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Exercise-Based Cardiac Rehabilitation: Analyzing Clinical Effectiveness

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Abstract

Introduction and Purpose: Cardiac rehabilitation (CR) is a critical component in the management of patients recovering from cardiac events and procedures. This review aims to critically analyze the clinical effectiveness of exercise-based interventions within cardiac rehabilitation programs.

State of Knowledge: Recent studies have highlighted the role of structured exercise programs in improving cardiovascular health metrics, such as blood pressure, lipid profile, and cardiac function. Exercise-based CR has shown significant benefits in reducing mortality, improving exercise capacity, and enhancing the quality of life in cardiac patients. Challenges persist, however, in the adoption of uniform protocols and the integration of these programs into standard care. The review discusses various types of exercises included in CR, such as aerobic, resistance, and flexibility training, and evaluates their effectiveness based on recent clinical trials and cohort studies.

Summary: Exercise-based cardiac rehabilitation is an effective strategy for enhancing cardiac health and patient recovery post-cardiac event. It is imperative that healthcare providers advocate for and integrate comprehensive exercise programs into the rehabilitation process. Future research should focus on optimizing exercise protocols and expanding access to these vital services to improve outcomes across diverse patient populations. This review underscores the importance of exercise therapy in cardiac rehabilitation and advocates for its broader implementation within healthcare systems.

Key Words: Cardiac Rehabilitation; Physical Endurance; Exercise Therapy

I. Introduction

1. 1. Definition of cardiac rehabilitation

Cardiological rehabilitation is a comprehensive medical and therapeutic process aimed at improving the health and quality of life of patients after cardiovascular events, such as myocardial infarction, coronary angioplasty, cardiac surgery or heart failure. Cardiological rehabilitation includes an integrated approach, including health education, lifestyle modification, psychological support and, above all, regular physical activity tailored to the

individual needs and capabilities of the patient [1].

The importance of cardiac rehabilitation in the treatment of cardiovascular diseases cannot be overestimated. Research has repeatedly confirmed that cardiological rehabilitation programs can significantly reduce the risk of relapse, reduce mortality, improve physical performance and quality of life. Regular exercise is a key component of these programs, benefiting the cardiovascular system, improving the control of risk factors such as hypertension, diabetes and hypercholesterolaemia, and supporting the mental health of patients [2,3].

1. 2. Purpose of the literature review

The main objective of this review is to analyze the effectiveness and mechanisms of action of cardiac rehabilitation with the use of physical exercise. We will focus on different training methods used in cardiac rehabilitation, such as Aerobic, Resistance, High Intensity Interval Training (HIIT) and Functional Training. We will also examine how these methods affect physical fitness, quality of life and clinical indicators of patients.|

The scope of work includes: Introduction to the topic and importance of cardiac rehabilitation, Discussion of physiological, biochemical and psychological mechanisms related to physical exercise, Review of training methods used in cardiac rehabilitation, as well as Analysis of the effectiveness of individual methods based on available scientific literature.

1. 3. Review methodology

The methodology of the review is based on a systematic approach to searching and analysing the scientific literature. Literature selection criteria include scholarly articles, systematic reviews, meta-analyses, clinical guidelines and academic textbooks published in English and Polish over the past two decades. We will focus on studies that assess the effectiveness of different training programs in cardiac rehabilitation and those that describe the mechanisms of action of physical exercise.

Data sources include reputable scientific databases such as PubMed, Scopus, Web of Science and Google Scholar. Search strategies have been developed to identify as many relevant studies as possible, using keyword combinations related to cardiac rehabilitation, exercise, training methods and clinical efficacy. All selected studies will be critically evaluated in terms of methodological quality and reliability of results.

Through a systematic review of the literature, this paper aims to provide a comprehensive

analysis that will help in a better understanding of the mechanisms of action and effectiveness of different methods of cardiac rehabilitation using physical exercise. The conclusions obtained will serve as a basis for further research and practical recommendations for clinicians and patients.

II. State of Knowledge

2. Mechanisms of Action of Physical Exercise in Cardiological Rehabilitation

2.1. Physiological basis of physical exercise

Regular physical activity has a multifaceted effect on the cardiovascular system, leading to numerous beneficial adaptations in both the heart and blood vessels [4].

