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ORIGINAL RESEARCH

The effect of acute high-intensity interval exercise on post-exercise blood pressure in post coronary artery bypass graft surgery patients: a pilot study

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Abstract. Coronary artery disease is the main cause of death worldwide. Coronary artery bypass graft (CABG) is a preferred treatment option for multi-vessel disease and left main disease patients. Physical training (recovery) enhances exercise tolerance, an activity of daily living, and quality of life in this patient. For this, the aim of the current study was to investigate the effect of acute high-intensity interval exercise on post-exercise blood pressure in CABG patients. In this study, all patients underwent open-heart surgery at least 1 month before involvement in the study. All Subjects were included after Medical rigorous screening. Participants carried out two experimental sessions of high-intensity interval exercise (HIIE) and mild continuous exercise (MCE) with a minimum of 72 h intervals: This study employed a randomized, cross-over design, Brachial systolic blood pressure (SBP) and diastolic blood pressure (DBP) and heart rate (HR) were measured Immediately before (pre) and after (post) and approximately15 min(post-15) and 30 min (post-30) after each exercise bout. The Split-Plot Analysis of Variance with repeated measures (group × time) was used to analyze the data. Significant post-exercise increases in SBP, and HR were seen following each protocol ($p<0.05$). Following two bouts, SBP decreased at 15- and 30-min post-exercise in two groups but this decline was more in the HIIE group than MCE. Based on the findings of this study, both high-intensity intermittent and continuous exercise can improve heart function in CABG patients by diminishing BP.

Keywords. Bypass surgery, hypertension, interval exercise, post-exercise hypotension.

Introduction

Coronary artery disease (CAD) is the main cause of death worldwide (Lozano et al., 2013) and in Iran (Ghashghaei et al., 2012). Although, Coronary artery disease patients are unremarkably associated with various risk factors and physical limitations. Potential identified risk factors for both males and females are hypertension, obesity smoking, and physical inactivity. Coronary artery bypass graft (CABG) is a preferred treatment option for multi-vessel disease and left main disease patients (Kaul et al., 2010). Cardiac Rehabilitation (CR) is an interdisciplinary team approach to patients with functional limitations secondary to heart disease and known to have favorable effects in post-CABG patients (Nauman et al., 2010). Physical training (aerobic exercise) enhances exercise tolerance, the activity of daily living, and quality of life. According to the American College of Sports Medicine (ACSM), any sport or activity that works large groups of muscles is continually maintained and performed rhythmically, which is defined as aerobic or cardiovascular exercise (ACSM, 2016).

The benefits of exercise-based cardiac rehabilitation on cardiovascular risk factors have

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been widely established in CAD patients. However, there is still controversy regarding the optimal exercise characteristics that yield the most beneficial effects in patients with CAD (Conraads et al., 2105). The “traditional” approach is to prescribe training at an intensity of 60 to 80% of peak VO_2, which results in an average increase of 20% for peak VO_2 (Guiraud et al., 2012). Intensity seems to be an important predictor of the effectiveness of cardiac rehabilitation programs, since a higher intensity leads to larger improvements in peak VO_2, even after adjustment for other training-related variables. However, higher intensity is difficult to maintain for a longer period; therefore, an interval structure is suggested by Mezzani et al. (Guiraud et al., 2010). Interval training consists of periods of high-intensity exercise alternated by periods of relative rest that make it possible for patients to complete short work periods at higher intensities. From a physiological point of view, high-intensity interval training (HIIT) stimulates cardiac contractility and poses a larger impact on the endothelium and skeletal muscle mitochondrial function compared to continuous training at moderate intensity (MCT), which could add to a more favorable effect on peak VO_2 (Mezzani et al., 2011). Whereas the implementation of high-intensity interval training (HIIT) is common practice in sports medicine, only a relatively small, single study has tested this approach in CABG patients (Ghashghaei et al., 2012). A recent meta-analysis, comprising 9 studies and 206 CAD patients, concluded that HIIT results in a 1.60 ml/kg/min larger benefit in peakVO_2 compared to MCT in patients with CAD. The HIIT group showed an improvement of 20.5% in peakVO_2 compared to only 12.8% in the MCT group, the latter being low compared to the average increase after three months of “traditional” cardiac rehabilitation (Pattyn et al., 2014).

