Women. Health. Bull. 2020; 7(3)
Published online 2020 July.

Research Article

Effect of Acute High-Intensity Interval Training and Isometric Handgrip Exercise on Hemodynamic Responses in Hypertensive Women

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Received April 10, 2020; **Revised** May 15, 2020; **Accepted** June 24, 2020

Abstract

Background: Exercise is believed to be a non-pharmacological approach to treat hypertension. The present study was conducted to investigate the impact of high-intensity interval training (HIIT) and isometric handgrip (IHG) exercise on hemodynamic responses of High blood pressure women.
Methods: In this experimental study 45 sedentary women (age, 45±5 years) from the Al-Zahra Heart Hospital, Shiraz-Iran (2019) with pre to stage 1 hypertension, without any chronic disease, who volunteered to participate in the research. The subjects were randomly divided into three groups of 15 members: Acute HIIT, Acute IHG exercise, and control. Blood pressure (systolic, diastolic, and mean), rate pressure product and heart rate were measured employing Aneroid Sphygmomanometer Polar HR recorder at the pre-workout time, 0 (immediately after exercise), 5, 10, 15, 30, 45, 60 minutes during the recovery period. The data were analyzed using repeated-measures ANOVA and Bonferroni post hoc test.
Results: Our results revealed a significant difference among the study groups regarding blood pressure factors (systolic and mean), heart rate and rate pressure product (P=0.001). The significant decrease in blood pressure in HIIT (P=0.001) and IHG (P=0.001) groups during 60 and 30 minutes of recovery was equal to 10 and 7 mmHg, respectively, and no significant difference was observed in the control group at different times. In response to the HIIT protocol, the heart rate and rate pressure product were significantly higher than the IHG and control groups.
Conclusion: Over the recovery period, there was a significant improvement in hemodynamic factors of hypertensive women independent of the type of exercise. However, HIIT training had a longer lasting decrease in blood pressure.

Keywords: High-intensity interval training, Isometric exercise, Hemodynamic, Hypertensive

How to Cite: Shakoor E, Salesi M, Daryanoosh F, Izadpanah P. Effect of Acute High-Intensity Interval Training and Isometric Handgrip Exercise on Hemodynamic Responses in Hypertensive Women. Women. Health. Bull. 2020;7(3):60-69.

1. Introduction

Hypertension (HTN) is the most prevalent, costly and modifiable main risk factor for cardiovascular diseases, which is responsible for 7.6 million morbidity and mortality cases per year worldwide. It has been estimated that the disease affects over 1 billion adults globally (1).

Regular (aerobic) exercise is a good intervention to avoid a non-pharmacological treatment, and the control of HTN can lower blood pressure (BP) among hypertensive patients (2). However, modest reductions in BP (~5 mm Hg) after acute exercise [post-exercise hypotension (PEH)] could decrease the risk of heart disease by 8% and that of stroke by 14%, it has been confirm that the clinical importance of exercise as an antihypertensive lifestyle therapy (3). PEH is a phenomenon known as sustained hypotension immediately after an exercise session that occurs right after training. During this prolonged phase, blood pressure can drop below resting levels before exercise, causing hyperemia that persists for most of the day. If repeated regularly, acute exercise training might be another important non-pharmacologic tool in the management of hypertension for hypertensive patients (4).

Accordingly, American and European hypertension guidelines have recommended 30 minutes or longer acute (5, 6) and chronic (7, 8) moderate-intensity continuous aerobic training (MICT) per day (150-180 min per week), preferably over all the weekdays (4, 9). However, moderate-intensity continuous training (MICT) is rarely practiced, which is attributed to time constraints in several studies; therefore, following two years of regular exercise, only 20% of patients are still active (10). The question is whether there are alternative exercises with greater adherence and prolonged post-exercise reduction in BP.

Recently, HIIT has attracted considerable attention in the clinical context as an alternative to MICT and is of a greater and more significant impact on various aspects of health, reducing the risk of cardiovascular diseases. Emerging research has indicated that HIIT is capable of stimulating changes in many physiological and health markers to a similar or even higher extent to MICT (11). Several studies have shown that acute HIIT (6, 12, 13) with lower volume of exercise can decrease blood pressure, and as a result can introduce it as a suitable strategy for achieving BP benefits.

It might be thought that greater intensity of HIIT increases the risk of cardiovascular diseases compared to MICT. However, the safety, low risk and greater influence of it on hypertension have been reported (11). Moreover, recent studies have demonstrated that high-intensity aerobic exercise leads to more PEH compared to moderate-intensity aerobic exercise since PEH lasts for a long time after a high-intensity workout (up to 22 hours after exercise (4, 14, 15). On the other hand, according to American Heart Association (AHA) research, isometric handgrip (IHG) exercise is another type of training suggested as an alternative strategy and antihypertensive exercise model in HTN individuals, which involves much less time commitment and may become a new tool in non-pharmacological treatment of hypertension (9, 16).

Compared with aerobic training, isometric exercise is believed to be physiologically associated with lower myocardial oxygen demand (due to low heart rate (HR) and muscle involvement) and cardiac output, but higher diastolic blood pressure (DBP) (as opposed to aerobic exercise) as well as increasing coronary blood flow. Despite the low volume of isometric handgrip resistance exercise, it significantly reduces blood pressure (17) and studies in this area have reported a substantial decrease in resting blood pressure following acute IHG exercise (18-20). Alternatively, blood pressure and heart rate are the simplest yet most alarming cardiovascular variables, and the mean blood pressure (MBP) determines the amount of blood flow in the general circulatory system. In addition, rate pressure product (RPP) as a product of systolic blood pressure (SBP) and heart rate is one of the most commonly used estimates of myocardial load and thus, oxygen consumption. RPP is highly correlated with direct measurement of coronary blood flow and myocardial oxygen consumption, which increases with the increase in cardiac output to supply sufficient blood for active cardiac muscle during the activity (21).

