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Research article

Resistance Band Exercise Training Prevents the Progression of Metabolic Syndrome in Obese Postmenopausal Women

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Abstract

Metabolic syndrome (MetS) is classified as a combination of risk factors for cardiovascular disease (CVD), and postmenopausal women are specifically at an increased risk for MetS, in part due to the hormonal and metabolic changes that occur at the menopause transition. It is crucial to combat the components of MetS with appropriate lifestyle interventions in this population, such as exercise. This study aimed to examine the effects of a resistance band exercise training program in obese postmenopausal women with MetS. A total 35 postmenopausal women were randomly assigned to either a control group (CON, n = 17) or a resistance band exercise training group (EX, n = 18). Participants in the EX group trained 3days/week. Levels of blood glucose, insulin, homeostatic model of insulin resistance (HOMA-IR), blood lipid profile, anthropometrics, and blood pressure (BP) were measured at baseline and after the exercise intervention. There were significant group by time interactions ($p < 0.05$) for blood glucose (Δ-4.5 mg/dl), insulin (Δ -1.3 µU/ml), HOMA-IR (Δ -0.6), triglycerides (Δ -9.4 mg/dl), low-density lipoprotein cholesterol(Δ -10.8 mg/dl), systolic BP(Δ -3.4 mmHg), body fat percentage (Δ -3.0 %), and waist circumference (Δ -3.4 cm), which significantly decreased ($p < 0.05$), and lean body mass (Δ 0.7 kg) and high-density lipoprotein cholesterol (Δ 5.1 mg/dl), which significantly increased ($p < 0.05$) after EX compared to no change in CON. The present study indicates that resistance band exercise training may be an effective therapeutic intervention to combat the components of MetS in this population, potentially reducing the risk for the development of CVD.

Key words: Hyperinsulinemia, HOMA-IR, insulin resistance, resistance training, triglycerides.

Introduction

Participating in sports is associated with many benefits Metabolic syndrome (MetS) comprises risk factors, including abdominal obesity, hypertension, and insulin resistance (Grundy et al., 2004), that are thought to increase the likelihood of developing adverse health conditions, such as type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD) (Garg et al., 2014; Lakka et al., 2002; Lorenzo et al., 2003). The Centers for Disease Control and Prevention reported that nearly 35% of adults in the United States have MetS (Moore et al., 2017), and the incidence of MetS is expected to rise dramatically worldwide (Han and Lean, 2016). Since there are many undetected and undiagnosed cases of MetS, it has recently been suggested to be a silent killer (Sherling et al., 2017). In particular, postmenopausal women have been reported to have an increased risk of developing MetS, thereby putting this population at a greater risk for developing CVD (Jouyandeh et al., 2013; Park et al., 2003). Interventions targeting the risk factors of MetS in postmenopausal women are urgently needed. Previous studies have shown that an exercise program is an effective intervention to reduce the risk factors of MetS such as abdominal obesity (Bharath et al., 2018; Coker et al., 2009; Son et al., 2017; Sung et al., 2019), elevated blood pressure (BP) (Bharath et al., 2018; Pekas et al., 2020; Son et al., 2017; Sung et al., 2019; Wong et al., 2018), dyslipidemia (Shaw et al., 2009), and insulin resistance (Bharath et al., 2018; Brooks et al., 2006; Son et al., 2017) in adolescents and postmenopausal women. Specifically, resistance training has been demonstrated to improve several risk factors of MetS in postmenopausal women by reducing blood glucose levels, waist circumference, body fat percentage, systolic BP, inflammatory markers, total cholesterol (TC), and low-density lipoprotein cholesterol (LDL-C), and increasing lean body mass (LBM) (Conceicao et al., 2013; Oliveira et al., 2015; Tomeleri et al., 2018; Wooten et al., 2011). These resistance exercise programs used free weights and weight machines for their exercise training protocols (Conceicao et al., 2013; Oliveira et al., 2015; Tomeleri et al., 2018; Wooten et al., 2011). Participating in an exercise program is considered difficult by many older people, partly because of various perceived barriers such as cost, scheduled time slots, and inaccessible equipment in fitness facilities (O'Neill and Reid, 1991). Accordingly, providing a readily available exercise program may be an ideal therapeutic intervention for postmenopausal women to combat the risk factors of MetS. Training with resistance bands as opposed to weight machines or free weights has been presented as an affordable and convenient exercise intervention that may be useful for improving muscular fitness and hyperglycemia in older adults (Cartee, 1994; Kwak et al., 2016; Smith et al., 2017). Resistance bands are less expensive, portable, and easier to use (Colado and Triplett, 2008). However, few studies (Gomez-Tomas et al., 2018; Tomeleri et al., 2018) have examined the effects of resistance band exercise training on the following parameters in obese postmenopausal women with MetS: insulin, glucose, homeostatic model, assessment of insulin resistance (HOMA-IR), blood lipid profile, BP, and anthropometrics. This study was designed to examine the impact of resistance band exercise training in obese postmenopausal women with MetS. We hypothesized that the risk factors of MetS would improve after completion of the exercise training program.

