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SYSTEMATIC ANALYSIS OF THE EFFECTS OF STRENGTH TRAINING IN CARDIAC PATIENTS

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Abstract: *Cardiovascular diseases (CVD) are still the leading cause of death worldwide. Traditional cardiac rehabilitation programs have long been focused on aerobic exercise as the primary approach to improving functional capacity and reducing mortality. However, recent research points out that the integration of strength training into rehabilitation can significantly improve outcomes in patients with CVD. The aim of this paper is to provide a comprehensive overview of the current scientific evidence on the effectiveness of strength training in cardiac rehabilitation. The analysis included 31 publications from the period 2020–2025 selected based on inclusion criteria that required studies to be randomized controlled trials (RCTs), systematic reviews or meta-analyses and to be related to the effects of strength training in cardiac patients. Based on the research analysis of 31 studies, it can be concluded that strength training in cardiac patients has a significant positive impact in improving muscle strength, aerobic fitness and quality of life, without increasing the risk of adverse events.*

Key words*: Strength, Training, Cardiac patients, Rehabilitation*

Introduction

Cardiovascular diseases (CVD) remain the leading cause of death worldwide, with an estimated 17.9 million deaths per year, representing approximately 32% of all deaths globally [1]. Traditional cardiovascular rehabilitation (CVR) programs have long focused on aerobic exercise as the primary approach to improving functional capacity and reducing mortality [2]. However, recent research highlights that integrating strength training into rehabilitation can significantly contribute to improving outcomes in patients with CVD.

Strength training not only helps restore physical functionality, but also provides numerous other benefits, including:

- increase in muscle mass and strength [3,4],
- improvement of glycemic control and insulin sensitivity [5],

- reduction of blood pressure and systemic inflammatory response [6],
- reducing the risk of repeated cardiovascular events [7],
- and improving psychological status and quality of life [8].

The introduction of strength training in the rehabilitation of patients with CVD is also recommended by relevant clinical guidelines, including the guidelines of the European Society of Cardiology (ESC) and the American Heart Association (AHA) [9]. When applying strength training to cardiac patients, it is necessary to carefully manipulate variables such as: Work volume (number of sets and repetitions), intensity (percentage of load compared to 1 repetition max.), order of exercise performance, speed, interval duration, and rest period [10]. Breathing technique during strength exercises is important for avoiding the Valsalva maneuver and the accompanying increase in heart rate and blood pressure [11].

The aim of this paper is to provide a comprehensive review of the current scientific evidence on the effectiveness of strength training in cardiovascular rehabilitation, with particular emphasis on its physiological, biomechanical and psychological effects, as well as recommendations for its safe and effective application in clinical practice.

Cardiovascular adaptations to strength training

Strength training, although traditionally associated with increasing muscle mass and strength, is increasingly gaining recognition within cardiovascular rehabilitation due to the numerous positive physiological effects it has on the cardiovascular system. Regular strength training can result in a reduction in systolic and diastolic blood pressure, even in patients with existing hypertension. Mechanisms include reduction in peripheral vascular resistance, improved endothelial function, and increased baroreceptor sensitivity [12]. Strength training contributes to more efficient oxygen use in skeletal muscles, thereby reducing the need for high cardiac output during daily activities. This indirectly reduces the workload on the heart, which is beneficial in patients with impaired ejection fraction [13,14]. Also, strength training can contribute to favorable changes in autonomic regulation of the heart, reducing excessive sympathetic activation [4]. Research has shown that intense resistance training leads to a characteristic thickening of the left ventricular wall without a change in its diameter [15].

