Journal of Cosmetic and Laser Therapy, 2011; 13: 166–171

informa
healthcare

ORIGINAL ARTICLE

New treatment of cellulite with infrared-LED illumination applied during high-intensity treadmill training

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Abstract

Phototherapy improves cellular activation which is an important factor for the treatment of cellulite. The objective of this research was to develop and evaluate the effects of a new (noninvasive and nonpharmacological) clinical procedure to improve body aesthetics: infrared-LED (850 nm) plus treadmill training. Twenty women (25–55 years old) participated in this study. They were separated in two groups: the control group, which carried out only the treadmill training ($n = 10$), and the LED group, with phototherapy during the treadmill training ($n = 10$). The training was performed for 45 minutes twice a week over 3 months at intensities between 85% and 90% maximal heart rate (HR_{max}). The irradiation parameters were 39 mW/cm^2 and a fluence of 106 J/cm^2. The treatment was evaluated by interpreting body composition parameters, photographs and thermography. This was primarily a treatment for cellulite with a reduction of saddlebag and thigh circumference. At the same time, the treadmill training prevented an increase of body fat, as well as the loss of lean mass. Moreover, thermal images of the temperature modification of the thighs are presented. These positive effects can result in a further improvement of body aesthetics using infrared-LED together with treadmill training.

Key Words: *body composition, cellulite, infrared-LED, thermography, treadmill training*

Introduction

Obesity and localized fat are not synonymous with cellulite, but can be associated with it. In obesity there are hyperplasia and hypertrophy of adipocytes, whereas in localized fat there is hypertrophy of adipocytes with different shapes and sizes, either disaggregated or united. With regards to cellulite, it can occur in obese and lean women, because it is characterized by alterations of the microcirculation and the lymphatic system plus a dysfunction of cutaneous and adipose tissue with a fibrotic reaction leading to an 'orange peel' skin appearance (1). Other terms which have been used for cellulite are nodular liposclerosis, edemato-fibrosclerotic panniculopathy, panniculosis, and gynoid lipodystrophy (2,3).

Cellulite is a common condition in women, frequently found on the thigh and buttock regions, and it shows four evolutionary grades or stages (4). Its aetiology is multi-factorial, including structural, genetic and endocrinal causes, as well as age, diet, a sedentary lifestyle and gender. Cellulite is predominantly found in women because the skin tissue architecture is different from that of men (5). The fibrous septae network is perpendicular to the women's skin surface, whereas for men it is criss-crossed (4,6). In addition, the connective tissue matrix is altered and adipogenicity is increased in women. This explains hypodermic (subcutaneous fat) invaginations inside the dermis (connective tissue) causing deformity (1,3,7).

The cosmetic problems caused are undesirable for women. The objective of this research was to develop and evaluate the effects of a new (noninvasive and nonpharmacological) clinical procedure to improve body aesthetics using infrared radiation originated from LEDs (850 nm) associated with treadmill training.

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(Received 3 May 2011; accepted 14 May 2011)

ISSN 1476-4172 print/ISSN 1476-4180 online © 2011 Informa UK, Ltd.
DOI: 10.3109/14764172.2011.594065

Materials and methods

The current research has been approved by the National Ethics Committee of the Ministry of Health in Brasilia, Brazil and by the Ethics Committee of the Federal University of São Carlos (UFSCar) in São Carlos, Brazil. All subjects signed written informed consents before their participation in the study.

The treatment was performed on 20 women (caucasian; aged between 25 and 55 years). They were separated into two groups: the control group, which carried out only the treadmill training ($n = 10$), and the LED group, which included phototherapy during the treadmill training ($n = 10$). The volunteers were instructed not to change their eating habits (not to diet) for the duration of this study.

The maximal effort test using a treadmill (Bruce Protocol for young women and Modified Bruce Protocol II for middle-aged women) (8–10) was performed for diagnosis and elaboration of training intensities based on HR_{max} via the electrocardiogram (Ergo; HW Systems – HeartWare Ltda, Belo Horizonte, MG, Brazil) and the cardiofrequencimeter monitor (Polar S830i; Polar Electro Inc., Woodbury, NY, USA). Treadmill training at intensities between 85% and 90% HR_{max} with or without phototherapy was performed twice a week for 3 months, each session lasting 45 minutes. The HR_{max} and HR of the training were, respectively, 170 ± 13 bpm and 150 ± 15 bpm for the LED group and 160 ± 8 bpm and 140 ± 9 bpm for the control group.

