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Effect of continuous high-intensity training on left ventricular and left atrial strain in patients with anterior ST-segment elevation myocardial infarction treated with primary PCI

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Abstract
Background: High intensity interval training (HIIT) was proved to be safe and effective but there is a gap of evidence regarding safety and efficacy of continuous high intensity exercise training (CHIT) in cardiac patients. This study aims to compare the impact of continuous high intensity versus continuous moderate-intensity training (CMIT) on left ventricular (LV) and left atrial (LA) strain parameters during cardiac rehabilitation.
Methods: A randomized controlled trial was conducted with 60 patients who underwent primary percutaneous coronary intervention (PCI) for anterior ST-segment elevation myocardial infarction. Patients were randomized into two groups: one group received CHIT, while the control group followed CMIT. Echocardiographic assessments, including LV global longitudinal strain (GLS) and LA strain (LAS) parameters, were performed before and after a six-week rehabilitation program.
Results: The CHIT group showed a greater improvement in LV GLS, with a mean increase from -11.27% to -13.58% ($P < 0.001$), compared to the moderate-intensity group, which increased from -12.28% to -13.66% ($P < 0.001$). LA reservoir strain improved from 21.6% to 27.27% in the CHIT group ($P < 0.001$) and from 27.3% to 31.1% in the moderate-intensity group ($P < 0.001$). However, no significant differences were observed between the groups in LA contractile or conduit strain.
Conclusion: CHIT was associated with a more significant improvement in LV function compared to CMIT in post-PCI anterior STEMI patients. However, both regimens resulted in comparable improvements in LAS parameters, suggesting that either training intensity may enhance atrial function in cardiac rehabilitation.

Keywords: STEMI, LV strain, LA strain, cardiac rehabilitation, high-intensity training

Introduction
Cardiac rehabilitation (CR) plays a pivotal role in the recovery process for patients post-myocardial infarction (MI), particularly for those who have undergone primary percutaneous coronary intervention (PCI) [1]. Exercise-based CR programs have consistently demonstrated benefits in improving cardiovascular performance, lowering the risk of subsequent cardiac events, and enhancing overall quality of life. Recently, high-intensity interval training (HIIT) has gained attention due to its potential to yield more significant improvements in cardiac function compared to traditional moderate-intensity exercise. While mounting evidence supports the use of HIIT in CR, its specific impact on heart mechanics, particularly in relation to left ventricular (LV) and left atrial (LA) strain, remains an area of active investigation [2, 3].
Left ventricular global longitudinal strain (LV GLS) has emerged as a sensitive marker of ventricular function, often more reliable than traditional EF measurements in detecting subtle changes in cardiac function [4]. Similarly, LA strain (LAS) parameters have been recognized as valuable indicators of atrial function, particularly in assessing diastolic dysfunction and the overall performance of the LA during the cardiac cycle. The role of LAS in predicting clinical outcomes in patients recovering from anterior ST-segment elevation myocardial infarction (STEMI) is of significant clinical interest,

given its association with adverse outcomes such as atrial fibrillation and heart failure [5].

Exercise training, particularly in the setting of cardiac rehabilitation, can lead to positive cardiac remodelling and improved myocardial function. However, the degree of improvement in LV GLS and LAS may vary depending on the intensity of exercise performed [6]. While continuous moderate-intensity training (CMIT) is the traditional approach in cardiac rehabilitation, recent studies suggest that high intensity interval training (HIIT) may offer superior benefits in enhancing both systolic and diastolic function [7, 8]. Nevertheless, the specific effects of HIIT on LV GLS and LAS in post-STEMI patients treated with PCI are not yet fully understood.

This study aims to evaluate the effect of continuous high-intensity training (CHIT) on LV GLS and LAS parameters in patients who have undergone successful primary PCI for anterior STEMI, compared to CMIT during a cardiac rehabilitation program.

Patients and Methods

This study was a two-arm parallel randomized controlled trial conducted at the CR Unit of the Cardiology Department at Ain-Shams University Hospital over a six-month period from February 2024 to August 2024. The study included male and female patients aged 18 years or older who were at least three weeks post-successful primary PCI for anterior STEMI. All patients had been fully revascularized before participating in the study. Patients were randomized to either the CHIT group or CMIT group.

