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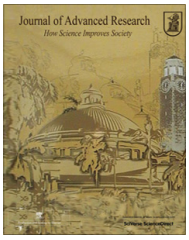

SHORT COMMUNICATION

Effect of laser acupuncture combined with a diet-exercise intervention on metabolic syndrome in post-menopausal women

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ABSTRACT

This study aimed to evaluate the effect of laser acupuncture combined with a diet-exercise intervention on features of the metabolic syndrome (MetS). Twenty-eight obese post-menopausal women were randomly distributed to the control and laser acupuncture group. The control group received the diet-exercise intervention and the study group received the same intervention and sessions of laser acupuncture, 3 times/week for 12 weeks. Anthropometric measurement, fasting blood glucose and insulin levels, homeostatic model assessment-insulin resistance (HOMA-IR), and lipid profile were assessed before and after the treatment course. Both groups showed a significant decrease in the anthropometric and metabolic parameters. However, laser acupuncture group showed a greater decrease in the waist ($P = 0.001$) and hip ($P = 0.001$) circumferences, cholesterol ($P = 0.04$), and insulin levels ($P = 0.043$) than the control group. These results suggest that laser acupuncture is a valuable approach that could be added to the diet-exercise intervention to correct features of the MetS.

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Introduction

Metabolic syndrome (MetS) is a group of metabolic abnormalities including insulin resistance, increased body weight, high abdominal fat mass, mild dyslipidemia and hypertension. MetS is now increasing worldwide, and considered an important health problem that boosts the risk of developing cardiovascular disease (CVD) and type 2 diabetes [1].

Post-menopausal women develop the MetS three times more than the pre-menopausal women [2]; this syndrome affects 32.6% to 41.5% of the post-menopausal women [3]. Estrogen loss, which leads to metabolic changes and increased abdominal obesity, is one of the hypotheses that explain the increased incidence of the MetS after menopause [4].

Previous studies have proved the association between the visceral obesity and the MetS. Abdominal obesity leads to a cluster of atherogenic and diabetogenic complications. There are an elevation in plasma triglyceride (TG) concentration, a marked decline in plasma high-density lipoprotein cholesterol (HDL-C) level, and an increased proportion of small, low

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dense lipoprotein (LDL) particles. Also, there is an insulin resistant state that results in a severe disturbance of plasma glucose-insulin homeostasis [5].

Lifestyle change through the diet and moderate-intensity exercise is an essential strategy for improving all features of the MetS. However, further research evaluating lifestyle change versus combined therapies is needed to find out which treatment is best to resolve the MetS [6]. Previous literature has described the use of laser acupuncture in obesity as reducing the body weight (BW) and body mass index (BMI) with [7] or without a low-calorie diet in obese post-menopausal women [8].

Acupuncture therapy significantly reduces BMI and abdominal fat by reducing the abdominal visceral adipose tissue content [9], which lead to decrease several atherogenic and metabolic complications. Currently, the effect of laser acupuncture on lipid metabolism and glucose-insulin homeostasis is still unclear. Therefore, this study aimed to examine the effect of combined laser acupuncture and a diet-exercise intervention on the anthropometric measurements, fasting blood glucose and insulin levels, homeostatic model assessment-insulin resistance (HOMA-IR), and lipid profile in obese post-menopausal women. It was hypothesized that adding laser acupuncture to a diet-exercise intervention had more effect on features of the MetS than a diet-exercise intervention did alone.

Subjects and methods

Subjects

Twenty-eight post-menopausal women diagnosed with the MetS had been referred by a doctor. Diagnosis of the MetS was performed using the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III). The post-menopausal women possessed three or more of the following criteria: increased fasting blood glucose ($\geqslant$110 mg/dl or $\geqslant$6.1 mmol/L), high TG ($\geqslant$150 mg/dl or $\geqslant$1.65 mmol/L), low HDL-C ($<$50 mg/dl or $<$1.30 mmol/L), and waist circumference of $\geqslant$88 cm. All post-menopausal women were obese (BMI $>$ 30 kg/m^2). The exclusion criteria included women diagnosed with hypothyroidism, ischemic heart disease (IHD) or diabetes, as well as those who received hormone replacement therapy (HRT) or anti-diabetic medications.

