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Contributions to the Optimization of Physical Effort Capacity in Patients with Cardiovascular Pathology

PhD THESIS ABSTRACT

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PHD THESIS OUTLINE

PART II

PERSONAL CONTRIBUTIONS

Introduction

Cardiovascular rehabilitation plays a pivotal role in the recovery process following percutaneous transluminal coronary angioplasty (PTCA), exerting a significant influence on the patient's health status. This process effectively serves the core objectives of such an intervention: it enhances physical effort capacity, prevents recurrence, and optimizes long-term cardiovascular function.

As with any scientifically grounded approach, cardiac rehabilitation is methodologically structured, with physical exercise representing its central component—forming the foundation of kinesitherapy. Its role encompasses both the prevention of complications and the mitigation of risk factors associated with coronary heart disease.

The present research is structured into six chapters, arranged in a logical sequence dictated by the thematic progression. The first chapter addresses, in general terms, the core concepts underpinning cardiovascular rehabilitation, with a particular emphasis on physical exercise. Within this section, terminological distinctions are made between notions such as "endurance training" and "strength training," and technical terms like "frequency" and "intensity" are clarified, along with the objectives of a structured rehabilitation program.

The chapter is grounded in an in-depth review of the relevant scientific literature, with a focus on the general characteristics of exercise prescription, the types of exercises applied in cardiac conditions, and associated cardiovascular risk factors. Furthermore, the chapter establishes the place and role of psychological factors through an examination of the impact of rehabilitation programs on patients' quality of life. The specific features of this concept are elaborated at the end of this introductory section.

Such an approach would not have been complete without acknowledging the key milestones in the evolution of rehabilitation in general, and cardiovascular rehabilitation in particular. We believe that the exploration of the historical processes that have shaped the modern science of rehabilitation is essential for understanding future development perspectives in this field.

Chapter II takes the form of a detailed analysis of the training methods employed in cardiovascular pathology. The emphasis on concepts such as continuous training and interval training anticipates the central role they will play throughout this doctoral thesis. The review of the scientific literature served to establish the indications and contraindications for cardiovascular rehabilitation through physical training, the appropriate levels of exercise intensity, as well as the overall structure of a rehabilitation program.

The inclusion of a subchapter dedicated to resistance training reflects its essential role in the two applied studies presented later in the thesis. Questions regarding the effectiveness of cardiac rehabilitation were addressed through evidence derived from scholarly studies, while the efficiency of combined training programs was supported by practical examples.

Chapter III focuses on a recurring theme in the field of cardiovascular rehabilitation, namely physical effort capacity. Considered by many to be the ultimate goal of exercise-based intervention in cardiac diseases, effort capacity was analyzed from the perspective of its potential for improvement, closely related to physiological parameters such as VO_2, VO_2max, and MET. All available data demonstrate a direct relationship between effort capacity and overall health status. In the case of patients with coronary artery disease, it holds a privileged position, representing the primary target of all forms of physical training.

Chapter IV places in context the non-invasive surgical intervention used as the basis for subject selection in the applied studies presented in the following chapters. A brief historical overview of percutaneous coronary intervention (PCI) is followed by a description of the activities included in post-PTCA cardiac rehabilitation programs, with emphasis on their influence in improving both effort capacity and quality of life.

The benefits of physical training include both the control of risk factors and substantial changes in lifestyle. It is also noteworthy that physical exercise contributes to the reduction of hospitalization duration and has a prophylactic effect in preventing disease recurrence. This thesis highlights the lack of consensus in the scientific literature regarding the type of training that offers the highest level of safety for patients undergoing cardiovascular treatment. Furthermore, the comparative performance of various training programs is analyzed, revealing fundamental and structural differences between them—an analysis supported by a comprehensive tabular representation.

The theoretical component of the thesis concludes with an extensive overview of the characteristics of strength and aerobic training, focusing on their role in improving the physical effort capacity of cardiovascular patients, particularly those who have undergone myocardial revascularization procedures. Special attention is given to the essential role of regulating exercise intensity within the broader framework of cardiac rehabilitation.

The practical component of the doctoral thesis is presented in Chapters V and VI. The pilot study is included in the former and was based on dividing participants into two groups. Patients in Group 1 underwent an intervention program consisting of two types of training—strength training and endurance training on a cycle ergometer—while patients in Group 2 followed a traditional rehabilitation program based solely on endurance training on a cycle ergometer.

The specific aim of the research was to demonstrate the role and importance of rehabilitation programs in improving the health status of patients with cardiovascular disease by increasing their physical effort capacity.

The study hypotheses focused on the potential of the intervention program to enhance effort capacity, functional capacity, and exercise tolerance. Additionally, it was assumed that the implementation of a combined training program would result in increased exercise intensity. The research variables, instruments used, and testing and measurement procedures were subsequently defined.

Following the presentation of the intervention program structure, each of the aforementioned hypotheses was systematically tested. The statistical analysis employed Shapiro-Wilk, Wilcoxon, Paired Sample T-Test, and Independent Samples T-Test, preceded by the calculation of sample means and coefficients of variation.

Both the statistical analysis and direct observation of the collected data indicated improvements in the physical effort capacity of the majority of subjects in the pilot study. Observed parameters—VO_2, MET, the 6-minute walk test (6MWT), and exercise intensity—recorded substantial increases during the rehabilitation program, with the most significant improvements found in Group 1. As a result, the primary hypothesis and the four secondary hypotheses on which the study was based were all confirmed.

Given these outcomes, the expansion of the initial sample size was considered necessary to enhance the statistical relevance and validity of the findings. In addition to the initial physiological parameters, the extended study incorporated subjective assessments of physical effort capacity using the Duke Activity Status Index (DASI) and the SF-36 questionnaire.

This numerical extension of the study sample involved the use of a single cardiac rehabilitation program—namely, the one applied to Group 1—which included both aerobic and strength training. The rationale for selecting this program is evident, as it produced the most substantial improvements in the studied parameters.

The hypotheses of this main study are centered on the assumption that a structured rehabilitation intervention program constitutes an effective tool in increasing the physical effort capacity of coronary patients who have undergone PTCA procedures. From this, five sub-hypotheses are derived, similar to those of the pilot study. These sub-hypotheses pertain to the potential of the intervention program to improve effort capacity, functional capacity, exercise intensity, muscular strength and endurance, as well as overall physical resilience.

Keywords: cardiovascular diseases, percutaneous transluminal coronary angioplasty, physical exercise, effort capacity, strength training

PART I

THEORETICAL FOUNDATION OF THE RESEARCH TOPIC

CHAPTER I – CONCEPTUAL FRAMEWORK AND EVOLUTIONARY PROCESSES IN CARDIAC REHABILITATION

1.1 Key Milestones in the Evolution of Cardiovascular Rehabilitation

Over the past four decades, cardiac rehabilitation has evolved from a simple monitoring program aimed at enabling patients to safely resume daily physical activities into a comprehensive, multidisciplinary cardiac care program. It now includes postoperative care, optimization of medical treatment, nutritional counseling, smoking cessation support, management of hypertension, and control of diabetes and dyslipidemia.

