

# The Impact of High-Intensity Interval Training Versus Moderate-Intensity Continuous Training on Carotid Intima-Media Thickness and Ankle-Brachial Index in Middle-Aged Women

## Abstract

**Objective:** Obesity has been linked to cardiovascular risk factors characterized by endothelial dysfunction and arterial wall thickening. Regular exercise training is recognized as a powerful tool to improve endothelial function and cardiovascular risk profile, but it is unknown which of high-intensity interval training or moderate-intensity continuous training is the best exercise. **Materials and Methods:** A total of 33 inactive and overweight women aged 40–50 years old and body mass index  $>27$  kg/m<sup>2</sup> were randomized to high-intensity interval training, moderate-intensity continuous training, or control. The exercise intervention consisted of 12 weeks of training and three supervised sessions per week. The moderate-intensity group was trained continuously for 47 min at 60–70% of maximal heart rate. High-intensity interval training consisted of four interval bouts of 4 min at 85%–95% of maximal heart rate with 3 min breaks at 50%–60% of maximal heart rate between the intervals. For all analyses, statistical significance was assigned at  $P < 0.05$ . **Results:** According to our findings, while carotid intima-media thickness decreased in both training groups, this reduction was not statistically significant. In the high-intensity training group, the right ankle-brachial index increased significantly ( $P = 0.007$ ). **Conclusion:** Twelve weeks of exercise training, especially in high-intensity interval training, have led to improving lipid profiles and endothelial function, it can be said that regular and prolonged exercise can probably be a preventive factor in cardiovascular disease in overweight women.

**Keywords:** Atherosclerosis, high-intensity interval training, overweight, vascular stiffness

## Introduction

The prevalence of obesity has increased at an alarming rate in many parts of the world.<sup>[1]</sup> In overweight people, increased levels of blood lipids and endothelial damage raise the risk of atherosclerotic plaques and other vascular disorders.<sup>[2,3]</sup> Inflammatory cytokines and oxidative metabolites produced in obesity also cause endothelial dysfunction, which contributes to vascular disorders.<sup>[4]</sup>

Following the extensive epidemiological studies, the association for atherosclerosis risk in community study and the cardiovascular health study determined the intima-media thickness (IMT) of the carotid artery as a marker for cardiovascular events.<sup>[5,6]</sup> The easy applicability and the noninvasive B-mode ultrasonography make it suitable for use as a surrogate endpoint for measuring the atherosclerotic burden in people with cardiovascular

risk factors.<sup>[7]</sup> Changing in IMT level over the threshold (900  $\mu$ m) is always clearly associated with the pathology of atherosclerosis.<sup>[8]</sup>

As atherosclerosis progresses, the peripheral vessels also get involved. About 8.5 million adults over 40 years old in the USA have the peripheral arterial disease (PAD),<sup>[9]</sup> a condition that lowers blood flow to the lower limbs, with functional limitations for the person with this disorder.<sup>[10]</sup> Also, PAD increases the risk of death from cardiovascular dysfunction by up to twofold.<sup>[11]</sup> In this regard, the ankle-brachial index (ABI) is an easy and noninvasive method for screening atherosclerosis in peripheral arteries.<sup>[12,13]</sup> This index is normal between the values of 0.9 and 1.4. The values of  $<0.9$  with a 95% sensitivity show peripheral vascular disease. The low index suggests more coronary artery

**Samaneh Farahati,  
Seyyed Reza  
Attarzadeh Hosseini,  
Mahtab Moazzami,  
Mahdi Hasanzadeh  
Daloe<sup>1</sup>,  
Shima Hasanzadeh  
Daloe<sup>2</sup>**

*Department of Sports  
Physiology, Faculty of Sport  
Sciences, Ferdowsi University  
of Mashhad, Mashhad, Iran,  
<sup>1</sup>Department of Cardiology,  
Faculty of Medicine, Mashhad  
University of Medical Sciences,  
Mashhad, Iran, <sup>2</sup>Department of  
Radiology, Mashhad University  
of Medical Sciences, Mashhad,  
Iran*