The post-menopausal women were randomly distributed into two groups using computer generated random numbers. Allocation was concealed in sequentially numbered opaque envelopes. The control group followed an energy-restricted diet, and engaged in a supervised treadmill-training program 3 times/week for 12 weeks; while the study group (laser acupuncture) received the same diet-exercise intervention and sessions of laser acupuncture 3 times/week for 12 weeks. The sample size was calculated based on a previous study according to the change in the weight post-treatment [10].

A sample of 14 women per group was recruited to detect an effect size of 0.727 at a power of 0.80 and alpha level of 0.05. The sample size was calculated using GPower 3.1. *The Ethical Committee of the Faculty of Physical Therapy, Cairo University approved this study. The study protocol was explained to all women, who had signed an informed consent form.*

Methods

Anthropometric measurements

Weight and height were measured for each post-menopausal woman wearing light clothes and without shoes. Then, BMI was calculated by dividing weight (kg) by height squared (m^2). The same therapist blinded to the group assignment measured the waist and hip circumferences. The therapist measured the waist circumference from the narrowest point between the lower border of the rib cage and the iliac crest at the end of normal expiration; she measured the hip circumference at the widest part of the hip. Then, waist-hip ratio was calculated by dividing waist circumference by hip circumference.

Biochemical analysis

Blood samples were drawn from all post-menopausal women on the morning after fasting for 6 h in clean tubes containing a few mg of K2EDTA. Blood samples were centrifuged, and plasma separated and stored frozen at-20° until analysis. Fasting blood glucose, serum insulin, total cholesterol (TC), HDL-C, LDL-C and TG levels were estimated according to the methods used by Kesim et al. [11]. HOMA-IR was computed with US formula: fasting plasma glucose (mg/dl) multiplied by fasting serum insulin (mU/l) and divided by 405 [12].

Interventions

Diet regime

All post-menopausal women followed an energy-restricted diet for 12 weeks. First, the recommended daily kilocalorie intake was computed by multiplying the Harris-Benedict equation by 1.55. Then, daily energy intake was restricted by 1000 kcal/day (daily kilocalorie requirement-1000 kcal). The diet caloric proportion of the protein, fat and carbohydrate was set at 15%, 30% and 55% respectively.

Each post-menopausal woman was given a booklet including a database of foods, and their energy and macronutrient values. The therapist asked each woman to select her foods freely, and give instructions about planning her meals to help adhere to the prescribed kilocalories and the assigned macronutrient. All women were advised to keep 3-day dietary records and interviewed by the therapist weekly. The therapist checked these records to ensure the total kilocalories per day did not exceed the previous calculated one, and give any advice about the meal plans when they did not meet the assigned macronutrient. All post-menopausal women had closely adhered to the assigned energy intake.

Treadmill training protocol

The treadmill-training program was performed 3 times/week for 12 weeks. Each exercise session consisted of warm up, active and cool down phases. The warm up phase started with walking on a treadmill at a speed of 4–5 km/h with 0% grade elevation for 5 min. The active period lasted for 30 min at (60–75)% of the heart rate reserve (HRR). The treadmill speed and inclination were increased gradually, and adjusted for each subject according to her prescribed intensity based on the target heart rate. The target heart rate was calculated from

Karvonen equation: [(maximum heart rate-resting heart rate × % intensity) + resting heart rate].

A polar heart rate monitor was used to monitor the heart rate every 5 min during exercise. If the target heart rate exceeded the calculated one, the treadmill speed was slowed down until heart rate adjustment took place. Then, the treadmill speed was slowed to 4 km/h with 0% grade elevation for 5 min for a cool-down phase [13].

The treadmill exercise was done in a conditioning room with maintaining the temperature at (20–22)°C, which is the recommended temperature for exercising indoors. The study program had been performed between August and November to avoid variation of the subjects' metabolism associated with changes in the temperature of the environment [14].