1.2 Physical Exercise in Cardiac Rehabilitation: Prescription, Recommendations, and Applications in Risk Factor Management

Cardiac rehabilitation is a cost-effective and indispensable component of comprehensive cardiovascular care for patients with heart disease, with an average program duration of 3–4 weeks (Wenger, 2008). The outcomes of rehabilitation programs have demonstrated their primary role in increasing exercise capacity and reducing cardiovascular risk factors. These improvements play a decisive role in enhancing quality of life by decreasing hospital readmission rates and lowering mortality (Oldridge et al., 2019).

1.2.1 General Characteristics of Exercise Prescription in Cardiovascular Recovery

The basic principles of exercise prescription in cardiac rehabilitation can be described using the "FITT" concept—**Frequency, Intensity, Time, and Type**.

Physical exercises are generally classified into two distinct categories: **endurance training (aerobic)** and **resistance training (anaerobic)**.

1.2.2 Recommendations for Physical Exercise in Individuals with Cardiovascular Disease

Exercise programs should be tailored according to biological age, prior experience, functional capacity, comorbidities, and lifestyle habits. Patients with cardiac conditions should perform both endurance and resistance exercises, along with activities specifically aimed at improving flexibility and balance (Liu & Latham, 2009; Rogers et al., 2017; Pahor et al., 2014).

Endurance exercises produce beneficial effects on the cardiorespiratory system, while resistance exercises help prevent muscle mass loss and sarcopenia (Vigorito & Giallauria, 2014).

1.2.3 Physical Exercises Recommended for Individuals at Cardiovascular Risk

Regular physical activity reduces the risk of many triggering factors associated with cardiovascular diseases, regardless of age, gender, ethnicity, or the presence of comorbid conditions. There is, indeed, a dose–response relationship between physical activity and both cardiovascular mortality and all-cause mortality, with studies indicating an approximate 30% reduction in adverse events compared to sedentary individuals (Wahid et al., 2018; Lear et al., 2017).

1.3 Psychological Factors and the Impact of Cardiovascular Rehabilitation Programs on Quality of Life

Over the past 30 years, significant knowledge has been accumulated regarding the role of psychosocial risk factors in cardiovascular diseases. Among cardiac patients, depression and anxiety are strongly associated with major adverse cardiovascular events such as rehospitalization and death.

The prevalence of depressive disorders ranges between 15% and 20%, and is particularly detrimental to the cardiovascular prognosis following myocardial infarction (Lichtman et al., 2014; Peters & McEwen, 2015).

1.3.1 The Impact of Cardiac Rehabilitation Programs on Quality of Life

Fifty years ago, Herman Hellerstein published the seminal work titled *"Exercise Therapy in Coronary Disease"*, initially presented at the New York Heart Association conference. In this study, he described the therapeutic effects of physical exercise in patients with coronary artery disease (Hellerstein, 1968).

1.3.1.1 Brief Historical Overview

The concept of happiness has been a subject of human inquiry since Antiquity. Aristotle addressed the topic in *"Nicomachean Ethics"*, equating the notion of "the nature of happiness" or "quality of life" with the pursuit of the "good life."

The activities that define a good life, along with a disposition toward morality, have, in the philosophy of the Stagirite, the ultimate aim of supporting ethical principles and fulfilling moral actions: *"Our task is to become 'human' or to attain the highest human good possible. That good is happiness, and happiness is an activity of the soul in accordance* *with virtues such as courage, morality, generosity, and justice, as well as intellectual virtues like knowledge and wisdom."*

1.3.1.2 Particularities of the Concept of Quality of Life

The term *quality of life* has acquired global and ubiquitous dimensions, with its perspective shifting from a macro-social-political approach to a "micro-individualistic-psychological" perspective (Haas, 1999; Finn & Sarangi, 2008).

This individual-centered perspective implies a subjective reaction to life experiences, encompassing well-being, happiness, and satisfaction, while also incorporating quality of life as it pertains to health and overall wellness. It is worth noting that the notion of quality of life is widely prevalent in the field of health, medical literature, and the social sciences.

1.3.1.3 Quality of Life in Cardiovascular Disease

Greater attention to the emotional health and social well-being of cardiac patients is just as essential to quality of life as achieving a high level of independence and mobility (Sevinc & Akyol, 2010).

The reverse is equally true: the presence of numerous cardiovascular risk factors and/or deterioration in any of the aforementioned domains is generally associated (depending on the patient's coping ability and social support mechanisms) with a decrease in quality of life (Bosworth, 2000).

CHAPTER II
TRAINING METHODS APPLIED IN MAJOR CARDIOVASCULAR DISEASES

2.1 Indications, Contraindications, and Utilization of Cardiovascular Rehabilitation

The majority of patients with cardiovascular diseases are considered eligible for inclusion in rehabilitation programs; however, certain absolute or relative contraindications may limit the application of physical exercise. These contraindications include unstable exertional angina, severe or symptomatic aortic stenosis, decompensated heart failure, severe obstructive cardiomyopathy, acute venous thrombosis, and pulmonary embolism. Additionally, other barriers such as musculoskeletal disorders, associated comorbidities, and acute infectious or inflammatory conditions may influence the therapeutic decision regarding patient enrollment in cardiovascular rehabilitation programs.

2.2 Structure of Cardiovascular Rehabilitation Programs

The development of structured and specialist-supervised cardiovascular rehabilitation programs has been primarily motivated by the risks associated with unsupervised physical exercise in patients with cardiovascular diseases. To optimize the benefits of physical training, Hellerstein and Ford (2000) proposed the organization of cardiovascular rehabilitation as a multidisciplinary process, a model widely adopted in clinical practice today. These programs generally encompass three distinct phases: the inpatient phase, the active rehabilitation phase, and the maintenance phase, each with specific objectives and tailored methods appropriate to the patient’s stage of recovery.

2.3 The Role and Importance of Exercise Intensity

Numerous clinical studies have demonstrated that high-intensity physical exercise significantly enhances exercise capacity, improves endothelial function, and ameliorates quality of life in patients with cardiovascular conditions (Warburton et al., 2005). By properly adjusting the intensity, rehabilitation programs can maximize positive physiological adaptations while ensuring patient safety throughout the intervention.

2.4 High-Intensity Interval Training vs. Continuous Training

Continuous moderate-intensity training (CT) has long been considered the most effective exercise modality for the prevention and management of cardiovascular diseases. However, more recently, high-intensity interval training (HIIT) has emerged in clinical practice as a potential alternative for improving cardiovascular health. Initially, HIIT was found to induce significant improvements in parameters such as blood pressure and heart rate, to a similar or even greater extent compared to continuous training.