For the phototherapy to be performed during treadmill training, the Optics Group from Instituto de Física de São Carlos (IFSC), University of São Paulo (USP) developed a system based on infrared-LEDs (850 nm) to be used during physical exercise (10).

A power meter fieldmaster (Coherent Inc., Santa Clara, CA, USA) in the milliwatt range was used. The average power density near the emitter is about 35 mW/cm^2. The distance between the LED devices and the volunteers' skin was 15 cm and the average power density on the skin was 39 mW/cm^2. This small increase of the power density of the emitters to the skin is caused by the curvature of the surface containing the LEDs. Such a curvature causes a small focusing effect of the light (as in a curved mirror) producing the observed increase in power density. The treatment time was 45 minutes, performed bilaterally on thighs and buttocks. These parameters led to an approximate fluence of 106 J/cm^2.

The volunteers wore safety glasses and swimwear to ensure infrared absorption through the bare skin during the treadmill training with infrared-LED (Figure 1).

Always at the same time of the day, photographic documentation of the skin was carried out in the laboratory before and after treatment. Body mass index [BMI: body weight (kg) divided by height (m) squared] and waist–hip ratio [waist (cm) divided by hip (cm)] measurements were performed. These consisted of performing measurements of body mass in kilograms (kg) and height in centimeters (cm) using a biometric scale. The measurements of the circumferences were performed with a tape measure, applied in a light way (not tight) on the skin surface only, in order to avoid measurement errors due to compression. The anatomical landmarks to measure the circumference (cm) in the upright position of the body were: (i) waist: measured at the midpoint between the lowest rib and the iliac crest; (ii) hip: measured at the level of maximum extension of the buttocks; and (iii) right and left thighs: saddlebags or 'culotte de cheval' as well as 10 cm, 20 cm and 30 cm from the hip joint. To measure the body fat and lean mass, the bipolar impedance of the upper limbs (OMRON®, Kyoto, Japan) was performed (11). Thermal images of the right and left thighs using a thermographic IR-CAM (FLUKE Corp., Everett, WA, USA) were performed before (rest) and during exercise (an interval of 45 minutes) with and without infrared-LED.

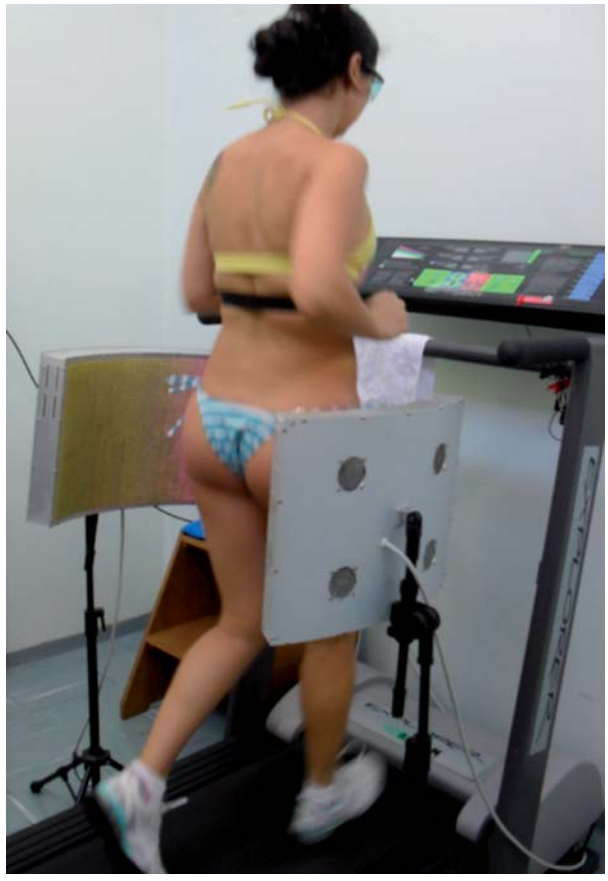

Figure 1. New clinical procedure for the treatment of cellulite.

Measurements were expressed by mean and standard deviations. The Shapiro-Wilk test was used to analyze the normality. The paired Student's *t*-test was used to compare changes in body composition before and after treatment. The unpaired Student's *t*-test was used to compare inter-group differences. All data were analyzed using Statistica for Windows Release

7 software (Statsoft, Inc.) and the significance level was set at 5% ($p < 0.05$).