Methods

Participants

Thirty-five participants were postmenopausal (cessation of

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menses for at least 12 consecutive months), abdominal obesity (waist > 80 cm), and hypertension (systolic BP ≥ 130 and/or diastolic BP > 80 mmHg). Study participants were classified as sedentary, defined as participation in <1 hour of exercise regularly per week within the previous year. Informed consent was obtained from all individual participants included in this study, and the potential benefits and risks of this study were addressed to each participant prior to signing the consent form.

Study design

After pre-measurements, the participants were randomly assigned to the non-exercise control group (CON, n = 17) or the resistance band exercise group (EX, n = 18) by using a two-armed, parallel design (Figure 1). Pre and post 12-week study period, participants reported to the laboratory in the morning at the same time of day (10:00 AM, ±1 h) for blood sampling, measurements of BP, and anthropometric assessment. The EX group participated in a supervised resistance band exercise training program for 12 weeks, which included a warm-up, main exercise session, and a cool-down. The CON group did not participate in any exercise program. The EX and CON groups were advised not to change their dietary habits throughout the 12-week study period. All study participants were fully supervised by qualified trainers during the exercise sessions. Laboratory measurements were taken by researchers who were blinded to the randomization of subjects.

Band exercise training program

The resistance band exercise training was performed for 60 minutes with 10 minutes of warm-up and cool-down and 40 minutes of the main exercise, 3 times a week (Mon, Wed, Fri) for 12 weeks. The warm-up and cool-down included static stretching. Furthermore, the resistance band exercise training program consisted of various resistance band exercises (shoulder abduction, shoulder flexion, biceps curl, triceps extension, seated row, squat, seated leg extension, seated leg curl, hip abduction and seated calf raise). Intensity of the resistance band exercise was gradually increased from 40–50% 1 repetition maximum (1RM) and rated perceived exertion (RPE) 11–12 in weeks 1 to 4, 50-60% 1RM and RPE 13-14 in weeks 5-8, and 60- 70% 1RM and RPE 15-16 in weeks 9-12 (Bharath et al., 2018). All of the sessions were supervised by the researcher (Table 1).

Blood sample analysis

Blood samples were collected around 9:00 AM following an overnight fast. Samples were collected from an antecubital vein in EDTA tubes and were centrifuged at 3500 RPM at 4°C for 10 min. The plasma samples were stored at -80°C for later analysis. Glucose concentrations were measured using a commercially available hexokinase activity assay kit (Glu-hk, Asan Pharmaceutical, Seoul, Korea). Insulin concentrations were measured in duplicate using a commercially available radioimmunoassay kit (Insulin IRMA, Biosource, Belgium). Insulin resistance was assessed by a HOMA-IR calculated as described by Matthews et al. (Matthews et al., 1985) Blood lipid profiles including triglycerides (TG), high-density lipoprotein (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were assessed and calculated as previously described (Pekas et al., 2020).