2.5 Strength Training

For a long time, strength training was regarded by specialists as inappropriate for cardiovascular rehabilitation due to a series of complications believed to be caused by this type of exercise. Current evidence, however, shows otherwise, and strength training is now a recommended component in cardiovascular rehabilitation programs (Ambrosetti et al., 2020).

2.6 Rehabilitation Programs Used and Relevant Studies in the Literature

Internationally, cardiac rehabilitation services are limited, available in less than 40% of countries. Current guidelines emphasize the importance of a multidisciplinary program coordinated by physiotherapists or qualified specialists. Such programs should include supervised exercise, psychological evaluation, stress management counseling, education on cardiovascular risk factors, nutrition guidance, smoking cessation support, and vocational reintegration.

2.6.1 Aerobic Training

Aerobic exercises are included in all international recommendations, though the intensity, frequency, and duration of training sessions vary.

2.6.2 Strength Training

While aerobic exercises are consistently recommended in international cardiac rehabilitation guidelines, strength training is not uniformly integrated. It is supported by detailed recommendations in most European countries and South America, whereas in regions such as Japan, Australia, New Zealand, and Northern Ireland, strength training is either omitted or insufficiently mentioned to allow for its systematic inclusion in rehabilitation programs.

2.6.3 Mobility Training

Similar to strength training, mobility exercises are not always included as a component in cardiac rehabilitation exercise programs.

CHAPTER III
THE ROLE OF CARDIAC REHABILITATION AND PHYSICAL EXERCISE IN INCREASING CARDIORESPIRATORY FITNESS

3.1 Cardiovascular Fitness – Theoretical Foundations

Cardiorespiratory fitness reflects the complex system of oxygen (O2) transport and consumption. It is closely related to cardiac function (both systolic and diastolic), pulmonary ventilation, and the vascular system's ability to deliver and transport oxygen. During physical exercise, these systems work together to meet the oxygen demand of muscles. The level of cardiorespiratory fitness is strongly influenced by many factors, including genetic ones. It is estimated that between 20% and 50% of the variability in fitness capacity is due to inherited factors, with the remainder attributed to traditional cardiovascular risk factors and low levels of physical activity (Zhang & Speakman, 2019).

3.2 Correlation between Fitness Capacity, Physical Exercise, Survival Rate, and Prognosis

The last 70 years have witnessed numerous studies regarding the relationship between survival rates and physical activity (PA), including exercise. It has been demonstrated that both participation in movement-based activities and the use of physical exercise are associated with reduced mortality.

3.3 Fitness Capacity and Psychological or Psychosocial Stress

In recent decades, it has increasingly been proven that psychological stress (PS) is a risk factor in cardiovascular disease (CVD), whether the disease is already present or not. One of the main psychosocial stress risks related to CVD is depression (Lespérance et al., 2000), but many studies have shown that other factors such as anxiety, hostility, and emotional disorders also play a significant role (Lavie et al., 2016). According to numerous studies, physical exercise significantly reduces all types of psychological stress and also contributes to lowering mortality rates.

3.4 Evaluation and Measurement of Fitness Capacity in the Literature

Maximum Oxygen Consumption

Functional capacity is represented by an individual's ability to perform aerobic effort under conditions of maximal oxygen consumption (VO2max). Aerobic capacity generally decreases by about 10% every 10 years in sedentary subjects (Thomas et al., 2018) due to reductions in stroke volume (Taylor et al., 2018), maximal arterial pressure (Oldridge & Taylor, 2020), blood flow to skeletal muscles, as well as their function (Maloberti et al., 2019). The rate of physical condition decline intensifies with age, ranging from 3% to 6% per decade in younger adults (20–30 years old) to about 20% per decade in older adults (70 years and above) (Shabani et al., 2011).

Six-Minute Walk Test

The six-minute walk test (6MWT) is the most commonly used tool for assessing fitness capacity in cardiovascular rehabilitation. The American Thoracic Society recommends the use of the six-minute walk test to establish functional capacity, either as a single measurement or as a repeated measurement for long-term morbidity prognosis and to assess therapeutic intervention response (Crapo et al., 2002).

Cardiopulmonary Exercise Testing

Cardiopulmonary exercise testing (CPET) or ergospirometry is one of the most frequently used methods to evaluate the fitness capacity of patients undergoing cardiovascular rehabilitation programs (Albouaini et al., 2007). It can be used to determine maximal exercise capacity, identify factors limiting the patient’s functional capacity, evaluate symptoms caused by exercise, and identify device-specific complications related to intracardiac devices that may occur during the rehabilitation program.

CHAPTER IV
CARDIAC REHABILITATION AFTER PERCUTANEOUS TRANSLUMINAL ANGIOPLASTY

4.1 Introduction to Percutaneous Transluminal Angioplasty

The main invasive methods for treating ischemic heart disease include coronary artery bypass grafting and percutaneous coronary intervention (PCI) (Kolh & Windecker, 2014; Bravata et al., 2007; Neumann et al., 2019). These procedures can be performed in the context of either acute or chronic ischemic heart disease, and the choice of appropriate intervention depends on the risk of intraoperative and postoperative mortality, the complexity of the coronary anatomical structure, as well as existing comorbidities (Neumann et al., 2019).

The concept of "percutaneous coronary intervention" refers to a medical procedure aimed at reopening occluded coronary arteries and improving myocardial perfusion without resorting to coronary bypass surgery. PCI typically begins with balloon inflation inside the stenosed coronary artery (percutaneous transluminal coronary angioplasty), followed by the implantation of one or more stents (Neumann et al., 2019).

4.2 Cardiac Rehabilitation in Percutaneous Transluminal Angioplasty

Coronary artery disease is common among the Western population (Virani et al., 2021), and chronic coronary syndrome (CCS) is considered a major public health issue (Benjamin et al., 2018). Patients with CCS benefit from preparatory medical treatment, usually followed by a percutaneous coronary intervention (PCI) targeting the stenosed coronary artery.

A significant number of studies have revealed that exercise-based cardiac rehabilitation (CR) increases exercise capacity, improves quality of life, and reduces mortality in patients with cardiovascular disease (de Vries et al., 2015; Kotseva et al., 2018).

4.3 Intervention Programs Used in PCI

In recent decades, numerous studies have highlighted the essential role of physical exercise on health status, emphasizing many benefits ranging from the most expected to even reducing the risk of dementia and providing protection against metabolic disorders, thereby positively impacting quality of life.

Cardiac rehabilitation after PCI plays a fundamental role in alleviating patient symptoms. Results can be significantly improved when physical exercise is combined with conventional treatment (Yamamoto et al., 2016).

