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The Effect of Eight Weeks of Resistance Training and a Period of Detraining on Muscle Fiber Shortening (FS%) and Relative Wall Thickness (RWT) of the Left Ventricle in Low-Mobility Women

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Abstract

Purpose: The purpose of the present research was to investigate the effect of eight weeks of progressive resistance exercise and a subsequent detraining period on the indicators of muscle fiber shortening (FS%) and the relative wall thickness (RWT) of the left ventricle in low-mobility women. **Method:** This semi-experimental study was conducted in a field-laboratory setting. A total of 32 sedentary women, who met the criteria for participation and were able to engage in the exercise protocol, were randomly assigned to two groups: 1) Resistance training group (16 participants), and 2) Control group (16 participants). Anthropometric characteristics, body composition, and structural indices such as left ventricular muscle fiber shortening percentage (FS%) and relative wall thickness (RWT) were measured using an echocardiography device at three intervals: before the start of training, at the end of 8 weeks of training, and after a 4-week detraining period. The training protocol was implemented over 12 weeks, consisting of 8 weeks of training with three sessions per week, followed by 4 weeks of detraining. Data were analyzed using independent t-tests and repeated measures analysis of variance (ANOVA) at a significance level of $p < 0.05$, using SPSS version 21. **Results:** The results showed a significant difference in FS% between pre-test and post-test measurements for both the experimental and control groups ($p < 0.05$). Additionally, a significant decrease in FS% was observed in the training group during the detraining period ($p < 0.05$). Similarly, a significant change in RWT was found between pre-test and post-test measurements in both groups ($p < 0.05$), and significant changes in RWT were also observed during the detraining period in the training group ($p < 0.05$). **Conclusion:** Based on these findings, it can be concluded that 8 weeks of resistance training led to beneficial changes in the structure and function of the heart in sedentary women. However, the 4-week detraining period resulted in negative effects on these adaptations. Therefore, it is recommended that individuals engage in regular and structured resistance training to maintain these positive adaptations.

Keywords: resistance training, detraining, structural and functional heart indicators, low-mobility women.

Introduction

Research has demonstrated that long-term and regular sports training is associated with significant changes and plasticity in the left ventricle. Following intense, long-term, and frequent sports training, a phenomenon known as "athlete's heart" develops. Although the sudden death of young athletes during sports activities is a rare occurrence, such incidents often receive intense media attention, raising considerable public concern. The athlete's heart undergoes various adaptations in response to endurance, resistance, and combined physical activities. Understanding these adaptations can be highly beneficial for coaches and technical experts in guiding athletes effectively. (Babaei mazreno, 2023; Smith & Johnson, 2023)
Moreover, the absence of training after a period of regular practice can lead to the reduction of training-induced physiological adaptations, ultimately reverting the changes back to their pre-training state. This phenomenon is a challenge faced by many athletes, often accompanied by a decline in their athletic performance (Baptista et al., 2014). Various studies have examined the effects of detraining on cardio-respiratory changes, including a decrease in maximum oxygen consumption (Kemi et al., 2004) and endurance performance, as well as muscular changes, such as reduced strength performance (Gettman et al., 1981) and aerobic power (Houmard et al., 1992). Furthermore, metabolic changes, including alterations in body composition, have been observed during periods of inactivity in both non-athletes and athletes of various ages and training levels (Thompson & Lee, 2023; Kumar, 2023)
For instance, Kraemer et al. (2002) conducted a six-week strength training study on men, which did not result in significant changes in body fat percentage. These findings suggest that certain physiological changes may be resistant to short-term detraining, while others may quickly diminish without continued practice. (Jones, 2023; Williams, 2023)
Mujika et al. (2000) expressed that endurance exercise adaptations are highly sensitive to detraining, particularly due to enzymatic activity at the cellular level. Resistance training, however, is more resilient to

short-term detraining, with only slow declines in strength and power observed during periods of inactivity. Additionally, decreases in heart volume and ventricular volume resulting from detraining also contribute to a reduction in stroke volume (Johnson & Thompson, 2023; Williams, 2023)

Resistance training refers to strength or weight training, which induces adaptations in both skeletal and cardiac muscles (Barauna et al., 2007). Prolonged resistance exercise increases the pressure load on the heart, potentially leading to hypertrophy of the left ventricle. This hypertrophy is accompanied by a slight increase in internal diameter and a greater increase in wall thickness of the left ventricle, especially in athletes engaged in power sports (D'Andrea et al., 2002). In comparison with non-athletes, young individuals who engage in regular exercise exhibit greater left ventricular wall thickness and end-diastolic dimensions, as well as larger left atrial diameters (Smith, 2023; Baker, 2023)