Results

The results obtained for body composition comparing pre- and post-treatment are shown in Table I. The treatment of cellulite is exemplified in Figures 2 and 3. The temperature of the thighs during rest did not show any significant inter-group difference (control group: T = 33.5 ± 0.5°C; LED group: T = 33.5 ± 0.5°C; $p \geq 0.05$). An increase of 1.08 ± 0.11°C for the LED group and a decrease of 0.86 ± 0.15°C during treadmill training for the control group were observed. The delta of the cutaneous temperature during the exercises showed a significant inter-group difference ($\Delta = 1.72 \pm 0.36$°C, $p = 0.000053$). The thermography images can be seen in Figure 4.

Discussion

To the best of our knowledge, this is the first study to report the use of phototherapy during physical exercise to treat cellulite. Other studies have already shown the benefits of various technologies during rest (5).

Phototherapy improves cellular activation via absorption of light by chromophores present in the protein components of the respiratory chain. Chromophores are located in the mitochondria, mainly NADH dehydrogenases and cytochrome-c oxidase, which lead to increased electron transport increasing the synthesis of adenosine triphosphate (ATP) and results in therapeutic effects (10,12).

The use of lasers (light amplification by stimulated emission of radiation) and LEDs (light-emitting diodes) are important tools in treating cellulite because phototherapy can result in several therapeutic effects to rejuvenate (13,14) the skin and improve body aesthetics (15), such as promoting tissue regeneration (12) with an antioxidant and anti-inflammatory action (16,17), or also increasing collagen synthesis (16), microcirculation and lymphatic drainage (18).

Moreover, the advantages of LEDs versus lasers are that LEDs have a comparably low operational cost, allowing irradiation of larger areas and producing light with a broad emission band and an absorption of photons by several chromophores (10,12,19).

Phototherapy applied before (20) or after (21) physical exercise, as well as during exercise training (10) has resulted in enhancing physical performance. Our results show that without any diet, the women could prevent an increase of both body mass and fat percentage, as well as a loss of lean mass. It is well known that treadmill training is very important to enhance both aerobic capacity and fat metabolism (8,22).

Research on body aesthetics has also showed the treatment of cellulite and the reduction of thigh measures in women who used both VellaSmooth™ (23) [a combination of infrared (700–1500 nm) and radio frequency with mechanical manipulation of the skin] and the TriActive™ System [combines infrared (diode laser 810 nm), contact cooling, suction and massage] (5,24). Studies using these optical devices also show that the treatment of cellulite can smooth out the bumpy and dimpling appearance of the skin. However, erythema, swelling and a feeling of warmth have been noted as side effects of these systems (5,24).

For the current clinical procedure, which combines physical exercise and infrared-LED, no side effects were related by the patients. Still, we believe

Table I. Statistical results of body composition.

	Control group		LED group	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Body mass (kg)	65.7 ± 11.9	65.1 ± 11.6	71.1 ± 11.5	70.3 ± 10.8
Body height (cm)	156.8 ± 5.8	156.7 ± 5.6	157.05 ± 7.0	157.1 ± 7.5
BMI (kg/m^2)	26.1 ± 3.9	26.5 ± 3.9	28.7 ± 4.7	28.5 ± 4.5
Waist (cm)	86.2 ± 11.1	86.5 ± 11.5	92.7 ± 10.9	91.4 ± 10.6
Hip (cm)	102.6 ± 6.3	101.7 ± 6.8	108.6 ± 11.2	107.3 ± 10.5
Waist-to-hip ratio (cm/cm)	0.83 ± 0.08	0.83 ± 0.09	0.85 ± 0.08	0.85 ± 0.09
Right saddlebags (cm)	62.2 ± 5.5	61.5 ± 4.7	65.9 ± 7.0	63.9 ± 7.1**
Left saddlebags (cm)	61.1 ± 6.3	60.9 ± 6.1	66.1 ± 7.6	63.8 ± 7.4**
Right thigh (10 cm)	58.8 ± 4.6	59.2 ± 5.2	64 ± 7.1	62.6 ± 7.2**
Left thigh (10 cm)	59.5 ± 5.1	58.9 ± 5.5	62.8 ± 6.3	61.4 ± 6.5**
Right thigh (20 cm)	49.5 ± 4.8	50.2 ± 5.9	55.5 ± 7.2	53.6 ± 7.58**
Left thigh (20 cm)	48.9 ± 5.1	48.1 ± 5.8	54.9 ± 6.8	53.6 ± 6.7**
Right thigh (30 cm)	41.7 ± 4.9	42.1 ± 5.2	46.2 ± 6.1	45 ± 6.0**
Left thigh (30 cm)	42.9 ± 4.6	42.1 ± 5.2	45.6 ± 7.5	44.3 ± 7.4*
Body fat (%)	35.7 ± 2.7	36.9 ± 3.6	38.4 ± 5.2	37.6 ± 5.5
Fat mass (kg)	23.8 ± 5.5	24.3 ± 6.1	27.3 ± 8.0	27.1 ± 6.0
Lean mass (kg)	42.7 ± 5.7	41.3 ± 6.2	44.1 ± 4.3	43 ± 6.0

Values given as mean and standard deviation.
*Significant difference for pre- versus post-treatment ($p < 0.05$).
**Significant difference for pre- versus post-treatment ($p < 0.01$).