Several meta-analyses have aimed to demonstrate the importance of cardiovascular recovery in improving health status, among the most well-known being those by Anderson et al. (2016) and Yang et al. (2017).

THEORETICAL CONCLUSIONS

Following the research undertaken, we have been able to formulate several appreciations and final conclusions, among which we mention:

- Cardiovascular diseases are the leading cause of mortality in contemporary society. They account for up to 30% of total deaths worldwide and 48% of deaths in Europe, and these numbers are expected to increase in the coming years.
- Exercise programs for patients with cardiovascular diseases have multiple beneficial effects on cardiovascular functional capacity, quality of life, modification of risk factors, psychological profile, hospital readmission, and mortality.
- Exercise-based interventions significantly improve cardiorespiratory capacity in patients who have suffered a cardiac event or surgery, but little is known about the differential effects of prescribed exercise intensities.
- The basic principles of exercise prescription in cardiovascular rehabilitation can be described using the "FITT" concept (Frequency, Intensity, Time, and Type).
- Regarding glycemic control, both aerobic and strength exercises have beneficial effects, while a combination of the two appears superior in terms of outcomes.
- To improve the lipid profile, performing moderate-intensity aerobic exercises is sufficient to improve triglyceride and cholesterol values. So far, high intensity has not been shown to produce better results in this regard, and the volume of physical exercise (frequency and duration), considering total energy expenditure, is more important than training intensity.

- There is indisputable evidence that physical exercise is a fundamental means for preventing, treating, and controlling arterial hypertension.
- Moderate-intensity aerobic exercise has been shown to improve both anxiety and depression.
- Interval training has been found to induce significant improvements in parameters such as blood pressure, VO2max, and heart rate, to a greater extent compared to continuous training.
- Research has highlighted the importance of inspiratory muscle training and breathing exercises in improving cardiac function, functional capacity, and quality of life in patients with cardiovascular diseases.

Cardiac rehabilitation aims primarily to improve the health status of patients with cardiovascular conditions through programs that incorporate regularly performed physical exercises, medical supervision, and psychosocial support. Therefore, it is crucial to understand how to structure rehabilitation programs, with an emphasis on their individualization. Most of these programs are based on interchangeable components designed to improve physical condition, exercise capacity, and lifestyle changes aimed at enhancing psychosocial well-being.

CHAPTER V
PRELIMINARY STUDY ON THE INFLUENCE OF RECOVERY PROGRAMS ON THE EXERCISE CAPACITY OF PATIENTS WITH CARDIOVASCULAR DISEASE

5.1 Purpose and Objectives of the Pilot Study

The purpose of the current research is to highlight and demonstrate the role and importance of recovery programs in improving the health status of patients with cardiovascular disease. The central role of our research is occupied by increasing the exercise capacity of coronary patients, achieved through the implementation of strictly individualized exercise programs, so that these lead to a significant improvement in key cardiovascular parameters, namely VO2 (oxygen consumption) and MET (metabolic equivalent). Additionally, an important objective is to increase the intensity and duration of the programs, synonymous with improving the functional capacity of the patients involved. Subsidiarily, we also monitored the evolution of blood pressure values and heart rate, referring to their dynamics throughout the training sessions.

For the execution of our research, we considered the following objectives:

- Designing and using training programs that contribute to reducing medical care costs, medication use, and treatment duration.
- Selecting, structuring, and applying recovery programs, experimenting with multiple possibilities for correlating and combining intervention methods until the most efficient ways to achieve the proposed goal are established.
- Demonstrating that a combined approach using two different forms of training leads to superior results in cardiovascular recovery compared to the use of classical methods based on a single type of training.

5.2 Subjects of the Pilot Study

The pilot study was conducted at the Iași Clinical Rehabilitation Hospital – Cardiovascular Medical Rehabilitation Department. The research sample consisted of 24 subjects who had undergone a minimally invasive surgical intervention, namely percutaneous transluminal coronary angioplasty (PTCA).

Inclusion criteria for participation in the pilot study were:

- Gender – male.
- Age between 50 and 68 years.
- Main diagnosis – patients with coronary artery disease who underwent percutaneous transluminal coronary angioplasty with stent implantation.
- Associated conditions – arterial hypertension, overweight, grade I obesity, and dyslipidemia.

5.3 Research Hypotheses

The scientific approach started from the following hypothesis:

- **Main hypothesis:** We assume that using an intervention program represents an effective tool to increase the exercise capacity of cardiovascular patients.

To validate this, we formulated four secondary hypotheses as follows:

- Hypothesis 1.1: We consider that the use of the intervention program will lead to an improvement in exercise capacity.
- Hypothesis 1.2: We assume that following the use of the intervention program, we will observe improvements in functional capacity.
- Hypothesis 1.3: We consider that the use of the intervention program will lead to improvements in exercise endurance.
- Hypothesis 1.4: We consider that following the application and use of the intervention program, the intensity of effort will increase.

5.4 Research Variables

Table 5.1. Variables analyzed in the research

Dependent Variables	Independent Variables
Oxygen consumption (VO_2)	**Intervention program (Strength exercises and endurance training on cycle ergometer)**
Metabolic equivalent (MET)	
Exercise intensity (IE)	
Exercise capacity (testul de mers de 6 minute)	

5.5 Instruments Used in the Research

The study used the Ergomoline cycle ergometer as the main instrument for evaluating and monitoring exercise capacity.

5.6 Tests and Measurements Used in the Study

- VO_2 parameter
- Metabolic equivalent
- Training intensity
- 6-minute walk test

5.7 Presentation of the Independent Variable and Research Results

In this study, the intervention program applied to subjects with coronary pathology consisted of two components: endurance training using a cycle ergometer and strength training exercises.

5.8 Presentation and Interpretation of Results

To test Hypothesis 1.1, which posits that the use of the intervention program will lead to an improvement in exercise capacity, the Shapiro-Wilk test was applied to assess the normality of the data distribution. For Group 1, the significance levels obtained for initial minimum and maximum intensities were 0.242 and 0.266, respectively, while for Group 2, these values were 0.266 and 0.932 for the same variables. Since all these significance values are greater than 0.05, the samples follow a normal distribution, allowing for further parametric statistical analysis.

Further application of the Shapiro-Wilk test on VO2 values revealed significance levels of 0.070 and 0.027 for Group 1, and 0.727 and 0.413 for Group 2. Given that $p > 0.05$ for the final minimum intensity in Group 1 and for both minimum and maximum final intensities in Group 2, these data are normally distributed, permitting parametric testing. However, the maximum final intensity in Group 1 had a p-value of 0.027, indicating a deviation from normality; therefore, the Wilcoxon signed-rank test was used for between-group comparisons for this variable.

