

The Effect of a Short-Term Circuit Resistance Training on Blood Glucose, Plasma Lipoprotein and Lipid Profiles in Young Female Students

Seyed Morteza Tayebi,^{1*} Shirin Mottaghi,² Seyed Aliakbar Mahmoudi,³ and Abbas Ghanbari-Niaki⁴

¹Faculty of Sport Sciences, Exercise Physiology Division, Allameh Tabataba'i University, Tehran, IR Iran

²Department of Sport Sciences, Science and Research Branch, Islamic Azad University, Rasht, IR Iran

³Faculty of Medicine, Department of Sports Medicine, Mazandaran University of Medical Science, Sari, IR Iran

⁴Faculty of Sport Sciences, Exercise Biochemistry Division, University of Mazandaran, Babolsar, IR Iran

*Corresponding author: Seyed Morteza Tayebi, Faculty of Sport Sciences, Exercise Physiology Division, Allameh Tabataba'i University, P. O. Box: 1485743411, Tehran, IR Iran. Tel: 98-2144118627, Fax: 98-2144118629, E-mail: tayebism@gmail.com

Received 2015 October 18; Revised 2016 April 11; Accepted 2016 June 06.

Abstract

Background: According to observations on the effect of exercise training on lipid profile, there is little evidence about the effect of short-term circuit resistance training in females because these researches often use aerobic methods in males.

Objectives: The current study aimed to examine the effect of a short term course of circuit resistance training on blood glucose and serum lipids in female students.

Methods: Twenty female students from the physical education in the luteal phase of their menstrual cycle were randomly selected and divided into two groups of 10 (resistance training and control groups). For seven consecutive days, the experimental group conducted a circuit resistance training including 10 exercises with the intensity of 60% of one maximum repetition and duration of 20 seconds for each exercise in four sets. Each session took 32 - 40 minutes including warm-up and cool-down time. To measure fasting blood glucose, three glyceride (TG), total cholesterol (TC), high density lipoprotein cholesterol (HDL-c), very low density lipoprotein cholesterol (VLDL-c) and low density lipoprotein cholesterol (LDL-c), blood samples were taken 24 hours before the first session and after the seventh session in a 12-hour overnight fasting.

Results: Analysis of variance for repeated measures revealed that although seven sessions of circuit resistance training with a moderate intensity had no significant effects on plasma HDL-c, VLDL-c, TC, and TG in the female students, a significant reduction was observed in the fasting blood glucose and plasma LDL-c.

Conclusions: Resistance training exercises in the present method can be considered as a prophylaxis attempt against related diseases by improving cardiovascular and metabolic health.

Keywords: Resistance Training, Circuit Training, Glucose, Low Density Lipoprotein Cholesterol

1. Background

According to anticipations, cardiovascular diseases, especially heart coronary disease and atherosclerosis, are the most common diseases in human societies (1). In the modern industrialized world, these lethal risks are results of inappropriate diet and physical inactivity (1).

Studying the factors that affect the development of cardiovascular diseases such as high blood pressure, increased low-density cholesterol lipoprotein, age, gender, smoking, glucose tolerance, elevated levels of some risk factors including fibrinogen, homocysteine, blood viscosity and changes in hemodynamic features, diabetes and physical inactivity play roles in its development and result in sudden deaths. On the other hand, research reports in-

dicating that improvements in cardiovascular health indices such as high density lipoprotein (HDL), apolipoprotein (A-I) and lipoprotein lipase activity have a direct relationship with preventing cardiovascular diseases (2, 3).

The effect of exercise on the reduction of cardiovascular risk factors and increasing the above mentioned variables is also of general consensus. However, the effect of exercise on these indices depends on duration, intensity and type of physical activity (2-5).

Given the varied physical activities (aerobic, resistance and combined), different patterns and subjects are studied the effect of exercise on lipid profile. Previous studies emphasized that aerobic training leads to reduced blood pressure (6, 7) and serum triglyceride (TG), increased high-density lipoprotein (HDL), increased insulin sensitiv-

ity and glucose homeostasis (8). Regarding its relationship with heart attack, on the other hand, adjusting blood lipid level is considered as an important health factor (9). Studies show that the appropriate level of training reduces intra muscle triglyceride and stimulates lipoprotein lipase. Increased lipoprotein lipase activity leads to higher blood TG use which in turn reduces the risk of cardiovascular diseases (10). A study on the effect of pyramid exercises on some blood lipid factors in young males without exercise background showed no significant changes in plasma high-density lipoprotein and triglycerides while low-density lipoprotein and total cholesterol significantly decreased (4). However, there are few studies on resistance trainings, often reporting conflicting results. In a study examining the effect of mere weightlifting exercises and Ramadan fasting on lipid profile, glucose and plasma lipoprotein, it was found that a month of weightlifting exercises had no significant effects on these variables (5). As a model of physical activity, resistance trainings are used to prevent and treat diseases such as osteoporosis and postural disorders. Compared to aerobic activities, resistance trainings seem to have insignificant effects on lipid profile due to not increasingly affecting the heart beating and metabolism. Research on the impact of resistance trainings on cardiovascular risk factors indicated that they decrease low-density lipoprotein (LDL) and increase HDL (11). In contrast, another study showed that resistance trainings do not improve the lipid profile and HDL levels in people prone to cardiovascular diseases (12).

