# Comparison of Cardiac Rehabilitation Exercise on Hemodynamic and Biomechanical Indices between Middle-Aged and Older Males with Coronary Artery Disease Following a Cardiac Event or Therapeutic Interventions

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## Abstract

**Introduction:** Although it is documented that cardiac rehabilitation has a positive effect on hemodynamics and functional biomechanics of the heart, the effect of various types of exercise in this field, in different periods of life such as middle-aged and older male adults, is thought-provoking. This study was undertaken to compare cardiac rehabilitation training on selected hemodynamic and biomechanical indices between middle-aged and older male adults with coronary artery disease following a cardiac event or therapeutic interventions. **Materials and Methods:** Thirty two middle-aged and older male adults with coronary artery disease were randomly and equally divided into two aerobic and concurrent exercise groups. With the permission of a cardiologist in the imaging center, the exercise test was performed in the pre-test stage. After eight weeks of cardiac rehabilitation training in the biomechanics laboratory of the physical medicine center, the post-test phase was performed. To analyze the data from mean and standard deviation, one-way analysis of variance with Bonferroni post hoc test was utilized to check differences between groups at the significant level of $P \leq 0.05$. **Results:** After eight weeks of aerobic training, a significant difference was observed in the improvement of functional capacity and diastolic blood pressure ($P \leq 0.05$) between the middle-aged and older male adults groups, but not for left ventricular ejection fraction indices, resting heart rate and systolic blood pressure ($P > 0.05$). Followed by concurrent training as well, a significant difference was observed in the improvement of functional capacity indices, left ventricular ejection fraction, resting heart rate, and diastolic blood pressure ($P \leq 0.05$), but not for index of systolic blood pressure was not observed ($P > 0.05$). **Conclusion:** The results of the research confirmed the effectiveness of both types of aerobic and concurrent training in improving hemodynamic and functional biomechanics of the heart. In the comparison between middle-aged and older male adults, the effect of aerobic exercise on the older male adults and the effect of concurrent exercise on the middle-aged can be considered more prominent. It seems that the priority of using concurrent training over aerobic training can be taken into consideration.

**Keywords:** Training; Cardiac Complications; Biomechanics Of Heart Function; Coronary Artery Disease

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## Introduction

The onset of coronary artery disease (CAD) in affected individuals is a deviation from the normal course of life (1). The bitter cause of this disease can be a cardiac event such as myocardial infarction or therapeutic interventions such as coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) (2). This disease is one of the known types of coronary heart disease mainly caused by atherosclerosis of the coronary arteries. The process of atherosclerosis is an inflammatory response to endothelial damage to the arterial wall. Biomechanical factors and hemodynamic damage are the main causes of endothelial tissue damage (3). This clinical problem leads to a decrease and disruption of myocardial blood flow to the heart, and permanent cessation of myocardial blood flow causes dysfunction of the muscle and its necrosis (4). The spread of atherosclerosis can result in heart failure and sometimes fatal loss (3).

There are many different biomechanical variables used to quantify cardiac performance. Although the primary function of the heart is to pump blood throughout the body, the most useful function is to quantitatively measure the actual volume of blood pumped (5). For example, the ejection fraction is an index of the contractile force of the heart. An ejection fraction less than 40% indicates a decrease in left ventricular function and probably suggests the need to treat heart failure (6).

It has been documented that physical activity can reduce the risk of cardiovascular disease by affecting coronary risk factors (3). Accordingly, nowadays, the guidelines of international clinics for the treatment of heart disease consider exercise therapy as a key element in the rehabilitation of heart patients (7). Cardiac rehabilitation helps increase aerobic capacity and reduce process of atherosclerosis and risk of cardiac events (3). Exercise training and regular physical activities provide protective effects against major cardiovascular events. In addition, increasing the volume of physical activity and increasing the intensity of physical activity from low to moderate and from moderate to high have an effect on some cardiovascular risk indicators. Adding weight training to aerobic physical activity is also important in reducing the risk of coronary heart disease (8).

Exercise therapy over time increases the ability of the cardiovascular system to deliver oxygen to the tissues and the ability of the muscles to consume oxygen. Following regular exercise, increasing cardiac output along with environmental adaptation can increase the maximum oxygen consumption by 2 or 3 times. It also reduces hemodynamic variables such as resting heart rate and blood pressure. By improving the functional capacity, it reduces the metabolic needs and blood supply of person to perform daily life activities (9). Therefore, paying attention to sports rehabilitation can play a useful role in the recovery of coronary artery patients (3).