The Wilcoxon test indicated a statistically significant difference between the initial and final data sets, with a Z value of -4.015 and a p-value of 0.000. This confirms that the final VO2 value at maximum intensity was significantly higher than the initial value. Analysis of the data also showed that all subjects included in the pilot study successfully completed the rehabilitation program, with the majority exhibiting improvements in the VO2 parameter. Only one patient in Group 2 did not show any improvement following the cardiac rehabilitation program.

The Paired Sample t-test further confirmed that the mean differences between initial and final intensities were statistically significant for both minimum and maximum intensities in Group 1 ($t = -10.485$, $p = 0.000$; $t = -7.914$, $p = 0.000$) and Group 2 ($t = -4.261$, $p = 0.001$; $t = -5.186$, $p = 0.000$).

Testing Hypothesis 1.2 – It is assumed that following the use of the intervention program, improvements in functional capacity will be observed.

The Shapiro-Wilk test yielded significance levels of 0.258 for Group 1 and 0.265 for Group 2. Since these values exceed the 0.05 threshold, the samples are considered to follow a normal distribution, permitting continuation with parametric statistical analysis. However, upon further application of the Shapiro-Wilk test to the metabolic equivalent (MET) parameter, a significance level of 0.024 was obtained for Group 1 and 0.839 for Group 2. The p-value below 0.05 for Group 1 indicates a non-normal distribution, while Group 2's data follow a normal distribution, thus the non-parametric Wilcoxon test was applied for comparisons involving Group 1.

The Wilcoxon test demonstrated a significant difference between the initial and final datasets, with a Z value of -3.066 and a p-value of 0.002, allowing the conclusion that the final MET value was significantly higher than the initial value. The analysis further showed that all participants exhibited improvements in the MET parameter, irrespective of group assignment. The coefficient of variation ranged between 10.1% and 12.2% across all groups, indicating homogeneity of the analyzed values. The Paired Sample t-test confirmed that the mean differences in both Group 1 ($t = -10.918$, $p = 0.000$) and Group 2 ($t = -8.249$, $p = 0.001$) were statistically significant.

Testing Hypothesis 1.3 – It is hypothesized that the use of the intervention program will lead to improvements in exercise endurance.

The Shapiro-Wilk test revealed significance values of 0.163 for Group 1 and 0.316 for Group 2. Since these values are greater than 0.05, the data are normally distributed, allowing for parametric statistical analysis. Additionally, the test applied to other endurance-related variables yielded p-values of 0.368 and 0.731 for Groups 1 and 2, respectively, confirming normality and permitting further statistical examination. The coefficient of variation ranged between 6.45% and 9.72% across all groups, demonstrating the homogeneity of the data. The Paired Sample t-test indicated statistically significant mean differences for Group 1 (t = -16.863, p = 0.000) and Group 2 (t = -14.660, p = 0.000).

Testing Hypothesis 1.4 – It is assumed that following the application and utilization of the intervention program, exercise intensity will increase.

The Shapiro-Wilk test yielded significance values of 0.635 for Group 1 and 0.066 for Group 2, both exceeding the 0.05 threshold, confirming a normal distribution of the data and justifying further parametric statistical analysis. Subsequent tests resulted in significance values of 0.897 for Group 1 and 0.106 for Group 2, reaffirming that the null hypothesis of normality cannot be rejected. Thus, statistical analysis proceeded accordingly.

Data analysis revealed that the majority of subjects exhibited increases in both minimum and maximum exercise intensity during cycle ergometer training throughout the rehabilitation program. In Group 2, improvements were noted in 9 out of 12 subjects, while 3 subjects maintained similar minimum and maximum intensity values at the beginning and end of the intervention. The coefficient of variation ranged between 10% and 27.9% across all groups, indicating relative homogeneity of the data. The Paired Sample t-test revealed significant mean differences for minimum intensity in Group 1 (t = -9.212, p = 0.000) and Group 2 (t = -7.966, p = 0.000), as well as for maximum intensity in Group 1 (t = -4.304, p = 0.001) and Group 2 (t = -5.000, p = 0.000).

PARTIAL CONCLUSIONS OF THE PRELIMINARY STUDY

The present study aimed to demonstrate the beneficial effects of physical exercise on patients with coronary artery disease through a rehabilitation program comprising two types of training. Specifically, it focused on comparing two distinct recovery programs by evaluating their effectiveness based on the changes observed in key parameters discussed throughout the work: exercise intensity, metabolic equivalent (MET), maximal oxygen consumption (VO2max), and the six-minute walk test (6MWT). Both the statistical analysis and direct observation of the resulting data revealed improvements in the exercise capacity of the majority of subjects included in the pilot study

An initial hypothesis was formulated for this research and was subsequently validated through the course of the study. The obtained data highlighted the efficacy of the recovery program incorporating two different types of training, which resulted in improvements across all analyzed parameters. Regarding VO2, average increases were observed for both minimum and maximum intensity levels in Group 1. These improvements were notably greater than those seen in Group 2. It is important to note that these positive outcomes were also accompanied by reductions in resting heart rate.

Concerning the metabolic equivalent (MET), although percentage changes were relatively modest, the results confirmed an enhancement in the exercise capacity of the subjects. Measurements in Group 1 showed a significantly higher mean level of this indicator compared to baseline values. In contrast, Group 2 exhibited a smaller average increase.

The six-minute walk test, a widely used parameter for evaluating exercise capacity, was applied to the sample as part of Hypothesis 1, yielding positive results across all participants. Group 1 showed marked improvements in this parameter, whereas Group 2 demonstrated significantly more modest gains.

Exercise intensity within the recovery programs was also a critical factor in assessing the subjects' physical performance. Both groups recorded significant improvements in minimum and maximum intensities. Notably, Group 1 exhibited approximately double the average increases in both minimum and maximum intensity levels compared to Group 2.

Chapter VI

Contributions Regarding the Application of Recovery Programs in Optimizing Exercise Capacity in Patients with Cardiovascular Pathology – Main Study

6.1. Aim and Objectives of the Study

The primary aim of this research is to highlight and demonstrate the fundamental role and importance of rehabilitation programs in improving the health status of patients with cardiovascular disease. The central focus of this study is the enhancement of exercise capacity in coronary patients, achieved through the implementation of strictly individualized exercise programs consisting of strength training and endurance training performed on a cycle ergometer. These interventions are intended to produce significant improvements in key cardiovascular parameters, namely VO2 (oxygen consumption) and MET (metabolic equivalent).

Another important objective is to increase the intensity of the programs performed on the same apparatus, which is indicative of an improved functional capacity of the patients. Additionally, the study monitored the evolution of blood pressure and heart rate values in relation to their dynamics during the training sessions.