Patients were excluded if they had poor echocardiographic windows, severe ventricular dysfunction, decompensated HF, hemodynamic instability, severe valvular disease, uncontrolled arrhythmias, incomplete revascularization, or severe comorbidities such as hepatic or renal impairment. Other exclusion criteria included physical disabilities preventing exercise, chronic obstructive airway disease, morbid obesity, clinical depression, and patients with high-risk features on the initial modified Bruce protocol. Patients with high-risk features upon initial risk stratification with symptom limited modified bruce protocol: Angina/symptoms <5 METS, Ventricular arrhythmias, abnormal hemodynamics and silent ischemia (ST segment depression ≥2mm).

Sample Size

Using the PASS 15 program for sample size calculation with an 80% power and 5% alpha error [9], a minimum of 60 patients (30 per group) was required based on expected effect size differences in LV and LA function parameters, with an additional 10% adjustment for potential dropouts.

Ethical Considerations

The study was approved by the Research Ethics Committee (REC) of Ain Shams University Faculty of Medicine (Approval number: FWA 000017585/ MS 215/2024). All participants provided written informed consent and were assigned unique code numbers to ensure confidentiality.

Exercise Protocol and Data Collection

Cases were randomized to receive either CHIT or CMIT as part of their CR program. Each training session consisted of a warm-up phase, a training phase, and a cool-down phase. The intensity of exercise was determined based on target heart rate calculations using the Karvonen formula [10] after initial symptom limited treadmill exercise stress test with Modified Bruce Protocol. CHIT targeted training heart rate range of ≥60% of heart rate reserve (HRR) or ≥80% of maximal heart rate (HRmax), while CMIT targeted training heart rate of 40-60% of HRR or 60-80% of HRmax. Patients underwent 18 supervised CR sessions over six weeks, with continuous ECG monitoring during treadmill exercise. Each treadmill exercise session consisted of a warm up phase for 10 minutes, training phase till the predetermined target heart rate range for 20 minutes and cool down phase for 10 minutes. Any unusual or adverse symptoms during exercise were reported and addressed.

Echocardiographic Evaluation

Expert echocardiographers performed echocardiography for all patients both before and after the six-week CR program. Echocardiographic assessments included LAS analysis from apical four-chamber and two-chamber views, and LV GLS measured using speckle-tracking echocardiography (STE). LAS parameters, including reservoir, conduit, and contractile strain, were analyzed alongside LV GLS. Diastolic function was assessed using mitral peak flow velocities and tissue Doppler imaging to calculate E/A and E/e' ratios. Standard values for LA and LV strain, as well as diastolic function, were used for comparison.

Statistical analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS) version 26 (IBM, Armonk, New York, United States). Continuous variables were characterized using suitable measures of central tendency and dispersion, presented as means±standard deviations (SDs), whilst categorical data were conveyed as percentages. Independent t-tests were used for comparisons of continuous variables, while categorical data were analyzed using the chi-square test. Pearson correlation coefficients were used to evaluate the correlations among various variables, while multivariate linear regression analysis was employed to identify the independent predictors of outcomes. All statistical tests were two-tailed, with a significance threshold established at $p < 0.05$.

Results

The mean age of patients in CHIT group was 49.5±11.58 years, while in the MICT group it was 54.13±10.47 years (P = 0.109). Gender distribution was similar, with 96.7% males in the CHIT group and 86.7% in the moderate-intensity group (P = 0.161). Smoking prevalence was 70.0% in the high-intensity group and 60.0% in the moderate-intensity group (P = 0.417). Other risk factors like DM, HTN, ISHD, cerebrovascular disease, and dyslipidemia showed no significant differences between groups (p> 0.05 for all). Table 1

Table 1: Comparison between both groups regarding demographic data and risk factors

		Moderate	High	Test value	P-value
		No. = 30	No. = 30		
Age	Mean± SD	54.13±10.47	49.5±11.58	1.626•	0.109
	Range	33 – 70	24 – 68		