The effect of exercise on the cardiovascular system

Exercise stimulates the cardiovascular system by increasing muscle oxygen demand. Regular training leads to improved cardiovascular function by increasing the heart's minute apacity and improving blood flow. By increasing the ejection volume and decreasing the frequency of cardiac contractions at rest, the heart becomes more efficient. In addition, physical exercise helps to dilate blood vessels and improve their flexibility, which reduces peripheral resistance and lowers blood pressure [5,6].

Adaptations of the heart and blood vessels to regular exercise

Adaptations of the heart to regular exercise include both structural and functional changes. Athletes and regular trainers experience an increase in heart muscle mass (physiological hypertrophy), which allows for a larger ejection volume with each contraction. The increase in the number of capillaries in skeletal muscles, called angiogenesis, improves the delivery of oxygen to tissues, which is crucial for increasing physical performance. In addition, the activity of oxidative enzymes also increases, which improves the ability of muscles to utilize oxygen [5-8].

2.2. Biochemical mechanisms of physical exercise

Exercise affects numerous biochemical processes in the body, leading to beneficial metabolic changes and improved overall health [9].

Changes in muscle and energy metabolism

Regular physical activity leads to increased aerobic muscle performance through an increase in the number and activity of mitochondria, whichare responsible for the production

of ATP in the process of oxidative phosphorylation. It also increases the activity of enzymes involved in the Krebs cycle and the respiratory chain, allowing for more efficient use of energy substrates such as glucose and fatty acids. Exercise also increases muscle insulin sensitivity, which is key to maintaining normal glucose homeostasis and reducing the risk of type 2 diabetes [9-11].

The role of anti-inflammatory and antioxidant factors

Physical activity also affects the balance between pro-inflammatory and anti-inflammatory cytokins, which contributes to the reduction of chronic inflammation, which often accompanies cardiovascular diseases. Regular exercise increases levels of anti-inflammatory cytokines such as IL-10 and decreases levels of pro-inflammatory markers such as TNF-α and CRP. In addition, exercise stimulates the production of endogenous antioxidants such as glutathione, which helps to neutralize free radicals and reduces oxidative stress, protecting cells from damage [12,13].

2.3. Psychological Aspects of Physical Exercise

Physical exercise also has a significant impact on the mental health of patients undergoing cardiac rehabilitation [14].

Impact on mental health of patients

Studies show that regular physical activity can significantly reduce the symptoms of depression and anxiety that often accompany patients after cardiovascular events. Mechanisms that may explain this effect include improving the function of neurotransmitters such as serotonin and dopamine, and increasing brain neuroplasticity. In addition, physical exercise promotes the release of endorphins, which act as natural painkillers and improve mood [15,16].

The importance of motivation and psychological support

Motivation to participate regularly in exercise programmes is key to achieving long-term health benefits. Psychological support, both from medical staff and loved ones, is extremely important to keep patients motivated. Rehabilitation programs often include educational components that help patients understand the importance of regular exercise and strategies for coping with motivational difficulties. In addition, group exercise sessions can provide social support and a sense of community, which also positively affects patient engagement [17,18].

The mechanisms of action of physical exercise in cardiac rehabilitation include both physiological, biochemical and psychological changes. Regular exercise leads to the adaptation of the cardiovascular system, improves muscle metabolism, reduces inflammation and oxidative stress, as well as supports the mental health of patients. Understanding these mechanisms is key to optimizing rehabilitation programs and maximizing health benefits for cardiac patients.

3. Overview of Cardiological Rehabilitation Methods Using Physical Exercise

3. 1. Aerobic training

Aerobic training is one of the most commonly used forms of physical exercise in cardiac rehabilitation. It includes a variety of activities such as walking, running, cycling, swimming and aerobics. The goal of aerobic training is to increase cardiovascular performance through moderate to intense physical exertion that involves large muscle groups.

Types of aerobic training:

Walking: This is the safest and most accessible form of aerobic exercise, ideal for the elderly and those with limited physical fitness.

Running: A more intense form of aerobic training that can be adapted to the patient's level of advancement.