**Address for correspondence:**  
Prof. Seyyed Reza Attarzadeh  
Hosseini,  
Department of Sports  
Physiology, Faculty of Sport  
Sciences, Ferdowsi University  
of Mashhad, Mashhad, Iran.  
E-mail: attarzadeh@um.ac.ir

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disease, with an index of  $<0.4$  suggesting advanced ischemia.<sup>[14]</sup>

According to the new results of the researches, the intensity of exercise is an important index in reducing the risk of metabolic syndrome and thus improving vascular parameters. Previous studies have shown that HIIT caused reactive oxygen species (ROS) levels increased and antioxidant activity decreased.<sup>[15]</sup> Increasing ROS in high-intensity interval training (HIIT) exercises may result in rapid deactivation of nitric oxide (NO) into peroxynitrite, which can worsen oxidative vascular stress and decreased NO production.<sup>[16]</sup>

Contrary to these results, in some studies, the positive effects of HIIT on the improvement of vascular parameters are shown. Based on this theory, it can be assumed that repetitive shear stress by HIIT can trigger changes in the molecular level in which potassium channels of endothelial cells are more sensitive to shear stress and endothelial NO synthase activity will increase as a result.<sup>[17]</sup> Also, recent research suggests that enough recovery time between high-intensity training steps can avoid the adverse effects of high-intensity exercises on cardiovascular function.<sup>[16]</sup>

Therefore, according to the results of previous studies and the possible effects of training intensity on vascular parameters, this study aims to determine the effects of high-intensity interval and moderate-intensity continuous training (MICT) programme on some endothelial performance indicators of overweight middle-aged women.

## Materials and Methods

### Participants

This study was quasi-experimental research with a pre-test and post-test design. A total of 33 inactive and overweight women aged 40–50 years old and body mass index over 27 kg/m<sup>2</sup> were recruited for this study. The sampling method was convenient sampling method.

### Inclusion criteria

All subjects were nonsmokers and had no history of respiratory, cardiovascular, renal, liver diseases, and hypertension. Subjects were not menopausal and did not have a caloric restriction programme (special diet) during the past year. All subjects were inactive and had not participated in regular physical activity for at least 1 year.

### Exclusion criteria

Exclusion criteria were using medications (e.g. statins, angiotensin-converting enzyme inhibitors and certain beta blockers). Also, women with severe musculoskeletal disorders and other disabilities limiting the ability for physical activity (such women with osteoporosis) that prevented them from participating in the study and lack of exercise for more than three sessions in intervention groups excluded.

At the first meeting, the purpose of the study was explained and informed written consent obtained from the subjects. Then, through random allocation, the participants were divided into three groups of 11 subjects. All subjects were asked not to change their dietary pattern throughout the study. This study was conducted after being approved by the Ethics Committee (IR.MUM.FUM.REC.1397.09).

We excluded three women during the study based on the exclusion criteria. Subjects were randomly divided into three groups: HIIT ( $n = 10$ ), MICT ( $n = 11$ ), and control group ( $n = 9$ ).

Before the experimental period, the pretest was carried out to measure anthropometric measurements, blood sample, and endothelial function. The same tests were carried out after 12 weeks of experimental period.

## Procedures and variable assessments

### *Measurement of anthropometric characteristics*

Anthropometric indices were measured using a body composition analyzer device (Inbody-720 Body Composition Analyzer, Korea), whereas height was measured with a stadiometer (SECA, Germany).

### *Collection and analysis of blood samples*

Participants arrived at the laboratory at 7.30 am after overnight fasting. Blood samples collected after 12 h of fasting and 24 h of no intense physical activity. Serum triglyceride, low-density lipoprotein (LDL), and total cholesterol concentrations were measured by the clinical assay using Biosystem kits. The lab technician was blinded about study groups.

### Endothelial function

The same day, between 4:00 and 6:00 PM, Doppler ultrasound device M-Turbo model manufactured by Sonosite America was used by the Doppler sonography specialist to assess the carotid IMT and ABI of the subjects, who was blinded about study groups.