Gender	Female	4 (13.3%)	1 (3.3%)	1.964*	0.161
	Male	26 (86.7%)	29 (96.7%)		
Smoker	No	12 (40.0%)	9 (30.0%)	0.659*	0.417
	Yes	18 (60.0%)	21 (70.0%)		
Shisha	No	27 (90.0%)	29 (96.7%)	1.071*	0.301
	Yes	3 (10.0%)	1 (3.3%)		
Hash	No	28 (93.3%)	24 (80.0%)	2.308*	0.129
	Yes	2 (6.7%)	6 (20.0%)		
DM	No	17 (56.7%)	24 (80.0%)	3.774*	0.052
	Yes	13 (43.3%)	6 (20.0%)		
HTN	No	21 (70.0%)	19 (63.3%)	0.300*	0.584
	Yes	9 (30.0%)	11 (36.7%)		
ISHD	No	27 (90.0%)	26 (86.7%)	0.162*	0.688
	Yes	3 (10.0%)	4 (13.3%)		
CVS	No	27 (90.0%)	29 (96.7%)	1.071*	0.301
	Yes	3 (10.0%)	1 (3.3%)		
Alcohol	No	30 (100.0%)	29 (96.7%)	1.017*	0.313
	Yes	0 (0.0%)	1 (3.3%)		
Single Kidney	No	29 (96.7%)	30 (100.0%)	1.017*	0.313
	Yes	1 (3.3%)	0 (0.0%)		
Tramadol	No	29 (96.7%)	29 (96.7%)	0.000*	1.000
	Yes	1 (3.3%)	1 (3.3%)		
Paroxysmal AF	No	29 (96.7%)	30 (100.0%)	1.017*	0.313
	Yes	1 (3.3%)	0 (0.0%)		
Hypothyroid	No	29 (96.7%)	29 (96.7%)	0.000*	1.000
	Yes	1 (3.3%)	1 (3.3%)		
HCV	No	30 (100.0%)	29 (96.7%)	1.017*	0.313
	Yes	0 (0.0%)	1 (3.3%)		
BA	No	28(93.3%)	29 (96.7%)	1.017*	0.313
	Yes	2 (6.7%)	1 (3.3%)		
Dyslipidemic	No	29 (96.7%)	30 (100.0%)	1.017*	0.313
	Yes	1 (3.3%)	0 (0.0%)		
Positive family	No	27 (90.0%)	28 (93.3%)	0.218*	0.640
	Yes	3 (10.0%)	2 (6.7%)		

*: Chi-square test, DM: Diabetes Mellitus, HTN: Hypertension, ISHD: Ischemic Heart Disease, CVS: Cerebrovascular Stroke, HCV: Hepatitis C Virus, BA: Bronchial Asthma.

In the CHIT group, LV GLS improved from -11.27±4.2% to -13.58±4.2% ($p < 0.001$). LA reservoir strain increased from 21.6±7.79% to 27.27±10.08% ($p < 0.001$), LA conduit strain improved from -11.5% to -14% ($p < 0.001$), and LA contractile strain increased from -10% to -13% (P = 0.001). The E/A ratio decreased from 1.17±0.22 to 1.03±0.14 ($p < 0.001$), and the E/E' ratio decreased from 7.73±0.92 to 7.48±0.9 ($p < 0.001$). LA diameter and LA volume max showed no notable change (P = 0.610). Table 2

