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Effect of Strength Training and Short-term Detraining on Muscle Mass in Women Aged Over 50 Years Old

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Original Article

ABSTRACT

Background: The loss of muscle mass is associated with aging. The aim of this study was to determine the effects of resistance training and detraining on muscle mass in elderly women.

Methods: Twenty post-menopausal women aged ≥50 years old were enrolled. Matching for age, they were randomly assigned into control and resistance training group (RT). The intervention consisted of three sets of 10 repetitions for 10 movements with Thera-Band tubing (based on 80-100% 10-RM), three times a week, for 12 weeks and thereafter, four weeks detraining. Skinfold thickness was determined by caliper. Percentage of body fat was estimated from skinfold thickness (triceps and subscapular) by McArdle method. Fat mass (FM) and fat-free mass (FFM) were calculated. Range of motion for trunk flexion and extension was determined.

Results: During 12 weeks of intervention, significant increases were observed in 1-RM of biceps curl, FFM, trunk flexion and extension and significant decreases during four weeks detraining in RT group. The RT group demonstrated significant decreases during resistance training and increases during detraining in skinfold thickness. FFM, trunk flexion, and extension decreased and skinfold thickness, %FM, and weight of body fat increased in the control group ($P < 0.05$).

Conclusions: Resistance training with Thera-Band enhanced strength and muscle endurance in elderly women and a 4-week detraining period had an adverse effect on muscle power. This suggests that a strength training program is an effective intervention to prevent functional reductions, and can contribute to improve neuromuscular function in older adults.

Keywords: Aging, body composition, strength training

INTRODUCTION

Loss of muscle mass, particularly of fast-twitch or Type II fibers that accompany advanced age, is associated with muscle weakness, increased fatigability, and a loss of functional independency.[1] Reduced muscle strength in older people has been associated with both muscle atrophy and reduced ability to rapidly produce force, which may increase the risk of falling.[2] Increases in muscle cross-sectional area in response to training in old age have been reported by several authors.[3] It has been shown that resistance exercise training increases rate of muscle protein synthesis and therefore improves muscle mass and function.[1] Some examples of resistance training include lifting of weights or working out on resistance machines in the gym and for older people, hand weights, light free weights or stretching bands can be used.[4] Progressive resistance exercise training increases muscle strength, gait velocity, and stair climbing power in physically frail elderly people.[1] Kimura *et al*. reported that after 12 weeks of resistance exercise training, muscle strength and quality of life increased among older adults by improving physiological function.[5] Arai *et al*. found that short-term and low-frequency resistance exercise (2 days/week for 12 weeks) have beneficial effects on physical function in older adults.[6]

Women around 50 years of age are characterized by the beginning of hormonal alterations denoting the transitional phase or the premenopausal state. The high variability in hormone levels, as an increase in follicle stimulating hormone (FSH) or a decrease in estradiol, influences the loss in skeletal muscle mass (women 42-63% lesser than men) and adversely affects the activities of daily living in females with advancing age.[7] Menopause is associated with the well-documented loss of bone mass, muscle weakness,[8] increase in body fat mass and a decline in lean tissue mass (sarcopenic obesity), by muscular and bone-joint complaints, and by hot flashes.[7] While physical exercise, in general, is beneficial, strength training (ST) is often referred to as an effective type of exercise to enhance skeletal muscle function in women.[7] These problems associated with increasing of age can have adverse effects on various aspects of life and performance of daily activities in women.[4]

In addition, periods of inactivity are more common in older adults, because of illness, hospitalization, and limited period of disability that reduces muscle strength, and neural adaptation. Some studies have examined the effect of detraining after a period of strength training. Lovell *et al*. reported that older adult may lose some neuromuscular performance after a period of short-term detraining.[2] Results from the Elliott study show that 10-RM muscle strength decreased after eight weeks of detraining.[9]