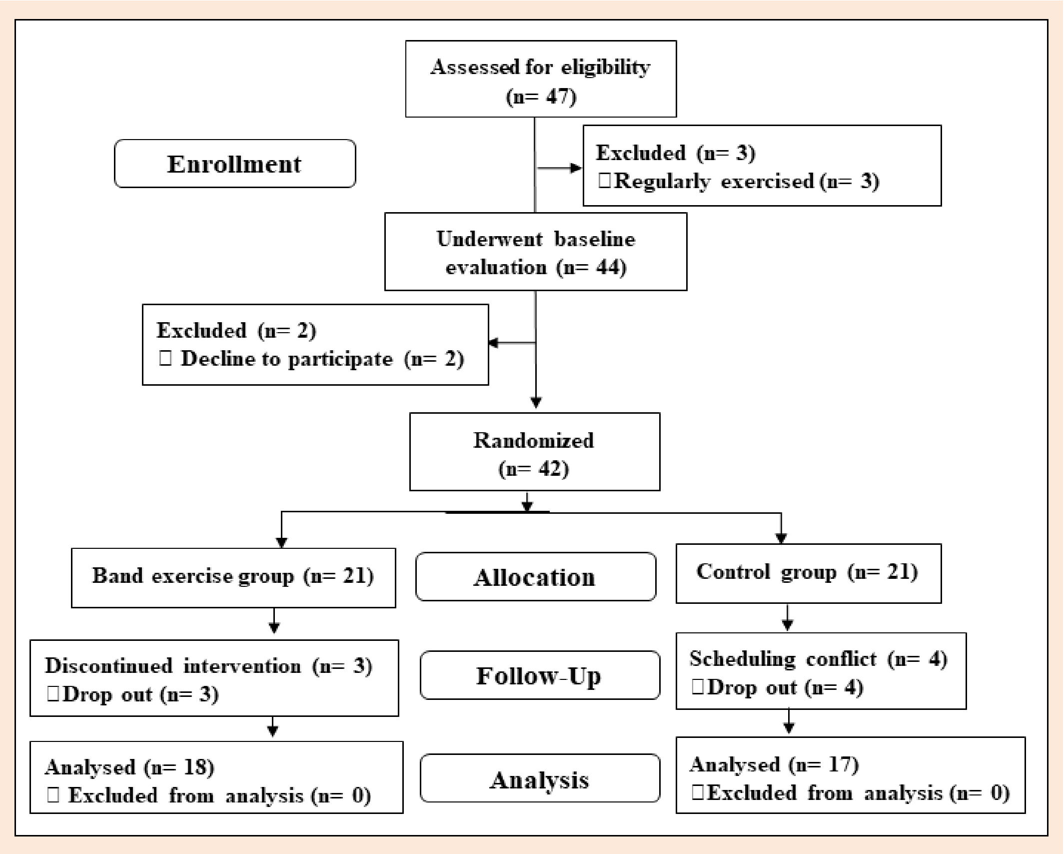

Figure 1. Diagram for the experimental study.

Table 1. **Resistance band exercise training program.**

Order	Exercise	Duration	Week	Intensity	Sets/ Repetitions	Frequency
Warm-up	Static stretching	10 min				
Main Exercise	Shoulder lateral flexion Shoulder flexion	40 min	1 - 4	1RM: 40-50% RPE: 11-12	2 - 3 sets/ 10-15 reps	3 times/week
	Biceps curl					
	Triceps extension					
	Seated row		5 - 8	1RM: 50-60% RPE: 13-14	2 - 3 sets/ 15-20 reps	
	Squat					
	Seated leg extension					
	Seated leg curl		9 - 12	1RM: 60-70% RPE: 15-16	3 - 4 sets/1 5-20 reps	
	Hip abduction					
	Seated calf raise					
Cool-down	Static Stretching	10 min				

1RM: 1 repetition maximum, RPE: rating of perceived exertion

Blood pressure

Systolic BP (SBP) and diastolic BP (DBP) were measured after an overnight fast and 5 min of quiet rest in a seated position using an automatic sphygmomanometer (BP-200, Omron, Kyoto, Japan) before and after 12 weeks of training intervention. The measurements were performed in duplicate, and the average of the 2 measurements was recorded as the resting BP (Pickering et al., 2005).