Table 2: Comparison between ECHO parameters before and after among CHIT group

CHIT group		Before No. = 30	After No. = 30	Test value	P-value
LV GLS %	Mean ±SD	-11.27±4.2	-13.58±4.2	7.921•	0.000
	Range	-19.5 – -2.8	-22.4 – -3.3		
LA reservoir Strain %	Mean ±SD	21.6±7.79	27.27±10.08	-7.071•	0.000
	Range	6 – 36	7 – 45		
LA conduit Strain %	Median (IQR)	-11.5 (-15 – -7)	-14 (-19 – -10)	-3.606≠	0.000
	Range	-23 – -3	-31 – -3		
LA Contractile Strain %	Median (IQR)	-10 (-14 – -5)	-13 (-16 – -9)	-3.424≠	0.001
	Range	-21 – -1	-24 – -2		
LA diameter	Mean ±SD	38.57±4.48	38.57±4.48	–	–
	Range	32 – 47	32 – 47		
LA Volume Max (biplane)	Mean ±SD	51.87±22.17	50.6±19.82	0.516•	0.610
	Range	22 – 132	26 – 107		
E/A	Mean ±SD	1.17±0.22	1.03±0.14	6.298•	0.000
	Range	0.9 – 1.5	0.9 – 1.3		
E/E'	Mean ±SD	7.73±0.92	7.48±0.9	8.795•	0.000
	Range	6.25 – 9.3	6 – 9		

P-value < 0.05, •: Paired t-test; ≠: Wilcoxon Signed Ranks test, LV GLS: Left Ventricular Global Longitudinal Strain, LA: Left Atrial, E/E': Mitral Peak Early to Tissue Doppler Velocity Ratio, E/A: Mitral Peak Early to Atrial Flow Velocity Ratio.

In the CMIT group, LV GLS improved from -12.28±4.45% to -13.66±4.74% ($p < 0.001$). LA reservoir strain increased from 27.3±8.88% to 31.1±8.63% ($p < 0.001$), LA conduit strain improved from -13% to -17.5% ($p < 0.001$), and LA contractile strain increased from -13.5% to -15% (P = 0.014). The E/A ratio decreased from 1.17±0.2 to 1.03±0.15 (p< 0.001), and the E/E' ratio decreased from 8.03±1.14 to 7.73±1.02 (p< 0.001). LA diameter and LA volume max showed no significant change (P = 0.336). Table 3

Table 3: Comparison between ECHO parameters before and after among MICT group

CMIT group		Before	After	Test value	P-value
		No. = 30	No. = 30		
LV GLS %	Mean ±SD	-12.28±4.45	-13.66±4.74	6.042•	0.000
	Range	-22 – -5.5	-23 – -5.7		
LA reservoir Strain %	Mean ±SD	27.3±8.88	31.1±8.63	-6.277•	0.000
	Range	10 – 46	17 – 47		
LA conduit Strain %	Median (IQR)	-13 (-19 – -7)	-17.5 (-23 – -10)	-3.721≠	0.000
	Range	-31 – 0	-33 – -5		
LA Contractile Strain %	Median (IQR)	-13.5 (-16 – -10)	-15 (-18 – -12)	-2.462≠	0.014
	Range	-24 – -4	-25 – -6		
LA diameter	Mean ±SD	37.23±4.09	37.23±4.09	–	–
	Range	29 – 47	29 – 47		
LA Volume Max(biplane)	Mean ±SD	45±18.97	42.03±14.24	0.979•	0.336
	Range	21 – 110	18 – 74		
E/A	Mean ±SD	1.17±0.2	1.03±0.15	5.662•	0.000
	Range	0.9 – 1.6	0.9 – 1.5		
E/E'	Mean ±SD	8.03±1.14	7.73±1.02	4.903•	0.000
	Range	6 – 10	6 – 9.5		

P-value < 0.05, •: Paired t-test; ≠: Wilcoxon Signed Ranks test, LLA: Left Atrial, E/A: Mitral Peak Early to Atrial Flow Velocity Ratio, V GLS: Left Ventricular Global Longitudinal Strain, E/E': Mitral Peak Early to Tissue Doppler Velocity Ratio.

