

Retrospective comparative analysis of short-term outcomes of inpatient rehabilitation following acute myocardial infarction

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Abstract

Background. Cardiac rehabilitation is a key element of the multidisciplinary approach to treating patients with acute myocardial infarction. The location of the infarction and the timing of primary percutaneous coronary intervention influence the benefits of rehabilitation.

Material and methods. An early rehabilitation program was implemented for 111 patients with ST-segment elevation myocardial infarction, both with and without primary percutaneous coronary intervention. The study involved an analysis of heart rate, systolic blood pressure, and subjective ratings of physical exertion.

Results. Patients who underwent percutaneous coronary intervention within the first 12 hours of the infarction demonstrated the most favorable physical response to exertion throughout the program sessions. Statistically significant differences were observed primarily in heart rate values and subjective ratings of exertion. Patients with inferior myocardial infarction showed a better physical response regarding the studied parameters compared to those with anterior myocardial infarction.

Conclusions. Regardless of the treatment method, the implementation of an early rehabilitation program involving a gradual increase in exercise intensity is safe and effective and is recommended for all patients.

Keywords: percutaneous coronary intervention, myocardial infarction, inpatients, rehabilitation, exercise

Introduction

Cardiovascular diseases remain the leading cause of mortality and disability worldwide [1]. One of the major advances in the management of patients with acute myocardial infarction (AMI), particularly ST-segment elevation myocardial infarction (STEMI), has been the implementation of primary percutaneous coronary intervention (PCI). Importantly, primary PCI is associated not only with reduced mortality but also with improved quality of life and a lower risk of recurrent coronary events [2].

Cardiac rehabilitation is a key element of the multidisciplinary management approach in patients with AMI. Numerous randomized controlled trials have demonstrated that participation in cardiac rehabilitation programs is associated with reduction in all-cause mortality, cardiovascular

mortality, and the risk of recurrent myocardial infarction [3,4]. Beyond its prognostic benefits, cardiac rehabilitation has a significant positive impact on patients' quality of life, which represents a key outcome from the patients' perspective following hospital discharge [5,6].

Cardiac rehabilitation for patients following myocardial infarction has evolved considerably in recent decades and has become an established component of clinical practice in most countries. Meta analyses of numerous studies have demonstrated that both inpatient and outpatient rehabilitation programs are safe and effective interventions for improving patients' physical and psychological well-being [7,8]. Standardized nursing care plans for these patients also encompass rehabilitation during postoperative period, and a holistic approach ensures quality of care. Rehabilitation programs should not be regarded as an isolated component of care. Their effectiveness has been shown to be significantly enhanced when combined with appropriate nutritional counseling, structured physical activity, emotional support, and mental health care interventions [9,10]. Cardiac rehabilitation is recommended and recognized as an essential component of effective clinical management following myocardial infarction in both international studies and officially adopted guidelines [9,11,12].

Aim of the work

The aim of the study was to present a retrospective comparative analysis of short-term outcomes of inpatient rehabilitation after AMI in patients with and without PCI.

Material and methods

Study design

The study is retrospective and was conducted between March and April 2026, based on recorded data from a rehabilitation program for patients following an AMI.

The overall study comprises two stages of assessing patient responses to the implemented rehabilitation program. The first stage takes place during the patients' hospital stay, while the second stage follows ongoing rehabilitation following discharge. This publication presents results only from the hospital stay.

A study analyzing the results of a rehabilitation program for patients with STEMI was conducted over a period of approximately one year (2019-2020). The study was carried out at the Specialized Hospital for Active Treatment in Cardiology in Pleven, Bulgaria. The following inclusion and exclusion criteria were applied. Inclusion criteria: patients with STEMI treated with PCI via radial access, patients at low and moderate risk, informed consent signed personally by the patient. Exclusion criteria: patients at high risk, prior myocardial infarction, post-infarction angina, severe aortic stenosis, uncontrolled arrhythmias (until hemodynamic stability is achieved), uncontrolled diabetes and metabolic disorders, concomitant chronic diseases significantly limiting physical functional capacity – musculoskeletal disorders, central and peripheral nervous system disorders, chronic respiratory failure, chronic renal failure (requiring hemodialysis), patients with significant stenosis of a coronary artery other than the infarct-related artery.