Laser acupuncture

A gallium Arsenide infrared (GaAlAs) laser (FISIOLINE S.R.I., lumix® 2 HFPL, ITALY), with a wavelength at 904 nm and power of 5mW irradiated the post-menopausal women. It was applied with an energy density of 2 J/cm^2, a pulse radiation of 200 ns, and with a pulse frequency of 5000 Hz. According to traditional Chinese medicine, the fundamental causes of obesity are spleen and kidney deficiencies. Sometimes, stomach heat and qi stagnation are associated. So, the following acupuncture points were selected for laser irradiation: Cv4 Guanyuan (3 cun inferior to the center of the umbilicus); Cv9 Shuifen (1 cun above the center of the umbilicus); Cv12 Zhongwan (4 cun above the center of the umbilicus); St25 Tianshu (2 cun lateral to the midline of the umbilicus); St36 Zusanli (one finger width lateral from the anterior crest of the tibia); Sp6 Sanyinjiao (3 cun directly above the tip of the medial malleolus); and St40 Fenglung (8 cun superior to the tip of the external malleolus) [15]. The laser was applied to the skin vertically with irradiation time 2 min/point, 3times/week for 12 weeks.

Statistical analysis

Results are expressed as mean ± standard deviation (SD). Kolmogorov–Smirnov test assessed the normality of the data. In normally distributed data, unpaired *t* test compared variables between groups, while paired *t* test compared variables within the same group. In not normally distributed data, Mann–Whitney *U* test compared variables between groups, while Wilcoxon Signed Ranks test compared variables within the same group. The mean difference was calculated as follows: pre-assessment–post-assessment. The percentage of change was calculated by dividing the mean difference by the pre-assessment value and multiplying by 100. SPSS computer program (version 16 windows) was used for data analysis. *P*-value <0.05 was significant and <0.01 was highly significant.

Results

Subjects' characteristics

Table 1 represents baseline characteristics of the control and laser acupuncture group. None of these variables showed significant differences between both groups pre-treatment. The control group had completed (34.50 ± 0.85) sessions of the treadmill exercise, while laser acupuncture group completed (34.14 ± 1.03) of 36 sessions, which showed no significant difference between groups.

Anthropometric and metabolic results

Table 2 represents the anthropometric measurements and metabolic parameters of the two groups pre- and post-treatment. The control group showed a highly significant decrease in the -weight, BMI, waist and hip circumferences and TC. It also showed a significant decrease in the fasting blood glucose and insulin levels, HOMA-IR, LDL-C and TG, as well as a significant increase in HDL-C after treatment. Laser acupuncture group showed a highly significant decrease in the weight, BMI, waist and hip circumferences, TC and TG. It also showed a significant decrease in the waist-hip ratio, fasting blood glucose and insulin levels, HOMA-IR, and LDL-C, as well as a significant increase in HDL-C.

Table 3 represents the comparison between the mean differences of all variables in both groups. Laser acupuncture group showed a highly significant decrease in the waist and hip circumferences; and a significant decrease in the TC, and insulin levels when compared with the control group.

The percentages of changes in the control group versus acupuncture group were as follows: 9.53 vs 10.95% for BW; 9.52 vs 10.94% for BMI; 8.94 vs 13.41% for waist circumference; 9.21 vs 12.73% for hip circumference; 0.001 vs 1.05% for waist hip ratio; 7.08 vs 9.54% for fasting blood glucose; 16.65 vs 30.08% for fasting blood insulin; 23.51 vs 32.1% for HOMA-IR; 8.68 vs 11.56% for TC; 2.38 vs 3.54% for HDL-C; 6.41 vs 9.33% for LDL-C; 21.64 vs 24.62% for TG.

Discussion

Changes in the body composition, fat distribution, and hormonal or metabolic changes following menopause lead to the

Table 1 Baseline characteristics of the post-menopausal women.

Variable	Control group (n = 14)	Laser acupuncture group (n = 14)	*P*-value
Age (Yrs)	52.78 ± 4.62	54.43 ± 4.38	0.34^{NS}
Height (cm)	161 ± 4.17	160.57 ± 3.46	0.77^{NS}
Weight (kg)	110.89 ± 14.14	102.96 ± 10.03	0.10^{NS}

Data are expressed as mean ± SD.
$^{*}p < 0.05$ = significant; $^{**}p < 0.01$ = highly significant.
$^{NS}p > 0.05$ = non-significant.