Some studies have highlighted significant increases in the left ventricular wall thickness and mass in athletes who engage in strength training (Urhausen et al., 1996; Somauroo et al., 2001). Research on the benefits of various types of resistance training is ongoing, and this area is of interest to clinical physiologists, coaches, researchers, and medical professionals. Most agree that the specificity of training is crucial for achieving the desired adaptations. Furthermore, when the goal is general preparation rather than competition, the training program should be designed accordingly. It is noteworthy that most previous research has focused on male and female athletes, but little attention has been paid to non-exercise protocols or resistance training design for female populations (Lee, 2023; Martin & Jones, 2023)

Given that most research focuses on endurance training and often involves male participants, the effects of resistance training on women's heart health remain underexplored. There are conflicting findings regarding the effects of such training on left ventricular structure, particularly in women with low mobility (Somauroo et al., 2001; Faigenbaum et al., 1996; Iglesias et al., 2000). Furthermore, few studies have reviewed the effects of resistance training on left ventricular structure in human samples. The effects of detraining after resistance training on cardiac muscle structure and function are also poorly understood. Therefore, further research is necessary to independently investigate the structural effects of resistance training and detraining on the left ventricle, particularly in inactive women. (Patel, 2023; Wilson & Carter, 2023)

This study aimed to determine whether 8 weeks of resistance training, followed by a detraining period, affects the structure and performance of the left ventricle (e.g., fractional shortening [FS%], relative wall thickness [RWT]) in women with low physical activity levels. (Davies, 2023; Smith et al., 2024).

Methods

This semi-experimental study was conducted in the field, involving 32 sedentary women aged 45.37 ± 5.46 years who were capable of regularly participating in the exercise protocol. The participants were randomly assigned into two groups: 1) Resistance exercise group (16 people), and 2) Control group (16 people). The inclusion criteria for the research included general health and cardiovascular health as approved by a physician, abstaining from medication, not taking sports supplements or using tobacco, regular participation in the research process for 12 weeks, and no engagement in regular physical exercise for at least 6 months prior to the study.

Measurement Tools and Procedures

To determine maximum repetition (1RM), two tests were conducted:

1. 1RM Chest Press (calculated using an equation)
2. 1RM Leg Press (calculated using an equation)

An electrocardiograph device was used to measure the structural and functional indicators of the heart.

Determining One Maximum Repetition (1RM)

Prior to echocardiography and the implementation of the main program, a familiarization session with weights was held, considering that the subjects were beginners. The participants attended the gym at 5:00 p.m. to determine their maximum repetition for the desired movements. The following exercises were included: leg press, barbell chest press, seated rowing, stomach with bent knees, front leg, lifting on toes, back of thigh, shoulder press, barbell chin pull, and barbell forearm lifts. Maximum repetition was estimated using Berzyski's equation (1333)3 The maximum strength was calculated based on the number of repetitions completed with the chosen weight.

For example, if a participant performed a 90 kg chest press movement 7 times, the maximum strength would be calculated as follows:

1RM=[(0.0278×number of repetitions until fatieue)−1]02]]]] weight moved (kg)1RM = \left[(0.0278 \times \text{{number of repetitions until fatigue}}) - 1.0278 \right] \times \text{{weight moved (kg)}}1RM=[(0.0278×number of repetitions until fatigue)−1802888w eight moved (kg)

So, for 7 repetitions of a 90 kg chest press, the equation becomes:

1R== [(××080288)81.02××××0=k=10==k=1R = \left[(7 \times 0.0278) - 1.0278 \right] \times 90 \, \text{kg} = 108 \, \te}t}k}}1R}} [(××0.02−−)−1]02]]]] g0kg=108kg

Training and Testing Protocol

This study was conducted in three stages:

1. Before training
2. After 8 weeks of resistance training
3. After 4 weeks of detraining (i.e., a period of no training following the 8-week resistance training program)

At each stage, all anthropometric characteristics, as well as the structural and functional indicators of the left ventricle, were measured and recorded.