According to the above-mentioned statements, there is not a complete systematic evaluation of HIIT and IHG protocols, and there is little evidence of PEH responses after acute IHG and HIIT exercise in hypertensive women. It is not yet known which of the two exercise types cause more PEH, so that they could be recommended for treating and preventing high blood pressure The present study aimed to investigate the Acute HIIT and IHG exercise on hemodynamic responses (blood pressure [systolic, diastolic, mean arterial pressure], rate pressure product and heart rate) in women with hypertension.

2. Methods

2.1. Participants and Design of the Study

This study is an experimental research design. Forty-five sedentary 35- to 55-year-old women with pre to stage 1 hypertension (systolic blood pressure (SBP), 138±2; diastolic blood pressure (DBP), 89±3 mmHg), who referred to Alzahra Hospital of Shiraz, and voluntarily participated in this study (Table 1).

The sample size was calculated as 15 subjects per group (a total of 45) according to Ash and other colleagues (22) Table 1, Row 10 (Awake DBP), considering m1=92.1, m2= 87.2, s1=1.4, s2=3.3, α equal to 0.05, 80% power and 30% loss.

$$n_1 = n_2 = \frac{\left(S_1^2 + S_2^2\right)\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2}{\left(\bar{X}_1 - \bar{X}_2\right)^2}; \alpha = 0/05, \beta = 0/2$$

$$\begin{aligned} &\bar{X}_1 = 92.1 \\ &\bar{X}_1 = 87.2 \quad Z_{1-\frac{\alpha}{2}} = 1.96, Z_{1-\beta} = 0/84 \\ &S_1^2 = 1.4 \\ &S_2^2 = 3.3 \end{aligned}$$

All the subjects were premenopausal and regularly menstruating women without any chronic, cardiovascular, metabolic, renal or respiratory disease, musculoskeletal, articular or neurological disorders and were non-smokers. In addition, they had no physical or functional limitations for exercise.

The exclusion criteria were as follows: 1) use of any medications that may affect blood pressure and cardiovascular responses, 2) regular exercise within the last six months, 3) history of myocardial infarction and angioplasty, 4) pregnancy, 5) abnormalities of ECG, echo, and stress test. All the participants filled out an informed consent form following an examination by a physician and a full explanation of

Table 1: Characteristics of the study participants (Mean±SD)

Variables	HIIT group	IHG group	Control	P-value
Age (Years)	44.93±1.37	46.06±1.55	44.60±1.67	0.78
weight (kg)	71.66±1.45	74.46±1.50	72±1.96	0.43
height (cm)	161.26±1.41	162.93±1.64	162.0±1.70	0.76
BMI (Kg/m^2)	27.65±0.75	28.08±0.56	27.41±0.54	0.74
Waist circumferene (cm)	0.89±0.004	0.89±0.004	0.88±0.01	0.76
SBP (mmHg)	138.40±0.33	138.46±0.32	137.46±0.72	0.23
DBP (mmHg)	89.60±0.90	89.13±0.37	88.46±0.97	0.16
Resting HR (bpm)	73.40±3.13	74.13±2.98	72.40±2.44	0.26

HIIT: High Intensity Interval Training, IHG: Isometric Handgrip, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, HR: Heart Rate

the research implementation. This study was approved by the Research Ethics Committee of Shiraz University of Medical Sciences-Iran (IR.SUMS.REHAB.REC.1398.001) in accordance with standards of the National Council for Research Involving Humans and the Helsinki Declaration as well as World Medical Association Declaration of Helsinki.

2.3 Experimental Design and Exercise Protocols

Herein, we investigated the acute effect of HIIT & IHG on PEH responses (for example SBP, DBP, MBP, HR, RPP) on 45 hypertensive women in eight states of time (before the exercise protocol, 0 [immediately after exercise], 5, 10, 15, 30, 45, 60 minutes during the recovery). Initially, 94 people with hypertension were recruited voluntarily and participated in the study, 60 of whom were eligible to take part. Following the medical examinations, electrocardiogram, echocardiography, and stress test, 45 subjects were selected and randomly assigned to three groups of 15 subjects (HIIT, IHG, and control). The randomization was performed with a computer random number generator. The subjects were asked to avoid consumption of food 3 hours, and caffeine 4 hours ahead of exercise program. The participants were also recommended to get enough sleep (7-8 hours) the night before the test and to take note of their meals the day before the test in order to avoid the effects of sleep and diet on the study findings. The subjects of each group performed 10-min warm-up, and 5-min cool down at 50-60% peak HR (23) followed by a training session based on the below protocols:

1) HIIT: The exercise protocol was performed on Quinton treadmill (Medtrack ST; Quinton, Seattle, WA, USA), and 4×4 min intervals at 85-95% peak HR, interspersed with a 3-min active recovery period at ≈70% Peak HR (15, 24). The wrist-worn activity monitors were applied to monitor heart rate (HR) during the exercise program.

2) IHG: 4×2 min isometric contractions at 30% of Maximal Voluntary Contraction (MVC), separated by 2 minutes rest, overall session with non-dominant hand unilaterally (20, 22).

3) Control: Did not do any exercise

The intensity of exercises in the three groups was controlled with the Borg Rating of Perceived Exertion (RPE) scale 6-20. All the workout sessions were held between 8 and 11 a.m. under the supervision of the researcher, and a physician in the laboratory free of any noise or external distractions.