Most of these studies have used dumbbells or resistance training machines based on more than 12 weeks resistance training programs which are not accessible for all individuals. In this study, we used the Thera-Band tubing in the form of a short-term (12 weeks) strength training that has fewer barriers to performance of resistance exercise for elderly persons to avoid doing these training. Exercise with Thera-Band tubing is a unique type of resistance training and the resistance provided by Thera-Band tubing is based on the amount that the band or tubing is stretched. Thera-Band tubing produces similar forces between similar colors. The force produced by bands and tubing is directly related to elongation. Each color will provide a specific amount of resistance at the same percent elongation, regardless of initial resting length.[10] There are limited studies available about resistance training and its effects on muscle mass in Iranian adult populations. This is an interventional study, conducted to examine whether resistance exercise training with Thera-Band tubing increases muscle mass in ≥50-year-old women. In addition, the effect of four weeks detraining was also assessed.

METHODS

Participations

Twenty apparently healthy post-menopausal women, aged ≥50 years old participated in this study. According to the previous similar studies sample size and based on the minimum sample size required for such studies, we invited 30 women to be enrolled in this study. We excluded 5 women before starting the intervention based on exclusion criteria and 5 other subjects did not complete the intervention because of fracture, traveling, age mismatch and were excluded during the study. Thus, matched for weight and age, 20 women, randomly assigned into the control (n = 10) and resistance training groups (n = 10), completed the study. All subjects were inactive and had not participated in regular physical activity for at least 1 year. A written consent was obtained from each participant and all of them received a comprehensive explanation of the proposed study and its benefits and inherent risks. Before beginning the exercise program, according to the recommendation of American College of Sport Medicine (ACSM), some questions were asked to determine participant's suitability for beginning an exercise program.[11] Volunteers were excluded at baseline if they had diabetes, Parkinson's disease and peripheral neuropathy or if they were taking hormone replacement therapy (HRT) or medications like β-adrenergic blockers, β-agonists, Ca^{2+} channel blockers and corticosteroids that would influence muscle amino acid metabolism. Moreover, a physician examined all the participants to detect possible medical problems such as osteoporoses that could prevent them from the training. The study was approved by the Research Ethics Committee of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences. All participants signed informed consent forms.

Training and detraining programs

The experimental design program consisted of 12 weeks of resistance training and four weeks of detraining. Resistance training program, designed to develop muscle mass and strength, was performed three times a week (non-consecutive session) for 12 weeks at a local fitness center. Each session lasted 60 min, and had a warm-up and cool-down period of 10 min stretching and flexibility exercise for limbs and trunk, before and after the strength programs. The exercise sessions were monitored under direct supervision of an exercise specialist to ensure correct technique, safety, and proper exercise intensity. The exercise testing equipment used in this investigation was Thera-Band tubing. We used the charts that show the resistance strengths for the Thera-Band color sequences[10] to determine the force that were produced by Thera-Band. Then, for each subject, the 1 repetition maximum (1-RM) was estimated using the following formula to adjust the exercise intensity:[12]

$\text{1-RM} = w/[1.0278 - (0.0278 \times r)]$ (w = force produced by Thera-Band and r = number of repetitions).

Based on the related tables,[13] 10-RM for arm muscles was derived and the resistance exercise program was designed for each participant, based on 80%, 85%, and 100% 10-RM. The resistance exercise consisted of 10 movements with three sets of 10 repetitions that were separated by 3 min of rest. At the end of each month, 1-RM with the Thera-Band tubing was determined and the resistance exercise program was designed based on the new record. The resistance training (RT) group performed the chest press, biceps curl, triceps extension, side shoulder raise, seated row, seated shoulder press, up right row, lateral raise, lat pull down and front raise. Following completion of the resistance training program, the RT group was instructed to maintain their normal lifestyle and avoid starting any new exercise program during the detraining period. The control (C) group was instructed to keep their normal pattern of activity during the 12 weeks' intervention period and the four weeks of detraining. Measurements were done to three times points; at baseline, after 12 weeks intervention, and subsequently, after four weeks of detraining in both groups. Also, 1-RM for biceps was determined using the dumbbell for both groups.