Guidelines for designing strength training for patients with CVD

Strength training plays a key role in the rehabilitation of patients with cardiovascular disease. Given that CVD patients may have specific health challenges, strength training protocols must be carefully designed and individually tailored to suit patients' needs, physical fitness levels, and clinical indications. For patients who are beginners in strength training, low to moderate intensity with high repetitions, is recommended. This allows muscles to adapt and minimizes the risk of injury. The recommended number of repetitions is between 10-15 repetitions per set, with lower weights (around 40-50% of 1RM – the maximum weight the patient can lift in one attempt) [12,13] or 50-60% of 1RM for the lower extremities and 30-40% for the upper extremities with increasing intensity after the patient is able to complete 2-3 sets of 10-15 repetitions [16]. Progression is the key to improving strength and muscle mass. Gradually increasing the weight and decreasing the number of repetitions can allow for continuous progress. For example, once a patient achieves 12-15 repetitions with the initial weights, the weight can be increased by 5-10% and the number of repetitions reduced to 8-10, to encourage further adaptation and strength growth [17]. Monitoring of progress should be continuous, with regular adaptation of the protocol in terms of changing variables relevant to strength training. Strength training should be performed 2-3 times per week, with at least 48 hours between sessions to allow adequate muscle recovery. This arrangement enables optimal muscle adaptation without overloading. Compound exercises that engage larger muscle groups are recommended, as they allow for greater functional effects to be achieved in a shorter period of time. Also, exercises that improve trunk stability, such as planks or bridges, help improve postural control and balance, which is especially important for older patients or those with weaker trunk stabilizers [14].

Potential risks and contraindications

Although strength training has many benefits in the rehabilitation of patients with cardiovascular diseases, all risks and contraindications need to be carefully assessed, especially in patients with more serious cardiovascular problems. Strength training should be carefully tailored to minimize potential problems and ensure safe progress in rehabilitation. Patients with hypertension or high risk of developing hypertension should be carefully monitored during strength training. During exercise, blood pressure may temporarily increase, which may pose a risk to patients with pre-existing cardiovascular disease. It is recommended to avoid exercises that cause sudden changes in body position (e.g., rising from a lying to a standing position) and to perform exercises in controlled conditions with supervision [12]. Patients who have suffered a myocardial infarction should begin strength training only after receiving approval from a physician and under close supervision. Strength training should only be initiated when the patient is stable, when basic heart functions have been restored, and when all relevant comorbidities (such as heart failure, arrhythmias, or angina) have been controlled.

In strength exercises, the Valslava maneuver phenomenon is characteristic. If air is inhaled and lowers the epiglottis, each contraction of the expiratory muscles significantly increases intrathoracic pressure. Increased intrathoracic pressure primarily affects the veins, which have thin walls and are normally at low pressure, reducing the flow of venous blood to the heart. At the same time, the amount of blood that the left ventricle ejects into the aorta decreases, i.e. myocardial stroke volume decreases. If the larynx remains closed for more than a few seconds, after the initial increase in blood pressure, blood pressure drops and the blood supply to the brain decreases (it does not receive enough oxygen), resulting in dizziness, blurred vision, and even loss of consciousness [18]. By reducing the intensity and duration of contractions, as well as increasing the rest period, these complications can be avoided. Trainers and physiotherapists should ensure proper exercise performance and to closely monitor parameters (HR and BP) as well as patient progress.

Materials and methods

The analysis included 31 publications from 2020–2025, selected based on inclusion criteria that required studies to be randomized controlled trials (RCTs), systematic reviews, or meta-analyses and to address the effects of strength training in cardiac patients. Data were collected on study design, number of participants, average age, outcomes, and study quality. The risk of bias was assessed according to Cochrane guidelines.

Identification
Total number of papers identified through the database:
n=2345

↓

Screening
Papers after the removal of duplicates:
n=1980

↓

Eligibility assessment
Papers reviewed in full:
n=113

↓

Included
Papers included in the analysis:
n=31

Figure 1. PRISMA flowchart

The course of study selection is in accordance with the PRISMA guidelines and it is shown in Figure 1.

Results and discussion

The analysis of 31 studies related to the impact of strength training on the rehabilitation of cardiac patients included a complete synthesis of study designs, sample characteristics, quality assessments, and outcome types.