### *Assessment of carotid IMT*

Carotid IMT was measured at the diastolic phase as the distance between the leading edge of the first and second echogenic lines of the far walls of the distal segment of the common carotid artery on both sides, with a duplex ultrasound system with 7.5 MHz scanning frequency in the B-mode. The B-mode scanning protocol included the scanning of the right and left common carotid arteries 3 cm before the carotid bifurcation. Carotid IMT measurements were always performed in plaque-free arterial segments, then the mean of these two numbers is calculated and recorded in the subject's form. All examinations and measurements were performed by the same examiner to exclude examiner bias.<sup>[18]</sup>

### *Assessment of ABI*

ABI was derived from systolic blood pressures measured in the arms and legs after 10 min of rest in a supine position

with arms and legs straight and at rest. Manual cuffs were used for all blood pressure measurements, and arm circumference was determined during screening to select the proper cuff size consistent with JNC7 recommendations. The same cuff size used for the lower leg and a straight wrapping technique was employed. Arm blood pressures were measured using a sphygmomanometer and a stethoscope though leg blood pressures were measured with a sphygmomanometer and an 8 MHz Doppler to detect pulses. One measurement was made at each of the six sites in the following order: left arm, left ankle (dorsalis pedis, posterior tibialis), right arm, and right ankle (dorsalis pedis, posterior tibialis). Right ABI was calculated as the ratio of the higher right ankle pressures (dorsalis pedis or posterior tibialis) divided by the higher brachial pressure (right or left side) or, in the case where right and left brachial pressures differed by >10 mm Hg, the average of the right and left brachial pressures. Left ABI calculated similarly. The lower ratio of either side was considered the participant's overall ABI.<sup>[19]</sup>

### Interventions

The exercise intervention consisted of 12 weeks of training and 3 supervised sessions per week, based on guidelines. Subjects in the control group only performed their usual activities and did not participate in any exercise programme.

Exercise training in the HIIT and MICT groups was by treadmill walking or running. High-intensity interval training consisted of four interval bouts of 4 min at 85%–95% of maximal heart rate with 3 min breaks at 50%–60% of maximal heart rate between the intervals. The exercise session ended with a 5-min cool-down period.<sup>[20]</sup>

The MICT group walked continuously for 47 min at 60%–70% of maximal heart rate to ensure that the training protocols were isocaloric. The subjects were instructed to control the intensity of the exercise by monitoring their heart rate, thereby adjusting the speed or incline of the treadmill to correspond to the preferred exercise intensity.<sup>[20]</sup>

### Statistics

Statistical analysis was performed using SPSS for Windows software, V.18 (SPSS Inc., Chicago, IL, USA). Data normality was determined by the Kolmogorov–Smirnov test. A paired *t*-test was used for within-group comparison, and repeated measure analysis of variance was used for between-groups comparison. The LSD *post hoc* test was used to determine the difference between groups.  $P < 0.05$  shows significant differences.

### Results

Anthropometric measurements of the subjects in the training and control groups are shown in Table 1.

The results of Table 2 showed that cholesterol, LDL, and triglyceride levels decreased significantly in the

**Table 1: Anthropometric measurements of subjects in training and control groups**

Variable	MICT (Means±SD) (n=11)	HIIT (Means±SD) (n=10)	Control (Means±SD) (n=9)
Age, year	43.90±3.80	42.80±2.69	44.22±3.63
BMI, kg/m <sup>2</sup>	30.79±2.79	29.20±2.28	31.63±3.97
Body fat, %	44.28±5.10	40.55±4.52	43.11±6.29
WHR	0.98±0.05	0.95±0.04	0.98±0.07

BMI: Body mass index, HIIT: High-intensity interval training, MICT: Moderate-intensity continuous training, SD: standard deviation, WHR: Waist-to-hip ratio

MICT group ( $P = 0.001$ ). In addition, while cholesterol and triglyceride levels significantly decreased in the HIIT group ( $P = 0.018$  and  $P = 0.037$ , respectively), no significant changes were observed in the levels of cholesterol, LDL, and triglyceride in the control group.

