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АЛГОРИТМЫ ЭХОКАРДИОГРАФИЧЕСКОЙ ОЦЕНКИ ДЛЯ ПЕРСОНАЛИЗАЦИИ ПРОГРАММ МЕДИЦИНСКОЙ РЕАБИЛИТАЦИИ ПОСЛЕ ИНФАРКТА МИОКАРДА

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АННОТАЦИЯ

Актуальность. Инфаркт миокарда остаётся одной из ведущих причин смертности и инвалидизации, а эффективность медицинской реабилитации во многом определяет отдалённый прогноз пациентов. В современных условиях особое значение приобретает персонализация реабилитационных программ с учётом функционального состояния сердечно-сосудистой системы. Цель исследования. Оценить роль эхокардиографических параметров в разработке алгоритмов персонализации медицинской реабилитации у пациентов после инфаркта миокарда.

Материалы и методы. В исследование включено 111 пациентов, разделённых на основную группу (n=68), получавшую персонализированную реабилитацию с учётом эхокардиографических показателей, и контрольную группу (n=43), получавшую стандартную терапию. Проводилась оценка систолической и диастолической функции левого желудочка, показателей физической работоспособности (VO_2max, 6-минутный тест ходьбы, PWC170).

Результаты. У пациентов основной группы отмечено достоверное улучшение фракции выброса левого желудочка, снижение показателя E/E′, улучшение функции правого желудочка и значительный прирост физической работоспособности. Установлены достоверные корреляции между эхокардиографическими параметрами и функциональным состоянием пациентов. Заключение. Использование эхокардиографических алгоритмов позволяет эффективно персонализировать программы медицинской реабилитации, улучшая клинические исходы и качество жизни пациентов после инфаркта миокарда.

Ключевые слова: инфаркт миокарда, эхокардиография, кардиореабилитация, персонализация, фракция выброса, диастолическая функция

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ECHOCARDIOGRAPHIC ASSESSMENT ALGORITHMS FOR PERSONALIZATION OF CARDIAC REHABILITATION PROGRAMS AFTER MYOCARDIAL INFARCTION

ABSTRACT

Background. Myocardial infarction remains a leading cause of mortality and disability worldwide, while the effectiveness of cardiac rehabilitation significantly determines long-term outcomes. Personalization of rehabilitation programs based on functional cardiovascular assessment is becoming increasingly important.

Objective. To evaluate the role of echocardiographic parameters in developing algorithms for personalized cardiac rehabilitation in patients after myocardial infarction.

Materials and methods. The study included 111 patients divided into a main group (n=68), who underwent personalized rehabilitation based on echocardiographic parameters, and a control group (n=43), who received standard rehabilitation. Systolic and diastolic left ventricular function as well as functional capacity (VO_2max, 6-minute walk test, PWC170) were assessed. Results. The main group demonstrated a significant improvement in left ventricular ejection fraction, reduction in E/E′ ratio, improved right ventricular function, and a marked increase in exercise capacity. Significant correlations between echocardiographic parameters and functional performance were identified. Conclusion. Echocardiography-based algorithms allow effective personalization of cardiac rehabilitation programs, improving clinical outcomes and quality of life in post-myocardial infarction patients.

Keywords: myocardial infarction, echocardiography, cardiac rehabilitation, personalization, ejection fraction, diastolic function

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MIOKARD INFARKTIDAN KEYIN TIBBIY REABILITATSIYA DASTURLARINI SHAXSIYLASHTIRISH UCHUN EXOKARDIOGRAFIK BAHOLASH ALGORITMLARI

ANNOTATSIYA

Dolzarbligi. Miokard infarkti butun dunyoda o‘lim va nogironlikning asosiy sabablaridan biri bo‘lib qolmoqda, reabilitatsiya samaradorligi esa bemorlarning uzoq muddatli prognozini belgilaydi. Shu sababli yurak-qon tomir tizimining funksional holatini hisobga olgan holda individual reabilitatsiya dasturlarini ishlab chiqish muhim ahamiyat kasb etadi.

Tadqiqot maqsadi. Miokard infarktidan keyingi bemorlarda exokardiografik ko‘rsatkichlarga asoslangan shaxsiylashtirilgan reabilitatsiya algoritmlarining ahamiyatini baholash.