It is worth noting that the sample size was increased compared to the preliminary study to ensure greater statistical relevance and validity of the results. The standard evaluation of the aforementioned cardiovascular parameters, which provides an objective interpretation of exercise capacity, was complemented by two subjective assessment tools: the Duke questionnaire and the SF-36. These instruments were employed to investigate exercise capacity and quality of life, two essential dimensions for understanding the physiological and psychological impact of interventions in post-PTCA patients.

The specific objectives of the study were as follows:

- To apply and implement a cardiac rehabilitation program composed of two types of physical training—namely aerobic and strength training—for patients who have undergone PTCA, with the goal of reducing healthcare costs, medication usage, and treatment duration. The inclusion of strength training constitutes a novel element of this research, as it remains a debated topic in the scientific literature.
- To continuously monitor and measure the principal cardiovascular parameters—blood pressure, heart rate, VO2, and MET—using the Ergoline ERS2 system.
- To evaluate the intensity levels applied in the individualized cardiac rehabilitation program at baseline and at the end of the intervention, aiming to identify changes in the patients' exercise capacity.
- To apply a set of strength exercises aimed at muscle toning, with progress monitored and compared using the Ruffier test at the beginning and end of the rehabilitation program.
- To administer the Duke Index and compare its results with those of the exercise test to assess baseline exercise capacity.
- To utilize the six-minute walk test as one of the primary instruments to detect potential variations in exercise capacity.
- To employ the SF-36 questionnaire to observe possible changes in the subjects' quality of life.

6.2. Research Hypotheses

The main hypotheses underpinning this scientific inquiry are as follows:

Hypothesis 1: The use of an interventional rehabilitation program is an effective tool for increasing the exercise capacity of coronary patients who have undergone PTCA.

Supporting this hypothesis, four secondary hypotheses were formulated:

- Hypothesis 1.1: The application of the intervention program will lead to improvements in exercise capacity.
- Hypothesis 1.2: The rehabilitation program will result in enhanced functional capacity.
- Hypothesis 1.3: The implementation and use of the intervention program will increase exercise intensity.
- Hypothesis 1.4: The intervention program will improve exercise endurance.

Hypothesis 2: Patients who have undergone post-PTCA intervention will experience an improvement in quality of life.

- Secondary Hypothesis 2.1: There exists an association between exercise capacity and quality of life.

6.3 Materials and Methods

The present study was conducted at the Iași Clinical Recovery Hospital – Cardiovascular Medical Rehabilitation Department. The sample consisted of 30 subjects who underwent a minimally invasive surgical procedure, specifically percutaneous transluminal coronary angioplasty (PTCA).

6.4 Research Variables

The inclusion criteria for participants in the main study were as follows:

- Gender: Male
- Age: Between 48 and 68 years old
- Primary diagnosis: Coronary artery disease patients who underwent percutaneous transluminal angioplasty with stent placement
- Associated conditions: Hypertension, overweight/obesity grade 1, dyslipidemia, and congestive heart failure (CHF) class II or III according to NYHA classification

6.5 Instruments Used in the Study

The ERGOLINE bicycle ergometer is the primary device used in this research, specifically designed for the evaluation and training of the cardiovascular system.

6.6 Tests and Measurements Employed

- Maximal oxygen consumption (VO2max)
- Oxygen consumption (VO2)
- Duke Activity Status Index (DASI) for cardiovascular disease assessment
- Metabolic equivalent of task (MET)
- Exercise intensity
- Six-minute walk test (6MWT)
- Adapted Ruffier test
- SF-36 questionnaire for quality of life assessment

6.7 Presentation of the Independent Variable and Intervention Program

The intervention program applied to subjects with coronary pathology consisted of:

- Endurance training on the cycle ergometer
- Strength training

6.8 Presentation and Interpretation of Results

Hypothesis 1.1 Testing: The use of the intervention program will lead to improvements in exercise capacity.

The Shapiro–Wilk test for VO2 at minimal initial intensity yielded a significance value of $p = 0.901$, and for minimal final intensity, $p = 0.090$. Since $p > 0.05$ in both cases, the null hypothesis is not rejected, indicating normal data distribution and allowing further parametric statistical analysis. For VO2 at maximal intensity, significance values were $p = 0.200$ (initial) and $p = 0.687$ (final), also confirming normal distribution.

The Paired Sample t-Test revealed a significant difference between initial (VO2max initial) and final (VO2max final) measurements, demonstrating an increase in oxygen consumption at maximal intensity following the intervention program.

Next, we will present the results and statistical tests related to the Duke Activity Status Index to further support Hypothesis 1.1.

Table 6.1: Pearson Correlation between MET values, VO2max, and Total Score of the Duke Activity Status Index

	VO_2max Duke	**MET Duke**	**Scor Total Duke**
VO_2max Duke	1	r=.874 **p=0.000**	.842 **p=0.000**
MET Duke	r=.874 **p=0.000**	1	r=.956** **p=0.000**

Scor Total Duke	r=.842 **p=0.000**	r=.956** **p=0.000**	1

The results of the Pearson analysis revealed strong and statistically significant correlations between VO2max, MET, and the total Duke score, suggesting the internal consistency of the questionnaire data. The high correlations among the investigated variables indicate that VO2max and MET assessments are fundamental metrics for monitoring patient progress within cardiovascular rehabilitation programs.

Table 6.2. Linear Regression – Assessing the Impact of VO2max on MET

Variabila independentă	**Variabila dependentă**	**Ecuație**	**R**	**R^2**	**F**	**t**	**Sig. F**
VO_2max	**MET**	MET.Duke = 2.220 +0.213 * VO_2max	.874	.764	90.800	9.529	**.000**

The regression model is statistically significant, supported both by the significance value Sig. F < 0.005 and the high F value of 90.800, which emphasizes that the relationship between VO2max and MET is not random and is statistically valid.

Testing Hypothesis 1.2 – The interventional rehabilitation program will lead to improvements in functional capacity.

The Shapiro–Wilk test revealed a significance threshold above 0.05 for the MET value at the final measurement (p = 0.753). Regarding the initial MET value, the test showed a p-value less than 0.05, suggesting that the data do not follow a normal distribution. Therefore, the Wilcoxon test was used to statistically compare and validate the two data sets.

The Wilcoxon test, applied to compare the two sets of data, indicated a significant difference between them, with a Z value of -4.708. Given that the significance threshold is 0.000, we can conclude that the final metabolic equivalent value is significantly higher than the initial one.

Testing Hypothesis 1.3 – The application and use of the intervention program will increase exercise intensity

The Shapiro–Wilk test applied to both initial measurements of minimum intensity returned significance values greater than 0.05. Thus, the sample has a normal distribution, and we can proceed with further statistical analysis.To investigate the complex relationships between exercise intensity, MET, and VO2, we chose Spearman's correlation for the dependent variables at baseline and Pearson's correlation for the final values of the same variables.