According to our findings [Table 3], while carotid IMT decreased (HIIT:  $0.47 \pm 0.09$  to  $0.45 \pm 0.08$ ; MICT:  $0.49 \pm 0.10$  to  $0.45 \pm 0.06$ ), this reduction was not statistically significant in HIIT and MICT groups ( $P = 0.524$  and  $P = 0.068$ , respectively). It was also observed that the overall ABI increased in HIIT and MICT groups, but these changes were not significant ( $P = 0.108$  and  $P = 0.807$ , respectively). A significant increase was observed in the right ABI in the HIIT group ( $P = 0.007$ ).

Finally, systolic blood pressure levels in HIIT and MICT groups were not significantly different in posttest compared with pretest ( $P = 0.524$  and  $P = 0.703$ , respectively). The results of the LSD *post hoc* test showed that there was a significant difference in the right ABI between MICT and HIIT groups ( $P = 0.009$ ).

### Discussion

The results of this study showed that 12 weeks of HIIT and MICT improved the index of carotid IMT and ABI of training groups, but these changes were not significant.

In a study that compared the carotid IMT in sedentary postmenopausal women with athletic postmenopausal women, there was no difference found between groups.<sup>[21]</sup> In Tanaka *et al.*'s study, when a 3-month endurance training programme, including walking and running 25 to 45 min per session, three to six sessions per week, and intensity of 60%–75% maximum heart rate, in 18 inactive middle-aged men was carried out, carotid IMT and systolic blood pressure did not change after the exercise intervention.<sup>[22]</sup> These studies suggest that short-term physical training is not likely to be an effective stimulant for improving and reducing the thickness of the arterial wall. Also, Gelinas suggested that the duration of exercise may have influenced the desired changes in endothelial parameters.<sup>[23]</sup>

In this study, changes in the carotid IMT between the two training groups were not significant. In 2008, the study

**Table 2: Changes in lipid profiles of subjects in training and control groups**

Variable	groups	Pre-test (means±SD)	Post-test (means±SD)	Within group P	Between group P
Total cholesterol (mg/dL)	MICT (n=11)	201.45±16.91	171.82±23.52	0.001*	0.198
	HIIT (n=10)	194.60±27.68	171.80±19.88	0.018*	
	Control (n=9)	171.22±30.39	162.67±29.39	0.453	
LDL (mg/dL)	MICT (n=11)	120.27±12.31	101.55±20.24	0.001*	0.081
	HIIT (n=10)	112.00±23.39	102.70±16.30	0.162	
	Control (n=9)	96.88±19.56	97.00±16.76	0.987	
Triglyceride (mg/dL)	MICT (n=11)	89.63±22.81	71.18±20.26	0.001*	0.060
	HIIT (n=10)	102.20±41.56	71.00±24.00	0.037*	
	Control (n=9)	116.22±44.27	116.44±51.52	0.976	

\* $P < 0.05$  is significant, For comparison of between-group differences by repeated measure analysis of variance test and for comparison of within-group differences by a paired  $t$ -test. HIIT: High-intensity interval training, LDL: Low-density lipoprotein, MICT: Moderate-intensity continuous training, SD: standard deviation

**Table 3: Evaluation of changes in vascular variables in subjects of exercise and control groups**

Variable	groups	Pre-test (Means±SD)	Post-test (Means±SD)	Within group P	Between group P
Carotid IMT (mm)	MICT (n=11)	0.49±0.10	0.45±0.06	0.068	0.310
	HIIT (n=10)	0.47±0.09	0.45±0.08	0.524	
	Control (n=9)	0.52±0.13	0.54±0.13	0.570	
Overall ABI	MICT (n=11)	1.00±0.14	1.01±0.09	0.870	0.217
	HIIT (n=10)	0.95±0.12	1.04±0.12	0.108	
	Control (n=9)	0.95±0.09	0.96±0.06	0.572	
Right ABI	MICT (n=11)	1.01±0.16	1.01±0.10	0.991	0.027*
	HIIT (n=10)	0.92±0.09	1.06±0.11	0.007*	
	Control (n=9)	0.94±0.09	0.99±0.08	0.166	
Left ABI	MICT (n=11)	0.99±0.13	1.00±0.10	0.775	0.712
	HIIT (n=10)	0.97±0.18	1.02±0.16	0.587	
	Control (n=9)	0.96±0.14	0.94±0.08	0.629	
Systolic blood pressure (mm Hg)	MICT (n=11)	119.2±17.2	120.1±11.7	0.703	0.743
	HIIT (n=10)	109.7±6.1	108.0±6.0	0.524	
	Control (n=9)	121.3±14.0	122.3±11.1	0.788	