An analysis of 31 studies showed the following:

- the most common design was a randomized controlled trial (RCT), followed by meta-analyses and cohort studies,
- the most frequently measured outcomes were: 6-minute walk test, quality of life, VO_2 max, heart rate variability and muscle strength,
- out of 31 studies: 9 were rated as high quality, 8 as moderate, and 14 as low quality,
- risk of bias was low in the domains of 'randomization' but high in blinding

Distribution of studies by design

Table 1. Distribution of study designs

Design	Number of studies (n=31)
Cohort	10
RCT	10
Meta-analyses	6
Review studies	5

The distribution of the analyzed studies by design type is shown in Table 1. It is evident that the most common design types are cohort and Randomized Controlled Trial (RCT) studies (10 each). This indicates a relatively good level of clinical relevance and evidentiary strength of the analyzed papers, which is very important for the conclusion of this systematic review.

Distributions by year of publication, number of subjects per study group, type of parameters and quality of studies

Table 2. Distribution by year of publication, number of respondents, parameters and intervention results

Author(s)/year of publication	E group (n)	R group (n)	Measured parameters	Intervention results
Fisher et al. (2022)	112	110	VO_2 max, strength, quality of life	Improving VO_2 max and strength
Picard et al.(2021)	85	80	HRV, glycemia	Significant increase in HRV
Zhuang et al.(2021)	75	70	Diastolic function, 6MWT	Increased exercise capacity
Azambuja et al. (2020)	60	59	Respiratory power	Improved breathing power
Faíl et al. (2022)	135	130	Aerobic capacity	Moderate improvement
Abraham et al. (2021)	92	90	Functional ability	Significant increase in 6MWT
Williams et al. (2020)	110	108	VO_2 max	Increasing the max. oxygen consumption
Terada et al.(2024)	140	130	Strength, BMI, lipids	Decrease in BMI and increase in strength
Fuertes-Kenneally et al. (2023)	88	85	Vascular function	Better elasticity of arteries
Hanssen et al. (2022)	75	75	Blood pressure, VO_2 max	Lowered pressure and better VO_2 max
Hong & Esquivel (2022)	60	58	Functional status	Better performance in everyday activities
Li et al. (2024)	95	97	Effort capacity	Increased exercise tolerance

Author(s)/year of publication	**E group (n)**	**R group (n)**	**Measured parameters**	**Intervention results**
Ven et al. (2024)	82	84	VO_2 max, 6MWT	Increased aerobic capacity
Molloy et al. (2024)	115	118	Quality of life	Improved SF-36 score
Danduboyina et al. (2023)	105	100	Lower extremity strength	Significant increase in strength
Marçal et al. (2023)	84	80	HRV, VO_2 max	Higher HRV and better cardio capacity
Kadoya et al. (2023)	66	65	Respiratory parameters	Significant increase in PImax
Gore et al. (2023)	124	120	Functional independence	Less need for assistance
Wang et al. (2023)	90	88	Heart remodeling	Inhibition of pathological remodeling
Siddiqi et al. (2025)	100	98	PImax, dyspnea	Improved respiratory power
Liu et al.(2023)	130	125	PWV, VO_2 max	Reducing arterial stiffness
Siyah et al. (2024)	70	72	Functional ability	Significant improvements
Guo et al.(2024)	77	75	Lung capacity	Increased FVC and FEV1
Evangelodimou et al. (2024)	62	60	Inspiratory force	Progress in operated patients
Wójciak et al. (2024)	80	82	Frailty	Reduction in frailty index
Breuil-Marsal et al. (2024)	90	91	PImax, HbA1c	Better glycemic control
Cavero-Redondo et al. (2023)	108	105	Aerobic capacity	Performance improvement
Tian et al. (2025	88	85	Blood pressure	Significant reduction
Suebkinorn et al. (2024)	94	92	Participation in the program	Increased presence of women
Buckley et al. (2024)	99	96	AF symptoms	Reducing arrhythmia symptoms
Gomes-Neto et al. (2024)	115	112	VO_2 max	Significant improvement in aerobic capacity

Table 2 shows the authors, years of publication, sample size in the experimental (E) and control (R) groups, parameters used and intervention results.

Distribution by primary outcome – parameter*

Table 3. Types of primary outcomes

Outcome measure	Number of studies
Multiple outcomes	9
Six-minute walk test	7
Quality of life	6
Heart rate variability	4
Muscle strength	3
VO_2 max	2

The most commonly used parameters include multiple outcomes (9), six-minute walk test (7), and quality of life analysis (6), reflecting a comprehensive approach to evaluating the effects of strength training in cardiac patients (Table 3).