HIIT has become a very popular form of exercise in recent years. This type of training is used in multiple places such as clinical settings, sports facilities, and recreational sports. HIIT has gained considerable attention as a suitable exercise program for a patient with cardiovascular diseases including CAD and heart failure. Investigations using various types of high-intensity interval training in CAD patients showed training-induced improvements in numerous physiological indices. In addition when compared with the current exercise program used in cardiac rehabilitation of high volume moderate-intensity endurance exercise (END), interval exercise has been shown to elicit superior improvements in indices of cardiorespiratory fitness, and endothelial function (Mezzani et al., 2011).

Beyond the classical increase in VO_2max that is the cornerstone of the fitness community, another favorable outcome of exercise training, as a modulating factor for cardiac risk factors, is hypertension (Jibala et al 2008). There are predictable reductions in blood pressure (BP) after a period of regular exercise. There are also acute reductions in BP following a single exercise bout. The term post-exercise hypotension (PEH), coined in 1993 by Michael Kenney and Douglas Seals, was used to describe the exaggerated decrease in BP after an exercise bout, post-exercise hypotension has been shown to last up to 22 hours.

To our knowledge, the post-exercise BP response to moderate-intensity exercise training was investigated in healthy people. Some researchers compared MCT and HIIT exercise from the metabolic and hormonal and neuromuscular perspectives (Pattyn et al., 2014). The effect of HIIT on PEH in CABG patients is not investigated and any research was not performed in this area. For this, the main purpose of this study was to determine whether PEH occurs following HIIT. A secondary purpose was to compare this response to MCT recommended common rehabilitation exercise bout.

Methods

In this study, all patients underwent open-heart surgery at Amirkabir hospital in Arak of IRAN between January to February of 2017. Following Institutional and Hospital Ethical Committee approval (IR.SSRI.REC.2020.205), a sample size of 21 patients was estimated as study subjects. All post-operative CABG subjects age group of 45-60 yrs. mentally stable, subjects willing to participate in the study enrolled in phase II cardiac rehabilitation were included in the study. Subjects were excluded if they fell in the high-risk category according to American College of Sports Medicine risk stratification guidelines, conditions that were contraindicated to exercise training (American College of Sports Medicine guidelines).

Five patients were excluded from this study; hence, 16 patients were included after obtaining informed consent. The inclusion criteria in both females and males were CABG patients, aged ≥45 years old, left ventricular ejection fraction (LVEF) ≤50%, and New York Heart Association criteria II or III. Patients with peripheral or vascular problems of the lower limb, abnormal body geometry such as amputation of the lower limbs, and unstable vital signs were excluded from the study. Demographic data were obtained through interview technique, which included occupation, smoking habit, history of musculoskeletal or neurological problem, family history of CAD, and physical activity level. Anthropometric measurements such as height, weight, and body mass index (BMI) were calculated using wall-mounted stadiometer and weight scale (SECA).

Procedures

Before initiating the tests, the participants underwent an anamnesis, a clinical evaluation, and BP, body fat mass, body mass index, weight, and height measurements. Then all of them underwent a familiarization session and participated in the peak power output (PPO) test. Afterward, participants carried out two experimental sessions with a minimum of 72 h intervals: This study employed a randomized, cross-over design. Participants were tested >2 h postprandial and were instructed to avoid caffeine, medications, and exercise on the day of testing. the participants were instructed not to ingest alcoholic or caffeinated drinks, not to perform strenuous physical activity in the previous 48 h, and to have their last meal 2 h before the beginning of the experimental sessions, two exercise bouts were performed at 10:00-12:00 AM to control diurnal variation in BP. The laboratory had a mean temperature of 21 ∘ C and a mean relative air humidity of 4o% to 45%.