\* $P < 0.05$  is significant, For comparison of between-group differences by repeated measure analysis of variance test and for comparison of within-group differences by a paired  $t$ -test. ABI: Ankle-brachial index, HIIT: high-intensity interval training, IMT: Intima-media thickness, MICT: Moderate-intensity continuous training, SD: standard deviation

compared the effect of 6 weeks of HIIT and endurance training on vascular functional parameters. The findings of the study showed that popliteal artery dilatation improved in both training groups; however, there was no change in carotid IMT and carotid arterial compliance.<sup>[24]</sup> These studies suggest that low-intensity exercise may not be enough stimulant to improve endothelial function, whereas high-intensity exercises with higher oxidative stress may have a negative effect on vascular adaptation.<sup>[23]</sup>

The results of this study showed that the overall ABI and left ABI increased in continuous and interval exercise groups, but these changes were not significant. Gibbs *et al.* looked at the effects of exercise training on the ABI of middle-aged people. The results of the study showed that there was a significant increase in the ABI in the subjects who had ABI  $< 1$  at the beginning of the intervention, whereas there were no significant changes in subjects who had ABI  $> 1$  at the start of the programme. The researchers concluded that the ABI index was improved further in

people with low ABI. They also stated that the increase in ABI after exercise correlated with decreased systolic and diastolic blood pressure.<sup>[25]</sup> Momeni *et al.* showed that carotid IMT also correlated with age and systolic blood pressure.<sup>[7]</sup> However, in this study, changes in systolic blood pressure in brachial arteries were not significant in the training groups.

In this study, changes in cholesterol, triglyceride, and LDL were investigated. The results of this study showed significant changes in training groups. Poblete *et al.* compared lipid profiles in three groups of high interval exercises, moderate exercise, and control in type 2 diabetic patients. The findings of the study showed significantly decreased cholesterol and LDL in the interval exercise group, and LDL changes in the continuous training group were significant. The researchers stated that both types of exercise training were able to improve lipid indices and increase the level of physical health of people with type 2 diabetes, although they stressed

the positive effects of high interval exercises.<sup>[26]</sup> Some researchers studied the effects of exercises on the lipid profile, suggesting that physical activity seems to raise the ability of skeletal muscles to use fats compared with glycogen; this process may be because of a rise in lysine cholesterol acyltransferase enzyme responsible for the transfer of ester to high-density lipoprotein, caused by physical activity, which leads to increased lipoprotein lipase activity and reduced fat levels. It has been shown that the increase in caloric metabolism by aerobic physical activity (either by increasing the intensity or duration of activity) positively affects the activity of lipoprotein lipase and lipid profiles.<sup>[27,28]</sup>

### Limitations

The limitations of this study must be considered. The small sample size is a limitation in our study, so we suggest more studies to be carried out using a larger sample size. The follow-up time in this study was 12 months, and this period is a relatively short time.

### Conclusion

Based on these findings, we can conclude that 12 weeks of exercise training with two different intensities decrease the carotid IMT of overweight middle-aged women. Therefore, it can be said that regular and prolonged exercise can probably be a preventive factor in cardiovascular disease in overweight women. Also, the results of this study showed that the overall ABI increased in continuous and interval exercise groups, but these changes were not significant. For this reason, further research should be carried out over a longer period or with diet plans. Furthermore, the subjects of this study did not have any cardiovascular problems, whereas if subjects had vascular disorders, the effect of physical training on the ABI index was probably more pronounced.

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### Conflicts of interest

There are no conflicts of interest.

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