Body composition

Body composition was measured using the subjects' weight, height, and skinfold thickness. Body weight of participants were assessed using a digital electronic weighing scale (Seca 707; range 0.1-150 kg, Hanover, MD) with an accuracy of up to 1 kg for body weight. With shoes removed and wearing light clothing, standing height was measured barefooted to the nearest 0.1 cm and body mass index (BMI) was calculated as weight (kg)/height (m^2). Three sites of skinfold thickness (triceps, subscapular, and suprailiac) were determined using the Harpenden caliper to the nearest 0.1 mm in triplicate on the right side of body and the mean values between two nearest measurements were used for analysis.

Percentage of body fat were estimated from skinfold thickness (triceps and subscapular), based on McArdle method. Fat mass was calculated by multiplying percentage of body fat to body weight, and fat free mass (FFM) was estimated by subtracting fat mass from body weight.[14]

Percentage of body fat: 0.55 (SF thickness of triceps) + 0.31 (SF thickness of subscapular) + 6.13

Mid-arm circumference (MAC) was measured using the non-elastic measuring tape at the midpoint between the acromion process and the olecranon process and then muscle mid-arm circumference (MAMC) was estimated using the following formula:[15]

MAMC = MAC (cm) − (3.14 × skinfold thickness of triceps).

Dietary control

Before initiating the resistance exercise program, after training, and detraining, a three-day-diet recall was completed at three times point to determine any weight changes and body composition from pre- to post-training. All subjects were asked not to change their dietary pattern throughout the duration of study.

Measurement of flexibility

A 10-min warm up, stretching, and flexibility exercise for limbs and trunk was done before flexibility testing. Range of motion for trunk flexion (sitting position) was determined by the sit-and-reach test. The participants were asked to sit on the floor with legs fully extended and bare feet against the standard sit-and-reach box, and then to bend over and touch the box with both hands as far as possible. The best of three trials was recorded. For trunk extension (prone position), participants were asked to lie face down with arms at the side and extended the spine by lifting the shoulders and chin from the floor as far as possible. The distance between the floor and chin was recorded as maximal trunk extension.[14]

Statistical analyses

The Kolmogorov Smirnov test was used to determine normality of the distribution for outcome measures and data are reported as the mean and standard deviations. For comparing the means of two groups, independent sample *t*-test was used to examine any differences between the RT and the C groups for each variable. Repeated measures were used to examine any differences between baselines, after intervention, and detraining values in the RT and the C groups. Data were analyzed using SPSS version 15 and an alpha level <0.05 was considered significant.

RESULTS

All participants completed the 16 weeks study without any case of injury. There were no significant differences between the training and control groups in age, height, weight, BMI, and dietary intake [Table 1]. The mean and standard deviations of skinfold thickness, maximum force, MAMC, trunk flexion, and extension at baseline, 12 weeks of resistance training and detraining are shown in Table 2.

Mean ± S.D for age and height in the C group was 56.7 ± 3.9 years, 155.9 ± 7.3 (cm) and for the RT group was 54.4 ± 4.7 years, 157.0 ± 6.6 (cm), respectively. There were no significant differences in BMI and caloric intake (kcal) in the RT and the C groups throughout the 16-week experimental period. However differences between the RT and the C groups after 12 weeks of resistance training and at the end of study in triceps skinfold thickness, percentage of body fat, and trunk extension were statistically significant ($P < 0.05$). In the RT group, there was a significant increase in maximum force for biceps curl [Table 2] from 4.7 ± 1.3 kg to 5.3 ± 1.2 kg after intervention, and a decrease from 5.3 ± 1.2 kg to 5.1 ± 1.2 kg after detaining ($P < 0.05$). During 12 weeks of intervention, significant increases were observed in MAMC (from 24.5 ± 3.1 to 25.7 ± 3.3 cm), FFM (from 49.4 ± 7.3 to 51.6 ± 7.9 kg), trunk flexion (from 7.1 ± 3.7 to 9.4 ± 3.9 cm) and extension (from 17.3 ± 5.5 to 20.5 ± 6.0 cm) and after four weeks detraining, significant decreases were observed in MAMC (from 25.7 ± 3.3 to 25.6 ± 3.2 cm), trunk flexion (from 9.4 ± 3.9 to 9.0 ± 4.1 cm) and extension (from 20.5 ± 6.0 to 19.9 ± 6.0 cm) in RT group [Table 2]. The RT group demonstrated significant decreases during resistance training

