Section: Physiology

JAMP

Original Research Article

THE EFFECTS OF ACUTE EXERCISE ON CARDIOVASCULAR FUNCTION IN HEALTHY INDIVIDUALS: AN OBSERVATIONAL STUDY USING ECHOCARDIOGRAPHY

B.A. Madhuri[1], G. Geethavani[2], Qureshi Samar Afreen[3], Tangellapalli Sreenivas[4]

[1]Associate Professor, Department of Physiology, RVM Institute of Medical Sciences, Laxmakkapally Village, Mulugu, Siddipet, Telangana, India.
[2]Associate professor, Department of Physiology, Malla Reddy Institute of Medical sciences, Jeedimetla, Hyderabad, Telangana, India.
[3]Assistant Professor, Department of Physiology, Ayaan Institute of Medical Sciences, Moinabad, Telangana, India.
[4]Assistant Professor, Department of Physiology, Government Medical College and General Hospital, Bhadradri Kothagudem, Telangana, India.

Received : *17/07/2024*
Received in revised form : *14/09/2024*
Accepted : *29/09/2024*

Keywords:
Acute exercise, cardiovascular function, echocardiography, heart rate, cardiac output, left ventricular ejection fraction, fitness levels, VO2 max.

Corresponding Author:
Dr. Tangellapalli Sreenivas,
Email: sreenivast2024@gmail.com

DOI: 10.47009/jamp.2024.6.5.51

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2024; 6 (5); 277-281

Abstract

Background: Acute exercise is known to significantly impact cardiovascular function. This study aimed to assess the effects of acute exercise on cardiovascular parameters in healthy individuals using echocardiography. **Materials and Methods:** A total of 100 healthy participants (50 males, 50 females) with a mean age of 30.4 ± 4.2 years were enrolled in this observational study. Resting cardiovascular function was assessed using echocardiography before exercise. Participants underwent an acute exercise protocol, and post-exercise echocardiographic parameters were measured. Subgroup analysis was conducted based on fitness levels, as determined by VO2 max. **Results:** Following acute exercise, heart rate increased significantly from 72 ± 8 bpm to 125 ± 10 bpm ($p < 0.001$). Cardiac output also increased from 5.9 ± 0.6 L/min to 9.8 ± 1.1 L/min ($p < 0.001$). A slight reduction in stroke volume was observed, decreasing from 82.3 ± 12.7 mL to 78.5 ± 10.4 mL ($p = 0.04$). Left ventricular ejection fraction (LVEF) increased from 61.8 ± 4.1% to 65.2 ± 3.7% ($p < 0.01$). Subgroup analysis revealed greater cardiovascular changes in participants with higher fitness levels, including a more significant increase in LVEF ($p < 0.01$) and cardiac output ($p = 0.04$). **Conclusion:** Acute exercise induces significant changes in cardiovascular function, particularly heart rate, cardiac output, and LVEF. Participants with higher fitness levels demonstrated more pronounced cardiovascular adaptations. These findings highlight the acute effects of exercise on heart function and suggest that fitness level may modulate cardiovascular responses.

INTRODUCTION

Acute exercise plays a critical role in the cardiovascular system by inducing both immediate and long-term physiological changes. Understanding these effects is essential for optimizing exercise regimens and improving cardiovascular health.[1] Echocardiography, a non-invasive imaging technique, provides valuable insights into cardiac function by allowing detailed assessments of parameters such as heart rate, stroke volume, cardiac output, and left ventricular ejection fraction.[2] (LVEF).

During physical exertion, the heart adapts by increasing its pumping efficiency to meet the elevated oxygen and nutrient demands of active muscles.[3,4] These changes are manifested in measurable shifts in hemodynamic parameters, including elevated heart rate, increased stroke volume, and augmented cardiac output.[5,6] The ability of the heart to adjust efficiently to these demands is an important indicator of cardiovascular health, and it can vary significantly based on individual fitness levels.[7]

Previous studies have demonstrated that individuals with higher cardiorespiratory fitness exhibit more favorable cardiovascular responses to exercise, including greater cardiac efficiency and reduced heart strain. However, the specific changes in cardiovascular function during acute exercise, especially in a healthy population, remain less well-documented.