Blood Pressure Measurements

Brachial systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using a standard mercury sphygmomanometer (ALPK2, Japan), taking the first and the fifth phases of Korotkoff sounds as SBP and DBP values, respectively. BP was taken in duplicate, and if values were within 5 mmHg of each other, the average of the two values was used for analysis. BPs were measured until two values within 5 mmHg were obtained. After a 5-min rest in the seated position, BP was measured three times during two different visits to the laboratory. On the occasion of each visit, BP was measured Participants were excluded if the average of the last two values obtained during each visit for SBP and DBP was greater than 139 and 89 mmHg, respectively. Immediately before (pre) and after (post) and approximately15 min(post-15) and 30 min (post-30) after each exercise bout, BP, and heart rate was assessed (Pattyn et al., 2014).

Peak Power Output Test

A 3-min warm-up at 20 W was performed before the test. Thereafter, initial power was set at 60W and increased by 15 W every minute. Verbal encouragements were given throughout the test. Criteria for exercise test cessation were RPE ≥8 IN 1-10 Scale, significant ECG abnormalities (ST-depression > 2 mm or ventricular arrhythmias), or abnormal blood pressure response. The power of the last completed stage was considered as the peak power output (PPO, in W) (Pescatello et al., 2004).

MCT Session

This exercise session was based on recommendations of the American Heart Association on exercise prescription in CHD patients, suggesting that exercise intensity should lie between 50% and 80% of PPO. We opted for an intensity of 70% of PPO. We chose to include the warm-up and the recovery in the exercise session and kept the intensity of exercise at 70% of PPO. Mean duration of 20 minutes was adopted as continuous exercise.

High-intensity Interval Exercise (HIIE) Session

HIIE session consists of a 10-min warm-up at 50% of PPO, followed by two sets of 10 min composed of repeated phases of 15 s at 100% of PPO interspersed by 15 s of passive recovery. Four minutes of passive recovery were allowed between the two sets, as well as a 5-min cool-down after the last 15-s exercise phase (Pescatello et al., 2004).

Statistical Analysis

All data were expressed as mean ± SD and were analyzed using SPSS software (v. 20). The Split-Plot Analysis of Variance (SPANOVA) with repeated measures (group × time) was used to analyze data and when the difference presented was significant, the Bonferroni post-hoc test was used for multiple comparisons. For all tests, $p<0.05$ was considered statistically significant.

Results

Subject characteristics, including age, high, body weight, and BMI are shown in Table 1. Figures 1, 2, and 3 compare the PEH and HR responses between protocols ($p<0.05$). A significant time effect was found for SBP, and HR ($p<0.05$). Significant post-exercise increases in SBP and HR were seen following each protocol (p<0.05). A significant interaction effect (group × time) was seen in SBP and HR variables (p<0.05). following two bouts, SBP increased from baseline at post-exercise and then decreased at 15- and 30-min post-exercise in two groups but this decline was more in the HIIT group than MCT (P<0.05). HR and DBP increased from baseline at post-exercise and then decreased at 15- and 30-min post-exercise in two groups (p<0.05). Regarding heart rate, between-group differences were significant only after exercise and it was higher in HIIT to MCT (p<0.05).

Discussion

In this study, 16 CABG patients (aged: 45 to 60 years) attended. The aim of this current study was to investigate the effect of acute high-intensity interval exercise on post-exercise blood pressure in post coronary artery bypass graft surgery patients. HR increased from baseline at post-exercise and then decreased at 15- and 30-min post-exercise in two groups but HR increase immediately after exercise was more in HIIT than MCT. This finding is in agrees with Rossow et al. (2011), this result is logical because HR is related to exercise intensity and HIIE is more intensive than MCT bout.

Systolic blood pressure (SBP) as a result of the exercise had raised up and then significantly decreased in both groups after 15 and 30 minutes. although, the reduction in the 30 min was more in HIIE than in MCT bout and SBP decreased in HIIE post 30 min slightly lower than the baseline level representing the favorable impact of these methods in reducing blood pressure.

Ramezani & Heidari (2016) showed that the acute resistance exercise could decrease SBP (Pescatello et al., 2004). Meyer et al. (1998) and Ciolac et al. (2009) showed a reduction in systolic and diastolic blood pressure during aerobic interval exercise. It is concluded from the findings of this study that doing high-intensity interval exercise caused a significant reduction in systolic blood pressure even lower than baseline. These results study protocol used lower extremity exercise as exercise protocol.