Table 1: Subjects' characteristics at baseline, after resistance training, and after detraining

	Resistance group (*n*=10)*			Control group (*n*=10)*		
	Baseline	**Endpoint**	**Follow-up**	**Baseline**	**Endpoint**	**Follow-up**
Weight (kg)	70.1±10.8	69.8±11.0	70.1±10.8	69.2±8.6	69.6±8.4	69.4±8.7
Body mass index (kg/m2)	28.5±4.7	28.4±4.8	28.5±4.7	28.6±4.8	28.8±4.9	28.7±5.0
Dietary intake (kcal/day)	1316.8±292	1310.1±229	1350.2±243	1491.8±327	1497.0±323	1496.2±307

*Values are means±S.D

Table 2: Effects of resistance training on physical measurements

	Group	Baseline	Endpoint	Follow-up
			Means±S.D	
Dynamic strength of biceps curl (kg)	RT	4.7 ± 1.3	$5.3\pm1.2^{\dagger}$	$5.1\pm1.2^{\dagger\ddagger}$
	C	4.8 ± 1.1	4.7 ± 1.2	4.7 ± 1.2
MAMC (cm)	RT	24.5 ± 3.1	$25.7\pm3.3^{\dagger}$	$25.6\pm3.2^{\dagger\ddagger}$
	C	25.0 ± 2.0	$24.0\pm1.7^{\dagger}$	$23.7\pm1.7^{\dagger\ddagger}$
Body fat mass (kg)	RT	20.6 ± 4.9	$18.2\pm4.4^{\dagger}$	$18.2\pm4.4^{\dagger}$
	C	19.1 ± 4.7	$21.2\pm4.8^{\dagger}$	$21.8\pm4.9^{\dagger\ddagger}$
Percentage body fat (%)	RT	29.1 ± 4.7	$25.9\pm4.2^{*\dagger}$	$25.9\pm4.3^{*\dagger}$
	C	27.4 ± 4.3	$30.2\pm3.8^{*\dagger}$	$31.0\pm3.8^{*\dagger\ddagger}$
Fat free mass (kg)	RT	49.4 ± 7.3	$51.6\pm7.9^{\dagger}$	$51.5\pm8.0^{\dagger}$
	C	50.0 ± 5.0	$48.3\pm4.1^{\dagger}$	$47.7\pm4.0^{\dagger\ddagger}$
Trunk flexion (cm)	RT	7.1 ± 3.7	$9.4\pm3.9^{*\dagger}$	$9.0\pm4.1^{\dagger\ddagger}$
	C	7.2 ± 3.4	$6.1\pm3.4^{*\dagger}$	$5.9\pm3.3^{\dagger}$
Trunk extension (cm)	RT	17.3 ± 5.5	$20.5\pm6.0^{*\dagger}$	$19.9\pm6.0^{*\dagger\ddagger}$
	C	16.0 ± 2.6	$14.4\pm2.6^{*\dagger}$	$13.6\pm2.8^{*\dagger\ddagger}$

MAMC=Muscle mid-arm circumference, RT=Resistance training group, C=Control group. *Significant difference between C and RT ($P<0.05$). †Significant difference from baseline ($P<0.05$). ‡Significant difference from training ($P<0.05$)

and increases during detraining in skinfold thickness (triceps, subscapular, and suprailiac) [Figures 1-3]. MAMC, FFM, trunk flexion, and extension decreased and skinfold thickness (triceps, subscapular, and suprailiac) [Figures 1-3]; percentage of body fat, and weight of body fat increased in the control group ($P < 0.05$) [Table 2].