2.4 Anthropometry and Hemodynamic Measurements

Anthropometric measures, including waist and hip circumference (cm), height (m), and weight (kg), were evaluated utilizing standard techniques. BMI was obtained by dividing weight (kg) by height (m^2), and waist/hip ratio (WC/HC) was then calculated. Blood pressure (systolic and diastolic) of the participants was measured employing Aneroid Sphygmomanometer) Exacta LF1350 (in a calm and quiet environment, in seated position with the cuff on left arm supported at heart level. HR was measured in eight states of time and recorded on a beat-by-beat basis using a Polar HR recorder. According to the guidelines of the American Heart Association, BP and HR were measured once before the protocols and then after performing exercise protocols at seven mentioned periods (25).

The mean blood pressure (MBP) was calculated with the following Equation: 1/3 SBP+2/3 DBP, and rate pressure product (RPP) was evaluated according to HR×SBP value.

The stress test (Bruce protocol) was used to measure HR peak and to assess the cardiovascular health status of the subjects. Before this test, the subjects were advised to have adequate rest, fast for at least 3 hours,

Table 2: Repeated measures ANOVA results difference in systolic and diastolic blood pressure, Mean blood pressure, Heart Rate, and Rate pressure product between and within groups

Variable	Group	Pre test	Immediately After Exercise	5 min	10 min	15 min	30 min	45 min	60 min	Time effect P-value	Group effect P value	Time * group effect P value
Systolic Blood Pressure	IHG	138.46±0.32	141.60±8.93	137.26±7.64	135±4.32	132.73±2.98	131.40±6.08	136.06±6.29	137.26±4.68	<0.001	<0.001	<0.001
	HIIT	138.40±0.33	160.40±2.35	148.66±1.95	148.80±2.36	139.33±1.75	134.20±1.42	128.33±2.13	126.73±1.57	<0.001		
	Control	137.46±0.72	138.33±2.09	138.33±1.58	137.60±2.79	137.60±2.82	137.86±2.47	137.93±2.34	138.40±1.95	0.46		
Between group comparison P value		0.23	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			
Diastolic Blood Pressure	IHG	89.13±0.37	90.80±2.65	88.86±3.99	89.86±2.26	88.46±3.02	88.40±3.39	90.26±1.16	90.26±1.53	0.018	0.79	<0.001
	HIIT	89.60±0.90	93.46±2.64	92.46±3.06	91.66±3.01	88.46±2.55	86.23±2.86	87.56±1.95	86.46±2.09	<0.001		
	Control	88.46±0.97	90.20±1.20	90.06±0.96	89.86±1.12	89.86±0.99	90.26±0.88	90.13±0.99	90.60±1.05	0.14		
Between group comparison P value		0.16	<0.001	<0.001	0.054	<0.001	<0.001	<0.001	<0.001			
Mean Blood Pressure	IHG	90.72±0.70	92.60±3.60	90.18±3.79	89.93±1.09	88.47±2.08	88±2.95	90.48±2.36	90.89±1.52	<0.001	<0.001	<0.001
	HIIT	91.76±1.93	100.20±1.74	95.78±1.86	94.43±1.41	90.67±1.29	88.43±1.57	86.77±1.35	86.31±1.33	<0.001		
	Control	90.05±2.33	91.21±0.93	91.14±0.70	90.80±0.95	90.80±0.89	91.08±0.97	91.04±0.98	91.43±0.95	0.19		
Between group comparison P value		0.13	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			
Heart Rate	IHG	74.13±2.94	72.13±2.79	73.13±2.58	74.13±2.72	73.20±2.30	73.66±2.55	71.80±2.56	73.26±2.65	<0.001	<0.001	<0.001
	HIIT	73.40±3.13	157.80±8.82	137.86±3.58	127.80±6.31	108.50±4.51	98.73±2.96	94.66±3.30	80.26±3.10	<0.001		
	Control	72.40±2.44	71.26±1.70	72.20±1.37	72.53±1.84	72.73±1.66	73.13±1.64	73.40±1.76	73.46±1.30	0.05		
Between group comparison HIIT P value		0.26	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			
Rate pressure product	IHG	10264.40± 404.84	10217.13± 796.61	10036.93± 626.47	10003.53± 382.50	9715.73± 363	9674.26± 448.12	9772± 601.24	10056.26± 477.04	<0.006	<0.001	<0.001
	HIIT	10232.20± 20	25309.46± 1436.56	20496.66± 611	18628.80± 870.54	15133.46± 702.89	13348.13± 403.51	12164± 346.65	10250.73± 357.97	<0.001		
	Control	9951.06± 349.79	9858.33± 269.26	9987.66± 221.14	9979.66± 292.36	10006.60± 249.86	10081.33± 235.396	10123.46± 264.53	10166.93± 186.14	0.10		
Between group comparison P value		0.70	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.34			

not consume voluminous food and wear comfortable shoes and clothing. To conduct the stress test, the heart rate and blood pressure were primarily measured, the electrocardiograms (12 derivatives) were attached to the subjects, and primary ECG was taken. Afterwards, the participants performed the protocol of Bruce test (four steps) on a treadmill (Quinton, USA); every three minutes the slope of ECG increased by 2% and the speed of movement was about 1.2 km/h. The test was implemented by a trained nurse and supervised by a cardiologist up to fatigue and voluntary helplessness or reaching the target heart rate. The decision to terminate the test was based on defined exercise testing guidelines established by the American College of Cardiology/ American Heart Association (26).

To measure MVC using a handgrip device (Saehan Grip, DHD-3 model, South Korea), the subjects were seated with a non-dominant hand on an armchair, in a way that the soles of their feet were on the ground and their knees made a 90-degree angles. The subjects' elbows were also in contact with armrest or desk, and they were aware of their performance by the numbers indicated on the device. Before performing each protocol, the participants applied maximum force to the device by their non-dominant and training hand following low-intensity warm-up using a handgrip tool in three contractions without Valsalva maneuvering and the mean force recorded in the device was considered as Maximal Voluntary Contraction (MVC) of the subjects.