This study aims to investigate the effects of acute exercise on cardiovascular function in healthy individuals, focusing on key parameters such as heart rate, stroke volume, cardiac output, and LVEF, as measured by echocardiography. Additionally, the study examines whether fitness levels, determined by VO2 max, influence these cardiovascular responses. The findings could provide important insights for fitness professionals and clinicians in tailoring exercise programs to optimize cardiovascular health.

MATERIALS AND METHODS

Study Design and Location

This observational study was conducted at the RVM Institute of Medical Sciences, located in Laxmakkapalli Village, Siddipet District, Telangana, India. The study was carried out over a period of 12 months, from February 2023 to January 2024.

Participants

A total of 100 healthy individuals (50 males and 50 females) between the ages of 20 and 40 years were enrolled in the study. Inclusion criteria consisted of participants with no known cardiovascular, metabolic, or respiratory diseases. Individuals were excluded if they had any history of hypertension, diabetes, or recent acute illness that could affect cardiovascular function. Each participant provided informed consent prior to their involvement in the study.

Study Procedure

The study involved a baseline echocardiographic evaluation followed by an acute exercise session. Participants were instructed to avoid caffeine, alcohol, and vigorous exercise for 24 hours before testing. The protocol consisted of the following steps:

Pre-exercise Measurements: Each participant underwent an echocardiographic examination to assess baseline cardiovascular function. Parameters measured included heart rate, stroke volume, cardiac output, left ventricular ejection fraction (LVEF), and blood pressure (systolic and diastolic).

Acute Exercise Protocol: Participants performed a standardized moderate-intensity exercise session on a treadmill. The exercise intensity was based on the Bruce treadmill protocol, lasting 10-15 minutes, with an aim to reach approximately 75% of the participant's maximum heart rate (determined by the formula 220 - age).

Post-exercise Measurements: Immediately following exercise, echocardiographic measurements were repeated to assess cardiovascular responses to acute exertion. Blood pressure was also measured post-exercise.

Subgroup Analysis

Participants were divided into two groups based on their fitness levels, as determined by VO2 max, which was calculated using a submaximal treadmill test prior to the acute exercise protocol. The "higher fitness" group included participants with a VO2 max ≥ 45 mL/kg/min, while the "lower fitness" group included those with a VO2 max < 45 mL/kg/min.

Data Collection and Analysis

Echocardiographic data, including heart rate, stroke volume, cardiac output, and LVEF, were recorded before and after exercise. Blood pressure (systolic and diastolic) was measured using a digital sphygmomanometer. All data were analyzed using SPSS version 25.0. Paired t-tests were used to compare pre- and post-exercise parameters within groups, and independent t-tests were used to compare cardiovascular responses between the higher fitness and lower fitness groups. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee of RVM Institute of Medical Sciences. All procedures were conducted in accordance with the Declaration of Helsinki, and informed consent was obtained from all participants prior to data collection. Participants were informed about the study purpose, potential risks, and the confidentiality of their data.