On the other hand, circuit trainings have received attention because of generating a mood similar to aerobic exercises. Ghanbari-Niaki et al., studied the effect of a session of circuit resistance exercise on lipid profile and serum lipoprotein in male students and reported a significant effect of HDL-c, but not other variables (13).

However, due to some religious beliefs, Iranian females have fewer opportunities of active lifestyle thus facing the risk of cardiovascular diseases despite a healthy physical status (14). Accordingly, cardiovascular diseases account for a third of females' deaths (15).

2. Objectives

Given the limited studies on the effect of short term resistance trainings on some factors such as blood fat and plasma lipoproteins, inconsistent results of the mentioned studies and studies on females for specific reasons, authors attempted to answer these questions: Are plasma HDL, LDL and very low density lipoprotein (VLDL) such as lipoprotein indices affected by short term resistance trainings? Are plasma total cholesterol (TC), TG and fasting blood sugar (FBS) such as lipid profile and blood glucose

indices affected by short term resistance trainings? The results of the study can help a better understanding of a proper exercise training style to improve cardiovascular and metabolic conditions.

3. Methods

The research method was quasi-experimental with pre and post- test design, experimental and control groups. The study was approved by the research ethics committee of the Iranian sport sciences research institute, and conducted in accordance with the policy statement of the declaration of the Iranian ministry of health.

3.1. Variables and Information Collecting Method

Twenty female students volunteered through public call from the physical education field of the Shomal University. Inclusion and exclusion criteria of the study consisted of luteal phase of their menstrual cycle, not consuming caffeine, alcohol, cigarettes, tobacco and antioxidant supplements, no history of diseases affecting hematologic factors and use of anti-inflammatory drugs. The subjects had to have at least a 2-months background without resistance trainings. Three persons were excluded because of menstrual bleeding. Participants were selected in simple random sampling strategy and divided into two resistance training (n = 9) and control (n = 8) groups.

3.2. Training Protocol

Two weeks before the experiment, all subjects were taken to the training location in three non-continuous sessions to determine one repetition maximum (1RM) records and information on the experiment method. After the last session, subjects underwent a week of bed rest such that they were absent in their practical classes. Then, the main training sessions started (Figure 1).

3.3. Blood Sampling

24 hours before the first session and 24 hours after the seventh session, blood samples were collected by Venject needles from subjects' brachial veins while sitting in the laboratory and stored in vacuum bottles containing anti-coagulant substance. Furthermore, for coordinating pre-training nutritional conditions and its potential impact on the variables, the subjects were asked to overnight fast for at least 12 hours. All tests including fasting blood glucose, plasma triglyceride, and total cholesterol and plasma HDL-c measurements were performed using Iranian kits purchased from the MAN company according to the methods including glucose oxidase method; enzymatic method of

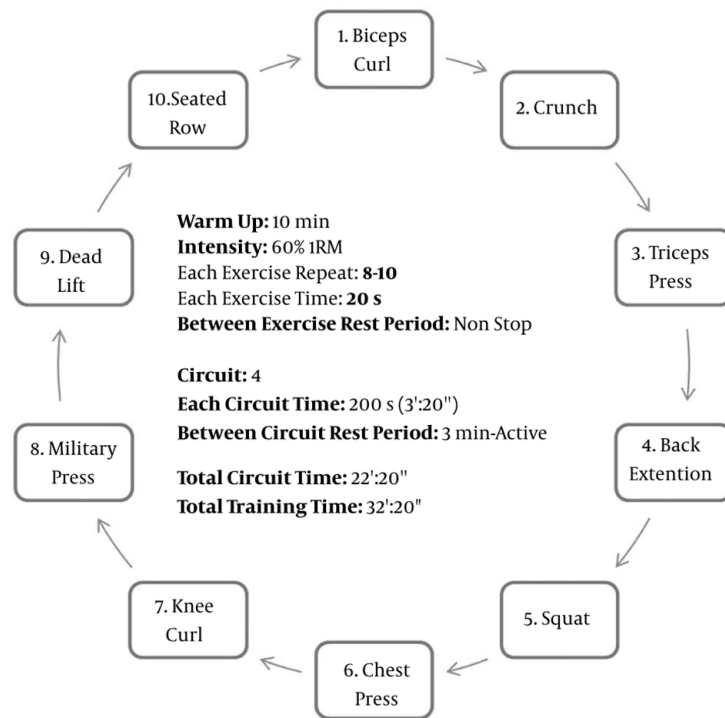


Figure 1. Exercise Protocol of Each Session

lipoprotein lipase-glycerol kinase reaction and the enzymatic method of cholesterol esterase-cholesterol oxidase reaction and deposition method of phosphorus Tangsitic-magnesium chloride ($MgCl_2$). In addition, Friedewald et al. (16) equation was used to compute plasma LDL-c.