Material va usullar. Tadqiqotga 111 nafar bemor kiritildi: asosiy guruh (n=68) exokardiografik ko‘rsatkichlar asosida shaxsiylashtirilgan reabilitatsiya oldi, nazorat guruhi (n=43) esa standart davolash oldi. Chap qorincha sistolik va diastolik funksiyasi hamda jismoniy faollik ko‘rsatkichlari (VO_2max, 6 daqiqalik yurish testi, PWC170) baholandi.

Natijalar. Asosiy guruhda chap qorincha chiqarish fraksiyasining oshishi, E/E′ ko‘rsatkichining pasayishi, o‘ng qorincha funksiyasining yaxshilanishi va jismoniy ish qobiliyatining sezilarli ortishi kuzatildi. Exokardiografik ko‘rsatkichlar bilan funksional holat o‘rtasida ishonchli bog‘liqlik aniqlandi.

Xulosa. Exokardiografik algoritmlardan foydalanish reabilitatsiya dasturlarini shaxsiylashtirish imkonini berib, bemorlarning klinik natijalari va hayot sifatini yaxshilaydi.

Kalit so‘zlar: miokard infarkti, exokardiografiya, kardio reabilitatsiya, shaxsiylashtirish, chiqarish fraksiyasi, diastolik funksiya

Myocardial infarction remains one of the leading causes of death and disability worldwide, despite significant progress in the field of reperfusion therapy and drug treatment. Modern treatment strategies can significantly reduce hospital mortality, but the long-term prognosis of patients is largely determined by the effectiveness of subsequent medical rehabilitation. The postinfarction period is a critical phase during which the processes of myocardial remodeling are formed, determining the functional state of the cardiovascular system and the risk of complications.

In recent years, the understanding of the pathophysiological mechanisms of post-infarction remodeling has significantly expanded. Along with the traditional assessment of the left ventricular ejection fraction (LVEF), indicators of diastolic function, regional myocardial contractility, and parameters of hemodynamic adaptation are becoming increasingly important. Echocardiography, being an accessible and highly informative imaging method, allows a comprehensive assessment of the structural and functional state of the heart and serves as an important basis for clinical decision-making.

Despite the proven effectiveness of cardiac rehabilitation, the problem of significant interindividual variability in patients' response to standard recovery programs remains in clinical practice. Some patients show a marked improvement in their functional state, while others have a limited effect. This is due to differences in the degree of myocardial damage, the functional reserve of the heart, the presence of concomitant diseases and the peculiarities of metabolic adaptation.

In this regard, the development of personalized approaches to medical rehabilitation is of particular relevance. The integration of echocardiographic parameters into clinical decision-making algorithms makes it possible to more accurately stratify patients by risk level and individualize physical activity. The use of such algorithms contributes to improving the safety of rehabilitation, preventing myocardial overload and achieving optimal functional recovery.

Thus, the development and implementation of echocardiographically oriented algorithms for personalization of rehabilitation is an important area of modern cardiology and rehabilitation aimed at improving clinical outcomes and quality of life of patients after myocardial infarction.

The purpose of the study

To evaluate the clinical and functional significance of echocardiographic parameters and their role in the personalization of medical rehabilitation programs in patients after myocardial infarction.

Materials and research methods

The study was conducted on the basis of the Republican Scientific and Practical Center of Cardiology of the Samarkand regional branch. The study included 111 patients who had suffered an acute myocardial infarction and were undergoing medical rehabilitation.

All patients were in stable clinical condition and were divided into two groups. The main group consisted of 68 patients, in whom the rehabilitation program was formed taking into account echocardiographic parameters and individual functional characteristics. The comparison group included 43 patients who received standard rehabilitation according to generally accepted clinical recommendations.

Before starting rehabilitation, all patients underwent a comprehensive clinical examination, including anamnesis collection, assessment of risk factors for cardiovascular diseases, electrocardiography and echocardiography. Special attention was paid to the assessment of systolic and diastolic function of the left ventricle.

Transthoracic echocardiography was performed in accordance with international guidelines. The following parameters were evaluated: left ventricular ejection fraction (LVEF), final diastolic and systolic volumes, regional myocardial contractility, as well as indicators of diastolic function, including the E/E' ratio. Additionally, the function of the right ventricle was analyzed using the TAPSE indicator.