Anthropometrics

Height was measured to the nearest 0.1 cm with without shoes. Body mass (nearest 0.1 kg), body fat percentage (nearest 0.1%), and lean body mass (nearest 0.1 kg) were determined in all participants by using a bioelectrical impedance meter with the InBody 230 (Biospace, Seoul, Korea) (Karelis et al., 2013; Seo et al., 2010; Sung et al., 2019). InBody 230 has been previously validated to be consistent with the doubly labeled water method for determining body composition (Beato et al., 2019). BMI was calculated as the body mass divided by height squared (kg/m2). Waist circumference was measured in duplicate using a standard tape measured to the nearest 0.1 cm at the midpoint between the iliac crest and the lower rib as an index of abdominal adiposity (Sung et al., 2019).

Statistical analysis

The Shapiro-Wilk test was used to examine the normality of the data. Independent t tests were used to determine baseline differences between the two groups. A two-way analysis of variance (ANOVA) with repeated measures [group (CON and EX) × time (pre and post 12 weeks)] was used to determine the difference of changes between pre- and post-resistance band exercise programs within and between groups on the dependent variables. The homogeneity of variance was assessed using the Levene's test. When significant interactions were noted, paired t-tests were used for post hoc comparisons. Prism GraphPad statistical software (version 6.01; GraphPad Software, Inc., San Diego, CA) was used for all analyses. Data are presented as Mean ± SD. Statistical significance was set to $p < 0.05$.

Results

No participants reported any adverse events or unfavorable symptom effects resulting from a resistance band exercise training program. Anthropometry, body composition, and BP pre and post 12 weeks for CON and EX groups are presented (Table 2). Participant comorbidities and other conditions (Table 3). Participants in the EX group demonstrated 95% adherence to the supervised resistance band exercise training program. No significant differences were observed between groups for baseline measurements ($p > 0.05$, Table 2). There is significant group x time interaction ($p < 0.05$) for glucose, insulin, HOMA-IR, TG, HDL-C, LDL-C, body mas, BMI, BF%, LBM, waist circumference, and SBP (Figure 2, 3, Table 2). Glucose (Δ-4.5±2.1 mg/dl), insulin (Δ-1.3±0 µU/Ml), HOMA-IR (Δ-0.6±0), TG (Δ-9.4±3.0 mg/dl), LDL-C (Δ-10.8±5.3 mg/dl), body mass (Δ-2.1±0.1 kg), BMI (Δ-0.8±0.1 kg/m^2), BF% (Δ-3.0±0.3 %), waist circumference (Δ-3.4±0.3 cm) and SBP (Δ-3.9±0.3 mmHg) were significantly decreased ($p < 0.05$) in the EX group (Figure 2 and 3, Table 2). HDL-C (Δ5.1±0.9 mg/dl) and LBM (Δ0.7±0.4 kg) were significantly increased ($p < 0.05$) in the EX group (Figure 3, Table 2).