A cardiac rehabilitation program developed by the authors was implemented based on extensive clinical experience in the management of patients with AMI, while adhering to the generally accepted principles of cardiac rehabilitation [12]. In addition to the conventional rehabilitation protocol, breathing and active rehabilitation exercises were introduced at an earlier stage following PCI, though no sooner than two hours after the removal of the compression dressing from the vascular access site.

A total of 124 patients met the predefined inclusion and exclusion criteria and were enrolled in the study. During the course of inpatient care, 13 patients were withdrawn. Consequently, 111 patients completed the rehabilitation program. Prior to the participation, all the patients were informed about the program and provided written informed consent. The patients were stratified into three groups (Table 1). The first group comprised 46 patients with AMI who underwent PCI within 12 hours of symptom onset. The second group included 51 patients with AMI who underwent PCI more than 12 hours after symptoms onset. The third group consisted of 14 patients with AMI who did not undergo PCI. The location of the myocardial infarction is significant for the patients' rehabilitation potential; therefore, all the patients were further divided into two groups: those with anterior AMI – 46 (41.4%) and those with inferior AMI – 65 (58.6%).

Table 1. Characteristics of the study population

Characteristics	AMI and PCI ≤12 hours (n=46)	AMI and PCI > 12 hours (n=51)	AMI without PCI (n=14)	Total (n=111)
Demographic characteristics				
Age, years (Mean±SD)	59.3±4.974	62.2±5.338	63.1±5.889	-
Female, n (%)	19 (41.3)	21 (41.2)	5 (35.7)	
Male, n (%)	27 (58.7)	30 (58.8)	9 (64.3)	
AMI, n (%)				
Anterior MI	21 (45.7)	19 (37.3)	6 (42.9)	-
Inferior MI	25 (54.4)	32 (62.8)	8 (57.1)	

Notes: MI – myocardial infarction; AMI – acute myocardial infarction; PCI – percutaneous coronary intervention.

In the evaluation of the results of the applied program, the heart rate values, systolic blood pressure values, and subjective complaints of the individuals were analyzed. Diastolic blood pressure values showed no significant differences and were therefore not included in the discussion of the results.

To assess subjective complaints and ensure the correct dosing of physical exertion, we applied the Borg Rating of Perceived Exertion scale after each procedure. We used the classic Borg first scale for rating perceived exertion from 6 to 20. The Borg Rating of Perceived Exertion provides a reliable method for assessing exercise tolerance, particularly in patients receiving beta-blocker therapy. In such patients, the use of heart rate as an indicator of exercise intensity may lead to substantial inaccuracies due to the modulating effects of beta-blockers on this hemodynamic parameter, which is usually included on the first day, and the dose is adjusted during the hospital stay.

Descriptive statistics were used to analyze the results; for quantitative variables, these included the arithmetic mean and standard deviation (Mean±SD), while qualitative variables were presented using absolute and relative frequencies (n, %). To assess the normality of the distribution, a P-P plot, a histogram, skewness coefficients, and the Kolmogorov-Smirnov test were used. The normality assessment revealed that the quantitative variables were normally distributed ($p>0.05$). Parametric methods were applied to determine statistically significant differences in mean values between independent samples (groups) for normally distributed variables: the Welch t-test was used for two samples, and analysis of variance (ANOVA) for three groups. Statistical data processing was performed using IBM SPSS Statistics v.25 software. Results were considered

statistically significant at a significance level of $p < 0.05$. The rehabilitation program had a duration of 4 days and was conducted by a physiotherapist under the supervision of a cardiologist.

Methodology of the rehabilitation program

Day 1. Within the first 24 hours following PCI, a rehabilitation session was performed. The patient does not perform active movements with the arm until the radial compression device is removed. Rehabilitation takes place two hours after the device is removed and includes: massage techniques applied to the distal parts of the upper and lower limbs, breathing exercises, and exercises for small and medium muscle groups while in a supine position. The dosage of exercises is 2-4 repetitions, with a duration of 3-5 minutes.

