100	22	52.4
Yes	20	95.2	0	0	20	47.6
$\chi^2 = 38.18$; $P < 0.001$*						
12 h postoperatively	21	100	21	100	42	100
No	1	4.8	21	91.3	22	50.0
Yes	20	95.2	2	8.7	22	500
$\chi^2 = 32.89$; $P < 0.001$*						
24 h postoperatively	21	100	21	100	42	100
No	0	0.0	17	81.0	17	40.5
Yes	21	100.0	4	19.0	25	59.5
$\chi^2 = 28.56$; $P < 0.001$*						

Fisher's exact test and Chi-square test

* Statistical significance ($P < 0.05$)

authors obtained significant relief of postoperative pain and decreased analgesic requirement by combining high-frequency TENS with dipyrone [24, 25, 27].

High-frequency TENS reduces pain by interfering with the transmission of the nociceptive input at the level of the spinal cord through activation of δ-opioid and $GABA_A$ receptors, subsequently reducing input through the ascending spinothalamic tract. In addition, stimuli can activate δ-opioid receptors in the periaqueductal gray and rostral ventromedial medulla, reducing glutamate release [17–20]. However, morphine inhibits C-fiber-evoked neuronal activity, while Aβ-fiber-evoked activities are unchanged [33]; it exerts agonist activity mainly at μ-opioid receptors [34]. A large dose of morphine can activate δ-opioid receptors [35]. Thus, low doses of morphine (acting through μ-opioid receptors) combined with high-frequency TENS can activate δ-opioid receptors and may increase the analgesic effect [36].

In this study, the comparison between baseline and immediate post-stimulation scores on the PRI measure of the Br-MPQ showed a significant decrease in pain perception in about 74 % of patients who received TENS, indicating that electrical stimulation can provide a substantial pain reduction, which is in agreement with the findings of Smith et al. [23]. The word descriptors that best represent pain intensity are those selected by at least 33 % of patients [37]. After TENS treatment, the word descriptors most chosen by patients in both groups to describe their subjective pain experience belong to the sensory domain of the Br-MPQ. Word descriptors characterize pain perception in both emotional and psychological aspects. Thus, TENS can reduce both the sensory-discriminative and motivational-affective components of pain [38].

Further studies with a larger number of patients and area-specific testing are necessary to investigate the effectiveness of TENS as an adjunct analgesic therapy for postoperative pain in liposuction patients with BMI $\geq$25 kg/m^2 or <20 kg/m^2, and when a larger volume of fat (>2,500 ml) is aspirated.

A limitation of this study was the short follow-up of 24 h for evaluation of postoperative pain intensity after TENS treatment, which corresponds to the length of hospital stay after liposuction.

Table 4 Quality of pain control based on Br-MPQ scores

Br-MPQ measures/groups	Immediately before stimulation		ES	Immediately after stimulation		
	Median (IQR)	*P* value		Median (IQR)	*P* value	ES
PRI						
Control	37.0 (35.0–40.0)			34.0 (32.0–35.0)		
TENS	37.0 (35.0–44.0)	0.849	0.03	9.0 (8.0–13.0)	<0.001*	0.86
NWC						
Control	20.0 (18.0–20.0)			18.0 (18.0–20.0)		
TENS	20.0 (18.0–20.0)	0.565	0.09	8.0 (8.0–9.0)	<0.001*	0.87
PPI						
Control	3.0 (2.0–3.0)			2.0 (2.0–2.0)		
TENS	3.0 (2.0–3.0)	0.860	0.03	1.0 (1.0–1.0)	<0.001*	0.90

Br-MPQ Brazilian version of the McGill Pain Questionnaire, *PRI* pain rating index, *NWC* number of words chosen, *PPI* present pain intensity, *IQR* interquartile range, *ES* effect size

Mann–Whitney test; * Statistical significance ($P < 0.05$)

Table 5 Perception of pain in both groups according to the Br-MPQ domain scores

Br-MPQ domains	Before stimulation		After stimulation	
	Control group $N = 21$	TENS group $N = 21$	Control group $N = 21$	TENS group $N = 21$
Sensory				
Median (IQR)	23 (20.5–24.0)	23 (20.5–24.0)	21 (20.0–23.0)	5.0 (4.0–8.5)
P value	0.979		<0.001*	
ES	0		0.86	
Affective				
Median (IQR)	8.0 (5.5–10.0)	8.0 (5.5–10.0)	6.0 (5.5–9.0)	2.0 (1.0–2.0)
P value	0.828		<0.001*	
ES	0.03		0.87	
Evaluative				
Median(IQR)	3.0 (2.0–4.0)	2.0 (2.0–4.0)	2.0 (2.0–2.0)	1.0 (1.0–1.0)
P value	0.400		<0.001*	
ES	0.13		0.81	
Miscellaneous				
Median(IQR)	5.0 (4.5–6.0)	6.0 (5.0–7.5)	4.0 (3.0–4.5)	1.0 (1.0–2.0)
P value	0.166		<0.001*	
ES	0.21		0.82	

Br-MPQ Brazilian version of the McGill Pain Questionnaire, *IQR* interquartile range, *ES* effect size

Mann–Whitney test; * Statistical significance ($P < 0.05$)

Conclusion

This randomized double-blinded, controlled trial showed that TENS can be safely used as adjunct analgesic therapy after liposuction. TENS effectively led to a substantial reduction in postoperative pain and analgesic consumption when administered in combination with morphine and dipyrone in a multimodal analgesic regimen.

Compliance with Ethical Requirements All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments.

Conflict of interest The authors declare that they have no conflicts of interest to disclose.

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