Table 2 Comparison between different variables measured pre- and post-treatment in the two studied groups.

	Control group (n = 14)			Laser acupuncture group (n = 14)		
	Pre-treatment	Post-treatment		Pre-treatment	Post-treatment	
Anthropometric parameters						
Weight (kg)	110.89 ± 14.14	100.32 ± 12.98	0.001**	102.96 ± 10.03	91.68 ± 9.60	<0.001**
BMI (kg/m^2)	42.78 ± 5.27	38.70 ± 4.88	0.001**	39.91 ± 3.43	35.54 ± 3.37	<0.001**
Waist circumference (cm)#	121.43 ± 11.24	110.57 ± 10.90	0.001**	120.86 ± 11.20	104.64 ± 8.50	<0.001**
Hip circumference (cm)	127.14 ± 11.05	115.43 ± 11.06	0.001**	126.79 ± 11.44	110.64 ± 9.38	<0.001**
Waist-hip ratio	0.95 ± 0.02	0.95 ± 0.02	0.765NS	0.95 ± 0.02	0.94 ± 0.02	0.016*
Metabolic parameters						
TC (mg/dl)	205.71 ± 21.83	187.86 ± 21.73	0.001**	211.93 ± 27.95	187.43 ± 25.48	<0.001**
LDL-C (mg/dl)	132.64 ± 23.38	124.14 ± 19.27	0.003**	134.79 ± 24.97	122.21 ± 21.05	0.002**
HDL-C (mg/dl)#	42.07 ± 3.02	43.07 ± 3.15	0.012*	42.00 ± 2.80	43.50 ± 2.85	0.003**
TG (mg/dl)	156.79 ± 43.31	122.86 ± 34.35	0.0014**	158.14 ± 39.41	119.21 ± 38.28	<0.001**
Fasting blood glucose (mg/dl) #	107.93 ± 13.97	100.28 ± 11.27	0.002**	111.50 ± 22.35	100.86 ± 11.06	0.003**
Serum insulin (mU/l)#	10.33 ± 4.77	8.60 ± 4.88	0.03*	13.33 ± 8.42	9.31 ± 8.32	0.004**
HOMA-IR #	2.85 ± 1.20	2.18 ± 1.33	0.013*	3.80 ± 3.01	2.59 ± 2.26	0.011*

TC, total cholesterol; LDL-C, low density lipoprotein-cholesterol; HDL-C, high density lipoprotein-cholesterol; TG, triglyceride; HOMA-IR, homeostatic model assessment-insulin resistance.
Data are expressed as mean ± SD.
* & ** Relative to comparison within the same group.
# Non-parametric statistics was performed.
NS $p > 0.05$ = non-significant.
* $p < 0.05$ = significant.
** $p < 0.01$ = highly significant.

Table 3 Comparison between values of the mean difference of different variables in the two studied groups.

	Control group (n = 14)	Laser acupuncture group (n = 14)	P-value
Anthropometric parameters			
Weight (kg)	10.57 ± 1.41	11.29 ± 3.07	0.437NS
BMI (kg/m^2)	4.07 ± 0.51	4.38 ± 1.15	0.376NS
Waist circumference (cm)#	10.86 ± 2.11	16.21 ± 3.36	0.001**
Hip circumference (cm)	11.71 ± 2.95	16.14 ± 3.42	0.001**
Waist-hip ratio	0.001 ± 0.017	0.010 ± 0.014	0.159NS
Metabolic parameters			
TC (mg/dl)	17.86 ± 6.42	24.50 ± 9.53	0.040*
LDL-C (mg/dl)	8.50 ± 8.79	12.57 ± 12.32	0.323NS
HDL-C (mg/dl)#	−1.00 ± 1.11	−1.50 ± 1.34	0.473NS
TG (mg/dl)	33.93 ± 31.33	38.93 ± 31.65	0.678NS
Fasting blood glucose (mg/dl)#	7.64 ± 7.57	10.64 ± 13.65	0.679NS
Serum insulin (mU/l)#	1.73 ± 2.14	4.01 ± 3.75	0.043*
HOMA-IR #	0.67 ± 0.78	1.22 ± 1.47	0.260NS