$$LDL-c = TC - (HDL-c + TG/5)$$

Based on the hemoglobin and hematocrit, blood plasma volume (PV) was calculated using the Dill and Costill (17) equation.

$$\text{Blood Volume}_{\text{before}} (BVb) = 100 \text{ mL}$$

$$\text{Blood Volume}_{\text{after}} (BVa) = BVb \times [\text{Hemoglobin}_{\text{before}} (\text{HGBb}) / \text{Hemoglobin}_{\text{after}} (\text{HGBa})]$$

$$\text{Red Cell Volume}_{\text{before}} (\text{RCVb}) = \text{Hematocrit}_{\text{before}} (\text{HCTb})$$

$$\text{RCVa} = BVa \times \text{HCTa}$$

$$\text{Plasma Volume}_{\text{before}} (\text{PVb}) = [1 - (\text{HCTb}/100) \times 100]$$

$$\text{PVa} = BVa - \text{RCVa}$$

3.4. Statistical Analysis

In order to use the appropriate parametric tests, the following were first verified: the assumptions of normality of data distribution, sphericity and equality of error variances by using one sample Kolmogorov-Smirnov test, Mauchly's and Levene's tests. ANOVA was used to determine the within group effects [(the effect of each dependent variable) and their interactive effect with the independent

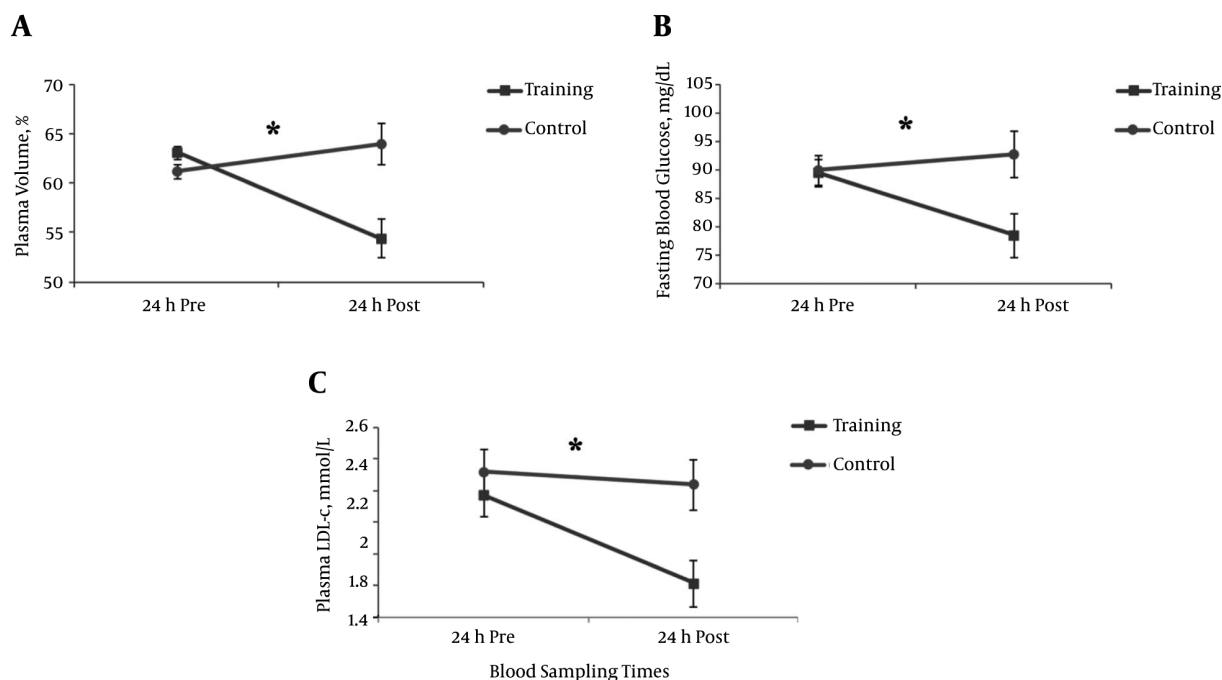
variable (the dependent variable \times Group)] and the between group effects (comparison between the two experimental and control groups). All data were processed using SPSS software. Data were expressed as mean \pm standard error of the mean. The significance level was set at $P \leq 0.05$.

4. Results

General findings of the subjects are summarized in Table 1.

For plasma volume, the effect of time ($F = 5.77, P = 0.03$), group effect ($F = 4.856, P = 0.044$) and interactive effect of time \times group ($F = 21.369, P = 0.001$) were significant (Figure 2A). In other words, given the significant reduction and insignificant change in training and control groups, respectively (the interactive effect of time \times group), PV was significantly reduced in short term adaption to 7 sessions of circuit resistance training.