Day 2. On the second day, the rehabilitation session is conducted twice daily – in the morning and the afternoon. The first session includes: massage techniques applied to the distal parts of the upper and lower limbs; exercises for small, medium, and large muscle groups in a supine position; transitioning to a sitting position followed by exercises for small, medium, and large muscle groups; and breathing exercises combined with exercises for small and medium muscle groups in a supine position. In addition to exercises for various muscle groups, the second session includes sitting up in bed, coordination and balance exercises, mobilizing the patient to a standing position, and walking around the bed (10-15 steps). The dosage of exercises is 4-6 repetitions, with a duration of 10-15 minutes.

Day 3. On the third day, the rehabilitation session is conducted twice daily – in the morning and the afternoon. The first procedure includes: exercises in lying and sitting positions; walking distances of 20 to 50 meters; and independent eating and personal hygiene. In the second procedure, the activity regimen is expanded to include walking up to 100 meters. Exercises in the lying position are also performed, with a dosage of 4-6 repetitions and a duration of 15-20 minutes.

Day 4. Rehabilitation takes place once daily. In addition to the exercise routine and walking up to 100 meters along the corridor at a moderate pace, stair climbing (ascending and descending) is introduced. The dosage of exercises is of 4-6 repetitions, with a duration of 20-25 minutes.

The proposed rehabilitation program adheres to the generally accepted principles of cardiac rehabilitation [12]. Patients are required to receive instructions regarding physical activity at home, as well as recommendations for healthy nutrition and training in self-monitoring of hemodynamic

parameters [10]. In hemodynamically stable patients with controlled angina symptoms and no complications, the protocol advances to changes in body position (sitting up in bed, sitting with legs dangling, standing, walking 100 meters, and climbing up and down stairs).

Indications for terminating the procedure include: onset of subjective symptoms (shortness of breath, perceived exertion, etc.), hemodynamic parameters exceeding permissible limits, pathological orthostatic response. Contraindicated exercises: high-intensity, rapid-pace exercises involving breath-holding, sudden bending of the torso or head, isometric exercises, abrupt changes in starting position, lifting the lower limbs from a lying position.

Results

The mean age of the patients differed between the study groups ($F(2, 108)=4.819$, $p=0.010$). Patients in Group 1 were younger with a mean age 59.3 ± 4.97 years compared to those in Group 2 with a mean age 62.2 ± 5.34 years and Group 3 with a mean age 63.1 ± 5.89 years. A statistically significant difference was observed between Group 1 and Group 2 (Welch t-test $= -2.769$, $df=94.89$, $p=0.007$) and between Group 1 and Group 3 (Welch t-test $= -2.188$, $df=19.00$, $p=0.041$), whereas no significant difference was found between Group 2 and Group 3 (Welch t-test $= -0.517$, $df=19.27$, $p=0.611$). Therefore, we have taken age into account when interpreting the results in the discussion. The distribution of anterior and inferior myocardial infarction was comparable across the three study groups, with no statistically significant difference observed between the groups ($\chi^2(2)=0.716$, $p=0.699$).

The results of the hemodynamic response to the prescribed physical exercise interventions and the degree of cardiovascular workload is demonstrated in increase in heart rate compared with resting values (Table 2).

Table 2. Increase in heart rate during the main phase of the rehabilitation session compared with resting values in the three patient groups

Day/session	Mean $\pm$ SD			T test		
	AMI and PCI ≤ 12 hours (n=46)	AMI and PCI > 12 hours (n=51)	AMI without PCI (n=14)			
	(1)	(2)	(3)	(1-2)	(1-3)	(2-3)
Day 1 1 st session	12.2 $\pm$ 2.860	11.6 $\pm$ 3.110	13.4 $\pm$ 4.320	1.010	0.990	1.480

Day 2						
2nd session	11.8±2.080	12.9±2.320	14.1±3.080	2.510*	2.650**	1.360
3rd session	15.9±2.430	17.1±2.370	17.4±3.650	2.470*	1.400	0.240
Day 3						
4th session	20.2±1.960	20.9±2.450	22.2±2.930	1.400	2.300*	1.510
5th session	21.1±2.780	22.4±3.390	24.0±3.610	2.000*	2.770*	1.530
Day 4						
6th session	21.4±2.200	24.6±2.620	26.9±3.050	6.360***	6.270***	2.650*

Notes: AMI – acute myocardial infarction; PCI – percutaneous coronary intervention; * $p<0.05$; ** $p<0.01$; *** $p<0.001$.