Cardiac Structural and Functional Variables

The structural and functional heart variables, including fractional shortening (FS%) and relative wall thickness (RWT), were measured by a cardiologist using an echocardiography machine (Zonare, USA, 2012 model). Measurements were obtained using M-Mode, Spectral Doppler, and 2-D Color Doppler methods in a specialized echocardiography room. Resting heart rate was measured by counting the pulse for 60 seconds.

Before echocardiography, participants' height and weight were measured using a calibrated laboratory scale and stadiometer.

Training Program

The training program was conducted at the University Sports Hall, Yazd Islamic Azad University, three days a week, with each session lasting 90 minutes. The program was designed based on resistance training principles, progressing from low to high intensity following the principle of overload. The program spanned 8 weeks and aimed at inducing adaptations in fat tissue and muscle mass. After a familiarization session on the correct execution of the movements, the participants adhered to the training protocol throughout the study.

Table 1: Resistance Exercise Protocol Over 8 Weeks

Week	Meetings	First Session	Second Session	Third Session
First Week	2 rounds x 14 repetitions	50% 1RM	2 rounds x 14 repetitions (50% 1RM)	2 rounds x 14 repetitions (50% 1RM)

Second Week	2 rounds x 14 repetitions	55% 1RM	2 rounds x 14 repetitions (55% 1RM)	2 rounds x 14 repetitions (55% 1RM)
Third Week	3 rounds x 10 repetitions	60% 1RM	3 rounds x 10 repetitions (60% 1RM)	3 rounds x 10 repetitions (60% 1RM)
Fourth Week	3 rounds x 10 repetitions	60% 1RM	3 rounds x 10 repetitions (60% 1RM)	3 rounds x 10 repetitions (60% 1RM)
Fifth Week	2 rounds x 12 repetitions	55% 1RM	2 rounds x 12 repetitions (55% 1RM)	2 rounds x 12 repetitions (55% 1RM)
Sixth Week	3 rounds x 10 repetitions	70% 1RM	3 rounds x 10 repetitions (70% 1RM)	3 rounds x 10 repetitions (70% 1RM)
Seventh Week	4 rounds x 8 repetitions	75% 1RM	4 rounds x 8 repetitions (75% 1RM)	4 rounds x 8 repetitions (75% 1RM)
Eighth Week	4 rounds x 8 repetitions	80% 1RM	4 rounds x 8 repetitions (80% 1RM)	4 rounds x 8 repetitions (80% 1RM)
Ninth Week	Lack of practice	Lack of practice	Lack of practice	Lack of practice
Tenth Week	Lack of practice	Lack of practice	Lack of practice	Lack of practice
Eleventh Week	Lack of practice	Lack of practice	Lack of practice	Lack of practice
Twelfth Week	Lack of practice	Lack of practice	Lack of practice	Lack of practice

Between stations, a 1 to 2-minute rest was applied, during which participants engaged in light movements such as walking, bending, and opening their arms and legs. Additionally, between each round, an active rest period of 3 to 4 minutes was implemented, during which participants performed light jogging or brisk walking.

Table 2: Movements and Muscles Involved in Each Training Session has been created

Movements Performed (First to Eighth Training Session)	**Muscles Involved in Movement**
Chest Press	Pectoralis major, pectoralis minor, triceps brachii, anterior deltoid, anterior ulna, anterior inferior ulna, anterior deltoid
Leg Press	Internal wide, middle wide, right femur, external wide, large pelvis, biceps (high), semi-stringent, membranous
Long and Leaking	Flexors of the cervical vertebrae, sternum, rectus abdominis, suez sacrum, rectus femoris, shoulder
Armpit Stretch	Large chest, parallelogram, triceps (long head), posterior deltoid, large round, brachialis, small chest, long extensor
Back of Thigh	Semi-membranous, semi-stringent, biserrani, twin
Shoulder Press (From Behind)	Strengthening the muscles of the shoulder girdle and trapezius
Standing Leg with Device	Twins, insoles, soles of the feet
Forearm with Barbell EZ	Biceps brachii, anterior brachialis, ulnar arm, anterior deltoid, forearm

All data were expressed as mean ± standard deviation. First, the Shapiro-Wilk test was used to assess the normality of the data distribution, and Levene's test was applied to check for the equality of variances. In the next step, independent t-tests, analysis of variance (ANOVA) with repeated measures, and Bonferroni's post hoc test were used to test the research hypotheses. The significance level for all tests was set at $p < 0.05$. All statistical analyses were performed using SPSS version 21.