For plasma glucose, the time effect ($F = 1.694, P = 0.213$) was insignificant but the group ($F = 4.532, P = 0.05$) and interactive effects of time \times group ($F = 21.369, P = 0.001$) were significant as shown in Figure 2B. In other words, given the significant reduction and insignificant increases in training and control groups, respectively (the interactive effect

Figure 2. Effect of 7 Consecutive Day of Circuit Resistance Training in Young Female College Student

LDL-c, low density lipoprotein-cholesterol. 24h Pre, 24 hours before beginning of Training; 24h Post, 24 hours after ending 7 sessions training; *, significant interaction effect of Group \times Time at $P < 0.05$ (significant reduction in Training group with insignificant change in Control group).

of time \times group), fasting blood glucose was significantly changed in short term adaption to 7 sessions of circuit resistance training.

For HDL-c, the effects of time ($F = 0.067$, $P = 0.799$), group ($F = 1.23$, $P = 0.285$) and time \times group ($F = 4.762$, $P = 0.045$) were insignificant as shown in Table 2. In other words, a short term of circuit resistance training had no significant effect on plasma HDL-c in female students.

For plasma LDL-c, the effects of time ($F = 11.644$, $P = 0.004$) and time \times group ($F = 6.68$, $P = 0.021$) were significant but the group effect ($F = 0.013$, $P = 0.909$) was insignificant (Figure 2C). In other words, given the significant reduction and insignificant change in training and control groups, respectively (the interactive effect of time \times group), plasma LDL-c significantly reduced in short term adaption to 7 sessions of circuit resistance training.

For plasma VLDL-c, the effect of time ($F = 1.107$, $P = 0.309$), group ($F = 0.188$, $P = 0.671$) and time \times group ($F = 0.633$, $P = 0.439$) were insignificant as shown in Table 2. In other words, 7 sessions of circuit resistance training had no significant effect on plasma VLDL-c in female students.

For plasma TC, the effect of time ($F = 0.86$, $P = 0.774$), group ($F = 0.125$, $P = 2.637$) and time \times group ($F = 2.11$, $P = 0.167$) were insignificant as shown in Table 2. In other words, 7 sessions of circuit resistance training had no significant effect on plasma TC in female students.

For plasma TG, the effect of time ($F = 0.672$, $P = 0.425$), group ($F = 0.934$, $P = 0.349$) and time \times group ($F = 0.003$, $P = 0.958$) were insignificant as shown in Table 2. In other words, 7 sessions of circuit resistance training had no significant effect on plasma TG in female students

Table 1. Morphological Characteristic of Participants

	Variables	Groups	Mean \pm SE
1	Weight, kg	Training	57.11 \pm 2.57
		Control	59.87 \pm 3.18
2	Height, cm	Training	163.66 \pm 1.87
		Control	163.62 \pm 2.14
3	BMI, kg/m ²	Training	21.26 \pm 0.68
		Control	22.26 \pm 0.82
4	HRrest, bit/min	Training	75.33 \pm 1.45
		Control	76.50 \pm 1.50

Abbreviations: BMI, body mass index; HRrest, resting heart rate.

Table 2. Effect of 7 Consecutive Day of Circuit Resistance Training in Young Female College Student

Variables	Groups	Mean \pm SE		Within Groups Effect ^a		Between Groups Effects ^b
		24 h Pre	24 h Post	Time (F)	Time \times Group (F)	Group (F)
HDL-c, mmol/L	Training	1.183 \pm 0.10	1.177 \pm 0.06	0.003	0.001	4.312
	Control	1.408 \pm 0.11	1.406 \pm 0.7			
VLDL-c, Mg/dL	Training	12.667 \pm 1.31	15.27 \pm 2.74	1.107	0.633	0.188
	Control	15.00 \pm 1.39	15.36 \pm 2.9			
TC, mmol/L	Training	3.69 \pm 0.19	3.32 \pm 0.21	0.86	2.11	2.637
	Control	3.71 \pm 0.2	3.95 \pm 0.22			
TG, mmol/L	Training	0.72 \pm 0.07	0.78 \pm 0.12	0.672	0.003	0.934
	Control	0.85 \pm 0.08	0.89 \pm 0.13			

Abbreviations: HDL-c, high density lipoprotein-cholesterol; VLDL-c, very low density lipoprotein-cholesterol; TC, total cholesterol; TG, Triglycerides.

^aThere is no significant within groups effect in the variables.

^bThere is no significant between groups effects in the variables.