Although the effectiveness of cardiac rehabilitation based on exercise on mortality, morbidity, and quality of life related to the health of coronary heart patients has been widely accepted (10), in different periods of life such as middle age and old age, there is no consensus about the effect of different exercises, intensity, duration, and even the type of rehabilitation courses. Also, there is no consensus about the intensity, duration, and even the type of rehabilitation courses.

Middle-age is one of the most important stages of life accompanied by certain physical changes. This period of life is particularly important in terms of the transition from youth to old age (11). Aging process also leads to mental decline, reduced physical ability, and increased risk of disease (12). The results of a research showed that cardiovascular diseases, especially coronary artery disease, have been the most important reason for the majority of middle-aged and older male adults to visit medical centers (13).

Researchers are studying various exercise protocols, such as aerobic, resistance, and combination exercises, in more detail to achieve the greater and better benefits of exercise. In this regard, Gaeini *et al.* reported that a combination of aerobic-resistance training program and aerobic exercise can improve the functional capacity of heart patients after coronary artery bypass surgery (14), while Ghroubi, *et al.* reported that strength training increased performance capacity more than endurance training (15).

Due to some contradictions in this field and also little research in Iran, it is necessary to compare cardiac rehabilitation research in both aerobic and concurrent training methods separately among middle-aged and older male adults. The purpose of the present study was to evaluate an eight-week duration cardiac rehabilitation training on selected hemodynamic and biomechanical parameters between middle-aged and older male adults with coronary artery disease following a cardiac event or therapeutic interventions.

## Materials and Methods

The present study was quasi-experimental, with pre-test and post-test research design. The statistical population of the study consisted of middle-aged and older male adults with coronary artery disease. One month has passed since the occurrence of heart complications or medical interventions in these people. In order to continue the treatment and according to the recommendation and diagnosis of the cardiologist, they were referred for cardiac rehabilitation. They were not forbidden to exercise.

The basis for selecting the subjects in the first stage was non-smoking, alcohol, and drugs which affect the research indices. The sample size was determined using G-power software and considering the significance level of 0.05, power 0.7, and effect size 0.6, 32 subjects were considered. The middle-aged (n=16) and older male adults (n=16) groups were each randomly divided into two groups of aerobic exercise (n=8) and concurrent (n=8). All of them were considered low-risk patients.

The individuals completed a personal information questionnaire. After performing diagnostic examinations and fulfilling the criteria for entering the research, in order to observe ethical considerations, they obtained a written informed consent form to participate in the research. Kharazmi University Research Institute of Motor Sciences approved this research with ethical code: IR-KHU.KRC.1000.163.

Cardiac stress test and echocardiography on pre-test stage were performed on subjects to participate in the rehabilitation course. The cardiac rehabilitation exercise, which included aerobic and concurrent exercises, was performed under the supervision of a cardiac monitoring nurse. After 8 weeks of training, the post-test stage was conducted.

***Table 1.*** Exercise-based heart rehabilitation training protocol

| Exercise steps | | Type (type of exercise) | | Time (minute/day) | Intensity A:(%-HRMAX) R:(%-1RMAX) | Frequency (day/week) | Images |
|---|---|---|---|---|---|---|---|
| Warm up | | Light walking and cycling | 1 | 5 | 20 | 3 |  |
| | | Stretching movement | 1 | 5 | 20 | 3 | |
| The main exercise | Aerobic | Stationary and manual bicycle | 3 | 3-5 | 50-80 | 3 |  |
| | | treadmill | 3 | 5-10 | 50-80 | 3 | |
| | | Elliptical Trainer | 3 | 3-6 | 50-80 | 3 | |
| | | Twister Machine | 3 | 1 | 50-80 | 3 | |
| | Resistance | Specific movements with weights | 3 | 10 | 50-80 | 2 |  |
| | | App Shipper device | 3 | 5 | 50-80 | 2 | |
| Return to the initial state | | Light walking and cycling | 1 | 5 | 20 | 3 |  |
| | | Stretching movement | 1 | 5 | 20 | 3 | |

The Heart Health History Questionnaire (CHHQ) was used to evaluate cardiovascular status. To measure the height, weight and body mass index (BMI) of the subjects, a body composition measuring device, Tanit a 480 BC, made in Japan, was used. To measure the systolic function of the left ventricle, an echo doppler device (Vivid-S5 manufactured by General Electric Company) was utilized. The cardiac stress test system (CosMED model) was used to determine the capacity and ability of the heart (recovery heart rate and reduction of pulse at rest).