Cycling: It can be done both outdoors and on stationary exercise bikes, which allows you to control the intensity of effort.

Swimming: An excellent form of exercise for people with joint problems, as it minimizes the load on the joints while engaging all major muscle groups.

Aerobics: Group activities that can be motivating and supportive for patients while promoting the social aspects of rehabilitation [19,20].

Effectiveness of aerobic training in cardiac rehabilitation

Studies show that regular aerobic exercise significantly improves heart function, increases VO2 max (the body's maximum capacity to absorb oxygen), and lowers blood pressure and cholesterol. Aerobic training is also effective in reducing weight and improving the overall quality of life of patients after cardiovascular events. Regular aerobic exercise helps prevent recurrence of coronary heart disease and reduces the risk of death from heart disease [19-21].

3. 2. Resistance training

Resistance training, also known as strength training, involves exercising with weights, resistance bands, or your own body weight. The goal is to increase muscle strength, endurance and muscle mass.

Types of resistance exercises and their implementation

Free weights: Exercises with dumbbells or barbells that allow for a variety of movements and the involvement of many muscle groups.

Resistance machines: Stabilize movement, which is beneficial for beginners or people with limited mobility.

Resistance straps: Flexible and portable, allow training in different conditions.

Exercises with own body weight: Pumps, squats, planks - involve the whole body and can be modified in terms of difficulty [22,23].

Benefits and Risks of Resistance Training

The benefits of resistance training in cardiac rehabilitation include improved muscle strength, increased muscle mass, better glycemic control and beneficial effects on bone health. Resistance training can also improve metabolic functions and contribute to the reduction of body fat. An important aspect is also the improvement of the ability to perform daily activities, which affects the quality of life of patients.

Risks associated with resistance training may include musculoskeletal injuries, especially if the exercise is performed incorrectly or without proper supervision. For patients with serious cardiac problems, intense resistance exercise can cause dangerous spikes in blood pressure [22-24].

3. 3. High Intensity Interval Training (HIIT)

HIIT is a form of training that consists of short, intense periods of physical exertion, interrupted by short periods of rest or low activity. HIIT is characterized by maximum effort for a short time, which allows you to achieve significant health benefits in a shorter time compared to traditional forms of training [25].

HIIT training characteristics

HIIT training can include a variety of exercises such as sprints, intense jumps, cycling at maximum effort, and even strength training at a fast pace. A typical HIIT session consists of intensive exercise cycles lasting from 20 to 60 seconds, followed by a rest or moderate exercise period lasting from 10 to 60 seconds [25,26].

The Effectiveness of HIIT in Improving Cardiovascular Health

Studies show that HIIT can be extremely effective in improving cardiovascular performance, increasing VO2 max and improving metabolic function. HIIT is also effective in reducing body fat and improving insulin sensitivity, which is important for patients with diabetes or metabolic syndrome. Despite its intensity, HIIT can be tailored to the patient's level of sophistication, making it safe and effective for people after cardiovascular events [25-27].

3. 4. Functional and combined training

Functional training focuses on improving the ability to perform daily activities by engaging multiple muscle groups at the same time. These exercises mimic the body's natural movements, such as bending down, lifting objects or climbing stairs. Combination training combines elements of different types of workouts, such as aerobic, resistance and HIIT, to achieve comprehensive health benefits.

Combination of different types of exercises

Circuit Training: Combines aerobic and resistance exercises performed in the circuit, allowing you to engage the whole body.

CrossFit: Integrates intense strength, endurance and fitness training to promote all-round fitness development.

Pilates: Focuses on strengthening deep muscles, improving flexibility and balance, which is important for overall fitness and injury prevention [28,29].

Individualization of training programs

Individualization of training programs is crucial in cardiac rehabilitation. Programmes must be tailored to the individual needs, capabilities and limitations of the patient. Taking into account age, baseline physical fitness, state of health and specific rehabilitation goals is essential to achieve optimal results. Personalised training also ensures that patients are more

motivated to participate in rehabilitation programmes on a regular basis, which translates into better health outcomes [30].