RESULTS

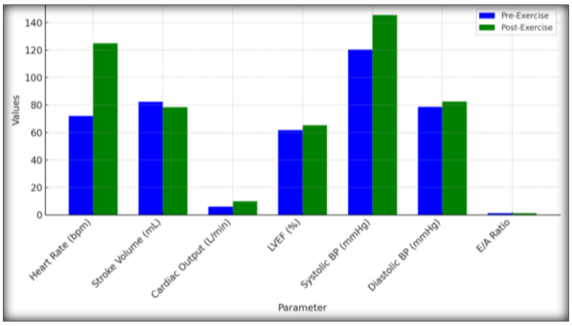

Figure 1: Pre- and Post-Exercise Echocardiographic Parameters

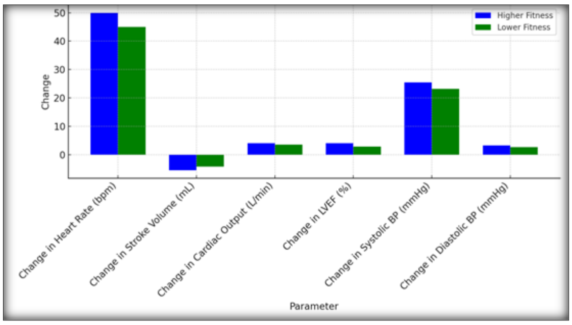

Figure 2: Subgroup Analysis Based on Fitness Levels (VO2 max)

Participant Demographics

A total of 100 healthy individuals (50 males and 50 females) participated in the study, with a mean age of 30.4 ± 4.2 years. The average body mass index (BMI) was 24.8 ± 2.5 kg/m². At baseline, the resting heart rate was 72 ± 8 bpm, with systolic and diastolic blood pressures averaging 120.4 ± 10.5 mmHg and 78.7 ± 7.9 mmHg, respectively. The participants' average fitness level, measured via VO2 max, was 45.3 ± 4.8 mL/kg/min. [Table 1]

Cardiovascular Changes Post-Acute Exercise

Following the acute exercise protocol, significant changes were observed in the cardiovascular function of participants (Table 2). The mean heart rate increased significantly from 72 ± 8 bpm at rest to 125 ± 10 bpm post-exercise ($p < 0.001$). Similarly, cardiac output increased from 5.9 ± 0.6 L/min to 9.8 ± 1.1 L/min ($p < 0.001$), driven by the increase in heart rate.

In contrast, stroke volume decreased slightly from 82.3 ± 12.7 mL to 78.5 ± 10.4 mL post-exercise ($p = 0.04$), indicating a reduction in preload. There was also a significant improvement in left ventricular ejection fraction (LVEF), which increased from 61.8 ± 4.1% at baseline to 65.2 ± 3.7% post-exercise ($p < 0.01$).

Blood pressure measurements demonstrated significant increases, with systolic BP rising from 120.4 ± 10.5 mmHg to 145.6 ± 12.3 mmHg ($p < 0.001$) and diastolic BP increasing from 78.7 ± 7.9 mmHg to 82.5 ± 9.4 mmHg ($p = 0.02$). Diastolic function, as indicated by the E/A ratio, showed a modest improvement post-exercise, increasing from 1.2 ± 0.2 to 1.3 ± 0.3 ($p = 0.03$).

Subgroup Analysis Based on Fitness Levels

Subgroup analysis revealed that participants with higher fitness levels (VO2 max = 50.6 ± 3.5 mL/kg/min) experienced more significant cardiovascular changes compared to those with lower fitness levels (VO2 max = 40.1 ± 2.4 mL/kg/min) (Table 3). The increase in heart rate post-exercise was slightly greater in the higher fitness group (+50 ± 10 bpm) compared to the lower fitness group (+45 ± 12 bpm), though this difference was not statistically significant ($p = 0.15$).

However, the higher fitness group showed a more pronounced decrease in stroke volume (-5.5 ± 1.4 mL vs. -4.2 ± 1.6 mL, $p = 0.03$) and a greater increase in cardiac output (+4.0 ± 0.7 L/min vs. +3.5 ± 0.6 L/min, $p = 0.04$). Additionally, the higher fitness group exhibited a greater improvement in LVEF (+4.0 ± 0.5% vs. +2.8 ± 0.7%, $p < 0.01$). Differences in systolic and diastolic blood pressure changes between the two fitness groups were not statistically significant ($p = 0.12$ and $p = 0.09$, respectively).