The difference in LV GLS between the CHIT and CMIT groups was -2.31±1.60% and -1.38±1.25%, respectively (P = 0.009). LA reservoir strain increased by 5.67±4.39% in the CHIT group and by 3.80±3.32% in the CMIT group (P = 0.115). The change in LA conduit strain was -3.03±3.97% for the CHIT group and -3.13±3.66% for the CMIT (P = 0.789). LA contractile strain increased by -2.93±4.27% in CHIT group and by -1.33±3.74% in the CMIT group (P = 0.110). LA volume max decreased by -1.27±13.45% in the CHIT group and by -2.97±16.59% in the CMIT group (P = 0.778). Table 4

Table 4: Comparison between CMIT AND CHIT regarding mean differences of ECHO parameters among the studied patients

Difference	CMIT	CHIT	Test value	P-value
	Mean± SD	Mean± SD		
LV GLS %	-1.38±1.25	-2.31±1.60	-2.61≠	0.009
LA reservoir Strain %	3.80±3.32	5.67±4.39	-1.58≠	0.115
LA conduit Strain %	-3.13±3.66	-3.03±3.97	-0.27≠	0.789
LA Contractile Strain %	-1.33±3.74	-2.93±4.27	-1.60≠	0.110
LA Volume Max (biplane)	-2.97±16.59	-1.27±13.45	-0.28≠	0.778
E/A	-0.14±0.14	-0.14±0.12	-0.09≠	0.927
E/E'	-0.30±0.34	-0.25±0.16	-0.57≠	0.568

P-value < 0.05, ≠: Mann-Whitney test, LA: Left Atrial, E/A: Mitral Peak Early to Atrial Flow Velocity Ratio, LV GLS: Left Ventricular Global Longitudinal Strain, E/E': Mitral Peak Early to Tissue Doppler Velocity Ratio.

Discussion

Current guidelines advocate for moderate-intensity exercise during cardiac rehabilitation for patients with anterior STEMI who have undergone primary PCI to improve cardiac function [11, 12]. However, recent research suggests that high-intensity exercise in rehabilitation programs may offer greater benefits in enhancing cardiac performance than moderate-intensity training [9]. While HIIT has been demonstrated to be both safe and effective, data on the safety and efficacy of CHIT in cardiac patients remains limited [13].

Echocardiographic GLS is now recognized as a more sensitive tool than traditional EF in detecting subtle changes in LV function [14]. Left atrial strain (LAS) can provide insights into functional recovery after myocardial infarction. Improved LAS over time may indicate positive remodelling and recovery of LA function, while persistently reduced strain could suggest ongoing dysfunction or incomplete recovery [15]. Monitoring LAS during follow-up allows for assessing the effectiveness of therapeutic interventions and adjusting treatment plans accordingly.

We investigated the impact of both moderate and CHIT on LV GLS and LAS in 60 patients with anterior STEMI who had undergone primary PCI. Participants were randomly assigned to either a CHIT group (Group 1) or CMIT group (Group 2) as part of their CR program.

The patients had a mean age of 51.82 years, with a predominance of males (91.7%). This gender distribution aligns with the higher incidence of cardiovascular diseases in males. Both groups had a similar mean age and gender distribution, which is crucial for comparing the effect of exercise intensity on cardiac function. A study conducted among Egyptian patients by Elbarbary *et al.* [16] found that men exhibited a higher prevalence of STEMI than women, with the most represented age group for both genders being between 56 and 65 years.

In the present study, comorbidities such as HTN, DM, smoking, and dyslipidemia were prevalent. Among the studied population, 33.3% were hypertensive, 65% were smokers, 53.3% were dyslipidemic, and 48.3% were diabetic. These findings highlight the importance of controlling various risk factors in preventing and treating ischemic heart disease.

Our findings align with those of Bhardwaj *et al*. [17], who examined the risk factors and angiographic characteristics in 124 patients under 40 years of age presenting with acute myocardial infarction (AMI) in India. Their study concluded that AMI in young adults almost exclusively occurs in males, with STEMI as the main presentation. Smoking, hypertension, low HDL, and high triglycerides were the major risk factors. Similarly, Elkersh *et al*. [18] found that 63.5% of patients with acute coronary syndrome (ACS) in Egypt were current smokers, with high prevalence rates of hypertension (57.5%), diabetes mellitus (60.5%), and dyslipidemia (57%).

In our study, the analysis of echocardiographic parameters before and after the CR program revealed significant changes in cardiac function in both groups. Comparison of these parameters between the CHIT and CMIT exercise groups also revealed several key findings. Both exercise regimens led to improvements in LV GLS, indicating that exercise, irrespective of intensity, positively influences cardiac function. This improvement may result from increased myocardial oxygenation, enhanced metabolic efficiency, or better myocardial adaptation to stress from regular exercise [19].