Table 2. **Participant characteristics. Values are Mean ± SD.**

	CON (n = 17)			EX (n = 18)		
	Pre	Post	Δ	Pre	Post	Δ
Age, y	68.2 ± 1.4	-	-	68.2 ± 1.6	-	-
Height, m	1.57 ± 0.04	-	-	1.57 ± 0.05	-	-
Mass, kg	66.2 ± 3.8	66.4 ± 3.9	0.2 ± 0.1	66.3 ± 5.9	64.2 ± 5.8*†	-2.1 ± 0.1
BMI, kg/m^2	27.1 ± 1.4	27.1 ± 1.4	0.0 ± 0.0	26.7 ± 3.2	25.9 ± 3.3*†	-0.8 ± 0.1
Body fat, %	37.4 ± 3.9	37.5 ± 4.1	0.1 ± 0.2	36.2 ± 4.5	33.2 ± 4.8*†	-3.0 ± 0.3
Lean body mass, kg	21.4 ± 1.9	21.1 ± 2.2	-0.3 ± 0.3	21.0 ± 2.4	21.7 ± 2.8*†	0.7 ± 0.4
Waist circumference, cm	89.8 ± 9.4	90.3 ± 8.3	0.5 ± 1.1	89.1 ± 7.8	85.7 ± 7.5*†	-3.4 ± 0.3
Systolic BP, mmHg	136.9 ± 3.4	137.4 ± 4.1	0.5 ± 0.7	136.3 ± 4.9	132.4 ± 4.6*†	-3.9 ± 0.3
Diastolic BP, mmHg	81.2 ± 9.7	81.5 ± 9.4	0.3 ± 0.3	80.9 ± 7.8	80.8 ± 7.9	-0.1 ± 0.1

BMI: body mass index, BP: blood pressure, CON: control group, EX: resistance band exercise training group; *$p < 0.05$ different than Pre; †$p < 0.05$ different than CON.

Table 3. Participant comorbidities and medications.

Comorbidity or condition	CON, n = 17	EX, n = 18
Diabetes mellitus	11	11
Hypertension	17	18
Dyslipidemia	15	15
Arthritis	8	6
Cardiac arrhythmias	3	3
Medications		
ACE inhibitors	12	8
Angiotensin II receptor blockers	4	3
Diabetic medication/insulin therapy	10	12
Beta Blockers	4	3
Calcium channel blockers	3	4
Diuretics	5	8
NSAIDs	13	12

ACE: angiotensin-converting enzyme, NSAID: non-steroidal anti-inflammatory medication.

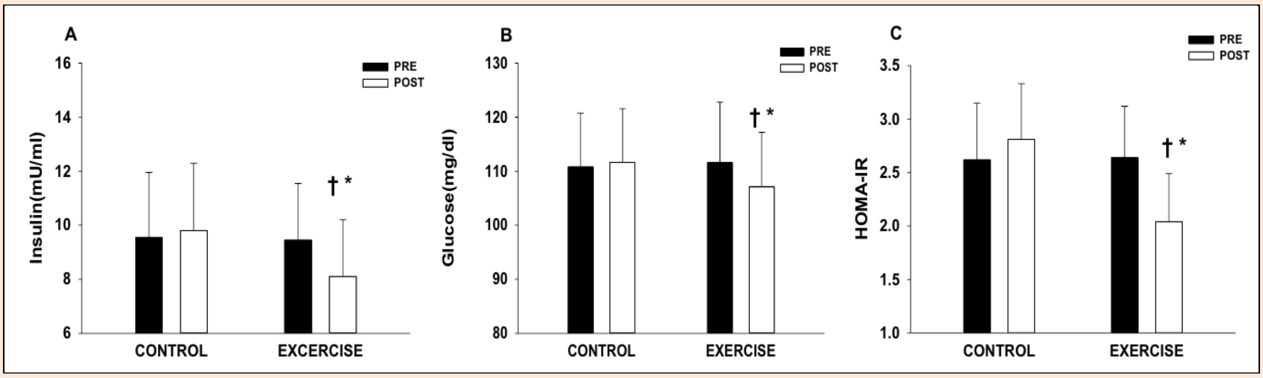

Figure 2. Changes in glucose, insulin, and HOMA-IR pre and post in control (CON) and exercise (EX) groups. (A) Glucose was significantly decreased in post EX compared to post CON. (B) Insulin was significantly reduced in post EX compared to post CON. (C) HOMA-IR was significantly decreased in post EX compared to post CON. Values are Mean ± SD. * $p < 0.05$ vs. pre. † $p < 0.05$ vs. CON.