TC, total cholesterol; LDL-C, low density lipoprotein-cholesterol; HDL-C, high density lipoprotein-cholesterol; TG, triglyceride; HOMA-IR, homeostatic model assessment-insulin resistance.
Data are expressed as mean ± SD.
Non-parametric statistics was performed.
NS $p > 0.05$ = non-significant.
* $p < 0.05$ = significant.
** $p < 0.01$ = highly significant.

development of the MetS [1]. Weight loss is the first line of treating the MetS. All features of the MetS can be improved by a combination of reduced caloric intake by 1000 kcal/day and a moderate-intensity exercise. This finding agreed with a systematic review, which studied different types of a moderate-intensity exercise such as brisk walking for 150 min/week, circuit-type resistance training, and aerobic exercise to correct metabolic abnormalities. These studies showed improvements in the waist circumference, lipid profile, fasting glucose and insulin levels [6], which are consistent with the results of the present study.

Adding laser acupuncture to the diet-exercise intervention induced more benefits on reducing waist and hip circumferences, but not, weight and BMI. These findings are in contrast with a previous study, which reported a decrease in the BW and BMI after application of laser acupuncture for 6 months

in the post-menopausal women [7]. The short duration of the present study may explain this disagreement. It also disagreed with the results of another study conducted on obese subjects with mean age and BMI lower than that of the present study [8]. This disagreement may be explained by the difference between younger and older subjects in the magnitude of fatty acid oxidation response. This difference results from the aging-related loss of fat-free mass and estrogen, and decrements in the muscle capacity for fat oxidation [16].

Improvement in the waist and hip circumferences suggests that laser acupuncture has a valuable role in reducing the abdominal and gluteal adiposity. The effect of laser acupuncture on the adipose tissues is still unknown, but the combined effect of acupuncture and biological effect of the laser application may explain this improvement. Acupuncture could modulate the adipose tissue gene expression without influencing the adipose tissue mass and cellularity [17]. Laser application induces many morphological changes in the adipocytes. These changes include less defined superficial adipose layer and septae, and much coalescent adipose tissue [18]. These changes result because low-level laser therapy stimulates the mitochondria in the adipocytes, which increase the adenosine triphosphate (ATP) synthesis and cyclic adenosine monophosphate (cAMP), resulting in activation of the cytoplasmic lipase. This enzyme converts the triglycerides into the fatty acids and glycerol that pass into the extracellular space through pores formed in the cell [19].

Reduced subcutaneous and visceral abdominal fat store, which accelerated after menopause, may improve the insulin resistance state and decrease the risk of progression of coronary heart disease [20]. In the present study, laser acupuncture group has showed a greater decrease in the insulin level without reducing the fasting glucose level than the control group. Therefore, these findings suggest that a combination of the diet-exercise intervention and laser acupuncture may improve glucose homeostasis without the risk of inducing hypoglycemia. Normally, insulin secretion must be proportional to insulin resistance for keeping normal glucose homeostasis [21]. Therefore, decreased insulin level and HOMA-IR reflect improvement in the insulin sensitivity and decrease in the insulin resistance. This finding agreed with a previous study, which reported that electroacupuncture at St36 and Cv4 improved the insulin resistance in obese mice due to increased skeletal muscle Sirtuin 1, which improves the insulin signal [22].