Our findings are consistent with Murray *et al*. [20], who reported that moderate-intensity exercise significantly enhanced LV GLS in patients with coronary artery disease. D'Andrea *et al*. [9] demonstrated that high-intensity interval exercise significantly improved LV GLS, correlating with enhanced myocardial function and recovery. Similarly, Murray *et al*. [20] found LV GLS to be a reliable marker for assessing improvements in cardiac function in patients undergoing high-intensity interval exercise during CR. Moreover, D'Ascenzi *et al*. [21] demonstrated that physical training, including both moderate and high-intensity interval exercise, improved LV GLS.

When we compared the mean difference in LV GLS between the two exercise groups, it was significantly greater in the CHIT group than in the CMIT group. Our results suggest that CHIT is safe and superior to CMIT in improving LV GLS. This aligns with Kaur *et al*. [22], who reported greater enhancements in LV GLS with high-intensity interval exercise in patients with ischemic heart disease. High-intensity exercise involves higher workloads and cardiovascular demands, leading to more pronounced physiological adaptations such as increased capillary density, improved mitochondrial function, and reduced myocardial stiffness, contributing to more substantial improvements in LV GLS [23].

LAS measurements also demonstrated significant positive changes in both exercise groups. LA reservoir, conduit, and contractile strains improved, implying that exercise, regardless of intensity, positively impacts the functional properties of the LA. Regular physical activity may lead to beneficial adaptations in atrial function through enhanced blood flow, reduced atrial stiffness, and improved myocardial elasticity [24].

Our results align with Tadic *et al*. [25], who reported significant improvements in LAS following moderate-intensity exercise. Huang *et al*. [26] observed similar improvements in LAS parameters following high-intensity interval training. Wang *et al*. [27] also demonstrated that LAS significantly improved with high-intensity interval exercise.

In our study, the difference in LA reservoir strain and LA conduit strain between the two groups was not statistically significant. Both exercise intensities were similarly effective at improving LA reservoir strain, as observed by Kim *et al*. [28]. In contrast, structural parameters such as LA diameter and LA volume max did not show significant changes. Exercise leads to functional improvements without causing substantial structural remodeling. This result is consistent with Atan *et al*. [29], who found that both moderate and high-intensity interval exercises improved LA functional parameters, but structural dimensions remained stable. Another study by Caminiti *et al*. [24] also showed that exercise improved LAS but did not significantly alter LA diameter or volume in older adults.

Diastolic function parameters also improved significantly in both exercise groups, with reductions in the E/A and E/E' ratios, reflecting better diastolic function. Marwick *et al*. [30] reported similar improvements with moderate-intensity exercise, while Amundsen *et al*. [31] demonstrated favorable diastolic changes with high-intensity interval training. The differences in diastolic function between the two groups were not significant, as supported by studies from Pearson *et al*. [32] and Cavero-Redondo *et al*. [33], which found comparable improvements in diastolic function with both exercise intensities.

One of the key limitations of our study is the relatively small sample size, which may limit the generalizability of the findings and reduce the power to detect subtle differences between the exercise intensity groups. Additionally, the short follow-up period of six weeks may not have been sufficient to observe long-term cardiac remodelling and sustainability of the improvements in LV and LA function. Another limitation is the exclusion of patients with significant comorbidities, which could affect the applicability of the results to a broader population of cardiac rehabilitation patients. Finally, the study relied solely on echocardiographic measurements, and incorporating other imaging modalities or biomarkers could have provided a more comprehensive evaluation of cardiac function and the effects of exercise training

Conclusion

CHIT was associated with a more significant improvement in LV function compared to CMIT in post-PCI anterior STEMI patients. However, both regimens resulted in comparable improvements in LAS parameters, suggesting that either training intensity may enhance atrial function.