2.5 Statistical Analysis

The Shapiro-Wilk test evaluated normality of the data. Repeated-measures ANOVA (3groups × eight times) was utilized to compare the SBP, DBP, MAP, HR and RPP values in the three groups over the previously-mentioned states of time. Before analysis the data, the results of Levene's test of homogeneity of variance and Box's M test of equality of covariance implied that the data met the required assumptions to conduct the repeated-measures ANOVA. Once ANOVA revealed a significant difference, Bonferroni post hoc test was employed to determine and locate the differences. The obtained data were analyzed with SPSS version 25.0 and presented as mean±SD, and Statistical significance level was set at $P \leq 0.05$.

3. Results

All the participants completed their training program. Anthropometric parameters and resting hemodynamics of subjects are represented in Table 1. No significant difference was observed between the factors under study at baseline.

Repeated-measures ANOVA results showed that there was a significant difference in the systolic blood pressure between the groups ($P<0.001$) within different test times ($P<0.001$) and there was a significant difference in interaction (groups*times) ($P<0.001$) (Table 2). Bonferroni post hoc test exhibited a significant decrease in systolic blood pressure in HIIT group at 30 ($P=0.001$), 45 ($P=0.001$) and 60 ($P=0.001$) minutes of recovery times (4, 10 and 11 mmHg, respectively), which were observed at 15 ($P=0.001$) and 30 ($P=0.01$) minutes of recovery (5 and 7 mmHg, respectively) in IHG group ($P<0.05$). Moreover, No significant change was seen in the control group at different times ($P>0.05$) (Figure 1).

Repeated-measures ANOVA result showed that there is no significant difference between groups for diastolic blood pressure ($P=0.79$), but there is significant within different times ($P<0.001$) and there was a significant difference in interaction (groups*times) ($P<0.001$) (Table 2). Bonferroni post hoc test indicated a significant decrease of diastolic blood pressure in the HIIT group at 30 ($P=0.002$), 45 ($P=0.007$) and 60 ($P=0.007$) minutes of recovery time (3, 2 and 3 mm Hg, respectively) ($P<0.05$); however, DBP did not change significantly in response to IHG and control groups ($P>0.05$) (Figure 2).

Moreover, repeated-measures ANOVA analysis indicated that the results of Mean Blood Pressure (MBP) were significantly different among the groups ($P=0.009$), within different test times ($P<0.001$). Moreover, there was a significant difference in interaction (groups*times) ($P<0.001$) (Table 2). Bonferroni post hoc test revealed a significant decrease of MBP in HIIT group at 30 ($P=0.001$), 45 ($P=0.001$) and 60 ($P=0.001$) minutes of recovery (3, 4 and 5 mmHg, respectively), which was seen at 15minutes ($P=0.03$) during recovery (2 mmHg) ($P<0.05$) in IHG group and there were no significant changes in the control group ($P>0.05$) (Figure 3).

In addition, repeated-measures ANOVA analysis of Heart Rate (HR) showed the significance difference between the groups ($P=0.001$) within different times ($P<0.001$) and interaction (groups*times) ($P<0.001$) (Table 2). Bonferroni post hoc test indicated a significant change of heart rate in HIIT group at all times and 5 ($P=0.004$), 15 ($P=0.03$) and 45 ($P=0.001$)

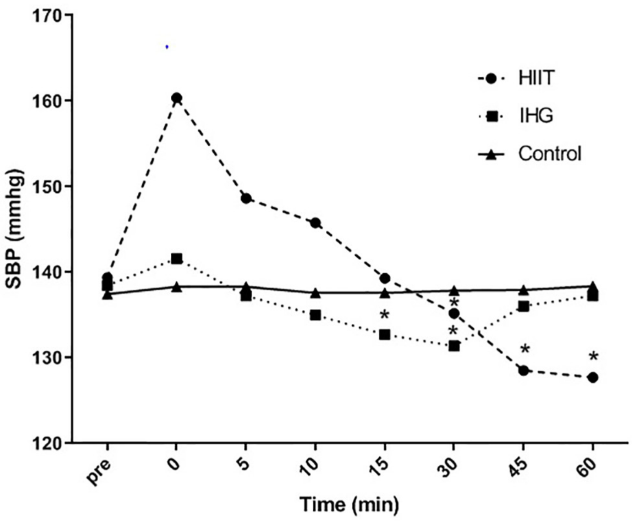

Figure 1: Mean values for SBP at baseline and during recovery following HIIT, IHG and control groups. * indicates a significant difference the between and within groups. HIIT: High Intensity Interval Training, IHG: Isometric Handgrip, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, HR: Heart Rate

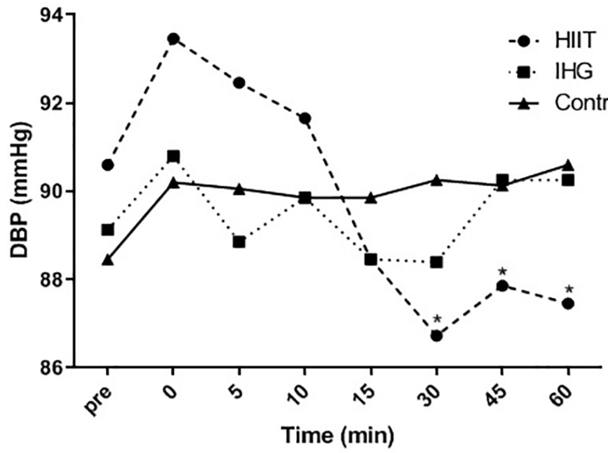

Figure 2: Mean values for DBP at baseline and during recovery following HIIT, IHG and control groups. * indicates a significant difference the between and within HIIT group. HIIT: High Intensity Interval Training, IHG: Isometric Handgrip, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, HR: Heart Rate