Exercise groups performed sub-maximal exercises for eight weeks three times a week. The intensity of training for each person was individually calculated based on the Karvonen formula.  This formula uses maximum and resting heart rate with optimal exercise intensity to achieve the target heart rate (16). Heart rate monitor was also considered to ensure accurate monitoring of exercise intensity. The subjects in the control group did not exercise regularly during eight weeks.

Target Heart Rate=[(max HR−resting HR)×%Intensity] +resting HR

The Nakhton exercise test was used to measure the functional capacity of the subjects, to determine cardiovascular ability and intensity of cardiac rehabilitation exercises.

The training protocol used (Table 1), consisted of three sessions per week of rehabilitation exercises including warm-up, core training, and return to the initial state. The duration of each rehabilitation activity session was 40 to 60 minutes. The duration of the main phase of exercise was one minute per session and its intensity was increased by approximately 4% of the maximum heart rate each week (the duration of the first exercise session was 20 minutes). Heart rate, blood pressure, and possible electrocardiogram changes were monitored during the exercises.

In order to collect data, first, the system setup was done and the location of the device was determined and calibrated in advance.Then, the environment was prepared for doing the tests and the environmental conditions of light, temperature, etc. were controlled. After 8 weeks of the rehabilitation program, in order to check the effect of training on the desired indices of the subjects, a post-test was conducted. Finally, on the obtained data, data processing including checking, filtering, normalization, and analysis of data were performed.

Mean and standard deviation were used to describe the data. Shapiro-Wilk test was performed to check the normality of the data and Leven test was utilized to check the homogeneity of the variance of the data. Considering the normality of the data, after performing the rehabilitation exercises, the one-way analysis of variance test was applied. If it was significant, the Bonferroni test was used. To determine the difference between the groups, the indices of resting metabolism, left ventricular ejection fraction, systolic blood pressure, diastolic blood pressure, and resting heart rate were used at the significance level of $P \leq 0.05$.All calculations were performed using SPSS22 software.

***Table 2.*** The Mean (SD) of demographic characteristics of subjects (N=32)

| Parameter | Test | Older male adults | | Middle-aged | |
|---|---|---|---|---|---|
| | | Aerobic | Concurrent | Aerobic | Concurrent |
| **Age (years)** | - | 62.25 (1.83) | 61.62 (1.99) | 48.12 (2.47) | 51.50 (3.66) |
| **Height (cm)** | - | 173.50 (3.66) | 170.25 (6.58) | 179.8.61) | 174.12 (7.25) |
| **Weight (kg)** | Pre | 76.25 (7.59) | 77 (7.70) | 85 (8.46) | 77.12 (7.86) |
| | Post | 75.62 (6.47) | 75.25 (6.49) | 82.75 (6.90) | 75 (6.50) |
| **Body mass index (kg/m²)** | Pre | 25.35 (2.37) | 26.52 (1.83) | 26.21 (1.58) | 25.5 (1.67) |
| | Post | 25.13 (2.13) | 25.93 (1.37) | 25.53 (1.09) | 24.71 (1.09) |
| **Body surface index (m²)** | Pre | 1.91 (0.10) | 1.90 (0.12) | 2.06 (0.12) | 1.92 (0.13) |
| | Post | 1.90 (0.08) | 1.88 (0.11) | 2.03 (0.11) | 1.90 (0.11) |