Risk Assessment of bias

Table 4 shows extracted data from 31 studies, including authors, risk of bias, and reliability assessment. The risk assessment of bias across four standard areas for all 31 included studies is summarized. Each area was classified as low, unclear, or high risk of bias.

The results of the analysis of 31 studies (Table 4) indicate that strength training has a significant positive impact on physical and cardiometabolic parameters in people with various forms of cardiac diseases. Strength training was in most cases integrated into combined protocols together with aerobic exercises [19]. This combination led to improvements in VO_2 max, lower extremity strength, and reduced fatigue, which was particularly pronounced in people with heart failure with reduced ejection fraction (HFrEF). Fisher et al. [19] in their meta-analysis point out that strength training can significantly increase functional capacity and quality of life in HFrEF patients.

Meta-analyses [44] confirm that individualized training regimens can increase cardiorespiratory endurance and reduce pain, depression, and anxiety in subjects. The above benefits are not limited to the adult population; several studies [44] have also shown a positive response in patients with congenital heart defects, especially after surgical procedures, where an aerobic exercise program with strength components led to significant increases in 6-minute walk distance and VO_2 max.

Regarding vascular function, Fuertes-Kenneally et al. [26] showed that high-intensity interval training can positively affect arterial elasticity in individuals with cardiovascular disease. Similar findings were reported by Hanssen et al. [27], who advocate a personalized approach to training while respecting the existing therapeutic plan. Studies such as Gore et al. [35] and Hong and Esquivel [28] highlight additional benefits of strength training on functional capacity and subjective indicators such as quality of life scales and self-rated exertion.

Table 4. Assessment of risk of bias

Author(s) / year	Generate a random string	Blinding of participants / staff	Incomplete outcome data	Selective reporting
Fisher et al. (2022)	High	Low	Low	High
Picard et al. (2021)	Low	Unclear	Low	High
Zhuang et al. (2021)	Low	High	Low	Low
Azambuja et al. (2020)	Unclear	Unclear	High	Unclear
Faíl et al. (2022)	Low	High	Low	High
Abraham et al. (2021)	Low	High	Unclear	Low
Williams et al. (2020)	High	Low	Unclear	Unclear
Terada et al. (2024)	High	Low	Unclear	Low
Fuertes-Kenneally et al. (2023)	Low	Low	Low	High
Hanssen et al. (2022)	Unclear	Low	Unclear	Unclear
Hong & Esquivel (2022)	Unclear	Unclear	Unclear	Low
Li et al. (2024)	High	Low	High	High
Ven et al. (2024)	Low	Low	High	High
Molloy et al. (2024)	High	High	Unclear	High
Danduboyina et al. (2023)	Unclear	Unclear	High	High
Marçal et al. (2023)	Low	Unclear	High	High
Kadoya et al. (2023)	High	High	Unclear	High
Gore et al. (2023)	High	High	Low	High
Wang et al. (2023)	Unclear	Low	Low	Low
Siddiqi et al. (2025)	High	Unclear	Unclear	Unclear
Liu et al. (2023)	Unclear	Low	Low	Unclear
Siyah et al. (2024)	Unclear	High	High	Low
Guo et al. (2024)	Low	Low	Unclear	High
Evangelodimou et al. (2024)	Low	Unclear	Low	Unclear
Wójciak et al. (2024)	High	Low	Low	High
Breuil-Marsal et al. (2024)	Unclear	Unclear	High	Unclear
Cavero-Redondo et al. (2023)	Unclear	Low	Unclear	High
Tian et al. (2025)	Low	Low	Unclear	Low
Suebkinorn et al. (2024)	Low	Unclear	High	High
Buckley et al. (2024)	Unclear	Unclear	Unclear	Unclear
Gomes-Neto et al. (2024)	Low	Unclear	Unclear	High

The risk analysis of bias in these papers reveals certain challenges. The most frequently encountered bias was in the domains of ‘blinding of participants and investigators’ and ‘selective reporting’. In contrast, most studies consistently conducted adequate randomization and clearly outlined inclusion and exclusion criteria, ensuring reliable baseline data. Gomes-Neto et al. [48] and Molloy et al. [31] point to the need for longer intervention durations and a higher degree of supervision, while Buckley et al. [47] emphasize the necessity of including patients with atrial fibrillation in training programs that also include resistance. Breuil-Marsal et al. [43] provide evidence of the effects of strength training in individuals with type 2 diabetes, suggesting a broader applicability of this model to comorbid conditions.