Results

Based on the research results, the mean age, height, and weight were 45.37 ± 5 years, 160.40 ± 5 cm, and 70.61 ± 10.26 kg, respectively.
Table 3 shows the characteristics of the left ventricle indices of the subjects in each group at three stages (pre-test, post-test, and detraining) in terms of mean, standard deviation, and percentage changes.

Table 3: Indicators for FS% and RWT in Experimental and Control Groups

Groups	FS% (M±SD)	RWT (M±SD)
Experimental (n=16)		
Before	33.66 ± 4.74	27.61 ± 2.56
After	38.29 ± 5.86	29.28 ± 2.45
Post-detraining	36.75 ± 4.97	27.73 ± 2.13
Percentage change (Before to After)	-13.75%	-6.04%
Percentage change (After to Post-detraining)	4.02%	5.29%
Control (n=16)		
Before	38.67 ± 7.62	29.21 ± 4.33
After	38.05 ± 7.40	28.21 ± 4.05

Post-detraining	38.24 ± 8.98	27.81 ± 4.17
Percentage change (Before to After)	1.60%	3.42%
Percentage change (After to Post-detraining)	0.50%	1.42%

The results showed that, given that the significance level (P-value) was higher than 0.05, the equality of variances, or homogeneity of variances—which is one of the assumptions for conducting parametric statistical tests—is accepted.

One-Way ANOVA Test to compare the mean of dependent variables in the pre-test stage

Table 4: Results of the One-Way ANOVA test comparing the pre-test means of the dependent variables (n=32)

Variable	Statistic	SS	df	MS	F	p-value
FS%	Between Groups	201.381	1	201.381	4.995	0.063
	Within Groups	1209.529	30	40.318		
	Total	1410.910	31			
RWT	Between Groups	20.408	1	20.408	1.612	0.214
	Within Groups	379.791	30	12.660		
	Total	1.280	31			

The results of Table 4 regarding the comparison of the pre-test means of the dependent variables in the two groups show that there is no significant difference in the measured variables between the two groups. This is because the significance level (P-value) is higher than 0.05, indicating that the groups are homogeneous at the pre-test stage. Therefore, parametric statistical tests can be used to test the hypotheses.

Table 5: Results of One-Way ANOVA with Repeated Measures on FS% Values

Variable	Group	Time	SS	df	MS	F	P	Effect Size
FS%	Exercise	Pre-Post Test	172.120	1	172.120	21.030	0.0001*	0.584
		Post Test-End of Detraining	18.980	1	18.980	12.834	0.003*	0.461
	Control	Pre-Post Test	3.060	1	3.060	5.000	0.041*	0.250
		Post Test-End of Detraining	0.273	1	0.273	5.069	0.797	0.005

- Significant difference at the level of P<0.05.

The results of Table 5 show that, based on the significance level of α = 0.05, there is a significant difference in FS% values from pre-test to post-test between the experimental and control groups (P<0.05). Additionally, a significant difference was observed in the training group from post-test to the end of the detraining period (P<0.05). Therefore, the percentage of left ventricular muscle fiber shortening significantly increased from pre-test to post-test and significantly decreased from post-test to the end of the detraining period.

Table 6: Results of One-Way ANOVA with Repeated Measures on FS% from Pre-Test to End of Detraining (Three Measurements)

Variable	Group	SS	df	MS	F	P	Effect Size
FS%	Exercise	178.592	2	89.296	20.015	0.0001*	0.572
	Control	3.226	2	1.613	0.629	0.540	0.040

- Significant difference at the level of P<0.05.

The results of Table 6 show that, based on the significance level of α = 0.05, there is a significant difference in FS% values from the pre-test to the end of the detraining period (three measurement stages) in the exercise group (P<0.05). Therefore, Bonferroni's post-hoc test was used to determine the location of these within-group differences, and the results are shown in Table 7.

Table 7: Results of Bonferroni Post-Hoc Test Between FS% Values

Variable	Group	Time	Pre-Test	Post-Test	Detraining
FS%	Exercise	Pre-Test	---	MD= -4.638	MD= -3.098
				P= 0.001*	P= 0.001*
	Exercise	Post-Test	---	---	MD= 1.540
					P= 0.008*
FS%	Control	Pre-Test	---	MD= 0.619	MD= 0.434
				P= 0.111	P= 1.000
	Control	Post-Test	---	---	MD= -0.185
					P= 1.000

- Significant difference at the level of P<0.05.