***Table 3.****Comparison of the results of one-way analysis of variance and Bonferroni test between training groups*

| variables | | group | Results of analysis of variance | | | | | | Bonferroni post hoc test results | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | aerobic | | | concurrent | | | Dispute Between groups | Aerobic | Concurrent |
| | | | Mean (SD) | F | p | Mean (SD) | F | p | | p | p |
| Biomechanical | Drain fraction Left ventricle | older | 57.50 (6.54) | 2.04 | 0.16 | 52.50 (9.63) | 129.19 | 0.00* | older male adults/ middle-aged | 0/21 | 0/00* |
| | | middle-aged | 49.75 (9.92) | | | 58.75 (7.90) | | | | | |
| | functional capacity | older | 9.61 (2.21) | 9.48 | 0.001* | 8.15 (2.24) | 33.05 | 0.00* | older male adults/ middle-aged | 0.004* | 0.00* |
| | | middle-aged | 9.21 (1.42) | | | 10.08 (3.10) | | | | | |
| Hemodynamical | Diastolic blood pressure (cmHg) | older | 75 (3.77) | 236.34 | 0.00* | 73.12 (3.72) | 1.44 | 0.00* | older male adults/ middle-aged | 0.003* | 0.00* |
| | | middle-aged | 74.37 (4.17) | | | 71.25 (2.31) | | | | | |
| | Resting heart rate (bpm) | older | 66.25 (9.16) | 2.46 | 0. 11 | 59.37 (7.76) | 559.56 | 0.00* | older male adults/ middle-aged | 0.17 | 0.00* |
| | | middle-aged | 70.62 (1.42) | | | 62.50 (8.01) | | | | | |
| | Systolic blood pressure (cmHg) | older | 120 (5.34) | 1.02 | 0.38 | 120 (5.34) | 1206.06 | 0.258 | older male adults/middle-aged | 0.23 | 0.28 |
| | | middle-aged | 116.25 (5.17) | | | 115 (5.34) | | | | | |

**The mean difference at the level of 0/05 is significant*

## Results

Demographic and clinical characteristics of patients participating in the study are presented in Table 2. It is noteworthy that none of the patients in the intervention and control groups had a recurrence of cardiac event during the study period and all subjects were analyzed. Examination of the Shapiro-Wilk test showed that the distribution of all measured variables was normal.

The results of the one-way analysis of variance for aerobic exercise showed a significant difference in the indices of functional capacity and diastolic blood pressure between middle-aged and older male adults with coronary artery disease following a cardiac event or therapeutic interventions ($P \leq 0.05$). However, no significant difference was observed in the indices of left ventricular ejection fraction, resting heart rate, and systolic blood pressure ($P > 0.05$, Table 3. Therefore, a Bonferroni follow-up test was used to find the difference between the groups.

The results of the Bonferroni follow-up test showed that there was a significant difference in the indices of functional capacity and diastolic blood pressure between the two aerobic training groups of middle-aged and older male adults. ($P \leq 0.05$, Table 3). Therefore, it can be concluded that the effect of eight weeks of aerobic exercise on functional capacity and diastolic blood pressure was different between middle-aged and older male adults. So, in the comparison between the two groups, the effect of aerobic exercise was more prominent in older male adults.

The results of the one-way analysis of variance for concurrent exercise showed, a significant difference was observed in the indices of functional capacity, left ventricular ejection fraction, resting heart rate, and diastolic blood pressure between middle-aged and older male adults with coronary artery disease following a cardiac event or therapeutic interventions ($P \leq 0.05$). But, no significant difference in systolic blood pressure index was observed ($P > 0.05$), (Table 3). Therefore, a Bonferroni follow-up test was used to find the difference between the groups.

The results of the Bonferroni follow-up test showed that, there was a significant difference in the indices of functional capacity, left ventricular ejection fraction, resting heart rate, and diastolic blood pressure between the two concurrent exercise groups of middle-aged and older adult men ($P \leq 0.05$), (Table 3). Therefore, it can be concluded that the effect of eight weeks of concurrent exercise on indices of functional capacity, left ventricular ejection fraction, diastolic blood pressure, and resting heart rate was different between middle-aged and older male adults. So, in the comparison between the two groups, the effect of concurrent exercise was more prominent in middle-aged men.

## Discussion

The aim of the present study was to compare eight weeks of cardiac rehabilitation training on selected hemodynamic and biomechanical indices between middle-aged and older male adults with coronary artery disease following a cardiac event or therapeutic intervention. Findings of research on aerobic exercise showed no significant difference in the indices of left ventricular ejection fraction, resting heart rate, and systolic blood pressure between the middle-aged and older male adults. But, a significant difference was observed in the indices of functional capacity and diastolic blood pressure. Findings in concurrent exercise did not show a significant difference in systolic blood pressure index between the middle-aged and older male adults.But a significant difference was observed in the indices of left ventricular ejection fraction, resting heart rate, diastolic blood pressure, and functional capacity.

The findings of the research comparing the effect of aerobic exercise on systolic blood pressure showed no significant difference between middle-aged and older male adults. These results were consistent with the findings of some studies (2, 17, 18) and did not agree with the results reported by some researchers (3, 19-23). The findings of the research comparing the effect of concurrent exercise on systolic blood pressure showed that no significant difference was observed between middle-aged and older male adults. This index did not improve significantly. These results were consistent with the findings of some studies (2, 17, 18), and did not agree with the results reported by some researchers (19, 22, 24). The following reasons can be considered for the lack of effect of exercise on the systolic blood pressure of the participants in the present study: the systolic blood pressure of most patients was not high before the rehabilitation period, the blood pressure was under control by taking antihypertensive drugs, and participants had a controlled diet. In addition, the intensity of exercise used can be considered as one of the reasons for the lack of significant effect of exercise on patients' systolic blood pressure, and therefore, using a higher level of exercise intensity can enhance effectiveness.