After four weeks of detraining period, values of MAMC, trunk flexion, and extension were still higher ($P < 0.05$) [Table 2] and skinfold thickness were lower ($P < 0.05$) compared to the baseline values in the RT group [Figure 1].

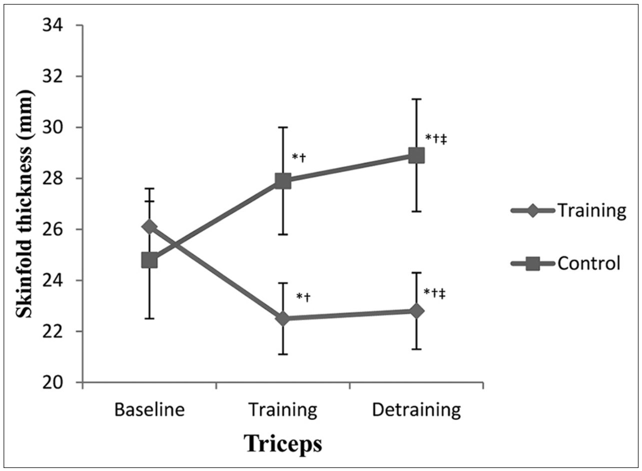

Figure 1: Skinfold thickness (triceps) in the resistance training group during a 12 weeks' strength program followed by a 4 weeks detraining period. *Significant difference between C and RT. †Significant difference from baseline. ‡Significant difference from training

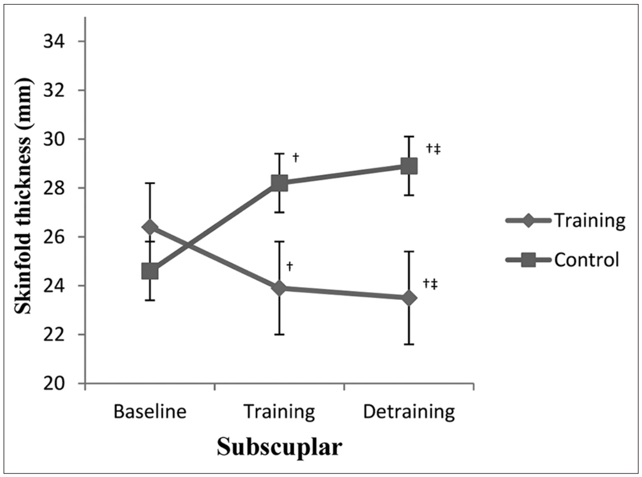

Figure 2: Skinfold thickness (subscapular) in the control group during a 12 weeks' strength program followed by a 4 weeks detraining period. †Significant difference from baseline. ‡Significant difference from training

DISCUSSION

Our findings showed that 12 weeks of resistance training with Thera-Band tubing significantly improved muscle function and enhanced strength and muscle endurance in postmenopausal women, whereas four weeks of detraining caused significant reduction in the muscle strength. In this study we used Thera-Band tubing for resistance exercise training because it is cheap, available, and easy to work with and, make no noise. However, in most studies in this area, strength training was performed with resistance-related machines, which are usually not available for everyone and increase the risk of injury and muscle damage. According to the ACSM reports, strength training is important for improving quality of life and physical function in older adults.[16] Moreover, resistance exercise training can be a safe and effective strategy to enhance the neuromuscular system of older adults.[17] However, recommendations of resistance exercise prescription for the elderly have emphasized that increase in exercise intensity should be slower and at a lower rate of progression, compared with younger adults.[18] In addition, previous studies