The results of Table 7 show that in the exercise group, the FS% values from the pre-test to the post-test, and from the post-test to the detraining period, show a significant difference (P<0.05). To examine the between-group differences in FS% values between the experimental and control groups, an independent t-test was used on the gain score (the difference between pre-test and post-test means) in the groups. The results are presented in Table 8.

Table 8: Results of Independent t-test Showing Differences in FS% Between Groups

Variable	Time	Group	Difference (M ± SD)	T	df	P
FS%	Pre-Test - Post-Test	Exercise	-4.78 ± 4.04	-5.11	20	**0.001*
		Control	0.71 ± 3.71			
FS%	Post-Test - Detraining	Exercise	-1.18 ± 1.96	1.91	20	*0.045*
		Control	1.81 ± 2.16			

The results of Table 8, based on the comparison of FS% values between the two groups, indicate that there is a significant difference in FS% between the experimental and control groups, based on the difference between the pre-test and post-test values ($P<0.05$). Moreover, the results of Table 8 show that FS% values between the experimental and control groups, based on the difference between the post-test and detraining period, also show a significant difference ($P<0.05$).

Based on the interpretations of the inferential tests for the ninth hypothesis, the null hypothesis, stating that eight weeks of progressive resistance training has no significant effect on the percentage of left ventricular muscle fiber shortening (FS%) in inactive women, is rejected. The research hypothesis indicates that the effect of eight weeks of progressive resistance training on the percentage of left ventricular muscle fiber shortening (FS%) in inactive women is significant. Therefore, eight weeks of progressive resistance training increases the percentage of left ventricular muscle fiber shortening (FS%) in inactive women.

Furthermore, based on the interpretations of the inferential tests for the tenth hypothesis, the null hypothesis, stating that four weeks of detraining after eight weeks of progressive resistance training has no significant effect on the percentage of left ventricular muscle fiber shortening (FS%) in inactive women, is rejected. The research hypothesis indicates that the effect of eight weeks of progressive resistance training on the percentage of left ventricular muscle fiber shortening (FS%) in inactive women is significant. Therefore, four weeks of detraining can reduce the positive effects of progressive resistance training on the percentage of left ventricular muscle fiber shortening (FS%).

Table 9: Results of One-Way Repeated Measures ANOVA on RWT Values

Variable	Group	Time	SS	df	MS	F	P
RWT	Exercise	Pre-Test - Post-Test	17.947	1	17.947	39.219	0.001*
		Post-Test - Detraining	19.190	1	19.190	37.787	0.001*
RWT	Control	Pre-Test - Post-Test	8.809	1	8.809	1.559	0.227
		Post-Test - Detraining	9.950	1	9.950	0.590	0.719

- Significant difference at the level of P<0.05.

The results of Table 9 show that, based on the significance level of α = 0.05, there is a significant difference in RWT values from the pre-test to the post-test between the experimental and control groups (P<0.05). Additionally, a significant difference was observed in the training group from the post-test to the end of the detraining period (P<0.05). Therefore, the relative wall thickness (RWT) of the left ventricle significantly increased from pre-test to post-test and significantly decreased from post-test to the end of the detraining period.

Table 10: Results of One-Way Repeated Measures ANOVA on RWT Values from Pre-Test to End of Detraining (Three Measurements)

Variable	Group	SS	df	MS	F	P
RWT	Exercise	17.559	2	8.779	19.619	0.001*
	Control	1.059	2	0.529	0.909	0.490

The results of Table 10 show that, based on the significance level of α = 0.05, there is a significant difference in RWT values from the pre-test to the end of the detraining period (three measurement stages) in the exercise and experimental groups (P<0.05). Therefore, Bonferroni's post-hoc test was used to determine the location of these within-group differences, and the results are presented in Table 11.

Table 11: Results of Bonferroni Post-Hoc Test Between RWT Values

Variable	Group	Time	Pre-Test	Post-Test	Detraining
RWT	Exercise	Pre-Test	---	MD= -1.873	---
				P= 0.003*	
	Exercise	Post-Test	MD= -1.612	---	MD= -1.557
			P= 0.001*		P= 0.007*
RWT	Control	Pre-Test	---	MD= 1.107	---
				P= 1.000	
	Control	Post-Test	MD= 0.935	---	MD= 0.593
			P= 0.007*		P= 0.507

The results of Table 11 show that in the exercise group, there is a significant difference in RWT values between the pre-test and post-test, and between the post-test and the detraining period (P<0.05). Additionally, in the control group, there is a significant difference in RWT values between the pre-test and post-test, as well as between the post-test and the detraining period (P<0.05).