The functional state of the patients was assessed using physical performance indicators, including maximum oxygen consumption (VO_2Max), a 6-minute walking test, and a PWC170 score. These parameters were used to assess the tolerance of physical activity and the effectiveness of rehabilitation measures.

The inclusion criteria were confirmed myocardial infarction, stable clinical condition, the possibility of an echocardiographic examination, and informed consent of the patient. Exclusion criteria included unstable state, severe arrhythmias, severe concomitant diseases that limit physical activity, as well as acute inflammatory processes.

Statistical data processing was carried out using the IBM SPSS Statistics program. Quantitative indicators are presented as an average value and a standard deviation (M ± SD). The Student's t-test was used to compare the groups, and nonparametric methods were used for abnormal distribution. The differences were considered statistically significant at $p < 0.05$.

The results of the study

An analysis of the clinical and demographic characteristics of the patients showed that the main and control groups were comparable in all key indicators, which confirms the correctness of the comparative study. The average age of patients was 57.4 ± 8.2 years in the main group and 58.1 ± 7.9 years in the comparison group ($p>0.05$). Both groups were dominated by men (72.1% and 69.7%, respectively), the body mass index was in the overweight range (27.8 ± 3.6 and 28.1 ± 3.9 kg/m2). The incidence of hypertension, diabetes mellitus, smoking, and

recurrent myocardial infarction did not differ significantly (p>0.05), which indicates a uniform distribution of risk factors and allows an objective assessment of the impact of rehabilitation approaches.

Table 1. Clinical and demographic characteristics of patients (M ± SD)

Parameter	Main group (n=68)	Control group (n=43)	p
Age, years	57.4 ± 8.2	58.1 ± 7.9	>0.05
Male, %	72.1	69.7	>0.05
BMI, kg/m²	27.8 ± 3.6	28.1 ± 3.9	>0.05
Arterial hypertension, %	76.5	74.4	>0.05
Diabetes mellitus, %	21.3	23.2	>0.05
Smoking, %	38.2	41.8	>0.05
Recurrent myocardial infarction, %	16.2	18.6	>0.05

Dynamic observation of echocardiographic parameters demonstrated marked differences between the groups in response to the rehabilitation. In the main group, which used a personalized approach based on echocardiographic parameters, there was a significant improvement in the systolic function of the left ventricle. The ejection fraction increased from 46.8 ± 6.4% to 52.6 ± 6.1% (p<0.01), reflecting the restoration of myocardial contractility. At the same time, the improvement in this indicator was less pronounced in the comparison group (from 47.1 ± 6.1% to 49.3 ± 5.8%; p<0.05), which indicates the limited effectiveness of standard rehabilitation programs.

Table 2. Dynamics of echocardiographic parameters (M ± SD)

Parameter	Main group (baseline)	Main group (after)	Control (baseline)	Control (after)	p
LVEF, %	46.8 ± 6.4	52.6 ± 6.1	47.1 ± 6.1	49.3 ± 5.8	<0.01
LVEDV, ml	158 ± 28	142 ± 25	155 ± 27	150 ± 26	<0.05
LVESV, ml	86 ± 19	72 ± 17	84 ± 18	80 ± 17	<0.01
E/E′	12.8 ± 3.1	10.6 ± 2.7	12.6 ± 3.0	11.8 ± 2.9	<0.05
TAPSE, mm	19.2 ± 2.4	21.1 ± 2.5	19.0 ± 2.3	19.8 ± 2.4	<0.05

In parallel with the improvement of systolic function in the main group, there was a significant decrease in the end-diastolic and end-systolic volumes of the left ventricle (p<0.05 and p<0.01, respectively), which indicates a regression of post-infarction remodeling and an improvement in the geometry of the heart. A decrease in the E/E ratio from 12.8 ± 3.1 to 10.6 ± 2.7 (p<0.05) reflects an improvement in diastolic function and a decrease in left ventricular filling pressure, which is important for increasing exercise tolerance. Improvement of the TAPSE index (from 19.2 ± 2.4 to 21.1 ± 2.5 mm; p<0.05) indicates a restoration of right ventricular function and an improvement in interventricular interaction. In the control group, similar changes were less pronounced and in most cases did not reach statistical significance.

