

Sixteen weeks of resistance training can decrease the risk of metabolic syndrome in healthy postmenopausal women

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Background: The postmenopausal phase has been considered an aggravating factor for developing metabolic syndrome. Notwithstanding, no studies have as yet investigated the effects of resistance training on metabolic syndrome in postmenopausal women. Thus, the purpose of this study was to verify whether resistance training could reduce the risk of metabolic syndrome in postmenopausal women.

Methods: Twenty postmenopausal women were randomly assigned to a resistance training protocol ($n = 10$, 53.40 ± 3.95 years, 64.58 ± 9.22 kg) or a control group ($n = 10$, 53.0 ± 5.7 years, 64.03 ± 5.03 kg). In the resistance training protocol, ten exercises were performed, with 3×8 – 10 maximal repetitions three times per week, and the load was increased every week. Two-way analysis of variance was used to evaluate specific metabolic syndrome Z-score, high density lipoprotein cholesterol, fasting blood glucose, triglycerides, waist circumference, blood pressure, strength, and body composition. The level of statistical significance was set at $P < 0.05$.

Results: The main results demonstrated a significant decrease of metabolic syndrome Z-score when the postmenopausal women performed resistance training ($P = 0.0162$). Moreover, we observed decreases in fasting blood glucose for the resistance training group ($P = 0.001$), and also significant improvements in lean body mass ($P = 0.042$, 2.46%), reduction of body fat percentage ($P = 0.001$, -6.75%) and noticeable increases in muscle strength after resistance training to leg press ($P = 0.004$, 41.29%) and bench press ($P = 0.0001$, 27.23%).

Conclusion: It was concluded that resistance training performed three times a week may reduce the metabolic syndrome Z-score with concomitant decreases in fasting blood glucose, improvements in body composition, and muscle strength in postmenopausal women.

Keywords: metabolic syndrome, resistance training, postmenopausal women

Introduction

The prevalence of metabolic syndrome has increased in recent decades, mainly in developing countries.¹ In Brazil, more than 30% of middle-aged adults are classified as having metabolic syndrome, and it has been shown that this syndrome predominantly affects women.¹ Nevertheless, the prevalence of metabolic syndrome may vary according to gender, age, and the diagnostic criteria used.^{2–4} There is a higher incidence of metabolic syndrome in the postmenopausal period, especially in middle-aged women, who after menopause undergo significant adverse changes in body composition, including loss of lean body mass, increases in fat body mass, and redistribution of fat from the periphery to the central region of the body.^{5–10} Other related modifications associated with menopause, such as increased blood pressure, reductions in glucose tolerance, atherogenic changes in the lipid and coagulation profiles, and impairment

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of endothelial function, are common and can also increase the incidence of metabolic syndrome.^{4,11–16} Further, the postmenopausal phase can induce severe reductions in strength and muscle mass (ie, sarcopenia) especially among sedentary women.^{8,17} These facts provide insights showing that the postmenopausal period itself is an independent risk factor for metabolic syndrome,^{17,18} increasing the chances of developing cardiovascular disease and consequently premature death.^{19–22} Therefore, it is necessary to develop strategies to reduce the risk of metabolic syndrome. It has been proposed that incorporation of daily physical exercise might be an effective strategy against development of metabolic syndrome.^{23,24}

Several studies have demonstrated the beneficial effects of aerobic training on the comorbidity of obesity and other cardiometabolic risk factors such as metabolic syndrome.^{21,25,26} Johnson et al²⁵ using 80 women (all postmenopausal) and 91 men with a sedentary lifestyle, aged between 40 and 65 years, showed that aerobic exercise of moderate intensity results in a significant reduction in the risk of metabolic syndrome.

On the other hand, resistance training induces differential benefits when compared with aerobic training, such as increases in muscle and bone mass, strength development, and improvement in functional capacity.^{27–29} Thus, these benefits observed after a resistance training intervention can prevent and/or amend sarcopenia and other related comorbidities.^{20,30} In addition, resistance training has been demonstrated to ameliorate the lipid profile³¹ and diminish intra-abdominal adipose tissue.³² Despite resistance training provides several benefits concerning different metabolic syndrome variables, few studies have investigated the beneficial impacts of resistance training on reduction of metabolic syndrome in postmenopausal women, who seem to be more susceptible to developing these risk factors. Therefore, the purpose of the present study was to investigate if resistance training itself is capable of reducing risk factors for metabolic syndrome in the postmenopausal years. It was hypothesized that resistance training could decrease this risk in postmenopausal women.