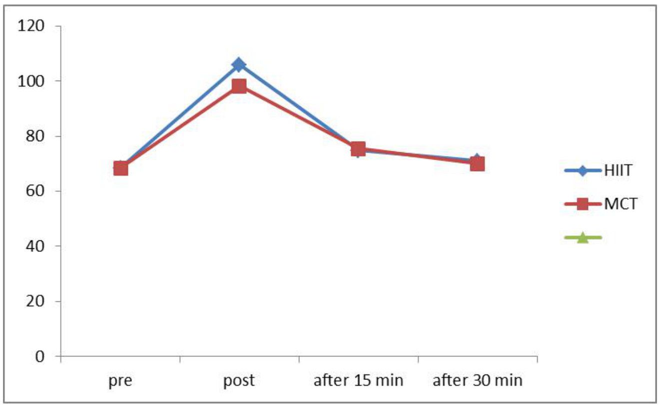

Figure 1. Heart rate in two groups at different times.

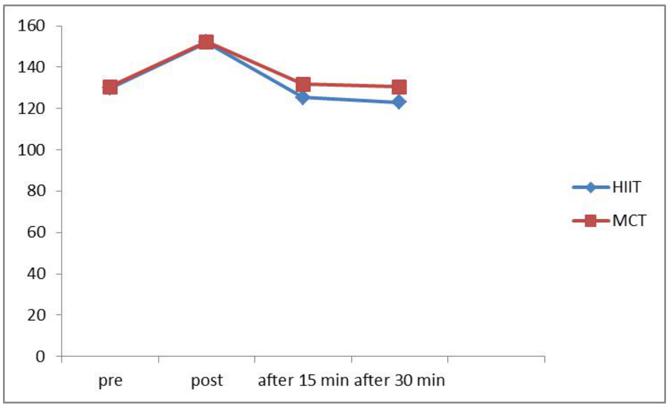

Figure 2. SBP in two groups at different times.

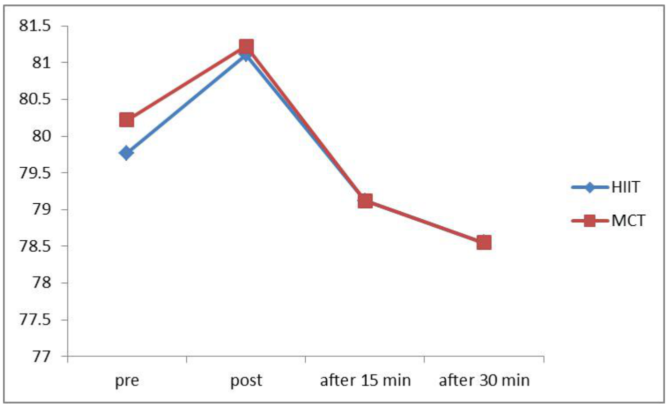

Figure 3. DBP in two groups at different times.