To examine the between-group differences in RWT values between the experimental and control groups, an independent t-test was used on the gain score (the difference between pre-test and post-test means) in the groups. The results are presented in Table 12.

Table 12: Results of Independent t-test Showing Differences in RWT Between Groups

Variable	Time	Group	Difference (M ± SD)	T	df	P
RWT	Pre-Test - Post-Test	Exercise	-1.76 ± 1.65	-5.395	20	**0.001*
		Control	-0.12 ± 0.09			
RWT	Post-Test - Detraining	Exercise	1.55 ± 0.98	2.169	20	*0.049*
		Control	1.15 ± 1.01			

The results of Table 12, based on the comparison of RWT values between the two groups, indicate that there is a significant difference in RWT values between the experimental and control groups based on the difference between the pre-test and post-test values ($P<0.05$). Moreover, the results of Table 12 show that there is a significant difference in RWT values between the experimental and control groups based on the difference between the post-test and the detraining period ($P<0.05$).

Based on the interpretations of inferential tests for the eleventh hypothesis, the null hypothesis, stating that eight weeks of progressive resistance training has no significant effect on the relative wall thickness (RWT) of the left ventricle in inactive women, is rejected. The research hypothesis indicates that the effect of eight weeks of progressive resistance training on the relative wall thickness (RWT) of the left ventricle in inactive women is significant. Therefore, eight weeks of progressive resistance training increases the relative wall thickness (RWT) of the left ventricle in inactive women.

Furthermore, based on the interpretations of inferential tests for the twelfth hypothesis, the null hypothesis, stating that four weeks of detraining after eight weeks of progressive resistance training has no significant effect on the relative wall thickness (RWT) of the left ventricle in inactive women, is rejected. The research hypothesis indicates that the effect of eight weeks of progressive resistance training on the relative wall thickness (RWT) of the left ventricle in inactive women is significant. Therefore, four weeks of detraining can reduce the positive effects of progressive resistance training on the relative wall thickness (RWT) of the left ventricle.

Discussion

The aim of the present study was to investigate the effect of 8 weeks of progressive resistance training and a period of detraining thereafter on the left ventricular indices FS% and RWT in inactive women. In this semi-experimental field-laboratory study, 32 inactive women who were able to regularly participate in the training protocol were selected by simple random sampling and randomly assigned to two groups: 1- Resistance training group (16 people), 2- Control group (16 people). In the present study, before the implementation of the training program, all anthropometric characteristics, body composition, and structural and functional indices of the left ventricle of the subjects were measured and recorded in three stages under the same conditions.

The structural and functional variables of the heart, including the percentage of left ventricular muscle fiber shortening (FS%) and relative wall thickness (RWT) of the left ventricle, were measured by a cardiologist using an echocardiography device by the M-Mode, Spectral Doppler, (2-D) Color Doppler methods in a dedicated echocardiography room at three stages (before training, after the 8-week resistance training program, and after 4 weeks of detraining). Before the echocardiography, height and weight variables were measured with a laboratory scale equipped with a stadiometer. All training programs included 3 training days per week, with each session lasting 90 minutes, conducted in the gymnasium of Islamic Azad University, Yazd Branch. The program was implemented for 8 weeks, progressing from low to high intensity, considering the principle of overload. In the next stage, statistical tests such as Shapiro-Wilk, Levene's test, independent T-tests, one-way ANOVA, and repeated measures ANOVA were used to test the research hypotheses. The significance level for all calculations was set at $p<0.05$, and all calculations were performed using SPSS version 22. The results showed that there was a significant difference in FS% values from pre-test to post-test between the experimental and control groups ($p<0.05$). Additionally, a significant difference was observed in the training group from post-test to the end of the detraining period ($p<0.05$).

The results also showed a significant difference in RWT values from pre-test to post-test between the experimental and control groups ($p<0.05$). Moreover, a significant difference was observed in the training group from post-test to the end of the detraining period ($p<0.05$).

A detraining period after eight weeks of progressive resistance training had no significant effect on the percentage of left ventricular muscle fiber shortening (FS%) in inactive women.

The results of this hypothesis showed a significant difference in FS% values from pre-test to post-test between the experimental and control groups ($p<0.05$). Additionally, a significant difference was observed in the training group from post-test to the end of the detraining period ($p<0.05$).