5. Discussion

The present study showed that seven consecutive sessions of circuit resistance training did not significantly change HDL-c, VLDL-c, TC, and TG in female students but LDL-c plasma was significantly reduced in the experimental group. Zanetti et al. (2016) reported the nonlinear resistance training group had reduced the levels of TC, LDL-c, and TG, and the HDL-c level increased (18); But their study period was 12 weeks in people living with HIV. Ribeiro et al. (2016) after 8 weeks resistance training (traditional and pyramidal systems), a significant improvements were observed for TG, HDL-C, and LDL-C of older women in both systems (19) but the present research was conducted in 7 training sessions in young female student. In other study by Ribeiro et al. (2015) found that after 8 weeks resistance training in older women with differing levels of resistance training experience (novice and advanced) the TG, HDL-c, and LDL-c had a significant improvement in both group (20). Correa et al. (2014) reported no differences in lipid profile of TC, TG, HDL-c and LDL-c between higher and lower volumes of resistance training (21); their trial was one session. In examining the effect of leucine supplementation and resistance training (a type of scot) in three non-consecutive days on lipid profile, Nicastro et al. (2012) reported that resistance training only led in significantly increased HDL-c and had no significant effect on TC, TG, LDL-c dyslipidemia and VLDL-c in dyslipidemic rats by dexamethasone (22).

Tayebi et al. (2010) investigated the effect of weightlifting training and Ramadan fasting on lipid profile, glucose and plasma lipoproteins, and observed that a month of weightlifting training had no significant effect on these variables (5). In examining the effects of circuit resistance

training (in three sets and only one session) in the present research method, Ghanbari-Niaki et al. (2007) reported a significant reduction in plasma LDL-c and VLDL-c in the recovery period (25 minutes after the training) and considered it independent of changes in plasma volume (23). The present study is also consistent with the latter one because seven consecutive sessions of circuit resistance training resulted in significant decreased plasma volume, which in turn should increase the LDL-c due to increased concentration in a certain unit of volume with a reduction in plasma volume. According to Ghanbari-Niaki et al. (2011), a significant increase in plasma TG and glucose was reported after a session of resistance training with intensities of 40%, 60%, and 80% but found that changes in HDL-c, LDL-c and TC were not significant (24).

On the other hand, Wagganer et al. (2015) reported that changes in blood lipids may result from cumulative effects over time than one training session because they found that three sessions of training led to higher increased HDL-c and reduced TG than one session, while LDL-c was repressed in one session (25). Mestek et al. (2006) also concluded that compared with a long session with the same amount of energy used, three consecutive short sessions had higher effects on transient increases of HDL-c (26). In this regard Ghanbari-Niaki et al. (2013) examined the effect of a month of pyramid trainings in young men without exercise on blood lipid factors and reported no significant changes in plasma HDL-c and TG while LDL-c and TC were significantly decreased (4).

The most common lipid abnormalities are elevated TG and reduced HDL-c, which the latter parameter is considered as a risk factor for cardiovascular disease. Despite, as an atherogenic factor, serum LDL-c particles increase with

increased triglyceride.

According to researches, there is no clear effect of the volume of exercise on lipoproteins. It has also been shown that relatively high volume of regular exercise can substantially improve overall lipoprotein profile (27). The investigations showed that triglyceride levels are inversely associated with HDL-c levels. An overall view of the research on the effect of aerobic training on lipid profile shows that according to some researchers, exercise trainings rarely affect the levels of TC and LDL-c, unless they are accompanied by diet and weight loss (28). Examining the survey results shows no significant reduction in total cholesterol. Fat tissues have autonomic nerves and numerous capillaries. Therefore, all of their metabolic actions are mainly controlled by thyroidal, sexual and neural hormones and many of them are by physical activity. This could be one reason for unchanged cholesterol levels (28). In the present study, insignificant reduction in triglyceride level can be attributed to the lipoprotein lipase (LPL) response to exercise. LPL is an enzyme serving as the regulator of the lipoproteins and triglyceride breakdown in triglyceride-rich lipoproteins. However, studies have shown reduced and inhibited hepatic lipase (HL) enzyme as the result of regular exercise. Therefore, triglyceride making in LDL-c is reduced. It seems that longer training leads to decreased triglycerides (28). In the present study, HDL-c levels were not significantly different between among the groups. The researchers believed that HDL-c and LDL-c are hardly affected by training. The intensity and duration of training is not been enough to significantly change HDL-c in this study. The researchers showed that the change mechanism of HDL-c after training is complex. Enzymes such as LPL, HL and cholesterol ester transfer proteins (CETP) play a major role in changing HDL-c concentration. Through hydrolysis of plasma triglyceride, LPL is the most important factor in changed HDL-c concentrations. However, increased LPL activity is not responsible for increasing HDL-c immediately after training. HDL-c concentration increasing immediately after training may be related to lower levels of CETP activity. Responsible for lipid transporting in HDL-c molecule and other lipoproteins, CETP is decreased after training. Decreased CETP is a reason for slowing the HDL-c catabolism (increased half-life) and eventually increasing HDL-c concentration (28). In our study, LDL-c level was significantly reduced in the experimental group than in the control group. In terms of mechanisms involved in LDL-c reduction, it can be said that the lipid profile is greatly affected in persons with higher baseline level of TG or LDL-C or lower HDL-c. In the present study, the initial levels of their HDL-c, VLDL-c, TG and TC were within the normal range. This is probably the reason of insignificant changes in lipid indices (29). There seems

to be a positive correlation between weight loss and exercise in lipid changes. In line with other studies, our study suggests that it may be necessary to further change body weight and fat percentage to observe significant effects on lipid profile after resistance training (29). In general, the results of this study suggested that circuit resistance training reduces plasma LDL-c, improves cardiovascular health and may possibly reduce related diseases.