Table 6.3. Spearman correlation coefficients between dependent research variables at baseline

	TI_Imin	**TI_Imax**	**TI_MET**	**TI_VO2_Imin**	**TI_VO2_Imax**
TI_Imin	1	r_s=.759 **p=.000**	r_s=.646 **p=.000**	r_s=.873 **p=.000**	r_s=.666 **p=.000**
TI_Imax	r_s=.759 **p=.000**	1	r_s =.661 **p=.000**	r_s=.682 **p=.000**	r_s=.877 **p=.000**
TI_MET	r_s=.646 **p=.000**	r_s=.661 **p=.000**	1	r_s=.787 **p=.000**	r_s=.816 **p=.000**
TI_VO2_Imin	r_s=.873 **p=.000**	r_s=.682 **p=.000**	r_s=.787 **p=.000**	1	r_s=.803 **p=.000**
TI_VO2_Imax	r_s=.666 **p=.000**	r_s=.877 **p=.000**	r_s=.816 **p=.000**	r_s=.803 **p=.000**	1

The results highlight the existence of significant monotonic relationships between most of the variables analyzed, demonstrating that variables related to exercise intensity, both minimum and maximum, are consistently associated with improvements in oxygen consumption (VO2) and metabolic equivalent (MET), although not necessarily in a linear manner.

Table 6.4. Pearson correlations between the final values of intensity, VO2, and MET

	TF_Imin	**TF_Imax**	**TF_MET**	**TF_VO2_Imin**	**TF_VO2_Imax**
TF_Imin	1	r=.934 **p=.000**	r=.780 **p=.000**	r=.895 **p=.000**	r=.838 **p=.000**
TF_Imax	r=.934 **p=.000**	1	r=.791 **p=.000**	r=.814 **p=.000**	r=.860 **p=.000**
TF_MET	r=.780 **p=.000**	r=.791 **p=.000**	1	r=.880 **p=.000**	r=.909 **p=.000**
TF_VO2_Imin	r =.895 **p=.000**	r=.814 **p=.000**	r=.880 **p=.000**	1	r=.957 **p=.000**
TF_VO2_Imax	r=.838 **p=.000**	r=.860 **p=.000**	r=.909 **p=.000**	r=.957 **p=.000**	1

The obtained p-values indicate that the results are statistically significant, demonstrating that the selected observational parameters are relevant for this study and that changes in one variable induce immediate changes in another. In relation to the central objective of our thesis, all these constitute fundamental predictors of exercise capacity. In other words, improving the functional capacity of the coronary patient can be achieved through specific interventions targeting these parameters.

Testing Hypothesis 1.4 – The intervention program will improve exercise endurance

Since the Shapiro–Wilk test result showed a p-value less than 0.05 for the initial 6-minute walk test (TM6), suggesting that the data do not follow a normal distribution, the Wilcoxon test was used to statistically compare and validate the two data sets.

The Wilcoxon test, applied to compare the two data sets (TM6 initial and TM6 final), indicates a significant difference between them. Given the significance threshold is 0.000, we can conclude that the final TM6 value is significantly higher than the initial TM6.

Testing Hypothesis 2 – We assume that patients who benefited from post-PTCA intervention experienced an improvement in quality of life

Table 6.5. Means and Standard Deviations for Each Individual Dimension

Abbreviation	Subdomain	Mean	Standard Deviation
Dimension 1	Physical Functioning	72.16	±20.37
Dimension 2	Role Limitations Due to Physical Health	45.00	±38.51
Dimension 3	Role Limitations Due to Emotional Problems	52.96	±41.58
Dimension 4	Energy	63.83	±14.66
Dimension 5	Emotional Well-being	74.26	±14.99
Dimension 6	Social Functioning	81.03	±22.41
Dimension 7	Pain	71.33	±22.19
Dimension 8	General Health	56.16	±14.72

Table 6.6. Pearson Correlation Between the Dimensions of the SF-36 Quality of Life Questionnaire

	Dim.1	**Dim.2**	**Dim. 3**	**Dim. 4**	**Dim. 5**	**Dim. 6**	**Dim. 7**	**Dim. 8**
Dim.1	1	r= .201 p= .287	r=.312 p=.093	r=.560 **p=.001**	r=.629 **p=.000**	r=.560 **p=.001**	r=.587 **p=.001**	r=.474 p=.008
Dim.2	r=.201 p=.287	1	r=.768 **p=.000**	r=.409 p=.025	r=.223 p=.235	r=.560 **p=.001**	r=.182 p=.337	r=.110 p=.565
Dim.3	r=.312 p=.093	r=.768 **p=.000**	1	r=.554 **p=.001**	r=.376 p=.040	r=.572 **p=.001**	r=.456 p=.011	r=.272 p=.147
Dim.4	r=.560 **p=.001**	r=.409 p=.025	r=.554 **p=.001**	1	r=.718 **p=.000**	r=.684 **p=.000**	r=.627 **p=.000**	r=.414 p=.023
Dim.5	r=.629 **p=.000**	r=.223 p=.235	r=.376 p=.040	r=.718 **p=.000**	1	r=.611 **p=.000**	r=.541 **p=.002**	r=.500 p=.005
Dim.6	r=.560 **p=.001**	r=.560 **p=.001**	r=.572 **p=.001**	r=.684 **p=.000**	r=.611 **p=.000**	1	r= .688 **p=.000**	r=.474 p=.008
Dim.7	r=.587 **p=.001**	r=.182 p=.337	r=.456 p=.011	r=.627 **p=.000**	r=.541 **p=.002**	r=.688 **p=.000**	1	r=.523 **p=.003**
Dim.8	r=.474 p=.008	r=.110 p=.565	r=.272 p=.147	r=.414 p=.023	r=.500 p=.005	r=.474 p=.008	r=.523 **p=.003**	1

Following the analysis of correlations between the investigated subdomains, it can be observed that significant relationships exist between most of them. For example, Dimension 4 (Energy) and Dimension 5 (Emotional Well-being) exhibit a strong correlation ($r = 0.718$) that is statistically significant ($p < 0.05$), suggesting a close connection between these two categories. Similarly, Dimension 6 (Social Functioning) and Dimension 7 (Pain) show a strong ($r = 0.688$) and significant correlation, indicating a solid relationship between these variables.

Testing secondary hypothesis 2.1 – We assume that there are associative relationships between exercise capacity and quality of life.