Materials and methods

Subjects

The experimental protocol was approved by the research ethics committee of the State University of Campinas. Thereafter, the subjects were recruited through newspaper, magazine, and Internet advertisements. Potential subjects completed a preliminary medical history, an exercise questionnaire, and all participants were informed of the purpose and risks of the study before signing their informed consent. Also,

before inclusion in the study, a complete medical examination was carried out and subjects were excluded if acute illness, severe hypertension, insulin-dependent diabetes, or myocardial infarction were diagnosed, or if they were taking medication known to affect plasma lipoprotein levels, had diabetes mellitus, or were on hormone replacement therapy. All women participating in the study were in the postmenopausal period (>12 months of amenorrhea), middle-aged (aged 45–60 years), and considered to have a sedentary lifestyle without any consistent exercise in the previous year. Sedentary lifestyle was measured and analyzed using the Baecke questionnaire on physical activity.³³

A sample size estimation was conducted using G*Power (version 3.0.10, Universität Kiel, Germany). Previous study data from our laboratory³¹, which compared the lipid profile (total cholesterol) between men and women, in which resistance training was the exercise model of intervention, were utilized to perform the sample size estimation. We based the calculation on an effect size of 1, an α level of 0.05, and a power ($1 - \beta$) of 0.80. Sample size estimation showed that it would be necessary to include at least 14 volunteers (seven subjects per group). Therefore, we recruited 20 volunteers who were randomly assigned into two groups: a resistance training group ($n = 10$; mean age 53.40 ± 3.95 years; body mass 64.58 ± 9.22 kg; height 1.57 ± 0.06 m; body mass index 26.22 ± 3.26 kg/m²; and 5.50 ± 3.21 years into the postmenopausal phase) and a control group ($n = 10$; mean age 53.0 ± 5.7 years; body mass 64.03 ± 5.03 kg; height 1.60 ± 0.05 m; body mass index 25.30 ± 1.81 kg/m²; and 7.46 ± 6.01 years into the postmenopausal phase) who did not perform any kind of exercise during the experimental period.

Experimental design

All subjects underwent three visits before beginning training. On the first visit, blood samples, anthropometric assessments, blood pressure, and familiarization with the training exercises were undertaken. On the following visit, the first maximal strength test session was performed. After 72 hours, a second maximal strength test was performed and the value obtained was used in this study, only for strength assessment. The resistance training group trained throughout 16 weeks, while the control group did not perform any kind of physical exercise. All assessments were performed again at the end of the experimental period for both study groups. To avoid circadian variations, all evaluations were done at the same time of day (between 8 am and 10 am), with controlled temperature conditions (22°C), at the same relative air humidity (about 60%) and atmospheric pressure. No dietary

prescriptions were provided to the participants. However, they were all advised to maintain their normal alimentary habits throughout the study period as well as to maintain their normal daily activities.

Z-score analyses

The metabolic syndrome Z-score was used in the present study as a continuous score of the five metabolic syndrome variables,³⁰ in agreement with the Adult Treatment Panel III criteria. A Z-score was calculated for each variable using individual subject data, and standard deviations of data for the entire group at baseline ($n = 52$, number of subjects recruited into the study at the beginning). Gender-specific metabolic syndrome Z-score equations were used following the Adult Treatment Panel III criteria. The equation used to calculate the metabolic syndrome Z-score³⁰ was as follows:

$$\begin{aligned} \text{Z-score} = & [(50 - \text{HDL})/14.1 + (\text{TG} - 150)/90.1] \\ & + [(\text{fasting blood glucose} - 100)/11.3] \\ & + [(\text{waist circumference} - 88)/7] \\ & + [(\text{mean arterial pressure} - 100)/14.1], \end{aligned}$$

where HDL is high-density lipoprotein and TG is triglycerides.