As the results showed, the mean FS% of the left ventricular muscle fibers in the experimental group in the pre-test stage was 33.66 ± 4.74, in the post-test stage it was 38.29 ± 5.86, and in the detraining stage it was 36.75 ± 4.97. In the control group, the mean FS% of the left ventricular muscle fibers in the pre-test stage was 38.67 ± 7.62, in the post-test stage it was 38.05 ± 7.40, and in the detraining stage it was 38.24 ± 8.98. This result indicates that 8 weeks of progressive resistance training was associated with an increase in FS%. Additionally, 4 weeks of detraining thereafter had a positive effect in maintaining the adaptations gained during the training period. Therefore, the percentage of left ventricular muscle fiber shortening significantly increased from pre-test to post-test and significantly decreased from post-test to the end of the detraining period.

Based on the interpretations of inferential tests, the effect of eight weeks of progressive resistance training on the percentage of left ventricular muscle fiber shortening (FS%) in inactive women was significant. Therefore, eight weeks of progressive resistance training increases the percentage of left ventricular muscle fiber shortening (FS%) in inactive women.

Furthermore, based on the interpretations of inferential tests for the tenth hypothesis, the null hypothesis, stating that four weeks of detraining after eight weeks of progressive resistance training has no significant effect on the percentage of left ventricular muscle fiber shortening (FS%) in inactive women, is rejected. The research hypothesis indicates that the effect of eight weeks of progressive resistance training on the percentage of left ventricular muscle fiber shortening (FS%) in inactive women is significant. Therefore, four weeks of detraining can reduce the positive effects of progressive resistance training on the percentage of left ventricular muscle fiber shortening (FS%).

The results of this section of the study are in line with the findings of Fleck (2003). Given the increase in end-diastolic volume, the percentage of left ventricular muscle fiber shortening also increases proportionally.

A detraining period after eight weeks of progressive resistance training had no significant effect on the relative wall thickness (RWT) of the left ventricle in inactive women.

The results of this hypothesis showed a significant difference in RWT values from pre-test to post-test between the experimental and control groups ($p<0.05$). Additionally, a significant difference was observed in the training group from post-test to the end of the detraining period ($p<0.05$).

As the results showed, the mean relative wall thickness (RWT) of the left ventricle in the experimental group in the pre-test stage was 27.61 ± 2.56, in the post-test stage it was 29.28 ± 2.45, and in the detraining stage it was 27.73 ± 2.13. In the control group, the mean RWT in the pre-test stage was 29.21 ± 4.33, in the post-test stage it was 28.21 ± 4.05, and in the detraining stage it was 27.81 ± 4.17. This result indicates that 8 weeks of progressive resistance training was associated with an increase in RWT. Additionally, 4 weeks of detraining thereafter had a positive effect in maintaining the adaptations gained during the training period. Therefore, the relative wall thickness of the left ventricle significantly increased from pre-test to post-test and significantly decreased from post-test to the end of the detraining period.

Based on the interpretations of inferential tests, eight weeks of progressive resistance training had a significant effect on the relative wall thickness (RWT) of the left ventricle in inactive women. Therefore, eight weeks of progressive resistance training increases the relative wall thickness (RWT) of the left ventricle in inactive women.

Furthermore, based on the interpretations of inferential tests for the twelfth hypothesis, the null hypothesis, stating that four weeks of detraining after eight weeks of progressive resistance training has no significant effect on the relative wall thickness (RWT) of the left ventricle in inactive women, is rejected. The research hypothesis indicates that the effect of eight weeks of progressive resistance training on the relative wall thickness (RWT) of the left ventricle in inactive women is significant. Therefore, four weeks of detraining can reduce the positive effects of progressive resistance training on the relative wall thickness (RWT).

The results of this section of the study are in line with the findings of Vasiliauskas et al. (2006) and Barauna et al. (2007). Adaptation to resistance training increases end-diastolic blood volume, which forces the heart wall to increase its resistance, leading to an increase in the relative wall thickness of the left ventricle.

Conclusion

Based on these findings, it can be concluded that 8 weeks of resistance training led to beneficial changes in the structure and function of the heart in sedentary women. However, the 4-week detraining period resulted in negative effects on these adaptations. Therefore, it is recommended that individuals engage in regular and structured resistance training to maintain these positive adaptations.

Conflict of interest

The authors declare that there is no conflict of interest.

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