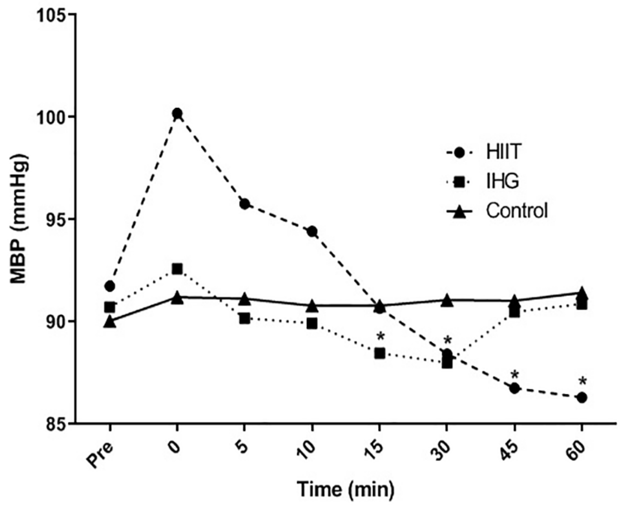

Figure 3: Mean values for MBP at baseline and during recovery following HIIT, IHG and control groups. * indicates a significant difference the between and within groups. HIIT: High Intensity Interval Training, IHG: Isometric Handgrip, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, HR: Heart Rate

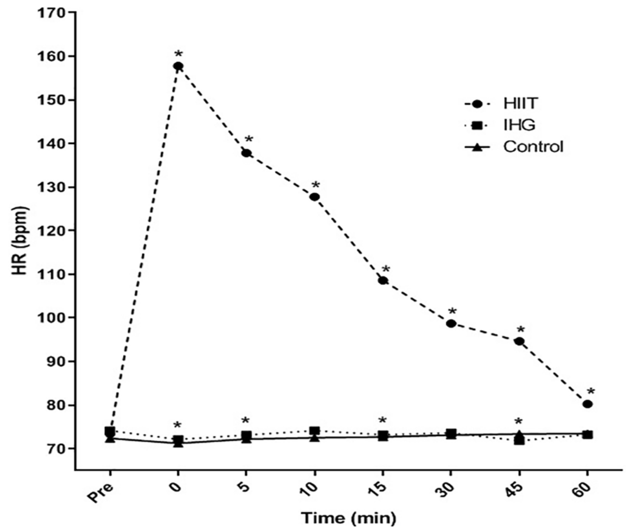

Figure 4: Mean values for HR at baseline and during recovery following HIIT, IHG and control groups. * indicates a significant difference the between and within groups. HIIT: High Intensity Interval Training, IHG: Isometric Handgrip, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, HR: Heart Rate

minutes of recovery in IHG group ($P<0.05$). Yet there was no significant change in the control group ($P>0.05$) (Figure 4).

Repeated-measures ANOVA of Rate Pressure Product (RPP) data illustrated that there were significant differences between groups ($P=0.001$), within different times ($P<0.001$) and there was a significant difference in interaction (groups*times) ($P<0.001$) (Table 2). Bonferroni post hoc test showed that RPP was significantly different in HIIT group at 0 ($P=0.001$), 5 ($P=0.001$), 10 ($P=0.001$), 15 ($P=0.001$), 30 ($P=0.001$) and 45 ($P=0.001$) minutes as well as 15 ($P=0.001$), 30 ($P=0.003$) and 45 ($P=0.04$) minutes of recovery in IHG group. In the control group, a significant change was observed only at 45 minutes ($P<0.05$) (Figure 5).

4. Discussion

Our study is of several important features as follows: 1- It was the first randomized controlled trial comparing the acute effect of HIIT training and IHG exercise on hemodynamic responses of 45 hypertensive women. 2- The subjects of this study did not take antihypertensive drugs due to the possibility of drug therapy overlap with mechanisms of blood pressure

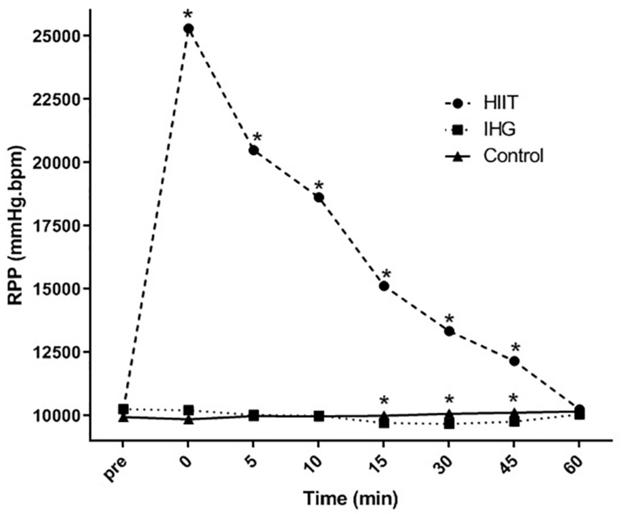

Figure 5: Mean values for RPP at baseline and during recovery following HIIT, IHG and control groups. * indicates a significant difference the between and within groups. HIIT: High Intensity Interval Training, IHG: Isometric Handgrip, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, HR: Heart Rate

following the exercises, so that we would be able to attribute blood pressure reduction to the exercises. 3-All the exercises were monitored. To implement this project, we intervened three groups of HIIT, IHG, and control to investigate which of the protocols caused the Prolong magnitude of PEH.

Our findings revealed that HIIT reduced systolic and diastolic blood pressure by 12 and 3 mmHg, respectively. In contrast, IHG significantly decreased systolic blood pressure by 7 mmHg whereas it had no significant effect on diastolic blood pressure. In general, the present study indicated PEH in SBP during recovery between both training groups independent of the exercise type. PEH was seen in the IHG group (15 min) sooner compared to HIIT group (30 min). Meanwhile, in the HIIT group, PEH showed a higher value (11 mmHg) and longer persistence (up to 60 min). Concerning DBP, the results showed a significant decrease only in the HIIT group at 30, 45 and 60 minutes of recovery (equal to 3, 2 and 3 mmHg, respectively). The highest significant decrease in MBP was observed in the HIIT group at 60 minutes (5 mmHg) and in IHG group at 15 minutes (2 mmHg).