The present study showed the significant reduction in blood glucose after 7 sessions of resistance training with moderate intensity. Resistance trainings are recommended as effective tools in the prevention and treatment of metabolic diseases (30). This is based on evidence suggesting that resistance trainings improve muscle mass and increases GLUT-4, protein kinase B and glycogen synthase (31). Ribeiro et al. (2016) observed a significant improvements for glucose of older women after 8 weeks resistance training in both traditional and pyramidal systems (19). Ribeiro et al. (2015) found that the glucose had a significant improvement after 8 weeks resistance training in older women with differing levels of resistance training experience (novice and advanced) (20). In a pilot research, Tibana et al. (2011) found that plasma glucose, triglyceride and HDL-c levels in obese/overweight women were not significantly changed after 8 weeks (24 sessions, 3 sessions per week) (each exercise 3 rounds and each round 8-12 iterations) (30). However, after 7 weeks of high-intensity-resistance-focused training, Russell et al. (2014) reported that the fasting glucose levels were reduced in people with a family history of diabetes and the matched control group (32).

In a meta-analysis, Cornelissen et al. (2011) found that dynamic resistance training (more than 4 weeks) in healthy adults (over 18 years) had no significant effect on TC, HDL-c, LDL-c and fasting blood glucose and significantly decreased plasma triglyceride (33). In a meta-analysis by Kelly and Kelly (2009), it was reported that progressive resistance training (more than 4 weeks) in men and older women (over 18 years) significantly improved TC, TC:HDL-c, and LDL-c with no effects on HDL-c (34).

5.1. Conclusion

In general, the results of this study indicate that moderate-intensity circuit resistance training for 7 consecutive sessions - lasting at least half an hour each - can reduce plasma LDL-c and fasting blood glucose, which are probably associated with improved cardiovascular/ metabolic health and reduced diseases. In this regard, using short-term circuit resistance training is recommended to enhance cardiovascular and metabolic health in girls.

Footnotes

Authors' Contribution: Study concept and design, Seyed Morteza Tayebi and Abbas Ghanbari-Niaki; acquisition of data, Shirin Mottaghi and Seyed Aliakbar Mahmoudi; analysis and interpretation of data, Seyed Morteza Tayebi and Abbas Ghanbari-Niaki; drafting of the manuscript, Seyed Morteza Tayebi and Abbas Ghanbari-Niaki and Shirin Mottaghi; critical revision of the manuscript for important intellectual content, Abbas Ghanbari-Niaki; statistical analysis, Seyed Morteza Tayebi and Seyed Aliakbar Mahmoudi; administrative, technical, and material support, Seyed Morteza Tayebi and Shirin Mottaghi; study supervision Seyed Morteza Tayebi.

Financial Disclosure: Authors have no relevant financial interests.

Funding/Support: This article was the result of a thesis in Islamic Azad University, without any financial, scientific, or any support from it.