Our findings were inconsistent with Heidi et al. (2021) results. They assessed if post-exercise central hemodynamics are modified due to an upper and lower body and altered thermal state related to exercise in the cold in patients with coronary artery disease (CAD). CAD patients ($n = 11$) performed moderate-intensity lower-body exercise (walking at 65–70% of HRmax) and rested in neutral (+ 22 °C) and cold (− 15 °C) conditions. In another protocol, CAD patients ($n = 15$) performed static (five 1.5 min work cycles, 10–30% of maximal voluntary contraction) and dynamic (three 5 min workloads, 56–80% of HRmax) upper-body exercise at the same temperatures. The results showed acute dynamic lower and upper-body exercise mainly lowers post-exercise central BP in CAD patients irrespective of the environmental temperature. In contrast, central systolic BP was elevated after static exercise in the cold. They concluded that CAD patients likely benefit from dynamic exercise peripherally from lower body exercise. Blood pressure may be related to different BP and health status, for these (Costa et al., 2022) in cross-sectional research investigated whether the immediate post-exercise systolic BP following brief moderate exercise is associated with arterial stiffness in older females with different BP statuses. This cross-sectional study included 191 older females aged 60–80 years without known cardiovascular disease (CVD). Arterial stiffness was determined by aortic pulse wave velocity (aPWV). Systolic BP was measured before and immediately following a 3-min moderate walking test. Specific quartile-based thresholds were used to define an exaggerated immediate post-exercise systolic BP for hypertensive and normotensive older females. Traditional CVD risk factors were assessed (covariates). Older females from the highest quartile of immediate post-exercise absolute systolic BP showed higher aPWV compared to their peers from the lowest quartile ($\beta = .22$ m/s, $p = .018$). The quartile-based threshold to define the exaggerated post-exercise systolic BP was higher in hypertensive than in normotensive older females (174 vs. 172 mmHg). These researchers concluded that exaggerated immediate post-exercise systolic BP following a brief moderate exercise is associated with higher arterial stiffness in older females with different BP statuses.

These results demonstrated that an acute bout of exercise increased heart rate more in the HIIE group and after recovery heart rate decreased to baseline level in the two groups similarly. Villelabeitia-Jaureguizar et al. (2017) performed a protocol to compare the effects of a moderate continuous training (MCT) versus a high-intensity interval training (HIIT) program on VO_2peak and HRR. Their subjects were Seventy-three coronary patients assigned to either HIIT or MCT groups for 8 weeks. Incremental exercise tests in a cycle ergometer were performed to obtain VO_2peak data and heart rate was monitored during and after the exercise test to obtain heart rate recovery data. Their results showed both exercise programs significantly increase VO_2peak with a higher increase in the HIIT group (HIIT: 4.5 ± 4.46 ml/kg/min vs MCT: 2.46 ± 3.57 ml/kg/min; $p = 0.039$). High-intensity interval training resulted in a significant increase in HRR in the first and second minutes of the recovery phase (15.44 ± 7.04 vs 21.22 ± 6.62, $p < 0.0001$ and 23.73 ± 9.64 vs 31.52 ± 8.02. $p < 0.0001$, respectively). The results of this research showed that the application of HIIT to patients with chronic ischemic heart disease of low risk resulted in an improvement in VO_2peak, and also improvements in post-exercise heart-rate recovery, compared with continuous training.

Potential mechanisms of PEH include a decrease in cardiac output (CO) and stroke volume (SV), although, a decrease in total peripheral resistance (TPR) is thought to play the primary role in decreasing BP. The vasodilation, causing a decrease in TPR as well as a decrease in sympathetic nerve activation, contributes the most to PEH. Also, potentially contributing is the effect that exercise has on resetting baroreceptors. Afferent skeletal muscle receptors apparently play a large role in setting the baroreflex to keep the pressure low in the vascular system. Another aspect of vasodilation that has been studied in the production of nitric oxide (NO). Nitric oxide is released from the endothelium of the vessels during exercise, especially more vigorous exercise to allow for blood flow to the working muscles (Ciolacet al., 2009).

Today, a limited number of studies are conducted on the implementation of interval training in patients who have heart disease. Thus, currently, the effects of interval exercise in these patients are unknown. Therefore, more research is needed in this area.

Conclusion

Based on the findings of this study, both high-intensity intermittent and continuous exercise can improve heart function in CABG patients by diminishing BP. However, a high-intensity interval training program not only is beneficial but also without risk to patients, this study provides preliminary evidence in support of HIIT prescriptions in patients with CABG and supports the continued investigation of alternative exercise prescriptions for individuals with CABG, including low-volume HIT protocols.

Authors' Contribution

Study Design: NH, MK, AR, KM, RG; Data Collection: NH, MK, AR; Statistical Analysis: NH, RG; Manuscript Preparation: NH, MK, AR; Funds Collection: KM, RG.

Ethical Approval

The study was approved by the Institutional and Hospital Ethical Committee (IR.SSRI.REC.2020.205) at Amirkabir Hospital and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Funding

The authors declare that the study received no funding.

Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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