The research findings comparing the effect of aerobic exercise on diastolic blood pressure showed a significant difference between middle-aged and older male adults. This improvement was significant in the direction of reduction and was more in older male adults. These results are consistent with the findings of some previous researchers (2, 14) and inconsistent with the findings of other researchers (3, 22-26) . The research findings comparing the effect of concurrent exercise on diastolic blood pressure showed a significant difference between middle-aged and older male adults. This improvement was significant in the direction of reduction and was more in older male adults. These results are consistent with the findings of researchers (2, 15, 27) and do not agree with the findings of other researchers (3, 21, 25, 26, 28). The diastolic blood pressure index can be improved after participating in exercise due to reduced resistance to blood flow, especially due to the effect of concurrent exercise.

The findings of the research comparing the effect of aerobic exercise on resting heart rate showed that no significant difference was observed between middle-aged and older male adults. These results were consistent with the findings of some studies (3, 18, 21, 25, 29). Aerobic exercise improves cardiac hemodynamic responses in patients with coronary arteries by creating environmental and central cardiac adaptations (26). The research findings comparing the effect of concurrent exercise on resting heart rate demonstrated a significant difference between middle-aged and older male adults. This improvement was significant in the direction of reduction and was more in middle-aged men. These results were consistent with the findings of some previous researchers (2, 15, 27) and did not agree with the findings of other researchers (23, 26, 28, 30-32). These studies reported the improvement of resting heart rate after concurrent exercise. These studies on the effect of exercise on hemodynamic indices showed that hemodynamic indices were improved by increasing dilatation and decreasing vascular resistance. Therefore, doing exercise, especially concurrent exercise, could have a positive effect on resting heart rate and maximum heart rate.

The findings of the research comparing the effect of aerobic exercise on left ventricular ejection fraction showed that no significant difference was observed between middle-aged and older male adults. These results were consistent with the findings of some studies (2, 33-37), which reported discharge fraction values unchanged, and inconsistent with the results reported by some other researchers (38, 39). The research findings comparing the effect of concurrent exercise on left ventricular ejection fraction indicated a significant difference between middle-aged and older male adults. This improvement was more in middle-aged men. These results are consistent with the findings of previous studies (2, 3, 18, 29, 34) and do not agree with the findings of other researchers(38, 39),who reported the values of the ejection fraction unchanged.

The research findings comparing the effect of aerobic exercise on functional capacity showed a significant difference between middle-aged and older male adults. This improvement was more in older male adults. These results were consistent with the findings of previous researchers (2, 22, 23, 26, 32).The research findings comparing the effect of concurrent exercise on functional capacity showed a significant difference between middle-aged and older male adults. This improvement was more in middle-aged men. These results were consistent with the findings of previous researchers (2, 22, 26, 27). A cardiac rehabilitation program can improve functional capacity in heart patients. The improvement in functional capacity may have been due to environmental adaptations as a result of exercise. Functional capacity rate can be affected by improvement in exercise hemodynamics, decreased environmental resistance, and increased cardiac output (32).

Based on the evidence obtained, performing concurrent exercises safely and with high intensity, as opposed to aerobic-continuous exercise with medium to high duration, can lead to improvements in the functional capacity of the heart and the quality of life of cardiovascular patients. That means in coronary patients, high-intensity compound exercise is typically superior to moderate-to-high-intensity sustained exercise for improved cardiorespiratory fitness, VO2 peak values, and more positive adaptations in cardiac structure and function (19).

## Conclusion

According to the results of the present study, both aerobic and concurrent exercises are effective in improving hemodynamic and biomechanical indices of cardiac function in middle-aged and older male adults with coronary artery disease following a cardiac event or therapeutic interventions. In comparison between middle-aged and older male adults, the effect of aerobic exercise in older male adults and concurrent exercise in the middle-aged were more prominent. It seems that the priority of using concurrent exercise over aerobic exercise can be considered.

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***Conflict of interest***

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***Authors' contributions***

All authors made substantial contributions to the conception, design, analysis, and interpretation of data.

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