On the first day of rehabilitation, the increase in heart rate was 12.2 beats/min in the first group, 11.6 beats/min in the second group, and 13.4 beats/min in the third group. On the second session of rehabilitation, statistically significant differences emerged. The increase in heart rate was lower in Group 1 compared with the other two groups, measuring 11.8 beats/min versus 12.9 beats/min (Welch t-test=2.510, $df=94.998$, $p<0.05$), and, respectively, 14.1 beats/min (Welch t-test=2.510, $df=94.998$, $p<0.05$). This trend persisted throughout the rehabilitation program and remained evident during the final rehabilitation session, when the differences in the mean increase in heart rate among the three groups reached statistical significance. The increase in heart rate was 21.4 beats/min in the first group, 24.6 beats/min in the second group, and 26.9 beats/min in the third group ($F(2,108)=33.73$, $p<0.001$).

The rise in systolic blood pressure during the main phase compared to the resting phase is smallest during the second procedure and greatest during the fifth procedure. Statistically significant differences are observed during the third session between the first and second groups, as well as during the fourth session, where differences also exist with the third group (without PCI) (Table 3).

Table 3. Increase in systolic blood pressure during the main phase of rehabilitation sessions compared with resting values in the three patient groups

Day/session	Mean±SD			T test		
	AMI and PCI ≤12 hours (n=46)	AMI and PCI >12 hours (n=51)	AMI without PCI (n=14)			
	(1)	(2)	(3)	(1-2)	(1-3)	(2-3)
Day 1						
1st session	10.4±5.340	9.3±4.680	8.5±6.210	1.090	1.050	0.450
Day 2						
2nd session	8.0±6.210	7.6±4.670	4.7±5.730	0.700	1.900	1.560
3rd session	10.9±6.450	13.9±5.580	12.7±4.530	2.450*	1.200	0.810

Day 3						
4th session	10.3±4.230	13.0±5.430	14.2±4.290	2.750*	3.020*	0.900
5th session	14.9±6.230	14.5±5.420	15.9±4.980	0.290	0.660	0.920
Day 4						
6th session	14.1±6.430	13.2±5.820	11.8±5.920	0.740	1.370	0.860

Notes: AMI – acute myocardial infarction; PCI – percutaneous coronary intervention. * Statistically significant differences at $p<0.05$.

At the end of each rehabilitation session, patients rated their perceived level of exertion using the Borg Rating of Perceived Exertion (Table 4).

Table 4. Rating of perceived exertion using the Borg Rating of Perceived Exertion

Day/session	Mean±SD			T test		
	AMI and PCI ≤12 hours (n = 46)	AMI and PCI >12 hours (n = 51)	AMI without PCI (n=14)			
	(1)	(2)	(3)	(1-2)	(1-3)	(2-3)
Day 1						
1st session	8.0±1.440	8.5±1.340	7.9±1.680	1.550	0.270	1.170
Day 2						
2nd session	7.9±1.480	8.6±1.620	8.2±1.530	2.220*	0.760	0.750
3rd session	8.2±1.390	8.9±1.580	9.1±1.640	2.220*	1.670	0.290
Day 3						
4th session	9.1±1.670	9.8±1.710	9.8±1.730	2.070*	1.240	0.120
5th session	9.8±1.460	10.5±1.290	10.9±1.520	2.420*	2.480*	1.030
Day 4						
6th session	10.5±1.520	11.1±1.480	11.7±1.680	2.030*	2.310*	1.090

Notes: AMI – acute myocardial infarction; PCI – percutaneous coronary intervention. * Statistically significant differences at $p<0.05$.