Table 1: Participant Demographics

Characteristic	Mean ± SD
Age (years)	30.4 ± 4.2
Gender (Male/Female)	50/50
Body Mass Index (BMI)	24.8 ± 2.5 kg/m²
Resting Heart Rate (bpm)	72 ± 8
Systolic BP (mmHg)	120.4 ± 10.5
Diastolic BP (mmHg)	78.7 ± 7.9
Fitness Level (VO2 max)	45.3 ± 4.8 mL/kg/min

Table 2: Pre- and Post-Exercise Echocardiographic Parameters

Parameter	Pre-Exercise	Post-Exercise	p-value
Heart Rate (bpm)	72 ± 8	125 ± 10	< 0.001
Stroke Volume (mL)	82.3 ± 12.7	78.5 ± 10.4	0.04
Cardiac Output (L/min)	5.9 ± 0.6	9.8 ± 1.1	< 0.001
Left Ventricular Ejection Fraction (LVEF, %)	61.8 ± 4.1	65.2 ± 3.7	< 0.01
Systolic BP (mmHg)	120.4 ± 10.5	145.6 ± 12.3	< 0.001
Diastolic BP (mmHg)	78.7 ± 7.9	82.5 ± 9.4	0.02
E/A Ratio (Diastolic Function)	1.2 ± 0.2	1.3 ± 0.3	0.03

Table 3: Subgroup Analysis Based on Fitness Levels (VO2 max)

Parameter	Higher Fitness (n = 50)	Lower Fitness (n = 50)	p-value
VO2 max (mL/kg/min)	50.6 ± 3.5	40.1 ± 2.4	< 0.01
Change in Heart Rate (bpm)	+50 ± 10	+45 ± 12	0.15
Change in Stroke Volume (mL)	-5.5 ± 1.4	-4.2 ± 1.6	0.03
Change in Cardiac Output (L/min)	+4.0 ± 0.7	+3.5 ± 0.6	0.04
Change in LVEF (%)	+4.0 ± 0.5	+2.8 ± 0.7	< 0.01
Change in Systolic BP (mmHg)	+25.5 ± 8.6	+23.2 ± 9.4	0.12
Change in Diastolic BP (mmHg)	+3.2 ± 1.2	+2.7 ± 1.0	0.09

DISCUSSION

The present study investigated the acute effects of exercise on cardiovascular function in healthy individuals, focusing on key parameters such as heart rate, stroke volume, cardiac output, and left ventricular ejection fraction (LVEF). Using echocardiography, the study assessed these parameters before and after a standardized exercise protocol, while also examining the impact of fitness

ISSN (O): 2687-5365; ISSN (P): 2753-6556

levels, as determined by VO2 max, on cardiovascular responses.

Cardiovascular Responses to Acute Exercise

As expected, acute exercise resulted in significant increases in heart rate and cardiac output. The heart rate increased by an average of 53 bpm, consistent with the physiological demand for increased oxygen supply during exercise, which aligns with findings from Lavie et al,[8] (2015), who emphasized the role of exercise in enhancing cardiovascular outcomes and improving overall heart function. The increase in cardiac output was primarily driven by the rise in heart rate, as stroke volume showed a slight but significant reduction post-exercise. This reduction in stroke volume is attributed to a decrease in preload due to blood redistribution to active muscles, a well-documented response during acute exercise, as also noted by Pinckard et al,[9] (2019).

The observed increase in LVEF post-exercise reflects enhanced systolic function, indicating that the heart pumped more efficiently after exertion. This finding is consistent with Alhumaid et al,[10] (2022), who demonstrated that exercise improves myocardial contractility and overall cardiac performance. Furthermore, the significant rise in systolic blood pressure post-exercise, driven by the need for increased systemic blood flow, is in line with established hemodynamic responses to physical activity, as described by Joseph et al,[11] (2019).

Impact of Fitness Levels

The subgroup analysis revealed that participants with higher fitness levels experienced more pronounced cardiovascular adaptations compared to those with lower fitness levels. Specifically, the higher fitness group demonstrated a greater increase in LVEF and cardiac output, suggesting that higher cardiorespiratory fitness is associated with greater cardiovascular efficiency. This supports the findings of Smarz et al,[12] (2021), who showed that regular aerobic training leads to improved cardiac performance and an enhanced ability to cope with physical stress.