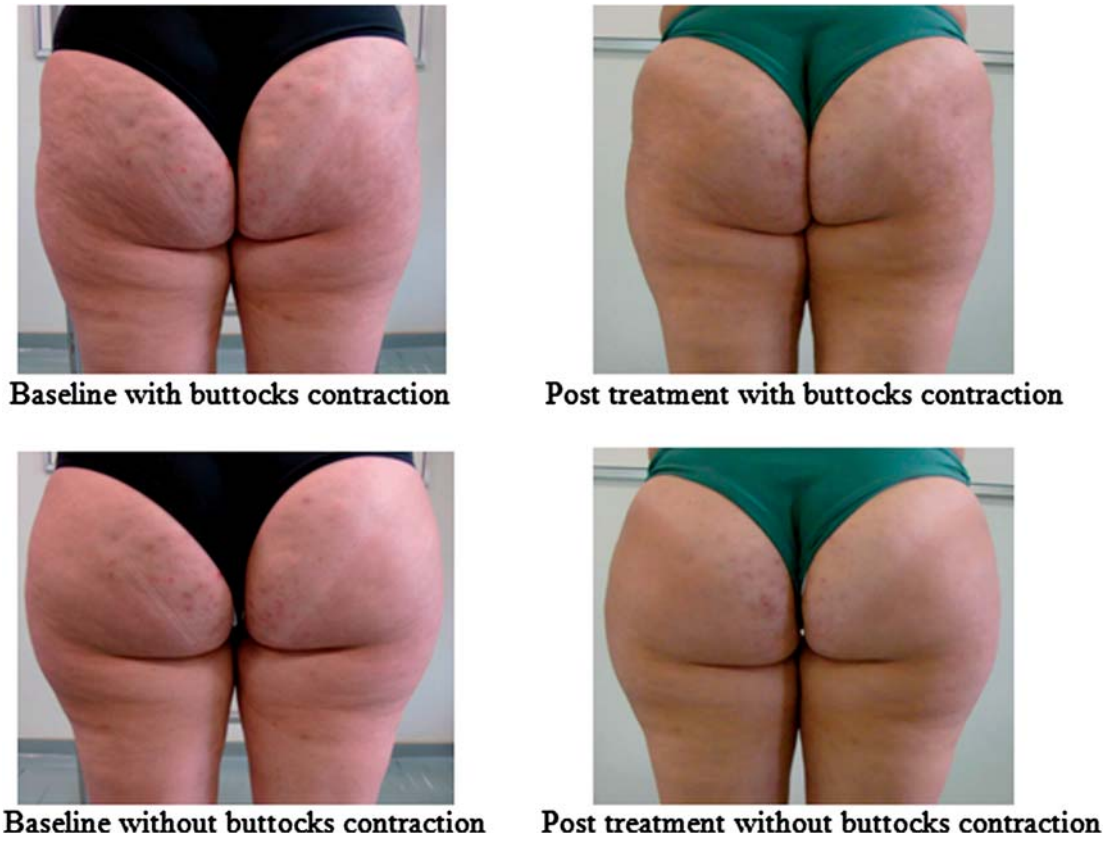

Figure 2. Pre- and post-treatment with and without contraction of the buttocks in a 27-year-old woman.

that the infrared-LED increased microcirculation, lymphatic drainage, as well as collagen synthesis. All of these resulted in a significant reduction of the perimeter of the saddlebags and thighs, as well as an improvement of the skin texture (buttocks and thigh) due to the rejuvenation and treatment of the cellulite.

According to the researchers' observations and the reports of the women who performed the infrared-LED plus treadmill training, the skin became smooth, soft and rejuvenated. Some patients' remarks: "*my husband asked if I was using a new cream*", "*my skin is smooth and soft*", "*my cellulite regressed*".

Figure 3. Pre- and post-treatment in a 55-year-old woman.