A review of cardiovascular rehabilitation methods using physical exercise shows that various forms of physical activity can significantly contribute to the improvement of cardiovascular health of patients. Aerobic, resistance, HIIT and functional and combined training have their specific advantages and can be used effectively in rehabilitation programs. A key element is the individualization of training programmes, which allows you to tailor the exercise to the needs and capabilities of each patient, thereby ensuring that the health benefits are maximized.

4. Effectiveness of Cardiological Rehabilitation through Physical Exercise

4. 1. Methods for assessing efficacy

Evaluating the effectiveness of exercise-based cardiac rehabilitation programmes requires the use of a variety of criteria and tools that allow a comprehensive analysis of the impact of exercise on patients' health.

Criteria and tools for evaluating the effectiveness of training programmes

The evaluation of the effectiveness of training programs is based on several key criteria:

Physical fitness: VO2 max measurement, exercise tests on a treadmill or cycle ergometer.

Cardiological parameters: Monitoring blood pressure, heart rate, cholesterol and glucose levels.

Body composition: Body weight measurement, BMI, body fat percentage.

Quality of life: Health-related quality of life questionnaires (e. g. SF-36, EQ-5D).

Mental functioning: Scales for depression, anxiety, stress (e. g. HADS, BDI).

Frequency of hospitalisations and mortality: Analysis of medical data on relapses, hospitalisations, deaths [31,32].

Short-term vs. long-term results

Short-term outcomes: Include the immediate effects of the rehabilitation program, such as improved physical performance, reduction of angina symptoms, lowering of blood pressure. Often evaluated after 12-16 weeks of regular exercise.

Long-term outcomes: Focus on lasting health changes, such as maintenance of improved physical performance, stabilization of cardiac parameters, reduction of hospitalization and mortality. Evaluated after a period of 6 months to several years [33-35].

4. 2. Effects on physical fitness

Changes in VO2 max and other performance parameters

VO2 max, the maximum amount of oxygen your body can use during intense exercise, is a key indicator of physical fitness. Regular exercise as part of cardiac rehabilitation leads to significant changes in VO2 max. Studies show that patients participating in rehabilitation programs may experience an increase in VO2 max of 15-25% [36].

Other performance parameters that are improving include:

Maximum Output Power: Ability to generate more power during physical exertion.

Anaerobic Threshold: Increasing the threshold at which the body begins to produce lactate, allowing for longer exercise without fatigue.

Time to Exhaustion: Extending the time the patient can maintain high intensity exercise [36-38].

Comparison of the effectiveness of different training methods

Aerobic training: Aerobic training such as walking, running or cycling has been shown to significantly improve VO2 max and other performance parameters. It is the most recommended form of exercise for cardiac patients due to its safe and effective nature.

Resistance training: Although traditionally less considered in cardiac rehabilitation, resistance training also contributes to improving physical performance, especially when combined with aerobic training.

HIIT: High Intensity Interval Training (HIIT) has proven to be very effective in improving VO2 max and other performance parameters, often delivering results faster than moderate-intensity aerobic training [19-27].

4. 3. Impact on quality of life

Quality of life assessment of patients undergoing rehabilitation

The quality of life of cardiac patients is a key aspect that should be assessed when analysing the effectiveness of rehabilitation. Quality-of-life assessment tools such as SF-36, EQ-5D and

CVD-specific questionnaires allow for a comprehensive assessment of the impact of rehabilitation on different aspects of patients' lives.

Studies show that regular participation in physical exercise programs significantly improves the quality of life of patients. Reducing symptoms of depression, anxiety and improving physical and mental well-being are key benefits of cardiac rehabilitation [39,40].

The role of exercise in improving well-being and social functioning

Exercise plays an important role in improving the well-being of patients, which is particularly important in the context of cardiac rehabilitation. Regular physical activity leads to the release of endorphins, which act as natural painkillers and improve mood. In addition, the group exercises and social support that patients receive during rehabilitation contribute to improved social functioning and a sense of community [41].

4.4. Impact on clinical indicators

Reducing the risk of relapse

One of the main goals of cardiac rehabilitation is to reduce the risk of recurrence of coronary artery disease. Studies show that regular participation in rehabilitation programs can reduce the risk of relapse by 20-30%. Exercise improves risk factors such as blood pressure, cholesterol and glycaemic control, which helps to reduce the risk of cardiovascular events [42-44].