The analysis of the functional state of the patients confirmed the clinical significance of the echocardiographic changes. In the main group, there was a significant increase in maximum oxygen consumption (VO_2Max) from 18.6 ± 3.2 to 22.4 ± 3.5 ml/kg/min (p<0.01), reflecting a significant improvement in aerobic performance. The PWC170 index increased from 630 ± 110 to 790 ± 125 kgm/min (p<0.01), and the 6-minute walking distance increased from 412 ± 58 to 495 ± 64 m (p<0.001), indicating an increase in physical endurance and functional status of patients. At the same time, there was a decrease in resting heart rate and systolic blood pressure, which indicates an improvement in autonomic regulation and hemodynamic adaptation. There was also a positive trend in the comparison group, but it was less pronounced and in some cases statistically insignificant.

Table 3. Dynamics of functional parameters (M ± SD)

Parameter	Main group (baseline)	Main group (after)	Control (baseline)	Control (after)	p
VO_2max, ml/kg/min	18.6 ± 3.2	22.4 ± 3.5	18.9 ± 3.4	20.1 ± 3.6	<0.01
PWC170, kgm/min	630 ± 110	790 ± 125	640 ± 115	710 ± 120	<0.01
6-minute walk test, m	412 ± 58	495 ± 64	418 ± 60	450 ± 62	<0.001
Resting heart rate, bpm	78 ± 9	70 ± 8	77 ± 10	73 ± 9	<0.05
Systolic BP, mmHg	138 ± 14	128 ± 12	137 ± 15	132 ± 13	<0.05

The correlation analysis revealed a close relationship between echocardiographic indicators and the level of physical performance. The most pronounced positive correlation was found between the left ventricular ejection fraction and VO_2Max (r=0.54; p<0.01), which confirms the key role of systolic function in the formation of aerobic capacity. A similar relationship was found between LVEF and the distance of a 6-minute walk (r=0.49; p<0.01). At the same time, an increase in the E/E' index reflecting diastolic dysfunction was accompanied by a decrease in physical performance (r=-0.51 for VO_2Max and r=-0.47 for a 6-minute walk; p<0.01), which indicates a significant effect of diastolic disorders on exercise tolerance. Additional correlations between LV BWT, TAPSE, and physical activity indicators confirm the complex nature of cardiohemodynamic and functional interactions.

The results of the ROC analysis demonstrated the high prognostic significance of echocardiographic parameters in assessing patients' physical performance. The E/E' ratio showed the greatest diagnostic value (AUC=0.81; p<0.001), which allows us to consider this indicator as one of the key markers of physical activity restriction. The left ventricular ejection fraction also showed high prognostic significance (AUC=0.78; p<0.001), whereas LVEF and TAP had moderate diagnostic accuracy.

Table 4. Correlation analysis (r)

Variables	r	p
LVEF and VO_2max	0.54	<0.01
LVEF and 6MWT	0.49	<0.01
E/E′ and VO_2max	−0.51	<0.01
E/E′ and 6MWT	−0.47	<0.01

LVEDV and VO_2max	−0.42	<0.05
TAPSE and 6MWT	0.45	<0.05

Thus, the results obtained convincingly demonstrate that the use of an echocardiographically oriented personalized approach to medical rehabilitation provides a more pronounced restoration of both the structural and functional state of the myocardium and the physical performance of patients compared with standard programs. The revealed interrelations between echocardiographic and functional parameters confirm the pathogenetic validity of the proposed approach and its clinical effectiveness.

Discussion

The results obtained confirm that the inclusion of echocardiographic parameters in the algorithm for choosing a medical rehabilitation program after a myocardial infarction can significantly improve its clinical effectiveness. In the main group, where physical activity was selected taking into account echocardiographic stratification, more pronounced positive changes were noted both from the side of the structural and functional state of the myocardium and from the side of physical performance. This allows us to consider a personalized echocardiographic approach not just as an additional diagnostic tool, but as an important component of clinical decision-making in cardiac rehabilitation.

One of the most significant results of the study is a significant increase in the left ventricular ejection fraction in the main group from 46.8 ± 6.4% to 52.6 ± 6.1%, while in the comparison group the positive dynamics was less pronounced. This indicates that metered-dose physical activity, adapted to the initial state of the myocardium, can contribute to more favorable postinfarction remodeling. The decrease in the final diastolic and final systolic volumes of the left ventricle in the main group additionally confirms the presence of positive structural adaptation and regression of unfavorable remodeling, which in the post-infarction period is one of the main pathophysiological mechanisms of heart failure progression.