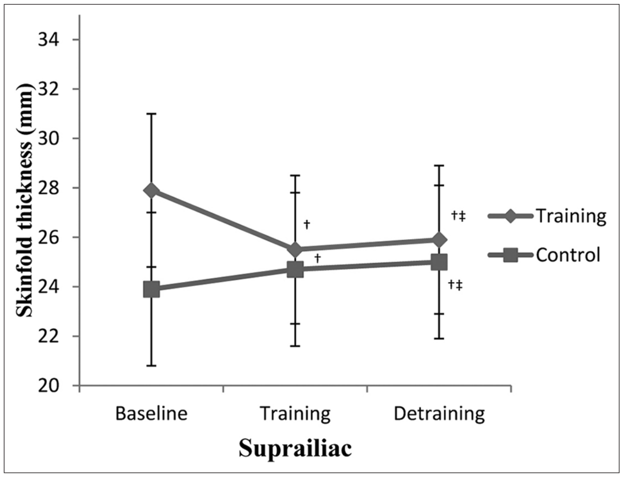

Figure 3: Skinfold thickness (suprailiac) in the control group during a 12 weeks' strength program followed by a 4 weeks detraining period. †Significant difference from baseline. ‡Significant difference from training

have reported that after a short-term detraining period, the muscle strength gain induced by resistance exercise programs is lost.[19,20] When physical exercise is stopped (detraining), the body may lose the beneficial adaptations, which is a response to diminished physiological demand.[21] Since, older adults are more likely to interrupt an exercise program due to various conditions, such as hospitalization, exercise programs should aim to obtain longer lasting effects on muscle strength. Decrement in strength, a greater potential of disability and functional impairment in activities of daily living, insulin resistance, an increased incidence of falls and hip fractures is likely the result of age-related atrophy in muscle mass.[2,22] Sarcopenia contributes significantly to decrease quality of life and health-care costs in the elderly.[23]

Our data revealed that 12 weeks of training improved maximum force for biceps curl, while in the detraining period, muscle strength was decreased, although the strength was greater in the resistance group compared to the baseline values and the control group. These findings are consistent with those of other studies.[2,19] Lovell *et al.* examined the effect of strength training and short-term detraining on maximum force and the rate of development of 24 older men (70-80 years),[2] during a 16-week training program, three times per week, three sets of six to ten repetitions at 70-90% of 1-RM and followed by 4 weeks of detraining; they concluded that high-intensity resistance training can improve maximum force and rate of development of older men, but these individuals may lose some performance after a period of detraining.[2] Evaluating the effects of 10 weeks of moderate resistance strength training followed by 6 weeks of detraining on muscle strength, Kalapotharakos *et al*.[19] studied 18 healthy older men (61-75 years); the moderate resistance strength group, performed resistance protocol for 1 h, 3 times per weeks 3 sets of 15 repetitions at 60% of 1-RM and were instructed to continue their usual leisure activities as before and not to perform any strength exercises; results showed that muscle strength improved after moderate resistance strength training and that short-term detraining period affects muscle strength and power in older adults.[19] Various strength training programs can be developed based on intensity of training (load), the number of sets and repetitions (volume), repetition velocity, length of exercise and rest between sets, and the number of exercise sessions per week (frequency). Nevertheless, it is unclear that how rate of intensity and volume are necessary to significantly improve strength gains and physical performance in this population. Previous study suggests that resistance training with 80% 1-RM may improve health and function in older adults. However, few studies have documented the effects of the low (50% 1-RM), moderate (70% 1-RM), and high intensity (90% 1-RM) resistance exercise on strength development in the elderly, and results show that the low, moderate, and high intensity training caused a significant strength improvement, but the high intensity training protocol caused the most impressive improvement of strength as compared to the low and moderate intensity training.[24]

Our findings showed that the resistance training program showed considerable improvements in muscle strength. The most important benefit of increased muscle strength in the elderly is a decreased risk of falling, helping them to maintain an independent lifestyle.