References

- Turk JR, Carroll JA, Laughlin MH, Thomas TR, Casati J, Bowles DK, et al. C-reactive protein correlates with macrophage accumulation in coronary arteries of hypercholesterolemic pigs. *J Appl Physiol* (1985). 2003;**95**(3):1301-4. doi: [10.1152/jappphysiol.00342.2003](https://doi.org/10.1152/jappphysiol.00342.2003). [PubMed: [12754176](https://pubmed.ncbi.nlm.nih.gov/12754176/)].
- Expert Panel on Detection Evaluation Treatment of High Blood Cholesterol in Adults . Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). *JAMA*. 2001;**285**(19):2486-97. [PubMed: [11368702](https://pubmed.ncbi.nlm.nih.gov/11368702/)].
- Hokanson JE, Austin MA. Plasma triglyceride level is a risk factor for cardiovascular disease independent of high-density lipoprotein cholesterol level: a meta-analysis of population-based prospective studies. *J Cardiovasc Risk*. 1996;**3**(2):213-9. [PubMed: [8836866](https://pubmed.ncbi.nlm.nih.gov/8836866/)].
- Ghanbari-Niaki A, Behzad Khameslo M, Tayebi SM. Effect of Pyramidal Training on Plasma Lipid Profile and Fibrinogen, and Blood Viscosity of Untrained Young Men. *Ann App Sport Sci*. 2013;**1**(3):47-56.
- Tayebi SM, Ghanbari Niaki A, Hanachi P, Ghaziani G. The effect of Ramadan fasting and weight-lifting training on plasma volume, glucose and lipids profile of male weight-lifters. *Iran J Basic Med Sci*. 2010;**13**(2):57-62.
- Church TS, Barlow CE, Earnest CP, Kampert JB, Priest EL, Blair SN. Associations between cardiorespiratory fitness and C-reactive protein in men. *Arterioscler Thromb Vasc Biol*. 2002;**22**(11):1869-76. [PubMed: [12426218](https://pubmed.ncbi.nlm.nih.gov/12426218/)].
- LaMonte MJ, Durstine JL, Yanowitz FG, Lim T, DuBose KD, Davis P, et al. Cardiorespiratory fitness and C-reactive protein among a triethnic sample of women. *Circulation*. 2002;**106**(4):403-6. [PubMed: [12135936](https://pubmed.ncbi.nlm.nih.gov/12135936/)].
- Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA, et al. American College of Sports Medicine position stand. Exercise and hypertension. *Med Sci Sports Exerc*. 2004;**36**(3):533-53. [PubMed: [15076798](https://pubmed.ncbi.nlm.nih.gov/15076798/)].
- Kenney WL, Wilmore J, Costill D. *Physiology of Sport and Exercise*. 6 ed.; 2015. p. 648.
- Ghahramanloo E, Midgley AW, Bentley DJ. The effect of concurrent training on blood lipid profile and anthropometrical characteristics of previously untrained men. *J Phys Act Health*. 2009;**6**(6):760-6. [PubMed: [20101919](https://pubmed.ncbi.nlm.nih.gov/20101919/)].
- Joseph LJ, Davey SL, Evans WJ, Campbell WW. Differential effect of resistance training on the body composition and lipoprotein-lipid profile in older men and women. *Metabolism*. 1999;**48**(11):1474-80. [PubMed: [10582560](https://pubmed.ncbi.nlm.nih.gov/10582560/)].
- Elliott KJ, Sale C, Cable NT. Effects of resistance training and detraining on muscle strength and blood lipid profiles in postmenopausal women. *Br J Sports Med*. 2002;**36**(5):340-4. [PubMed: [12351331](https://pubmed.ncbi.nlm.nih.gov/12351331/)].
- Ghanbari-Niaki A, Tayebi SM, Ghorban-Alizadeh F, Hakimi J. The effect of a single-circuit weight-training session on lipid profiles and serum lipoprotein changes in students of physical education [in Persian]. *J sports sci*. 2006;**2**(4):35-44.
- Ellis GS, Lanza-Jacoby S, Gow A, Kendrick ZV. Effects of estradiol on lipoprotein lipase activity and lipid availability in exercised male rats. *J Appl Physiol* (1985). 1994;**77**(1):209-15. [PubMed: [7961235](https://pubmed.ncbi.nlm.nih.gov/7961235/)].
- Rasaei MJ, Gaeini AA, Nazem F. *Hormon Adaptation to Exercise and Training*. Tehran: Tarbiat Modares University, scientific works publishing office [in Persian].1992 :208.
- Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*. 1972;**18**(6):499-502. [PubMed: [4337382](https://pubmed.ncbi.nlm.nih.gov/4337382/)].
- Dill DB, Costill DL. Calculation of percentage changes in volumes of blood, plasma, and red cells in dehydration. *J app physiol*. 1974;**37**(2):247-8.
- Zanetti HR, da Cruz LG, Lourenco CL, Ribeiro GC, Ferreira de Jesus Leite MA, Neves FF, et al. Nonlinear Resistance Training Enhances the Lipid Profile and Reduces Inflammation Marker in People Living With HIV: A Randomized Clinical Trial. *J Phys Act Health*. 2016;**13**(7):765-70. doi: [10.1123/jpah.2015-0540](https://doi.org/10.1123/jpah.2015-0540). [PubMed: [26901242](https://pubmed.ncbi.nlm.nih.gov/26901242/)].
- Ribeiro AS, Schoenfeld BJ, Souza MF, Tomeleri CM, Venturini D, Barbosa DS, et al. Traditional and pyramidal resistance training systems improve muscle quality and metabolic biomarkers in older women: A randomized crossover study. *Exp Gerontol*. 2016;**79**:8-15. doi: [10.1016/j.exger.2016.03.007](https://doi.org/10.1016/j.exger.2016.03.007). [PubMed: [26972635](https://pubmed.ncbi.nlm.nih.gov/26972635/)].
- Ribeiro AS, Tomeleri CM, Souza MF, Pina FL, Schoenfeld BJ, Nascimento MA, et al. Effect of resistance training on C-reactive protein, blood glucose and lipid profile in older women with differing levels of RT experience. *Age (Dordr)*. 2015;**37**(6):109. doi: [10.1007/s11357-015-9849-y](https://doi.org/10.1007/s11357-015-9849-y). [PubMed: [26499819](https://pubmed.ncbi.nlm.nih.gov/26499819/)].
- Correa CS, Teixeira BC, Macedo RC, Bittencourt A, Kruger RL, Gross JS, et al. Resistance exercise at variable volume does not reduce postprandial lipemia in postmenopausal women. *Age (Dordr)*. 2014;**36**(2):869-79. doi: [10.1007/s11357-013-9610-3](https://doi.org/10.1007/s11357-013-9610-3). [PubMed: [24414335](https://pubmed.ncbi.nlm.nih.gov/24414335/)].
- Nicastro H, da Luz CR, Chaves DF, das Neves W, Valente KS, Lancha AH. Leucine supplementation combined with resistance exercise improves the plasma lipid profile of dexamethasone-treated rats. *Lipids Health Dis*. 2012;**11**:7. doi: [10.1186/1476-511X-11-7](https://doi.org/10.1186/1476-511X-11-7). [PubMed: [22236609](https://pubmed.ncbi.nlm.nih.gov/22236609/)].
- Ghanbari-Niaki A, Naderi Afshar A, Tayebi M. Serum selenium, lipoproteins and testosterone responses to a single session of circuit resistance exercise in male college students. *Int J Human*. 2007;**14**(3):89-98.
- Ghanbari-Niaki A, Saghebjo M, Hedayati M. A single session of circuit-resistance exercise effects on human peripheral blood lymphocyte ABCA1 expression and plasma HDL-C level. *Regul Pept*. 2011;**166**(1-3):42-7. doi: [10.1016/j.regpep.2010.08.001](https://doi.org/10.1016/j.regpep.2010.08.001). [PubMed: [20727372](https://pubmed.ncbi.nlm.nih.gov/20727372/)].
- Wagganer JD, Robison CE, Ackerman TA, Davis PG. Effects of exercise accumulation on plasma lipids and lipoproteins. *Appl Physiol Nutr Metab*. 2015;**40**(5):441-7. doi: [10.1139/apnm-2014-0321](https://doi.org/10.1139/apnm-2014-0321). [PubMed: [25874645](https://pubmed.ncbi.nlm.nih.gov/25874645/)].
- Mestek ML, Garner JC, Plaisance EP, Taylor JK, Alhassan S, Grandjean PW. Blood lipid responses after continuous and accumulated aerobic exercise. *Int J Sport Nutr Exerc Metab*. 2006;**16**(3):245-54. [PubMed: [16948481](https://pubmed.ncbi.nlm.nih.gov/16948481/)].