The results on the scale show that statistically significant differences are observed primarily between the first and second groups, whereas no statistically significant difference is observed between the second and third groups in any of the sessions.

The extent of left ventricular functional impairment led us to hypothesize that infarct localization may influence patients' rehabilitation potential.

The patients are further divided into two groups: those with inferior myocardial infarction and those with anterior myocardial infarction. Table 5 summarizes the changes in heart rate during the main exercise phase relative to resting values. As early as the first rehabilitation session, the increase in heart rate was greater in patients with anterior AMI than those with inferior AMI, and

the difference was statistically significant. In the second and fifth sessions, no significant differences ($p>0.05$) were observed, while in the third and fourth sessions, there was a significant difference in the reported average heart rate of patients with anterior and inferior AMI ($p<0.05$). During the sixth rehabilitation session, the mean increase in heart rate reached 21.5 beats/min in the group with inferior myocardial infarction and 24.8 beats/min in the group with anterior myocardial infarction.

Table 5. Increase in heart rate during the main phase of the rehabilitation sessions compared with resting values in patients with anterior AMI and inferior AMI

Day/session	Mean±SD		T test (1-2)
	Inferior AMI (n=65)	Anterior AMI (n=46)	
	(1)	(2)	
Day 1 1 st session	10.2 ± 4.230	13.8 ± 4.610	4.150*
Day 2 2 nd session	12.0 ± 3.590	12.6 ± 3.780	0.910
3 rd session	13.4 ± 3.270	15.8 ± 2.680	4.330*
Day 3 4 th session	18.9 ± 3.510	21.9 ± 2.630	5.030*
5 th session	19.4 ± 2.780	21.7 ± 3.590	3.610
Day 4 6 th session	21.5 ± 3.940	24.8 ± 3.170	4.820*

Notes: AMI – acute myocardial infarction. * Statistically significant differences at $p<0.05$.

The increase in systolic blood pressure during the main exercise phase of the rehabilitation sessions was assessed relative to baseline values in patients with inferior and anterior myocardial infarction. The mean values and standard deviations for each group are presented in Table 6.

Table 6. Increase in systolic blood pressure during the main phase of the rehabilitation sessions compared with resting values in patients with anterior and inferior AMI

Day/session	Mean±SD		T test (1-2)
	Inferior AMI (n=65)	Anterior AMI (n=46)	
	(1)	(2)	
Day 1 1 st session	9.2±5.340	9.3±4.680	0.080
Day 2 2 nd session	7.6±6.210	8.0±4.670	0.430
3 rd session	12.2±6.450	12.8±5.580	0.440

Day 3 4th session	11.3±4.230	12.1±5.430	0.890
5th session	13.5±6.230	15.6±5.420	1.900
Day 4 6th session	13.2±6.430	14.0±5.820	0.610

Notes: AMI – acute myocardial infarction. * Statistically significant differences at $p<0.05$.

The analysis of systolic blood pressure shows no statistically significant differences between the first and fourth sessions nor in the sixth session ($p>0.05$). A difference approaching statistical significance was observed during the fifth procedure, where the mean value recorded for patients with inferior AMI was 13.5±6.230 mmHg, whereas higher values were registered for patients with anterior AMI (15.6±5.420; Welch t-test=1.900, df=104.30, $p=0.062$). The mean Borg Rating of Perceived Exertion scores demonstrated statistically significant differences between the two groups, as presented in Table 7.

Table 7. Borg Rating of Perceived Exertion scores following rehabilitation sessions in patients with anterior and inferior AMI

Day/session	Mean±SD		T test
	Inferior AMI (n=65)	Anterior AMI (n=46)	
	(1)	(2)	
Day 1 1st session	7.7±1.320	8.5±1.510	2.820*
Day 2 2nd session	8.0±1.470	8.6±1.390	2.260*
3rd session	8.3±1.340	9.1±1.430	2.790*
Day 3 4th session	9.1±1.450	10.0±1.600	3.070*
5th session	9.8±1.610	11.0±1.560	3.910*
Day 4 6th session	10.5±1.420	11.7±1.380	4.270*

Notes: AMI – acute myocardial infarction. * Statistically significant differences at $p<0.05$.