Additionally, the more pronounced reduction in stroke volume observed in the higher fitness group may reflect greater ventricular filling capacity and myocardial efficiency, as these individuals likely experience a more effective Frank-Starling mechanism during exercise. This mechanism, as highlighted by Jouffroy et al,[13] (2022), allows for improved cardiac function under stress, underscoring the benefits of superior aerobic fitness. The ability to sustain higher cardiac output and LVEF in response to exercise further confirms the advantages of regular aerobic conditioning, as suggested by Benda et al,[14] (2016).

Implications for Clinical and Fitness Applications

The findings of this study have important implications for both clinical and fitness applications. Understanding cardiovascular responses to exercise can help clinicians better assess cardiac function in healthy individuals, particularly in those undergoing fitness evaluations or cardiac rehabilitation. The differential responses between higher and lower fitness levels highlight the importance of personalized exercise programs to optimize cardiovascular health. Higher fitness levels confer significant advantages in cardiovascular function, suggesting that improving aerobic capacity through regular exercise can enhance cardiac efficiency during physical activity, as supported by research from Lavie et al,[8] (2015) and Pinckard et al,[9] (2019).

Limitations

There are several limitations to this study that should be acknowledged. First, the study was limited to healthy individuals between the ages of 20 and 40, which may limit the generalizability of the findings to older populations or those with underlying cardiovascular conditions. Second, the study used a single exercise protocol, which may not reflect the variability of cardiovascular responses to different types and intensities of exercise. Future studies could explore the effects of varied exercise protocols and include a broader range of participants, including those with cardiovascular diseases.

CONCLUSION

This study demonstrates that acute exercise leads to significant cardiovascular changes, including increases in heart rate, cardiac output, and left ventricular ejection fraction (LVEF). Heart rate rose from 72 ± 8 bpm to 125 ± 10 bpm ($p < 0.001$), and LVEF increased from $61.8 \pm 4.1\%$ to $65.2 \pm 3.7\%$ ($p < 0.01$). Participants with higher fitness levels showed more pronounced improvements in cardiac output and LVEF. These findings highlight the beneficial effects of regular aerobic conditioning on cardiovascular function, suggesting that tailored exercise programs based on fitness levels can optimize heart performance and promote better cardiovascular health.

REFERENCES

1. Nystoriak MA, Bhatnagar A. Cardiovascular Effects and Benefits of Exercise. Front Cardiovasc Med. 2018 Sep 28; 5:135. doi: 10.3389/fcvm.2018.00135. PMID: 30324108; PMCID: PMC6172294.
2. O'Keefe JH, Patil HR, Lavie CJ, Magalski A, Vogel RA, McCullough PA. Potential adverse cardiovascular effects from excessive endurance exercise. Mayo Clin Proc. 2012 Jun;87(6):587-95. doi: 10.1016/j.mayocp.2012.04.005. Erratum in: Mayo Clin Proc. 2012 Jul;87(7):704. PMID: 22677079; PMCID: PMC3538475.
3. Williams AM, Ma JK, Martin Ginis KA, West CR. Effects of a Tailored Physical Activity Intervention on Cardiovascular Structure and Function in Individuals with Spinal Cord Injury. Neurorehabil Neural Repair. 2021 Aug;35(8):692-703. doi: 10.1177/15459683211017504. Epub 2021 May 22. PMID: 34027716; PMCID: PMC8704204.
4. Ness HO, Ljones K, Gjelsvik RH, Tjønna AE, Malmo V, Nilsen HO, et al. Acute effects of high intensity training on cardiac function: a pilot study comparing subjects with type 2 diabetes to healthy controls. Sci Rep. 2022 May 17;12(1):8239. doi: 10.1038/s41598-022-12375-2. PMID: 35581305; PMCID: PMC9114004.