Serum lipid profile and glucose

Resting venous blood samples were collected via venipuncture from an antecubital forearm vein at 8 am after a 12-hour overnight fast and abstinence from exercise for 24 hours. The samples were centrifuged at 3000 rpm for 15 minutes. The resulting serum was then removed and stored at -70°C until subsequent analysis. Serum concentrations of glucose, TG, and HDL cholesterol were assessed using an automatic analyzer (RA 1000, Technicon Corporation, Tarrytown, NY, USA) and a commercially available kit. The intra-assay variability, interassay variability, and sensitivity were, respectively, 1.08%, 1.82%, and 1.8 mg/dL for glucose; 1.5%, 1.8%, and 4 mg/dL for TG; and 0.89%, 2.08%, and 3 mg/dL for HDL cholesterol.

Anthropometric variables

Subject body weight was measured on a balance scale (Filizola, São Paulo, Brazil) calibrated to the nearest 0.1 kg. Barefoot standing height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Waist circumference was measured using a constant tension tape at the midpoint between the lowest rib and the iliac crest. Body density was estimated using the skin-fold procedure according to Jackson et al,³⁴ using a skin-fold caliper (Lange, Beta Technology, Santa Cruz, CA, USA) at the chest, abdomen, thigh, triceps, subscapular, suprailiac, and

mid axillary points. The percentage of body fat was obtained from body density using the Siri equation.³⁵ All assessments were performed by the same professional.

Mean blood pressure

Blood pressure assessments were done after approximately 10 minutes of rest using a mercury sphygmomanometer and stethoscope. The women were positioned supine and the same professional made the measurements. All measurements were taken in duplicate and the mean of two assessments was used. The formula for mean blood pressure (MBP) assessment was:

$$\text{MBP} = \text{DBP} + [0.333 \times (\text{SBP} - \text{DBP})],$$

where DBP is diastolic blood pressure and SBP is systolic blood pressure.

Maximal strength assessments

Muscle strength was assessed by one maximal repetition test for bench and leg press exercises. Individuals were required to perform eight repetitions at 50% of one repetition maximum, estimated according to each participant's capacity, to rest for 1 minute, and then perform a further three repetitions at 70% of one repetition maximum. After a 3-minute rest, subsequent trials were performed for one repetition with progressively heavier weights until the one repetition maximum was determined within three attempts, with 3–5 minutes of rest between trials. Standardization of range of motion and performance of the exercises was done according to Libardi et al.³¹ Before the beginning of the study, participants performed two familiarization trial sessions composed of two sets of moderate intensity exercises, with 72 hours of rest between them. The purpose of this familiarization was to reduce learning effects.

Resistance training

The subjects performed 16 weeks of resistance training with three training sessions per week on alternate days (Mondays, Wednesdays, and Fridays). During the first 8-week period, subjects performed leg press, leg extension, leg curl, bench press, lat pulldown, lateral raise, triceps pushdown, arm curl, and basic abdominal crunch protocols. The training consisted of three sets of ten repetition maxima, with a 60-second rest between sets. After 8 weeks, the exercises were maintained; however, the subjects performed eight repetition maxima with a 90-second rest between sets.²⁷ The resistance training was based on the linear periodization or "classic" model, based on volume and intensity change during mesocycles

(8 weeks). It is characterized by high volume and low intensity in the initial training period and progresses to the extent that the volume is lower than the intensity, ie, the intensity increases and the volume decreases.³⁶ The numbers of repetitions were reduced (maintaining the minimal zone established for each cycle) as the intensity increased.

The workloads were adjusted weekly according to Libardi et al.²⁹ The participants were encouraged to perform the greatest number of repetitions they had achieved in the previous training session when they came to the last set of each exercise, maintaining the same range of motion and execution velocity as previously determined. Workloads were increased by 1 kg for the lower body and 0.5 kg for the upper body for each repetition performed over the established training protocol, according to the greatest number of repetitions accomplished by the participants in the previous week.