Analysis of the results shows a statistically significant difference across all sessions. The most substantial differences in mean values are observed in the fifth (Welch t-test=3.910, df=98.80, $p=0.000$) and sixth sessions (Welch t-test=4.270, df=98.80, $p=0.000$).

Discussion

Despite the slight increase in exercise intensity throughout the rehabilitation program, a decrease in heart rate values between the first and second procedures was observed. This finding may be explained by the effects of beta-blocker therapy, which modulates heart rate not only at rest but also during physical exertion. A gradual increase in heart rate values follows, with the rate corresponding to low- to moderate-intensity workloads during the final procedure. These findings indicate that the rehabilitation program adhered to the predefined exercise prescription and progression guidelines. Another notable observation was the gradual emergence of differences in peak heart rate responses among the three study groups. The smallest increase was observed in patients who underwent PCI within 12 hours of symptoms onset, whereas the greatest increase was recorded in patients who did not undergo PCI. By the final rehabilitation session, the differences in heart rate response among the three groups had reached statistical significance. The reason for this is likely early PCI combined with pharmacological treatment. The location of the infarction also plays a role in the heart's compensatory activity and its adaptation to increasing physical exertion intensity – a process most noticeably observed after the second day. Statistically significant differences indicate a greater rise in heart rate among patients with an anterior AMI. This increase is gradual and corresponds to the rise in intensity, despite the body's slower adaptability resulting from the more severe nature of the infarction.

Analysis of systolic blood pressure values shows the smallest increase by the 12th hour among patients undergoing PCI – an indication of better cardiovascular system adaptation to exertion. The rise in systolic pressure relative to the location of the infarction is gradual in both groups, with higher values recorded in patients with anterior AMI. The absence of statistically significant differences in systolic pressure between the two groups indicates that the implemented rehabilitation program is well tolerated. However, patients with inferior AMI show a better physical response.

Changes in hemodynamic parameters cannot always be correctly used to assess the intensity of the applied loads and the degree of the body's adaptation to them. In certain circumstances, patients' subjective perceptions of exertions may provide a more accurate assessment of exercise intensity [13]. Data on the subjective perception of exertion are lower for the first group throughout the program but differ from the ratings of the group undergoing later PCI, highlighting the

importance of earlier intervention. Differences compared to the third group emerge at the end of the program, likely due to a slower physical response and slower recovery as exercise intensity increases. Rehabilitation interventions for patients with AMI, initiated as early as the first week following the event, are safe and effective and have a positive impact on quality of life, including the subjective perception of physical exertion [14]. The localization of the infarction is primarily associated with the patients' subjective assessment of the exertion intensity. Consistently, patients with inferior AMI rate the effect of physical exertion lower than those with anterior AMI during all sessions.

The rehabilitation program used in this study continued after the patients' discharge, but the results are not the subject of the present publication.

Limitations of the study

The study limitations are as follows: an insufficient number of subjects in the third group; the Borg Rating of Perceived Exertion measures the subjective perception of physical exertion based on individual characteristics; a single-center study design, and insufficient data recorded in hospital documentation.

Conclusions

The presented results indicate that the rehabilitation potential of patients with AMI depends on the location of the infarction and the timing of the PCI. Patients in the study who underwent PCI within 12 hours of onset demonstrated the best hemodynamic response. Patients with inferior myocardial infarction showed better adaptation to the physical exertion prescribed in the rehabilitation program. Regardless of the treatment method, the implementation of an early rehabilitation program involving a gradual increase in exercise intensity is safe and effective and is recommended for all patients.

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The study was conducted retrospectively in accordance with the principles of the Declaration of Helsinki and the manuscript was approved by the Research Ethics Committee of the Medical University in Pleven, Bulgaria (No. 45/14.07.2026). The rehabilitation program was carried out in accordance with the principles of the Declaration of Helsinki and following the receipt of written informed consent from the patients.

Artificial intelligence (AI) was not used in the creation of the manuscript.

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