27. Boutcher SH, Meyer BJ, Craig GA, Astheimer L. Plasma lipid and fibrinogen levels in aerobically trained and untrained postmenopausal women. *J Sports Med Phys Fitness*. 2003;**43**(2):231-5. [PubMed: [12853906](#)].
28. Ye Y, Hou XH, Pan XP, Lu JX, Jia WP. Serum vaspin level in relation to postprandial plasma glucose concentration in subjects with diabetes. *Chin Med J (Engl)*. 2009;**122**(21):2530-3. [PubMed: [19951565](#)].
29. Kraus WE, Houmard JA, Duscha BD, Knetzger KJ, Wharton MB, McCartney JS, et al. Effects of the amount and intensity of exercise on plasma lipoproteins. *N Engl J Med*. 2002;**347**(19):1483-92. doi: [10.1056/NEJMoa020194](#). [PubMed: [12421890](#)].
30. Tibana RA, Navalta J, Bottaro M, Vieira D, Tajra V, Silva Ade O, et al. Effects of eight weeks of resistance training on the risk factors of metabolic syndrome in overweight /obese women - "A Pilot Study". *Diabetol Metab Syndr*. 2013;**5**(1):11. doi: [10.1186/1758-5996-5-11](#). [PubMed: [23448536](#)].
31. Ciccolo JT, Carr LJ, Krupel KL, Longval JL. The Role of Resistance Training in the Prevention and Treatment of Chronic Disease. *American Journal of Lifestyle Medicine*. 2009;**4**(4):293-308. doi: [10.1177/1559827609354034](#).
32. Russell RD, Nelson AG, Kraemer RR. Short bouts of high-intensity resistance-style training produce similar reductions in fasting blood glucose of diabetic offspring and controls. *J Strength Cond Res*. 2014;**28**(10):2760-7. doi: [10.1519/JSC.0000000000000624](#). [PubMed: [25051004](#)].
33. Cornelissen VA, Fagard RH, Coeckelberghs E, Vanhees L. Impact of resistance training on blood pressure and other cardiovascular risk factors: a meta-analysis of randomized, controlled trials. *Hypertension*. 2011;**58**(5):950-8. doi: [10.1161/HYPERTENSIONAHA.111.177071](#). [PubMed: [21896934](#)].
34. Kelley GA, Kelley KS. Impact of progressive resistance training on lipids and lipoproteins in adults: a meta-analysis of randomized controlled trials. *Prev Med*. 2009;**48**(1):9-19. doi: [10.1016/j.ypmed.2008.10.010](#). [PubMed: [19013187](#)].