Statistical analyses

Statistical analyses were performed using Statistica version 6.1 software (StatSoft Inc., Tulsa, OK, USA). First, a Shapiro-Wilk test was used to test the normality of the data. A two-way repeated-measures analysis of variance was used to evaluate within/between-group changes in metabolic syndrome Z-score, metabolic syndrome variables, and muscle strength, with groups and time set as independent variables and subjects set as a random factor. When a significant F was obtained, the Tukey post hoc test was used to identify significant differences. The effect sizes were classified as very large (<-2.0), large (-2.0 to -1.2), moderate (-1.2 to -0.6), small (-0.6 to -0.2), trivial (-0.2 to 0.2), small (0.2 to 0.6), moderate (0.6 to 1.2), large (1.2 to 2.0), and very large (>2.0). The level of statistical significance was set at $P < 0.05$. Data are presented as the mean \pm standard deviation unless otherwise stated.

Results

Metabolic syndrome Z-score

Metabolic syndrome Z-score values are shown in Figure 1. Only resistance training significantly reduced the metabolic syndrome Z-score after 16 weeks ($P = 0.0162$).

Risk factors for metabolic syndrome

The risk factors for metabolic syndrome are presented in Table 1. A significant group versus time interaction for HDL cholesterol ($F = 7.35$, $P = 0.014$, 13.20%), waist circumference ($F = 5.79$, $P = 0.027$, -0.25%) and glucose ($F = 9.75$, $P = 0.006$, -13.97%) was observed, with the post hoc test demonstrating that resistance training achieved a significant glucose reduction after 16 weeks ($P = 0.001$). However, the

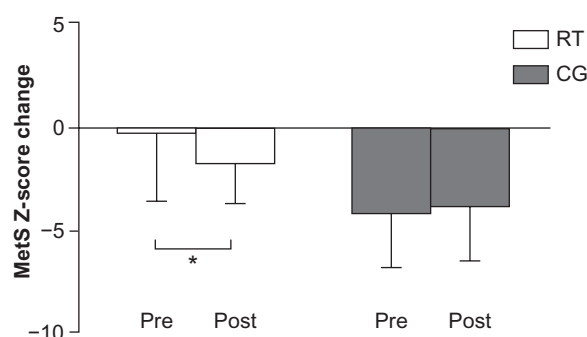


Figure 1 Comparison between the effects of resistance training ($n = 10$) and control group ($n = 10$) on changes in metabolic syndrome Z-score.

Note: *Significant difference ($P < 0.05$) between pre- and post- resistance training.

Abbreviations: MetS, metabolic syndrome; CG, control group; RT, resistance training group; Pre, baseline; Post, after 16 weeks intervention period.

post hoc test was not able to find exact differences for HDL cholesterol and waist circumference ($P > 0.05$). Further, there were no significant changes in TG and blood pressure (SBP, DBP, and MBP) in either of the groups.

Body composition and muscle strength

Table 2 shows the results for body composition and muscle strength. Regarding changes in body composition, we found a significant group versus time interaction for percentage of body fat ($F = 16.75$, $P = 0.001$, -6.75%), lean body mass ($F = 4.523$, $P = 0.042$, 2.46%), and fat body mass ($F = 16.58$, $P = 0.001$, -7.06%). The post hoc test showed that resistance training significantly decreased body fat percentage and fat body mass ($P = 0.001$ and $P = 0.004$, respectively) after training compared with the control group. Further, we found an increase in lean body mass after resistance training ($P = 0.042$) compared with the control group. There were no changes in either group for body mass and body mass index, and no significant changes in body composition were found in the control group. Regarding muscle strength, we observed a significant group versus time interaction for leg press ($F = 10.60$, $P = 0.004$, 41.29%) and bench press ($F = 25.47$, $P = 0.000$, 27.23%), with the post hoc test demonstrating that the resistance training group increased strength for leg press and bench press after a 16-week period ($P < 0.001$ for both exercises). There was no significant improvement of muscle strength in the control group after 16 weeks.