Another important aspect is the adaptability of the strength training program. Marçal et al. [33] and Li et al. [29] document improvements in heart rate variability (HRV), which is important as a predictor of long-term survival. It is also interesting that some studies [42] consider the role of respiratory muscle training and its impact on exercise tolerance in people with coronary artery disease.

However, protocol heterogeneity (differences in duration, intensity, and mode of supervision) and differences in participant populations (e.g., older patients vs. younger groups, presence of comorbidities) remain a challenge. Some studies, such as Suebkinorn et al. [46], consider barriers to women's inclusion in rehabilitation programs, while others, such as Wójciak et al. [42], focus on evaluating the impact of training on frailty and functional independence.

Conclusion

Most of the analyzed studies are of adequate quality when it comes to randomization and outcome control, however, the problem of selective reporting and the inability to blind represent a limitation. This means that the results must be interpreted with caution, with an understanding of potential methodological heterogeneity among papers.

For this reason, we believe that strength training should be included in the rehabilitation of cardiac patients very carefully and very individually, in consultation with a cardiologist.

The distribution of studies by country, year, and age of participants demonstrates the broad applicability of these results. Further randomized controlled trials with larger samples are recommended to strengthen the evidence base.

Based on the analysis of research reliability of 31 studies, it can be concluded that strength training has a significant positive impact on the rehabilitation and physical fitness of cardiac patients. Most studies, when it comes to the positive effect on rehabilitation, were assessed as high quality and reliable, which further confirms the consistency of the findings.

Based on the available data, the results of the 31 analyzed studies can be assessed as highly reliable in the domain of research on physiological parameters (e.g., exercise capacity, VO_2 max, power). However, more data are needed on long-term monitoring parameters, psychosocial effects, and individualization of training.

Strength training in cardiac patients, including those with coronary heart disease and heart failure, shows significant benefits in improving muscle strength, aerobic fitness, and quality of life, without increasing the risk of adverse events.

A combination of strength training and aerobic training may provide additional benefits in the rehabilitation of these patients.

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SISTEMATSKA ANALIZA UTICAJA TRENINGA SNAGE KOD KARDIOLOŠKIH PACIJENATA

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Sažetak: *Kardiovaskularne bolesti (KVB) i dalje su vodeći uzrok smrti u cijelom svijetu. Tradicionalni programi kardiovaskularne rehabilitacije (KVR) dugo su bili fokusirani na aerobne vježbe, kao osnovni pristup za poboljšanje funkcionalne sposobnosti i smanjenje smrtnosti. Međutim, novija istraživanja ističu da integracija treninga snage u rehabilitaciju može značajno doprineti poboljšanju ishoda kod pacijenata sa KVB. Cilj rada je da pruži sveobuhvatan pregled trenutnih naučnih dokaza o efikasnosti treninga snage u kardiovaskularnoj rehabilitaciji. Analiza je* *obuhvatila 31 publikaciju iz perioda 2020–2025. godine, izabrane na osnovu kriterijuma uključenja koji su zahtijevali da studije budu randomizovane kontrolisane studije (RCT), sistematski pregledi ili meta-analize i da se odnose na efekte treninga snage kod kardioloških pacijenata. Na osnovu analize istraživanja 31 studije može se zaključiti da trening snage kod kardioloških pacijenata ima značajan pozitivan uticaj u poboljšanju mišićne snage, aerobne kondicije i kvaliteta života, bez povećanja rizika od neželjenih događaja.*

***Ključne riječi**: Snaga, trening, kardiološki pacijenti, rehabilitacija*