5. Eijsvogels TM, Fernandez AB, Thompson PD. Are There Deleterious Cardiac Effects of Acute and Chronic Endurance Exercise? Physiol Rev. 2016 Jan;96(1):99-125. doi: 10.1152/physrev.00029.2014. PMID: 26607287; PMCID: PMC4698394.
6. Zaborska B, Smarż K, Makowska E, Czepiel A, Świątkowski M, Jaxa-Chamiec T, et al. Echocardiographic predictors of exercise intolerance in patients with heart failure with severely reduced ejection fraction. Medicine (Baltimore). 2018 Jul;97(28):e11523. doi: 10.1097/MD.0000000000011523. PMID: 29995821; PMCID: PMC6076165.
7. Smarz K, Jaxa-Chamiec T, Zaborska B, Tysarowski M, Budaj A. Combined use of stress echocardiography and cardiopulmonary exercise testing to assess exercise intolerance in patients treated for acute myocardial infarction. PLoS One. 2021 Aug 5;16(8):e0255682. doi: 10.1371/journal.pone.0255682. Erratum in: PLoS One. 2024 Jul 10;19(7):e0307152. doi: 10.1371/journal.pone.0307152. PMID: 34351993; PMCID: PMC8341484.
8. Lavie CJ, Arena R, Swift DL, Johannsen NM, Sui X, Lee DC, et al. Exercise and the cardiovascular system: clinical science and cardiovascular outcomes. Circ Res. 2015 Jul 3;117(2):207-19. doi: 10.1161/CIRCRESAHA.117.305205. PMID: 26139859; PMCID: PMC4493772.
9. Pinckard K, Baskin KK, Stanford KI. Effects of Exercise to Improve Cardiovascular Health. Front Cardiovasc Med. 2019 Jun 4; 6:69. doi: 10.3389/fcvm.2019.00069. PMID: 31214598; PMCID: PMC6557987.
10. Alhumaid W, Small SD, Kirkham AA, Becher H, Pituskin E, Prado CM, et al. A Contemporary Review of the Effects of Exercise Training on Cardiac Structure and Function and Cardiovascular Risk Profile: Insights from Imaging. Front Cardiovasc Med. 2022 Feb 21; 9:753652. doi: 10.3389/fcvm.2022.753652. PMID: 35265675; PMCID: PMC8898950.
11. Joseph G, Mogelvang R, Biering-Sørensen T, Nielsen G, Schnohr P, Sogaard P. The association between physical activity and cardiac performance is dependent on age: the Copenhagen City Heart Study. Int J Cardiovasc Imaging. 2019 Jul;35(7):1249-1258. doi: 10.1007/s10554-019-01566-0. Epub 2019 Mar 1. PMID: 30825135; PMCID: PMC6598956.
12. Smarz K, Jaxa-Chamiec T, Zaborska B, Tysarowski M, Budaj A. Mechanisms of Exercise Capacity Improvement after Cardiac Rehabilitation Following Myocardial Infarction Assessed with Combined Stress Echocardiography and Cardiopulmonary Exercise Testing. J Clin Med. 2021 Sep 9;10(18):4083. doi: 10.3390/jcm10184083. PMID: 34575194; PMCID: PMC8471103.
13. Jouffroy R, Hergault H, Antero J, Vieillard Baron A, Mansencal N. Relationship between echocardiographic characteristics and cardiac biomarkers during long-distance trail running. Front Cardiovasc Med. 2022 Aug 16; 9:954032. doi: 10.3389/fcvm.2022.954032. PMID: 36051277; PMCID: PMC9424639.
14. Benda NM, Hopman MT, van Dijk AP, Oxborough D, George KP, Thijssen DH, et al. Impact of prolonged walking exercise on cardiac structure and function in cardiac patients versus healthy controls. Eur J Prev Cardiol. 2016 Aug;23(12):1252-60. doi: 10.1177/2047487316631389. Epub 2016 Feb 8. PMID: 26858278.