Heart rate data revealed that after HIIT training, there was a greater increase in HR relative to IHG exercise, which led to an increase in RPP. RPP is the indicator of oxygen consumption and cardiac work at the time of post-exercise recovery, which is influenced by the fitness level of individuals. Able-bodied people have a better recovery, and RPP is an appropriate diagnostic index for post-exercise hemodynamic responses. No studies were found to directly compare the acute effects of both HIIT and IHG on hemodynamic responses, and our research is, therefore, a novelty. Thus, we discussed various studies that have examined each of these two protocols separately.

In this regard, our results concerning acute HITT training were consistent with those of Angadi and colleagues (27), Ramirez-Jimenez and colleagues (15), Ketelhut and colleagues (28). No studies were found to be inconsistent with ours. Concerning acute IHG exercise, our findings were in line with Van Assche et al. (20), Millar et al. (18), but in contradiction to Ash et al. (22), Olher et al. (29) and Pagonas et al. (30).

Indeed, the following differences can be mentioned for the inconsistency of our research on IHG exercise: type of exercise protocol, number, gender, and age of the sample size participants, hypertension stage, use or non-use of antihypertensive drugs and baseline hypertension. In a study by Ash and colleagues, bilateral IHG exercise protocol was used by recruiting 27 men and women who were 18-55 years old. In Olher's research, IHG exercise involved four sets of five 10-second contractions of 30% and 50% MVC on 12 elderly hypertensive women with the mean age of 64±1 years taking antihypertensive medications and baseline blood pressure of 122±7. Furthermore, in a study by Paganus, 25 hypertensive women aged 25-41 years taking antihypertensive medication were examined. Meanwhile, the training protocol of our research included four two-minute contractions with non-dominant unilateral hand on 15 women with the mean age of 45±5 years involved with hypertension who took no medication.

Physical activities and an active lifestyle are strongly recommended in current hypertension guidelines. Exercise is believed to be a non-pharmacological treatment with several effects on the reduction of hypertension and its associated factors. Epidemiological studies show that even a 2-mm Hg reduction of SBP probably reduces the mortality from stroke and CHD by 6% and 4%, respectively, indicating the importance of acute exercise as a non-pharmacological treatment for hypertension (31).

A feature of HIIT training is that it is interval with high and low intensities because HIIT reduces blood pressure after each frequency, and in fact, the chronic effect of exercise in lowering blood pressure is owing to the summation of acute effects from each exercise session in this physiological response

(15). The chronic exposure to exercise could in turn lead to parasympathetic dominance during rest (9). Additionally, HIIT with various intensities continuously and repetitively increases shear stress, which is a key driver for vascular adaptation induced by exercise, directly affecting the endothelium and improving vascular endothelial function and endothelin-1, as well as increasing nitric oxide bioactivity. It also inhibits the formation of free radicals by the frequency of training sessions (4, 11). On the other hand, exercise intensity is a key factor in improving cardiopulmonary fitness, hormonal, metabolic and hemodynamic changes as well as decreased blood pressure from exercise. Higher intensity of exercise triggers a greater reduction in blood pressure, and high-intensity aerobic exercise results in further PEH than moderate-intensity aerobic exercise, such that PEH lasts for a longer period after high-intensity exercise (14, 27).

Regarding IHG exercise, several investigations have demonstrated that decreasing blood pressure following such exercise is mostly mediated by changes in peripheral vascular resistance. Few studies have suggested that hypotension due to IHG exercise is associated with decreased vascular sympathetic tone (32). However, a large number of researches have examined the potential benefits of adaptation in vascular structure and function. In particular, IHG exercise increases endothelial-dependent vasodilation in response to reactive hypertension in patients with high blood pressure under treatment (33, 34). Moreover, adding IHG exercise to dynamic aerobic exercise reduces ST segment depletion and myocardial ischemia (35), which is another indication of appropriate and safe blood pressure response during IHG exercise to maintain spontaneous breathing without Valsalva maneuvering (breathing under closed glottis pressure) (36). IHG exercise has far less time commitment than dynamic and aerobic resistance training (11-20 minutes), significantly reducing blood pressure despite the low volume of isometric handgrip resistance exercises (17, 34).

Considering the fact that both types of exercises have significantly decreased blood pressure, more sustained decrease in blood pressure as a result of HIIT training may be attributable to the high intensity of exercise and involvement of all muscles (greater muscle mass mobilization) during training.

Ultimately, a number of important limitations need to be considered. Primarily, we have not evaluated the mechanisms of blood pressure reduction, for instance vascular, metabolic, hormonal and sympathetic following HIIT and IHG. Secondly, our sample size may have been low. Thirdly, our study was only performed on women with hypertension and we declined to measure lactate since we intended to assess real-life medical advice for exercise.

5. Conclusion

In summary, the findings of the present study indicated that both HIIT training and IHG exercise decrease blood pressure, but the HIIT significantly lead to more PEH than IHG. This decrease was observed after IHG exercise at 15 min and after HIIT at 30 min. Since the two exercise protocols are more effective in lowering blood pressure and given the increasing incidence of hypertension and its associated side effects, it is recommended to use these exercises as a non-pharmacological treatment for controlling hypertension with respect to time and facilities.

Acknowledgement

We would like to thank and appreciate all the participants who allowed us carry out this research with their presence. This paper reported the results of a PhD thesis.

Ethical Approval

The Ethical Review Board of the Shiraz University of Medical Sciences, approved the present study with the following number: IR.SUMS.REHAB.REC.1398.001

Funding: This study was financially supported by Shiraz University.