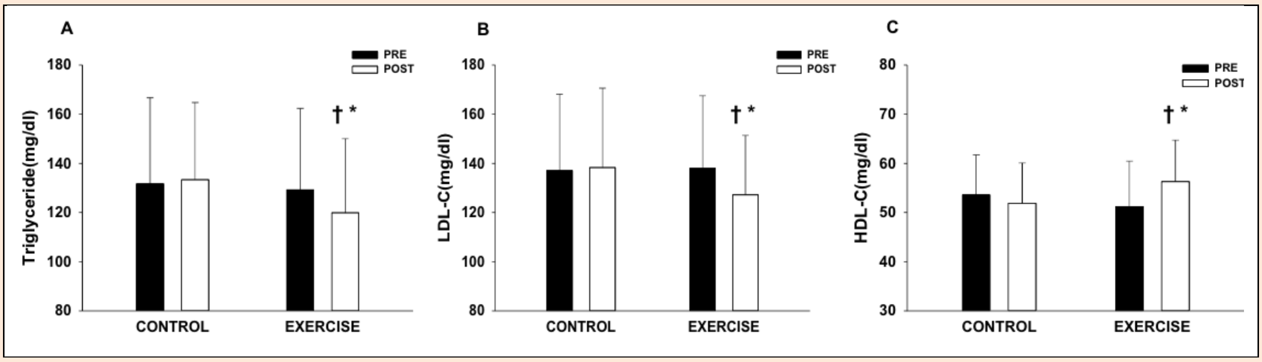

Figure 3. Changes in TG, HDL-C, and LDL-C pre and post 12 weeks in control (CON) and exercise (EX) groups. (A) TG was significantly reduced in post EX compared to post CON. (B) HDL-C was significantly greater in post EX compared to post CON. (C) LDL-C was significantly reduced in the EX group. Values are Mean ± SD. * $p < 0.05$ vs. Pre. † $p < 0.05$ vs. CON.

Discussion

The purpose of this study was to determine the effects of a resistance band exercise training program on insulin, glucose, HOMA-IR, blood lipid profile, BP, and anthropometrics in obese postmenopausal women with MetS. There were noteworthy findings observed in the present study. First, there were significant improvements in the levels of insulin, glucose, HOMA-IR, and blood lipid profile following the exercise training program. Second, body mass, body mass index (BMI), body fat percentage (BF%), SBP, and waist circumference significantly decreased, whereas LBM was found to be markedly increased after 12 weeks of the exercise training program. The findings of this study suggest that resistance band exercise training is useful for improving the risk factors of MetS in obese postmenopausal women.

Glucose, insulin, and HOMA-IR

It is well understood that MetS is a cluster of risk factors that are thought to increase the likelihood of developing CVD and other conditions such as T2DM (Garg et al., 2014; Grundy et al., 2004; Lakka et al., 2002; Lorenzo et al., 2003). Altered insulin sensitivity and glucose metabolism are considered primary factors in the pathogenesis of T2DM (Freeman et al., 2019; Wilcox, 2005). The risk of developing T2DM has been reported to increase with postmenopausal status (Ren et al., 2019). Abdominal adiposity is associated with reduced insulin sensitivity, and is considered a strong predictor of insulin resistance with aging (Racette et al., 2006). Reductions in abdominal fat mass and total fat mass have been reported to play a role in improving glucose tolerance and HOMA-IR (Buemann et al., 2005; Colman et al., 1995; Philipsen et al., 2015). Therefore, targeting reductions in abdominal adiposity and total fat mass may be advantageous for improving HOMA-IR and glucose metabolism in postmenopausal women. It has been demonstrated that aerobic exercise training decreases abdominal fat mass while reducing metabolism markers such as insulin, glucose, and HOMA-IR in obese postmenopausal women (Ryan et al., 2014). Traditional resistance exercise training has been reported to decrease body fat while improving blood HOMA-IR and glucose levels in postmenopausal women (Conceicao et al., 2013; Oliveira et al., 2015). In the present study, insulin, glucose, and HOMA-IR were reduced in post EX compared to post CON. The reductions in body fat mass observed in the present study may be a key player underlying these metabolic improvements.