Data on the dynamics of diastolic function are of particular importance. The decrease in the E/E' ratio in the main group reflects a decrease in the filling pressure of the left ventricle and an improvement in the processes of myocardial relaxation. This result has important clinical significance, since, as literature data show, it is diastolic function disorders that often become one of the key limitations of physical performance, even in patients without a sharply reduced ejection fraction. In a study by Fontes-Carvalho et al. It has been shown that increased E/E' is one of the strongest echocardiographic predictors of decreased exercise tolerance after myocardial infarction [9]. Our data, including the revealed negative correlation between E/E' and VO_2Max, are fully consistent with these observations and confirm the importance of assessing diastolic function in the rehabilitation planning process.

Equally important is the improvement in the function of the right ventricle, expressed in an increase in TAPSE in the main group. In modern cardiology, more and more attention is being paid to the role of right ventricular function in the formation of general exercise tolerance and prognosis in patients after an acute coronary event. Although TAPSE demonstrated only moderate prognostic value in ROC analysis, its positive dynamics indicates a more harmonious restoration of intracardiac hemodynamics in patients undergoing individualized rehabilitation.

The functional results of the study also deserve special attention. An increase in VO_2Max, an increase in PWC170, and a significant improvement in the 6-minute walking distance in the main group indicate a significant recovery in aerobic capacity and overall physical endurance. This is especially important because physical performance after myocardial infarction is considered not only as an indicator of quality of life, but also as an independent prognostic marker of cardiovascular outcomes. Literature data confirm that participation in structured cardiac rehabilitation programs is associated with improved survival and a decrease in the frequency of adverse events [4, 5, 16]. Our results expand these concepts, showing that the greatest effect is achieved precisely by personalizing the rehabilitation program based on objective echocardiographic parameters.

The correlation analysis confirmed the close relationship between indicators of cardiac function and physical performance. The positive correlation between LVEF and VO_2Max, as well as between LVEF and the 6-minute walking distance, shows that an improvement in contractile function is accompanied by a real increase in the patient's functional capabilities. At the same time, the negative relationship between E/E' and exercise performance confirms that diastolic dysfunction plays an important role in limiting physical reserves. These results correspond to the modern understanding of post-infarction rehabilitation as a process in which not only restoration of pumping function, but also complex hemodynamic adaptation of the heart to physical activity is crucial.

The ROC analysis demonstrated the high predictive value of the E/E' and LVEF indicators for identifying patients with reduced physical performance. It is particularly important that E/E' ≥13 showed the highest diagnostic accuracy. This allows us to consider this parameter as one of the key criteria for risk stratification when planning rehabilitation loads. In practical terms, this means that the inclusion of a standard echocardiographic assessment of diastolic function in the cardiac rehabilitation algorithm can contribute to a safer choice of training regimen and earlier identification of patients requiring a gentle and controlled approach.

The results obtained should also be considered in the context of current international trends. Experts from the European Association of Preventive Cardiology emphasize the need to move from standard cardiac rehabilitation programs to more personalized models that take into account the clinical, functional and instrumental characteristics of the patient [10]. Our study actually confirms the practical feasibility of this approach and demonstrates its effectiveness in real clinical conditions. Of additional importance is the fact that the proposed model is based on a widely available method — transthoracic echocardiography, which makes it applicable in everyday clinical practice.

Thus, the results of the study show that the personalization of medical rehabilitation programs after myocardial infarction based on echocardiographic assessment can not only improve the contractile and diastolic function of the heart, but also significantly improve the physical performance of patients. This confirms the pathogenetic and clinical validity of the use of echocardiographic algorithms in cardiac rehabilitation and determines the prospects for further implementation of such approaches in the post-infarction monitoring system.