We showed decrease in body fat and skinfold thickness in response to 12 weeks resistance training without any changes in BMI in the RT group. On the other hand, we found significant differences between the RT and C group only in triceps skinfold thickness and percentage of body fat, possibly because of changes in body fat distribution while the caloric intake was not changed in study population. Hunter *et al*. also reported that older adults can lose fat mass after 25 weeks of resistance training program when weight is maintained.[25] The results of Kang *et al*. indicated that after 12 weeks of light resistance exercise 3 day/wk and 40 min, using dumbbells and rubber band, both body weight and body fat were decreased. It seems weight loss in these subjects occurred because of the mild energy restriction during intervention.[26]

After detraining, we saw increase in percentage of body fat and skinfold thickness, although it was still lower than baseline values. Therefore, the resistance program, performed on a regular basis, can maintain the effects of exercise adaptations.

We found resistance training had a significant and positive effect on MAMC and FFM changes that accompanied the change in muscle function, and a significant negative effect on MAMC changes after a short term detraining period. Our findings are consistent with the results of the Melnyk[27] and Yarasheski[1] studies; Melnyk *et al*. examined the effects of 9 weeks of strength training and 31 weeks of detraining on regional muscle areas and they concluded that strength training induced increases in cross-sectional areas.[27] Yarasheski *et al*. reported that at 3 months of supervised weight lifting exercise, performed 3 days/wk at 65-100% of initial 1-RM, muscle contractile protein synthetic pathway, increased with progressive resistance exercise training in 76-92-year-old women and men.[1] Some other similar studies in older adults, assessing body composition with dual energy x-ray absorptiometer, also reported no significant change in total body weight with modest changes in FFM and fat mass.[28,29] Considering that women typically have a smaller muscle mass in both the upper and lower body and aging is associated with not only a loss muscle mass but also an increase in fatty infiltration in muscle, a program of resistance exercise may be an appropriate strategy to prevent disability induced by sarcopenia. Increase in the rate of muscle protein synthesis, which is greater than protein breakdown reflects the alteration in FFM, which is the rate of synthesis after a training period.

Our investigation showed that trunk flexibility improved during intervention and the flexibility gains were lost after detraining but the values still were greater than baseline. Flexibility losses leads to dysfunction and inability to perform everyday activities such as getting up from a chair, walking, and climbing stairs.[30] Fatouros *et al*. showed that resistance training with intensities greater than 60% of 1-RM improved range of motion and flexibility gains and detraining reversed these gains in elderly people; their findings suggested that adaptations in strength and flexibility performance are highly associated with the exercise intensity used.[30] Aging is strongly associated with significant loss in range of motion[31] and flexibility is important for maintaining or improving joint range of motion that can be related to a higher quality of life and independency for elderly people. Herriott *et al*. showed that the combination of resistance training and flexibility training produces a significant improvement in joint range of motion in older adults.[32] Therefore, it seems that resistance training with stretching, and flexibility exercise is an effective exercise to enhance flexibility, which are an important fitness parameter contributing to, optimal health functional status and independent living of elderly women.

Our study has some weaknesses. We studied older women, so the results cannot be generalized to men. In addition, we presented no data about the effects of resistance training on bio-chemical factors like urinary 3-methylhistidine or serum leucine, and studies are recommended to assess these factors.

CONCLUSIONS

The findings of the present study indicated that 12-week resistance training regimen with Thera-Band tubing is sufficient to enhance strength of healthy postmenopausal women which may contribute to prevent disabilities induced by sarcopenia with advanced age. In addition, a 4-week detraining period had an adverse effect on muscle strength. This suggests that a resistance strength training program is an effective intervention to prevent functional reductions, increase the quality of life and can contribute to the improvements in daily activities, prolonging independence, and the safety of women. Postmenopausal women should continue to train and minimize detraining periods, as increased physical activity levels are essential for the protection of neuromuscular function, muscle tissue, and functional performance.

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