Potential mechanisms are a significant decrease in BF% and abdominal adiposity, as well as improvements in LBM, which might have enhanced the systemic metabolic environment, such as that of glucose uptake and storage, and reduced the amount of insulin required to maintain normal glucose tolerance (Fenicchia et al., 2004; Mandrup et al., 2018; Miller et al., 1984), thereby reducing metabolism markers in this study population.

Blood lipid profile

Following the menopause transition, blood lipid profile shifts and becomes more atherogenic, as indicated by increased levels of TC, LDL-C, and decreased levels of HDL-C (Anagnostis et al., 2015; Polotsky and Polotsky, 2010; Saha et al., 2013). This physiological shift in blood lipid profiles makes postmenopausal women more susceptible to atherosclerosis, such as peripheral artery disease (PAD) and coronary artery disease (CAD) (Witteman et al., 1989). Prevention of atherosclerotic disease progression may be particularly significant for this study population, as atherosclerosis initially shows no symptoms until vascular damage has already occurred (Pahwa and Jialal, 2020). Therefore, it is important to achieve optimal blood lipid profiles to prevent and/or delay the manifestation of atherosclerotic diseases. Traditional resistance exercise programs specifically have been demonstrated to improve blood lipid profiles in postmenopausal women.

It has been previously reported that TC and LDL-C levels improved after a traditional resistance exercise program in obese postmenopausal women (Wooten et al., 2011). Another study suggested that levels of TC, TG, LDL-C, and HDL-C improved following a traditional resistance exercise program in overweight postmenopausal women (Fahlman et al., 2002). It has been demonstrated that a 1-year resistance band exercise program in postmenopausal women significantly increased levels of HDL-C and decreased that of TC, LDL-C, and TC/HDL-C ratio (BEMBEN and BEMBEN, 2000; Gomez-Tomas et al., 2018). The present study revealed significant improvements in TG, HDL-C, and LDL-C levels after 12 weeks in post-EX vs. post-CON, suggesting a comprehensive improvement in blood lipid profiles. The mechanisms by which blood lipid levels improved in the present study remains unclear, however, several relationships may be partially responsible for these improvements. Abdominal fat mass accumulation has been positively correlated with LDL and TC levels (Veldhuis et al., 2016). Changes in body composition following resistance training, such as reduced BF% and increased LBM, have been reported to play a role in improving blood lipid profiles in older adults (Arnarson et al., 2014). Additionally, a previous study suggested that decreases in BMI and waist circumference were associated with improvements in blood lipid levels (Kelley and Kelley, 2009). These potential mechanisms involving body composition may also have played a role in the present study population, as abdominal fat mass and BMI were significantly decreased and LBM significantly increased in post-EX vs. post-CON. An increase in the level of enzymes involved in the clearance of blood lipids, and HDL-C involved in the reverse transport of cholesterol were also observed (Durstine and Haskell, 1994; Ferguson et al., 1998).

Blood pressure

Aside from its role in metabolic regulation, adipose tissue synthesizes paracrine and autocrine compounds that are greatly involved in vascular homeostatic adjustment (Coelho et al., 2013). However, the altered synthesis and overproduction of adipokines in obesity is thought to guide endothelial dysfunction and oxidative stress, significantly contributing to BP elevation and subsequent development of hypertension (Zhou and Qin, 2012). Menopause accompanied by fat mass accumulation, poses a greater risk of increased adipose tissue accumulation (Wing et al., 1991). Therefore, development of hypertension in this population may be in part due to the increased oxidative stress and endothelial dysfunction associated with obesity and adipose dysfunction (Zhou and Qin, 2012). A previous, study demonstrated resistance training for 16 weeks to favorably improve LBM, fat mass, and BP in postmenopausal women (Conceicao et al., 2013). Our findings in the present study are consistent with this previous study, in which BF%, body mass, and SBP significantly decreased, while LBM significantly improved after the resistance band exercise training.