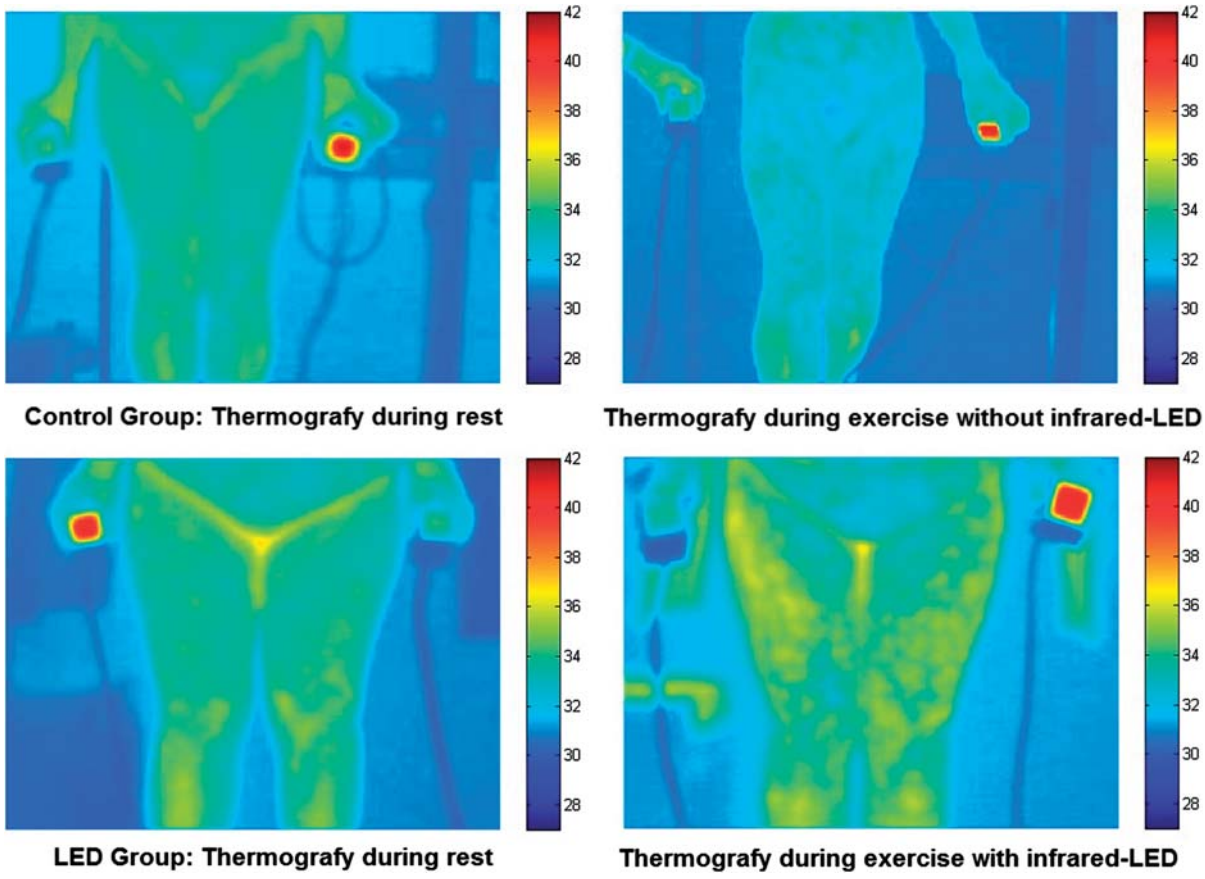

Figure 4. Thermography images during rest and exercise for the LED and control groups.

The mechanism of the treatment of cellulite can be explained using thermal images (25,26) of cutaneous temperature modifications; in our study these images indicated increased metabolic activity for the LED group because the infrared-LED resulted in significant temperature increases during the exercise and the images of the control group showed decreases. These results are in line with others studies. Merla et al. (27) showed that the cutaneous temperature was reduced during physical exercise and this indicated a cutaneous vasoconstrictor response. However, Makihara et al. (28) showed that phototherapy increased facial temperature because it improved the microcirculation via the vasodilator reflex with a warming of the same side of the face that received the application of the laser, as well as a warming of the opposite side of the face. This increase of circulation improves oxygen supply and promotes tissue regeneration, mainly of the skin (29,30), as well as lymphatic drainage (18).

Conclusion

The current study combines the benefits of physical training with the therapeutic effects of phototherapy. These positive effects lead to an improvement of body aesthetics with a reduction of saddlebag and thigh circumference as well as the treatment of cellulite, possibly due to the increased metabolic activity as observed in the thermal images, as well as also preventing the increase of body fat in both young and middle-aged women.

Acknowledgements

The authors acknowledge the Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) – Grant no. 98/14270-8, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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