Conflict of Interest

Not available

Financial Support

Not available

References

1. Nemani RRS, Gade BS, Panchumarthi D, Bathula B, Pendli G, Panjiyar BK. Role of cardiac rehabilitation in improving outcomes after myocardial infarction. Cureus. 2023, 15
2. Nam H, Jeon HE, Kim WH, Joa KL, Lee H. Effect of maximal-intensity and high-intensity interval training

on exercise capacity and quality of life in patients with acute myocardial infarction: A randomized controlled trial. European Journal of Physical and Rehabilitation Medicine. 2024;60:104-112.
3. Dun Y, Smith JR, Liu S, Olson TP. High-intensity interval training in cardiac rehabilitation. Clinics in Geriatric Medicine. 2019;35:469-487.
4. Sławiński G, Hawryszko M, Liżewska-Springer A, Nabiałek-Trojanowska I, Lewicka E. Global longitudinal strain in cardio-oncology: A review. Cancers (Basel). 2023, 15.
5. Nagueh SF, Khan SU. Left atrial strain for assessment of left ventricular diastolic function: focus on populations with normal LVEF. Journal of the American College of Cardiology: Cardiovascular Imaging. 2023;16:691-707.
6. Caminiti G, Volterrani M, Iellamo F, Marazzi G, Manzi V, D'Antoni V, *et al*. Changes in left atrial function following two regimens of combined exercise training in patients with ischemic cardiomyopathy: a pilot study. Frontiers in Cardiovascular Medicine. 2024;11.
7. Yue T, Wang Y, Liu H, Kong Z, Qi F. Effects of high-intensity interval vs. moderate-intensity continuous training on cardiac rehabilitation in patients with cardiovascular disease: A systematic review and meta-analysis. Frontiers in Cardiovascular Medicine. 2022;9:845225.
8. Eser P, Trachsel LD, Marcin T, Herzig D, Freiburghaus I, De Marchi S, *et al.* Short- and long-term effects of high-intensity interval training vs. moderate-intensity continuous training on left ventricular remodeling in patients early after ST-segment elevation myocardial infarction—the HIIT-EARLY randomized controlled trial. Frontiers in Cardiovascular Medicine. 2022;9:869501.
9. D'Andrea A, Carbone A, Ilardi F, Pacileo M, Savarese C, Sperlongano S, *et al*. Effects of high intensity interval training rehabilitation protocol after an acute coronary syndrome on myocardial work and atrial strain. Medicina (Kaunas). 2022;58.
10. Ma J, Tai Y, Fan M, Wang Z. Cardiac rehabilitation of patients with acute ST-elevation myocardial infarction undergoing primary percutaneous coronary intervention in a Han population in Northern China: a prospective cohort study. International Journal of General Medicine. 2021;14:4959-4965.
11. Lawton JS, Tamis-Holland JE, Bangalore S, Bates ER, Beckie TM, Bischoff JM, *et al*. 2021 ACC/AHA/SCAI guideline for coronary artery revascularization: executive summary: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation. 2022, 145
12. McGregor G, Powell R, Begg B, Birkett ST, Nichols S, Ennis S, *et al*. High-intensity interval training in cardiac rehabilitation: a multi-centre randomized controlled trial. European Journal of Preventive Cardiology. 2023;30:745-55.
13. Krishnasamy R, Isbel NM, Hawley CM, Pascoe EM, Burrage M, Leano R, *et al.* Left ventricular global longitudinal strain (GLS) is a superior predictor of all-cause and cardiovascular mortality when compared to ejection fraction in advanced chronic kidney disease. PLOS One. 2015;10
14. Gan GCH, Ferkh A, Boyd A, Thomas L. Left atrial function: evaluation by strain analysis. Cardiovascular Diagnosis and Therapy. 2018;8:29-46.
15. Elbarbary M, Shalaby HK, Elshokafy SM, Khalil MA. Gender differences in presentation, management, and outcomes among Egyptian patients with acute coronary syndrome: a single-centre registry. BMC Cardiovascular Disorders. 2024;24:364.
16. Bhardwaj R, Kandoria A, Sharma R. Myocardial infarction in young adults: risk factors and pattern of coronary artery involvement. Nigerian Medical Journal. 2014;55:44-47.
17. Elkersh AA, Samir A, Reda A. The risk factor profile in Egyptian patients with acute coronary syndrome: an observational study. Menoufia Medical Journal. 2022;35:359-363.
18. Anand V, Garg S, Garg J, Bano S, Pritzker M. Impact of exercise training on cardiac function among patients with type 2 diabetes: a systematic review and meta-analysis. Journal of Cardiopulmonary Rehabilitation and Prevention. 2018;38:358-365.
19. Murray J, Bennett H, Bezak E, Perry R, Boyle T. The effect of exercise on left ventricular global longitudinal strain. European Journal of Applied Physiology. 2022;122:1397-1408.
20. D'Ascenzi F, Pelliccia A, Alvino F, Solari M, Loffreno A, Cameli M, *et al*. Effects of training on LV strain in competitive athletes. Heart. 2015;101:1834-1839.
21. Kaur A, Sakul F, Dhaliwal A, Gwon Y, Balboul Y, Argulian E. Effects of high intensity interval training on cardiorespiratory fitness and left ventricular function in patients enrolled in cardiac rehabilitation after recent myocardial infarction. Journal of the American College of Cardiology. 2024;83:1756.
22. Aispuru-Lanche GR, Gallego-Muñoz M, Jayo-Montoya JA, Villar-Zabala B, Maldonado-Martín S. Low-volume and high-intensity aerobic interval training may attenuate dysfunctional ventricular remodeling after myocardial infarction: data from the INTERFARCT study. Reviews in Cardiovascular Medicine. 2023;24:20.
23. Caminiti G, Volterrani M, Iellamo F, Marazzi G, Manzi V, D'Antoni V, *et al*. Changes in left atrial function following two regimens of combined exercise training in patients with ischemic cardiomyopathy: a pilot study. Frontiers in Cardiovascular Medicine. 2024;11:1377958.
24. Tadic M, Grassi G, Cuspidi C. Cardiorespiratory fitness in patients with type 2 diabetes: a missing piece of the puzzle. Heart Failure Reviews. 2021;26:301-308.
25. Huang YC, Hsu CC, Fu TC, Wang JS. A randomized controlled trial of enhancing hypoxia-mediated right cardiac mechanics and reducing afterload after high intensity interval training in sedentary men. Scientific Reports. 2021;11:12564.
26. Wang Y, Wang Y, Xu D. Effects of different exercise methods and intensities on the incidence and prognosis of atrial fibrillation. Trends in Cardiovascular Medicine; c2024.
27. Kim M, Bae S, Park JH, Jung IH. Relative importance of left atrial reservoir strain compared with components of the HFA-PEFF score: a cross-sectional study. Frontiers in Cardiovascular Medicine. 2023;10:1213557.