Several potential mechanisms might underlay the BP reduction in this study. First, a reduction in abdominal adiposity and overall body fat percentage might have reduced the synthesis of inflammatory adipokines produced by the adipose tissue (Coelho et al., 2013). This adipose reduction might have served to decrease the levels of oxidative stress and inflammation, both of which greatly contribute to the development of hypertension (Zhou and Qin, 2012). Second, a previous study reported that increases in lean muscle mass may prevent hypertension (Butcher et al., 2018). In this study, LBM was significantly increased following resistance band exercise training, and may have played a role in BP reduction. Finally, it has been suggested that obesity-induced hypertension causes oxidative stress and reduces the bioavailability of nitric oxide, a potent vasodilator (Higashi et al., 2001). A previous study reported that a resistance exercise program improved endothelin function and increased bioavailability of nitric oxide which might explain the findings of this study (Beck et al., 2014; Ray and Carrasco, 2000).

Body composition

Approximately 20% of postmenopausal women have sarcopenia, which is the decrease in skeletal muscle mass with aging (Iannuzzi-Sucich et al., 2002). Sarcopenia also includes loss of muscular function, which is known to lead to mobility restriction and decreased quality of life (Janssen et al., 2002; Woo et al., 2016). Therefore, preserving muscle mass and function may reduce the likelihood of mobility restrictions and poor quality of life. It has been previously shown that a resistance band exercise program of 8-12 weeks duration is effective for improving LBM in postmenopausal women and older adults (Liao et al., 2018; Martins et al., 2015). Our results were consistent with this previous study in that LBM significantly increased following resistance band exercise training. Therefore, the present study implies that this exercise program may help improve and prevent sarcopenia in this population. Studies of longer duration are warranted to further expound these potential benefits and improvements in one's daily activities.

Postmenopausal women are at increased peril for developing central adiposity (Donato et al., 2006). Both central adiposity and general obesity may notably impact the prognosis of atherosclerotic disease (Giugliano et al., 2010). In addition to a significant increase in LBM, a significant decrease in BF% and central adiposity was noted following the exercise program. Interestingly, the decrease in overall body fat and waist circumference may be considered a primary mechanism for improvement in the metabolic and blood lipid profile, and BP in the present study (Arnarson et al., 2014; Coelho et al., 2013; Colman et al., 1995; Fenicchia et al., 2004; Mandrup et al., 2018; Philipsen et al., 2015; Veldhuis et al., 2016; Zhou and Qin, 2012), thereby contributing to the reduction of risk of MetS in this population.

The findings of the present study should not be interpreted as an extension in the context of the following limitations. First, we could not control the subject's daily activities. Second, the number of subjects was relatively small, and the study was of a short-term duration. This study was restricted to postmenopausal women, and therefore, it maybe be difficult to generalize the results to other populations.

Conclusion

The present study reveals that resistance band exercise training is a useful therapeutic intervention to improve insulin, glucose, HOMA-IR, blood lipid profile, BP, and anthropometrics in obese postmenopausal women. Old people often perceive exercise participation as difficult because of equipment expenses and accessibility(O'Neill and Reid, 1991), and the results of this study reveal resistance bands and effective alternative to using free weights or weight machines to improve risk factors for MetS. These results are clinically relevant, for reducing risk factors for MetS may help with prevention and/or slowing the progression of cardiovascular diseases in this population.

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Key points

- There are findings in the study that support the use of resistance band exercise for reducing risks for MetS in this population.
- There were significant improvements in insulin, glucose, HOMA-IR, and blood lipid profiles following the exercise training program.
- Body mass, BMI, BF%, SBP, and waist circumference were significantly decreased, while LBM significantly increased after 12 weeks of exercise training program.
- This is the first study to evaluate the impact of resistance band exercise training on risk factors for MetS in obese postmenopausal women.

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