Conflict of Interests: None to declare.

References

1. Organization WH. Global status report on noncommunicable diseases 2014: World Health Organization; 2014.
2. Whelton PK, Carey RM, Aronow WS, Casey DE, Collins KJ, Dennison Himmelfarb C, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J. Am. Coll. Cardiol.* 2018;**71**(19): 127-248. doi:10.1016/j.

jacc.2017.11.006.[PubMed: 29146534].

3. Corso LM, Macdonald HV, Johnson BT, Farinatti P, Livingston J, Zaleski AL, et al. Is Concurrent Training Efficacious Antihypertensive Therapy? A Meta-analysis. *Med Sci Sports Exerc*. 2016;**48**(12):2398-406. doi:10.1249/MSS.0000000000001056.[PubMed: 27471784].
4. Pescatello LS, MacDonald HV, Lamberti L, Johnson BT. Exercise for hypertension: a prescription update integrating existing recommendations with emerging research. *Curr Hypertens Rep*. 2015;**17**(11):87. doi:10.1007/s11906-015-0600-y.[PubMed: 4589552]; [PubMed Central: PMC4589552].
5. Ciolac EG, Guimaraes GV, D'Avila VM, Bortolotto LA, Doria EL, Bocchi EA. Acute aerobic exercise reduces 24-h ambulatory blood pressure levels in long-term-treated hypertensive patients. *Clinics (Sao Paulo)*. 2008;**63**(6):753-8. doi:10.1590/s1807-59322008000600008.
6. 6.Ciolac EG, Guimaraes GV, VM DA, Bortolotto LA, Doria EL, Bocchi EA. Acute effects of continuous and interval aerobic exercise on 24-h ambulatory blood pressure in long-term treated hypertensive patients. *Int J Cardiol*. 2009;**133**(3):381-7. doi:10.1016/j.ijcard.2008.02.005.[PubMed: 18501444].
7. Ciolac EG, Bocchi EA, Bortolotto LA, Carvalho VO, Greve JM, Guimaraes GV. Effects of high-intensity aerobic interval training vs. moderate exercise on hemodynamic, metabolic and neuro-humoral abnormalities of young normotensive women at high familial risk for hypertension. *Hypertens Res*. 2010;**33**(8):836-43. doi: 10.1038/hr.2010.72.[PubMed: 20448634].
8. Guimaraes GV, Ciolac EG, Oliveira V, Carvalho VMD, Bortolotto LA, Alcides E. Effects of continuous vs. interval exercise training on blood pressure and arterial stiffness in treated hypertension. *Hypertens Res*. 2010;**33**:627-32. doi:10.1038/hr.2010.42 [PubMed: 20379194].
9. Cornelissen VA, Smart NA. Exercise training for blood pressure: a systematic review and meta-analysis. J Am Heart Assoc. 2013;2(1):e004473. doi:10.1161/JAHA.112.004473.
10. Dishman RK. Advances in exercise adherence: human kinetics publishers; 1994.
11. Hussain SR, Macaluso A, Pearson SJ. High-intensity interval training versus moderate-intensity continuous training in the prevention/management of cardiovascular disease. *Cardiol Rev*. 2016;**24**(6):273-81. doi:10.1097/crd.0000000000000124.[PubMed: 27548688].
12. Miyashita M, Burns SF, Stensel DJ. Accumulating short bouts of running reduces resting blood pressure in young normotensive/pre-hypertensive men. *J Sports Sci*. 2011;**29**(14):1473-82. doi:10.1080/02640414.2011.593042.[PubMed: 21988649].
13. Nascimento L, Santos A, Lucena J, Silva L, Almeida A, Brasileiro-Santos M. Acute and chronic effects of aerobic exercise on blood pressure in resistant hypertension: study protocol for a randomized controlled trial. *Trials*. 2017;**18**(1):250. doi:10.1186/s13063-017-1985-5.[PubMed: 28578691]; [PubMed Central: PMC5457580].
14. Eicher JD, Maresh CM, Tsongalis GJ, Thompson PD, Pescatello LS. The additive blood pressure lowering effects of exercise intensity on post-exercise hypotension. *Am Heart J*. 2010;**160**(3):513-20. doi:10.1016/j.ahj.2010.06.005.[PubMed: 20826261].
15. Ramirez-Jimenez M, Morales-Palomo F, Pallares JG, Mora-Rodriguez R, Ortega JF. Ambulatory blood pressure response to a bout of HIIT in metabolic syndrome patients. *Eur J Appl Physiol*. 2017;**117**(7):1403-11. doi:10.1007/s00421-017-3631-z.[PubMed: 28493030].
16. Brook RD, Appel LJ, Rubenfire M, Ogedegbe G, Bisognano JD, Elliott WJ, et al. Beyond medications and diet: alternative approaches to lowering blood pressure: a scientific statement from the american heart association. *Hypertension*. 2013;**61**(6):1360-83. doi:10.1161/HYP.0b013e318293645f.[PubMed: 23608661].
17. Badrov MB, Bartol CL, DiBartolomeo MA, Millar PJ, McNevin NH, McGowan CL. Effects of isometric handgrip training dose on resting blood pressure and resistance vessel endothelial function in normotensive women. *Eur J Appl Physiol*. 2013;**113**(8):2091-100. doi:10.1007/s00421-013-2644-5.[PubMed: 23588257].
18. Millar P, MacDonald M, McCartney N. Effects of isometric handgrip protocol on blood pressure and neurocardiac modulation. *Int J Sports Med*. 2011;**32**(03):174-80. doi:10.1055/s-0030-1268473.[PubMed: 21165806].
19. Souza LR, Vicente JB, Melo GR, Moraes VC, Olher RR, Sousa IC, et al. Acute hypotension after moderate-intensity handgrip exercise in hypertensive elderly people. *J Strength Cond Res*. 2018;**32**(10):2971-7. doi:10.1519/JSC.0000000000002460. [PubMed: 29384998].
20. Van Assche T, Buys R, De Jaeger M, Coeckelberghs E, Cornelissen V. One single bout of low-intensity isometric handgrip exercise reduces blood pressure in healthy pre-and hypertensive individuals. *J*