28. Atan T, Karavelioğlu Y. Effectiveness of high-intensity interval training vs moderate-intensity continuous training in patients with fibromyalgia: A pilot randomized controlled trial. Archives of Physical Medicine and Rehabilitation. 2020;101:1865-1876.
29. Marwick TH. Measurement of strain and strain rate by echocardiography: ready for prime time? Journal of the American College of Cardiology. 2006;47:1313-1327.
30. Amundsen BH, Rognmo Ø, Hatlen-Rebhan G, Slørdahl SA. High-intensity aerobic exercise improves diastolic function in coronary artery disease. Scandinavian Cardiovascular Journal. 2008;42:110-117.
31. Pearson MJ, Mungovan SF, Smart NA. Effect of exercise on diastolic function in heart failure patients: a systematic review and meta-analysis. Heart Failure Reviews. 2017;22:229-242.
32. Cavero-Redondo I, Saz-Lara A, Martínez-García I, Bizzozero-Peroni B, Díaz-Goñi V, Díez-Fernández A, *et al*. Comparative effect of two types of physical exercise for the improvement of exercise capacity, diastolic function, endothelial function and arterial stiffness in participants with heart failure with preserved ejection fraction (ExIC-FEp study): protocol for a randomized controlled trial. Journal of Clinical Medicine. 2023, 12.

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