Discussion

The purpose of the present study was to investigate if resistance training can help to reduce the risk of metabolic syndrome in healthy postmenopausal women. The results showed a decrease in metabolic syndrome Z-score values,

Table 1 Metabolic syndrome components at baseline (pre) and after the 16-week intervention (post) period

Variables	Control group		$\Delta\%$	ES	Resistance training group		$\Delta\%$	ES
	Pre	Post			Pre	Post		
HDL-C (mmol/L)	54.72 \pm 8.21	52.00 \pm 7.24	-4.96	S	50.92 \pm 10.09	57.64 \pm 12.70	13.20	S
Glucose (mmol/L)	93.99 \pm 7.84	93.10 \pm 7.55	-0.95	T	98.74 \pm 13.41	84.94 \pm 6.33*	-13.97	L
Triglycerides (mmol/L)	109.21 \pm 62.07	117.80 \pm 47.13	7.87	T	191.28 \pm 75.98	232.31 \pm 77.98	21.45	S
WC (cm)	77.54 \pm 3.67	78.96 \pm 4.24	1.81	S	81.53 \pm 10.51	81.22 \pm 9.64	-0.25	T
DBP (mmHg)	78.40 \pm 6.50	78.00 \pm 7.70	-0.44	T	89.80 \pm 7.27	88.20 \pm 5.45	-1.60	S
SBP (mmHg)	111.80 \pm 7.30	113.30 \pm 8.40	1.56	T	138.40 \pm 15.37	130.80 \pm 16.06	-7.60	S
MBP (mmHg)	80.59 \pm 28.94	80.79 \pm 29.20	0.25	T	105.98 \pm 6.67	102.39 \pm 6.73	-3.39	S

Notes: *Significant difference ($P < 0.05$) between pre and post. Pre represents baseline values, post represents values after the 16-weeks intervention period. Pre and Post figures are shown as means \pm standard deviations.

Abbreviations: ES, effect size; T, trivial; S, small; L, large; HDL-C, high density lipoprotein cholesterol; WC, waist circumference; MBP, mean blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure.

so we can infer that resistance training is efficient in helping to decrease the risk of metabolic syndrome in middle-aged postmenopausal women. Further, the resistance training group showed significant decreases in fasting glucose levels and fat mass, and also increases in lean body mass and muscle strength.

Table 2 shows muscle strength before and after the intervention period. We observed significant improvements in leg press (41.29%) and bench press (27.23%) muscle strength for the resistance training group, but no changes were observed in the control group. Orsatti et al³⁰ demonstrated similar enhancement in muscle strength on bench press (29.5%) after 16 weeks of training. The similarity of these results could be attributed to the training model used, ie, resistance training based on a series of maximal repetitions. The resistance training method used in the present study and in the study realized by Orsatti et al³⁰ has been demonstrated to be the optimum method for improving strength and lean body mass.³⁷ Increased muscle strength seems to be extremely important in the prevention of metabolic syndrome.^{38,39} Also, our results for muscle strength confirm the efficacy of our training protocol and corroborate the findings of Wijndaele et al.³⁹ These authors, in a cross-sectional study including

1,019 (571 men) adults aged 18–75 years demonstrated that the risk of metabolic syndrome was inversely associated with muscle strength, independently of aerobic fitness and dietary intake, suggesting a possible protective effect of muscle strength in metabolic syndrome. Our results are also consistent with those of Wijndaele et al,³⁹ showing that resistance training improves muscle strength and can induce positive modifications in body composition.

After menopause, women are likely to experience significant changes in body composition, including increased body fat and decreased lean body mass (ie, sarcopenia)^{6,9,10,40} and these changes are related to several diseases.^{20,30,37} Like Johnston et al⁴¹ and Orsatti et al,³⁰ we noted a significant increase in lean body mass (2.46%) after a resistance training intervention (Table 2). Orsatti et al³⁰ observed a significant increase in muscle mass (about 10%) in sedentary postmenopausal women after 16 weeks of resistance training comprising three sessions per week. Although Orsatti et al³⁰ did not show a decrease in fat mass, our protocol was effective in decreasing percent body fat (by about 6.75%) and fat body mass (by about 1.56 kg). Although the skin-fold method is not a gold standard for assessing body composition and, thus, configures a limitation of the present study, previous work has shown its

Table 2 Body composition and muscle strength at baseline (pre) and after the 16 week intervention (post) period