Impact on mortality and hospitalisation rates

Cardiac rehabilitation has a significant impact on reducing mortality and hospitalization rates among cardiac patients. Studies show that participating in physical exercise programs can reduce cardiovascular mortality by as much as 25-30%. In addition, regular physical exercise leads to a reduction in the number of hospitalizations due to exacerbations of coronary artery disease, which significantly improves the quality of life of patients and reduces the burden on the healthcare system [45,46].

Cardiological rehabilitation through physical exercise is an effective tool to improve cardiovascular health, physical fitness, quality of life and reduce the risk of recurrence and mortality. Various methods of evaluating the effectiveness of rehabilitation programmes allow for a comprehensive analysis of their impact on patients' health. Regular physical exercise

leads to significant changes in VO2 max, other performance parameters, and has a beneficial effect on the mental well-being and social functioning of patients. Understanding and optimising these mechanisms is key to maximising the health benefits of cardiac rehabilitation.

III. Summary

A review of the literature on cardio rehabilitation through physical exercise reveals a number of important insights into the mechanisms of action and effectiveness of different training programs. Exercise plays a key role in cardiac rehabilitation, offering numerous health benefits to patients after cardiovascular events. Regular exercise, especially aerobic training, leads to a significant improvement in cardiovascular performance, increasing VO2 max and improving heart function. Exercise also helps to reduce blood pressure, cholesterol and weight control, which reduces the risk of recurrence of coronary heart disease. In addition, exercises such as resistance training and HIIT improve glycemic control, insulin sensitivity and reduce body fat, which is important for the prevention and treatment of type 2 diabetes. Regular physical activity also reduces symptoms of depression and anxiety, improving overall well-being and quality of life. Systematic exercise in cardiac rehabilitation programs can reduce cardiovascular mortality and reduce hospitalization rates.

The importance of physical exercise in cardiac rehabilitation cannot be overstated. Physical exercise is the foundation for effective rehabilitation, leading to multifaceted health benefits, both on a physiological, biochemical and psychological level. The effectiveness of various training methods, such as aerobic training, resistance training, HIIT and functional training, has been confirmed by numerous scientific studies, pointing to their key role in improving the health of cardiac patients.

In order to maximize the health benefits of cardio rehabilitation through physical exercise, it is necessary to implement several key practical recommendations for clinicians and patients. Rehabilitation programmes should be tailored to the individual needs, capabilities and limitations of patients. Taking into account age, baseline physical fitness, health status and specific rehabilitation goals is key to achieving optimal results. Regular monitoring of patient progress with fitness tests, blood pressure, cholesterol and glucose measurements, and quality of life assessments helps to adjust training programmes and motivate patients to continue exercising. Education about the importance of regular exercise and a healthy lifestyle is essential. Patients should be aware of the benefits of cardiac rehabilitation and how to deal with possible difficulties. Integrating psychological support into rehabilitation programs can help patients cope with anxiety, depression and motivation

issues, increasing their engagement and compliance with the exercise program.

Programmes should include a variety of forms of physical activity, such as aerobic, resistance, HIIT and functional exercises, to ensure comprehensive fitness development and maintenance of patient motivation. Ensuring patient safety through appropriate medical supervision and adjusting exercise intensity to their health is crucial to avoid overload and risk of injury. Exercise should be regular, with a recommendation of at least 150 minutes of moderate physical activity per week or 75 minutes of intense activity per week. Training sessions should last from 30 to 60 minutes, depending on the individual capabilities of the patient. The use of modern technologies such as telemedicine, mobile apps and wearables to monitor physical activity, health and motivate patients to exercise regularly can significantly increase the effectiveness of rehabilitation programmes.

In summary, cardiac rehabilitation through physical exercise is an effective method of improving cardiovascular health of patients. However, an individual approach to each patient, regular monitoring of progress, education and psychological support are crucial. The implementation of various forms of physical exercise, taking into account modern technologies, can significantly increase the effectiveness of rehabilitation programmes and bring long-term health benefits.

Disclosures

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Conceptualization- Daniel Gondko

Formal analysis- Patrycja Dębiec, Daniel Gondko, Jakub Roman

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