Table 6.7. Correlation between responses to the SF-36 questionnaire and VO2max, MET, and the Duke questionnaire scores

Items	Pearson Correlation Coefficient (r)	Significance Level	Interpretation
Physical Functioning – VO_2max	0.37	$p = 0.04679 < 0.05$	**Low to moderate correlation index, directly proportional correlation**
Energy – VO_2max	0.36	$p = 0.0474 < 0.05$	**Low to moderate correlation index, directly proportional correlation**
Emotional Well-being – VO_2max	0.33	$p = 0.07346 > 0.05$ but < 0.1	**Low to moderate correlation index, directly proportional correlation**
Social Functioning – VO_2max	0.36	$p = 0.05392 \approx 0.05$	**Low to moderate correlation index, directly proportional correlation**
Physical Functioning – MET	0.50	$p = 0.005887 < 0.01$	**Moderate correlation index, directly proportional correlation**
Energy – MET	0.49	$p = 0.006113 < 0.01$	**Moderate correlation index, directly proportional correlation**

Emotional Well-being – MET	0.47	$p = 0.009452 < 0.01$	**Moderate correlation index, directly proportional correlation**
Social Functioning – MET	0.53	$p = 0.002322 < 0.01$	**Moderate correlation index, directly proportional correlation**
Pain – MET	0.35	$p = 0.05958 \approx 0.05$	**Low to moderate correlation index, directly proportional correlation**
General Health – MET	0.36	$p = 0.05387 \approx 0.05$	**Low to moderate correlation index, directly proportional correlation**

Within the research, we evaluated the correlations between various variables such as physical functioning, energy, emotional well-being, social functioning, pain, and general health, on one hand, and VO2max and MET, obtained through the Duke questionnaire, on the other hand, using the Pearson correlation coefficient. The results provide valuable insights regarding the relationships among these variables, which are important for understanding the factors influencing exercise capacity and overall health status.

6.9. DISCUSSIONS

Physical exercise constitutes a central element in the prevention of coronary artery disease (CAD), playing a well-defined role in restoring functional capacity, protecting against metabolic disorders, and contributing to the improvement of quality of life (Zhang et al., 2019; Buckley et al., 2022; Pelliccia et al., 2021). For the physical recovery of patients who have undergone coronary revascularization procedures, participation in cardiovascular rehabilitation (CR) programs, which take the form of physiotherapy sessions, is essential (Pelliccia et al., 2021). Meta-analyses focusing on percutaneous coronary intervention (PCI) followed by specific physiotherapy programs have demonstrated the efficacy of such interventions, showing a reduction in the risk of death, myocardial infarction, stent restenosis, coronary angioplasty, or angina symptoms.

PARTIAL CONCLUSIONS OF THE MAIN STUDY

The comprehensive cardiac rehabilitation program, which integrates both aerobic and strength exercises, represents an effective intervention for improving exercise capacity and quality of life in patients diagnosed with coronary artery disease. This therapeutic approach not only optimizes cardiac function but also contributes to increased physical endurance, reduced risk of cardiovascular complications, and improved overall health status.

Considering the results of the statistical analysis, a significant correlation can be observed between exercise intensity, metabolic equivalent of task (MET), and oxygen consumption (VO2) in the analyzed subjects. This correlation suggests that intensity levels are closely linked to the body's oxygen demands. Specifically, an increase in intensity is associated with higher oxygen consumption, indicating more intense physical activity and greater cardiovascular effort. This correlation between MET and VO2 serves as an indicator of the cardiovascular system's efficiency and adaptation to exercise demands and can provide valuable information for managing and optimizing cardiac rehabilitation programs.

Our results show that performance in the 6-minute walk test is strongly associated with levels of muscular strength and endurance in patients with coronary artery disease. This association highlights the importance of developing strong and resilient musculature to improve the ability to perform physical activities such as walking, which may contribute to increased exercise capacity and enhanced quality of life in these patients.

Following the administration of the Duke and SF-36 questionnaires, we observed a direct and proportional relationship between subjects' exercise capacity and their quality of life. Moreover, the physical capacity parameters resulting from the rehabilitation program are determinative factors influencing quality of life.

FINAL CONCLUSIONS

This doctoral thesis aimed to highlight the role of physical exercise in cardiovascular rehabilitation as a primary element in improving the exercise capacity of patients with coronary artery disease. Throughout the work, we emphasized the exceptional importance of physical training, systematically implemented and grounded in scientific principles, as both a panacea and a product of secondary prevention in cardiovascular conditions.

It is nonsensical to speak about rehabilitation without the "science of movement." Operating with an interdependent system of methods and procedures, this science has, over recent decades, assumed a leading role in the treatment of cardiac patients—whether in postoperative interventions, conservative treatment, or preventive actions.

Under these circumstances, our research focused on emphasizing the increasingly complex and multidisciplinary role that physical training has acquired, influenced both by recent scientific research and by the diversification of pathologies subjected to rehabilitative treatment.

The tested data confirmed all the formulated hypotheses, allowing us to conclude that aerobic training and strength training complement each other, contributing to the increase of exercise capacity and to the reduction of cardiac complications risk.

The doctoral thesis explored how a comprehensive cardiac rehabilitation program, based on two distinct components once considered irreconcilable a few decades ago, can collaborate effectively as an essential tool to improve the exercise capacity of coronary patients.

LIMITATIONS AND FUTURE DIRECTIONS OF THE DOCTORAL THESIS

The primary limitation concerns the relatively small number of subjects included in the study. This was due to some patients' lack of cooperation and the inability of others to participate long-term in the rehabilitation program, especially those residing in rural areas or other cities in the Moldova region, facing difficulties with daily commuting.

Another important limiting factor was the relatively low number of subjects who underwent PTCA with stenting compared to patients diagnosed with more common cardiovascular diseases such as hypertension, chronic heart failure, angina pectoris, or rhythm disorders.

A further limitation relates to the subjective nature of assessing quality of life and exercise capacity through the Duke and SF-36 questionnaires. As these are self-assessment tools, we observed a tendency among subjects to overestimate their physical condition while hesitating to acknowledge deficits affecting their personal lives.

Regarding future research directions, potential studies could include expanding the sample size and conducting a comparative analysis between VO2max and MET values obtained from cardiopulmonary exercise testing and those calculated based on the Duke questionnaire.

DISSEMINATION OF RESULTS

Published Articles:

- Bogdan, M., Mardare, I., Moraru, C.S. (2021). Study regarding the level of strength as a motor quality among high school students in the context of the COVID-19 pandemic. Proceedings of the 7th International Conference of the Universitaria Consortium in Physical Education, Sport and Psychotherapy, November 12-13, pp. 61–66.

- Mardare, I., Moraru, C.S., Bogdan, M. (2022). Increasing Exercise Capacity in Patients With Hypertension - A Dual Perspective: Interval Training vs. Continuous Training. Proceedings of ICU 2022 - The 8th International Conference of the Universitaria Consortium, October, pp. 277–287.

- Mardare, I., & Moraru, C.S. (2023). A historical perspective of exercise in medical recovery. Sport and Society, Interdisciplinary Journal of Physical Education and Sports, Vol. 23, Issue 1. DOI:10.36836/2023/1/03.

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