Conclusions

The inclusion of echocardiographic parameters in the algorithm for planning medical rehabilitation after myocardial infarction provides a more pronounced improvement in the structural and functional state of the heart compared with standard rehabilitation. Personalized rehabilitation based on LVEF, E/E', LVEF, LVEF, and TAPSE assessments contributes to a significant increase in the contractile function of the left ventricle, improved diastolic function, and a more favorable adaptation of the right ventricle. The use of echocardiographic stratification can significantly improve physical performance indicators, including VO_2Max, PWC170 and the results of a 6-minute walking test, which confirms the clinical effectiveness of an individualized approach. The most informative echocardiographic predictors of decreased physical performance in patients after myocardial infarction are the E/E' ratio and the left ventricular ejection fraction. The threshold value E/E' ≥13 has high diagnostic accuracy for predicting low load tolerance. Statistically significant correlations have been established between echocardiographic indicators and physical performance parameters, which confirms the possibility of using EchoCG as an objective basis for the personalization of cardiac rehabilitation programs. The developed algorithm of echocardiographic assessment can be recommended for practical application in the system of medical rehabilitation of patients after myocardial infarction in order to increase the safety, effectiveness and prognostic significance of rehabilitation measures.

Список литературы / References/Iqtiboslar:

1. Ambrosetti, M.; Abreu, A.; Corra, U.; Davos, C.H.; Hansen, D.; Frederix, I.; Iliou, M.C.; Pedretti, R.F.; Schmid, J.P.; Vigorito, C.; et al. Secondary prevention through comprehensive cardiovascular rehabilitation: From knowledge to implementation. 2020 update. A position paper from the Secondary Prevention and Rehabilitation Section of the European Association of Preventive Cardiology. Eur. J. Prev. Cardiol. 2020, 28, 460–495.
2. Andjic, M.; Spiroski, D.; Ilic Stojanovic, O.; Vidakovic, T.; Lazovic, M.; Babic, D.; Ristic, A.; Mazic, S.; Zdravkovic, M.; Otasevic, P. Effect of short-term exercise training in patients following acute myocardial infarction treated with primary percutaneous coronary intervention. Eur. J. Phys. Rehabil. Med. 2016, 52, 364–369.
3. Conraads, V.M.; Pattyn, N.; De Maeyer, C.; Beckers, P.J.; Coeckelberghs, E.; Cornelissen, V.A.; Denollet, J.; Frederix, G.; Goetschalckx, K.; Hoymans, V.Y.; et al. Aerobic interval training and continuous training equally improve aerobic exercise capacity in patients with coronary artery disease: The SAINTEX-CAD study. Int. J. Cardiol. 2015, 179, 203–210.
4. De Schutter, A.; Kachur, S.; Lavie, C.J.; Menezes, A.; Shum, K.K.; Bangalore, S.; Arena, R.; Milani, R.V. Cardiac rehabilitation fitness changes and subsequent survival. Eur. Heart J. Qual. Care Clin. Outcomes 2018, 4, 173–179
5. de Vries, H.; Kemps, H.M.; van Engen-Verheul, M.M.; Kraaijenhagen, R.A.; Peek, N. Cardiac rehabilitation and survival in a large representative community cohort of Dutch patients. Eur. Heart J. 2015, 36, 1519–1528
6. Dhakal, B.P.; Malhotra, R.; Murphy, R.M.; Pappagianopoulos, P.P.; Baggish, A.L.; Weiner, R.B.; Houstis, N.E.; Eisman, A.S.; Hough, S.S.; Lewis, G.D. Mechanisms of exercise intolerance in heart failure with preserved ejection fraction: The role of abnormal peripheral oxygen extraction. Circ. Heart Fail. 2015, 8, 286–294.
7. Fletcher, G.F.; Ades, P.A.; Kligfield, P.; Arena, R.; Balady, G.J.; Bittner, V.A.; Coke, L.A.; Fleg, J.L.; Forman, D.E.; Gerber, T.C.; et al. Exercise standards for testing and training: A scientific statement from the American Heart Association. Circulation 2013, 128, 873–934.
8. Fontes-Carvalho, R.; Azevedo, A.I.; Sampaio, F.; Teixeira, M.; Bettencourt, N.; Campos, L.; Gonçalves, F.R.; Ribeiro, V.G.; Azevedo, A.; Leite-Moreira, A. The Effect of Exercise Training on Diastolic and Systolic Function After Acute Myocardial Infarction: A Randomized Study. Medicine 2015, 94, e1450.