Variables	Control group		$\Delta\%$	Resistance training group		$\Delta\%$
	Pre	Post		Pre	Post	
BM (kg)	64.25 \pm 5.03	64.90 \pm 5.13	1.01	64.58 \pm 9.22	64.07 \pm 9.18	-0.79
BMI (kg/m ²)	25.26 \pm 1.81	25.53 \pm 2.11	1.07	26.22 \pm 3.26	26.00 \pm 3.11	-0.083
% body fat	35.80 \pm 5.71	36.58 \pm 4.61	2.15	33.68 \pm 3.93	31.41 \pm 4.86*	-6.75
Lean body mass (kg)	41.05 \pm 2.43	41.01 \pm 2.49	-0.09	42.54 \pm 4.23	43.59 \pm 3.93*	2.46
Fat body mass (kg)	23.20 \pm 4.95	23.88 \pm 4.37	2.93	22.04 \pm 5.35	20.48 \pm 5.66*	-7.06
Bench press (kg)	35.50 \pm 5.13	37.40 \pm 6.60	5.35	38.20 \pm 7.89	48.60 \pm 7.66*	27.23
Leg press (kg)	134.00 \pm 24.29	150.60 \pm 21.89	12.39	128.60 \pm 12.71	181.70 \pm 42.98*	41.29

Notes: *Significant difference ($P < 0.05$) between pre and post. Pre represents baseline values, post represents values after the 16-weeks intervention period. Pre and Post figures are shown as means \pm standard deviations.

Abbreviations: BM, body mass; BMI, body mass index.

validity compared to the radiographic technique of computerized tomography and magnetic resonance imaging.^{42,43}

The increase in lean body mass is important for protection against sarcopenia, and can be related to improved glucose uptake. Although our sample had normal glucose levels, improved glucose intake can also be associated with qualitative changes in resistance-trained muscle.^{22,44} Holten et al⁴⁴ showed that, after 6 weeks of resistance training, insulin action in skeletal muscle was enhanced in both type 2 diabetics and healthy subjects. Consequently, the authors concluded that increased muscle glucose transporter isoform-4 content and expression and/or activity of various insulin signaling proteins are part of the mechanism underlying the improvement in insulin action. Therefore, we can speculate that the improvement in glucose control achieved in postmenopausal women during the present study (Table 1) could be due to both increased lean body mass and/or functional improvements in resistance-trained muscle, which has been shown to be important for this population. Further, decreased fasting blood glucose and improved body composition may also contribute to decreasing the risk of metabolic syndrome.

Taking into account the concept of the Z-score (ie, a standard score which indicates by how much the standard deviation, an observation, or datum point is above or below the mean), we can infer that resistance training was effective in improving the Z-score (see Figure 1) because the continuous score would be more sensitive to both small and large changes.²⁵ Hence, the decrease in fasting blood glucose levels coupled with the small modifications in blood pressure and HDL cholesterol (see effect size, Table 1) observed in the resistance training group after the intervention period could have contributed to the decrease in metabolic syndrome Z-score (Figure 1). On the other hand, we did not show a group versus time interaction for waist circumference, HDL cholesterol, or blood pressure. These results are probably due to the fact that our sample initially had normal levels for these parameters. Further, changes in HDL cholesterol, blood pressure, and waist circumference are more favorably modified when dynamic endurance training is performed.⁴⁵

Potteiger et al⁴⁶ undertook 6 months of resistance training in 35 overweight males, and showed that resistance training was effective in reducing the risk of cardiovascular disease by positively affecting waist circumference and mean arterial blood pressure, and by decreasing body fat, fat mass, fasting insulin, and insulin resistance. Nevertheless, the authors proposed both resistance training and dietary energy restriction. Even with these independent results, the Z-score did not show a significant positive change, in contrast with

our results, probably because the modifications in metabolic syndrome Z-score were moderate. The present study did not propose any nutritional changes, but analyses of the Z-score showed an important reduction in risk of metabolic syndrome for the resistance training group in comparison to the control group. Future studies using a resistance training protocol combined with dietary energy restriction in postmenopausal women could be performed in order to produce greater modifications in Z-score metabolic syndrome risk.

In summary, we conclude that resistance training is effective for reducing the risk of metabolic syndrome, given that resistance training helped in decreasing Z-score values in middle-aged postmenopausal women. In addition, resistance training was effective for increasing muscle strength in the upper and lower limbs, increasing lean body mass, and decreasing body fat and fasting blood glucose, which are desirable improvements for the health of postmenopausal women.

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Disclosure

The authors declare that they have no conflicts of interest in this work.

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