Sport Med Phys Fit. 2017;**57**(4):469-75. doi:10.23736/S0022-4707.16.06239-3.[PubMed: 27029960].
21. Carlson DJ, McFarlane JR, Dieberg G, Smart NA. Rate pressure product responses during an acute session of isometric resistance training: a randomized trial. *J Hypertens Cardio*. 2017;**2**(3):1.
22. Ash GI, Taylor BA, Thompson PD, MacDonald HV, Lamberti L, Chen MH, et al. The antihypertensive effects of aerobic versus isometric handgrip resistance exercise. *J Hypertens*. 2017;**35**(2):291-9. doi:10.1097/HJH.0000000000001176.[PubMed: 27861249]; [PubMed Central: PMC5713890].
23. Shakoor E, Salesi M, Jahromi MK, Sadeghi H, Karimi MH, Yusof A. The effect of exercise on interferon gamma, body fat and bmi of kidney transplant patients. *Rev Bras Med Esporte*. 2018;**24**(5):333-7. doi:10.1590/1517-869220182405187030.
24. Sharman JE, La Gerche A, Coombes JS. Exercise and cardiovascular risk in patients with hypertension. *Am J Hypertens*. 2015;**28**(2):147-58. doi: 10.1093/ajh/hpu191.[PubMed: 25305061].
25. Dorans KS, Mills KT, Liu Y, He J. Trends in prevalence and control of hypertension according to the 2017 American College of Cardiology/American Heart Association (ACC/AHA) guideline. *J Am Heart Assoc*. 2018;**7**(11):e008888. doi:10.1161/JAHA.118.008888.[PubMed: 29858369]; [PubMed Central: PMC6015372].
26. Gibbons RJ, Balady GJ, Beasley JW, Bricker JT, Duvernoy WF, Froelicher VF, et al. ACC/AHA guidelines for exercise testing: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (committee on exercise testing). *J Am Coll Cardiol*. 1997;**30**(1):260-311. doi: 10.1016/s0735-1097(97)00150-2.[PubMed: 9207652].
27. Angadi SS, Mookadam F, Lee CD, Tucker WJ, Haykowsky MJ, Gaesser GA. High-intensity interval training vs. moderate-intensity continuous exercise training in heart failure with preserved ejection fraction: a pilot study. *J Appl Physiol (1985)*. (Bethesda, Md : 1985). 2015;**119**(6):753-8. doi:10.1152/japplphysiol.00518.2014.[PubMed: 25190739].
28. Ketelhut S, Milatz F, Heise W, Ketelhut RG. Influence of a high-intensity interval training session on peripheral and central blood pressure at rest and during stress testing in healthy individuals. *Vasa*. 2016;**45**(5):373-7. doi:10.1024/0301-1526/a000560.[PubMed: 27594392].
29. Olher RRV, Bocalini DS, Bacurau RF, Rodriguez D, Figueira Jr A, Pontes Jr FL, et al. Isometric handgrip does not elicit cardiovascular overload or post-exercise hypotension in hypertensive older women. *Clin Interve Aging*. 2013;**8**:649-55. doi:10.2147/CIA.S40560.[PubMed: 23766641]; [PubMed Central: PMC3678710].
30. Pagonas N, Vlatsas S, Bauer F, Seibert FS, Zidek W, Babel N, et al. Aerobic versus isometric handgrip exercise in hypertension: a randomized controlled trial. *J Hypertens*. 2017;**35**(11):2199-206. doi:10.1097/hjh.0000000000001445.[PubMed: 28622156].
31. Carpio-Rivera E, Moncada-Jimenez J, Salazar-Rojas W, Solera-Herrera A. Acute Effects of Exercise on Blood Pressure: A Meta-Analytic Investigation. *Arq Bras Cardiol*. 2016;**106**(5):422-33. doi:10.5935/abc.20160064.[PubMed: 27168471]; [PubMed Central: PMC4914008].
32. Taylor KA, Wiles JD, Coleman DD, Sharma R, O'Driscoll JM. Continuous Cardiac Autonomic and Haemodynamic Responses to Isometric Exercise. *Med Sci Sports Exerc*.2017;**49**(8):1511-9. doi:10.1249/mss.0000000000001271.[PubMed: 28708775].
33. McGowan CL, Visocchi A, Faulkner M, Verduyn R, Rakobowchuk M, Levy AS, et al. Isometric handgrip training improves local flow-mediated dilation in medicated hypertensives. *Eur J Appl Physiol*. 2007;**99**(3):227-34. doi:10.1007/s00421-006-0337-z.[PubMed: 17106718].
34. Millar PJ, McGowan CL, Cornelissen VA, Araujo CG, Swaine IL. Evidence for the role of isometric exercise training in reducing blood pressure: Potential mechanisms and future directions. *Sports Med*. 2014;**44**(3):345-56. doi:10.1007/s40279-013-0118-x. [PubMed: 24174307].
35. Bertagnoli K, Hanson P, Ward A. Attenuation of exercise-induced ST depression during combined isometric and dynamic exercise in coronary artery disease. *Am J Cardiol*. 1990;**65**(5):314-7. doi:10.1016/0002-9149(90)90294-b.[PubMed: 2301259].
36. O'Connor P, Sforzo GA, Frye P. Effect of breathing instruction on blood pressure responses during isometric exercise. *Phys Ther*.1989;**69**(9):757-61. doi:10.1093/ptj/69.9.757.[PubMed: 2772038]