9. Fontes-Carvalho, R.; Sampaio, F.; Teixeira, M.; Rocha-Gonçalves, F.; Gama, V.; Azevedo, A.; Leite-Moreira, A. Left ventricular diastolic dysfunction and E/E' ratio as the strongest echocardiographic predictors of reduced exercise capacity after acute myocardial infarction. Clin. Cardiol. 2015, 38, 222–229.
10. Gevaert, A.B.; Adams, V.; Bahls, M.; Bowen, T.S.; Cornelissen, V.; Dörr, M.; Hansen, D.; Kemps, H.M.; Leeson, P.; Van Craenenbroeck, E.M.; et al. Towards a personalised approach in exercise-based cardiovascular rehabilitation: How can translational research help? A 'call to action' from the Section on Secondary Prevention and Cardiac Rehabilitation of the European Association of Preventive Cardiology. Eur. J. Prev. Cardiol. 2020, 27, 1369–1385.
11. Houstis, N.E.; Eisman, A.S.; Pappagianopoulos, P.P.; Wooster, L.; Bailey, C.S.; Wagner, P.D.; Lewis, G.D. Exercise Intolerance in Heart Failure With Preserved Ejection Fraction: Diagnosing and Ranking Its Causes Using Personalized O2 Pathway Analysis. Circulation 2018, 137, 148–161. [Google Scholar] [CrossRef]
12. Hurley, D.M.; Williams, E.R.; Cross, J.M.; Riedinger, B.R.; Meyer, R.A.; Abela, G.S.; Slade, J.M. Aerobic Exercise Improves Microvascular Function in Older Adults. Med. Sci. Sports Exerc. 2019, 51, 773–781.
13. Jayo-Montoya, J.A.; Maldonado-Martin, S.; Aispuru, G.R.; Gorostegi-Anduaga, I.; Gallardo-Lobo, R.; Matajira-Chia, T.; Villar-Zabala, B.; Blanco-Guzman, S. Low-Volume High-Intensity Aerobic Interval Training Is an Efficient Method to Improve Cardiorespiratory Fitness After Myocardial Infarction: Pilot study from the interfarct project. J. Cardiopulm. Rehabil. Prev. 2020, 40, 48–54.
14. Kjesbu, I.E.; Mikkelsen, N.; Sibilitz, K.L.; Wilhelm, M.; Pena-Gil, C.; González-Salvado, V.; Iliou, M.C.; Zeymer, U.; Meindersma, E.P.; Ardissino, D.; et al. Greater burden of risk factors and less effect of cardiac rehabilitation in elderly with low educational attainment: The Eu-CaRE study. Eur. J. Prev. Cardiol. 2021, 28, 513–519.
15. Knuuti, J.; Wijns, W.; Saraste, A.; Capodanno, D.; Barbato, E.; Funck-Brentano, C.; Prescott, E.; Storey, R.F.; Deaton, C.; Cuisset, T.; et al. 2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes. Eur. Heart J. 2020, 41, 407–477.
16. Kyuno, E.; Iso, Y.; Tsujiuchi, M.; Maeda, A.; Miyazawa, R.; Kowaita, H.; Kitai, H.; Sato, T.; Ebato, M.; Sambe, T.; et al. Impact of Exercise-Based Cardiac Rehabilitation on the Mid-Term Outcomes of Patients After Acute Myocardial Infarction Treated with Current Acute-Phase Management and Optimal Medical Therapy. Heart Lung Circ. 2021, 30, 1320–1328.
17. Lang, R.M.; Badano, L.P.; Mor-Avi, V.; Afilalo, J.; Armstrong, A.; Ernande, L.; Flachskampf, F.A.; Foster, E.; Goldstein, S.A.; Kuznetsova, T.; et al. Recommendations for cardiac chamber quantification by echocardiography in adults: An update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Eur. Heart J. Cardiovasc. Imaging 2015, 16, 233–271.
18. Lazzeroni, D.; Castiglioni, P.; Bini, M.; Faini, A.; Camaiora, U.; Ugolotti, P.T.; Centorbi, C.S.; Brambilla, L.; Brambilla, V.; Piepoli, M.F.; et al. Improvement in aerobic capacity during cardiac rehabilitation in coronary artery disease patients: Is there a role for autonomic adaptations? Eur. J. Prev. Cardiol. 2017, 24, 357–364.
19. Nichols, S.; Taylor, C.; Goodman, T.; Page, R.; Kallvikbacka-Bennett, A.; Nation, F.; Clark, A.L.; Birkett, S.T.; Carroll, S.; Ingle, L. Routine exercise-based cardiac rehabilitation does not increase aerobic fitness: A CARE CR study. Int. J. Cardiol. 2020, 305, 25–34.
20. Peixoto, T.C.; Begot, I.; Bolzan, D.W.; Machado, L.; Reis, M.S.; Papa, V.; Carvalho, A.C.; Arena, R.; Gomes, W.J.; Guizilini, S. Early exercise-based rehabilitation improves health-related quality of life and functional capacity after acute myocardial infarction: A randomized controlled trial. Can. J. Cardiol. 2015, 31, 308–313
21. Piepoli, M.F.; Hoes, A.W.; Agewall, S.; Albus, C.; Brotons, C.; Catapano, A.L.; Cooney, M.T.; Corrà, U.; Cosyns, B.; Deaton, C.; et al. 2016 European Guidelines on cardiovascular disease prevention in clinical practice: The Sixth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice (constituted by representatives of 10 societies and by