The mechanism, by which laser acupuncture affects the insulin sensitivity, is still unknown. However, there are many physiological suggestions that may explain the improvement in the insulin sensitivity. Laser decreases intercellular levels of cytokines such as TNF-alpha, IL-1 beta and IL-8 proteins [23], which are inflammatory products released from adipocytes and contribute to the insulin resistance [5]. Also, laser application improves the cation transport across the cell membrane because it stimulates the ATP synthesis and increases the proton gradient. This results in activation of the Na^+/H^+ and Ca^{2+}/Na^+ antiporters, as well as the ATP driven carriers for ions such as the Na^+/K^+ ATPase, and Ca^{2+} pumps [24]. The improvement in the cation transport across the cell membrane, altered in cases of hyperinsulinemia or insulin resistance, may improve the insulin action on the cells [25] contributing to a decrease in the insulin level. Glucose and lipid abnormalities may result from the pathway-selective insulin resistance, in which, insulin fails to suppress hepatic glucose production and promotes liver fat storage [26]. So, improvement of insulin resistance may improve lipid metabolism in the post-menopausal women.

Several studies have showed the effect of body and auricular acupuncture on the lipid profile in obese women. Recently, Li and his colleagues [27] have reported that electroacupuncture at St 36, Cv12, and Sp 6 improves the lipid metabolism in subjects with the MetS. In the current study, combined laser acupuncture and the diet-exercise intervention mediate a slight improvement in TG, LDL-C and HDL-C; however, it was more effective in reducing the TC than the diet-exercise intervention. This finding agreed with a study [28], which reported a significant decrease in the TC level after application of low-level laser therapy around abdomen for 20 min, 3 sessions/week for 2 weeks. Also, more recent study on rats has showed an improvement in the TC level following laser application and swimming training [29].

One explanation of this improvement is that laser application between 1 and 5 J stimulates the lipid peroxidation and increases the superoxide production. Increased production of the reactive oxygen species breaks down lipids found in the cell membrane. Lipids and fatty material pass through transitory pores formed in the cell membrane and enter the interstitial space where the lymphatic system removes the fatty debris [30]. Another explanation of the significant decline of the TC level in the acupuncture group is that laser irradiation reduces catalytic center of cytochrome C oxidase, which alters intercellular redox state [31]. Modulation of the cellular redox state activates the regulatory transcription factors that play an important role to suppress the cholesterogenesis [32]. Improvement in TG, LDL-C and HDL-C; though slight, is helpful for subjects with MetS because any decrease within the borderline value of any components of the MetS is enough for subjects to come back to normality.

Results of this study are important. One important result is that a combined diet regime and a moderate-intensity exercise can improve features of the MetS. Moderate-intensity exercise is a safe and useful method for untrained older women who may not be able to perform high intensity exercise due to chronic disease or fear from injury. The exercise intensity performed in the present study agreed with previous studies. These studies have reported that combined diet and a moderate-intensity exercise intervention is an effective strategy for reducing CVD risk because it improves microvascular activity and cardiorespiratory capacity [33]; it also improves insulin sensitivity through activation of glycogen synthase in the post-menopausal women [34]. A recent study, which conducted another intensity of exercise training protocol in the postmenopausal women, has reported that a high intensity interval training produced larger improvement in the cardiopulmonary function, but non-significant, than a continuous moderate-intensity training [35]. Further studies are needed to compare the effect of aerobic exercise versus high interval training on features of the MetS. Another important result is that adding laser acupuncture to the diet-exercise intervention is an effective strategy for improving the abdominal adiposity and total cholesterol, which lead to decrease the risk for the CVD. Also, reducing the insulin level may reflect the improvement in the insulin resistant state. It may give an insight that laser acupuncture may play a role on other metabolic abnormalities such as polycystic ovary syndrome; however, this needs further studies.

Laser acupuncture plays a role in improving features of the MetS in obese post-menopausal women; however, the underlying causes are still unknown, which recommend for further research to study the response of GLUT4 expression, serum adiponectin or cytokines levels such as IL-6, IL-8 and TNF-alpha to laser acupuncture. A limitation of this study is the lack of assessment of detailed content of the diet regime including saturated fat, polyunsaturated fat and cholesterol, which may affect the results of this study.

Conclusions

Laser acupuncture combined with the diet-exercise intervention improves waist and hip circumferences, and decreases TC concentration and fasting insulin level. These findings suggest that laser acupuncture may have a role for improving abdominal adiposity, lipid metabolism and glucose-insulin homeostasis in the post-menopausal women with the MetS.

Conflict of interest

The authors have declared no conflict of interest.

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