invited experts): Developed with the special contribution of the European Association for Cardiovascular Prevention & Rehabilitation (EACPR). Eur. J. Prev. Cardiol. 2016, 23, Np1–Np96.

22. Pugliese, N.R.; Fabiani, I.; Santini, C.; Rovai, I.; Pedrinelli, R.; Natali, A.; Dini, F.L. Value of combined cardiopulmonary and echocardiography stress test to characterize the haemodynamic and metabolic responses of patients with heart failure and mid-range ejection fraction. Eur. Heart J. Cardiovasc. Imaging 2019, 20, 828–836.

23. Shimiaie, J.; Sherez, J.; Aviram, G.; Megidish, R.; Viskin, S.; Halkin, A.; Ingbir, M.; Nesher, N.; Biner, S.; Keren, G.; et al. Determinants of Effort Intolerance in Patients With Heart Failure: Combined Echocardiography and Cardiopulmonary Stress Protocol. JACC Heart Fail. 2015, 3, 803–814.

24. 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, 16, e0255682.

25. Takagi, S.; Murase, N.; Kime, R.; Niwayama, M.; Osada, T.; Katsumura, T. Aerobic training enhances muscle deoxygenation in early post-myocardial infarction. Eur. J. Appl. Physiol. 2016, 116, 673–685.

26. Tashiro, H.; Tanaka, A.; Ishii, H.; Motomura, N.; Arai, K.; Adachi, T.; Okajima, T.; Iwakawa, N.; Kojima, H.; Mitsuda, T.; et al. Reduced exercise capacity and clinical outcomes following acute myocardial infarction. Heart Vessel. 2020, 35, 1044–1050.

27. Tucker, W.J.; Lijauco, C.C.; Hearon, C.M., Jr.; Angadi, S.S.; Nelson, M.D.; Sarma, S.; Nanayakkara, S.; La Gerche, A.; Haykowsky, M.J. Mechanisms of the Improvement in Peak VO2 With Exercise Training in Heart Failure With Reduced or Preserved Ejection Fraction. Heart Lung Circ. 2018, 27, 9–21.

28. Weatherald, J.; Sattler, C.; Garcia, G.; Laveneziana, P. Ventilatory response to exercise in cardiopulmonary disease: The role of chemosensitivity and dead space. Eur. Respir. J. 2018, 51, 1700860.

29. Werner, C.M.; Hecksteden, A.; Morsch, A.; Zundler, J.; Wegmann, M.; Kratzsch, J.; Thiery, J.; Hohl, M.; Bittenbring, J.T.; Neumann, F.; et al. Differential effects of endurance, interval, and resistance training on telomerase activity and telomere length in a randomized, controlled study. Eur. Heart J. 2019, 40, 34–46.

30. Witvrouwen, I.; Pattyn, N.; Gevaert, A.B.; Possemiers, N.; Van Craenenbroeck, A.H.; Cornelissen, V.A.; Beckers, P.J.; Vanhees, L.; Van Craenenbroeck, E.M. Predictors of response to exercise training in patients with coronary artery disease—A subanalysis of the SAINTEX-CAD study. Eur. J. Prev. Cardiol. 2019, 26, 1158–1163.