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Effect of Physical Activity on Postoperative Recovery in Coronary Artery Bypass Graft (CABG) Patients

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Abstract: ***Background*****:** Coronary Artery Bypass Grafting (CABG) surgery is a common treatment for coronary artery disease, but postoperative recovery can be challenging. Physical activity has been shown to improve outcomes in various cardiac populations, but its impact on postoperative recovery in CABG patients remains unclear.***Objective*****:** To investigate the impact of physical activity on postoperative recovery in CABG patients, focusing on functional capacity, quality of life, and cardiovascular parameters.***Methods*****:** This randomized controlled trial included 100 CABG patients, randomized into an Exercise Group (n=50) and a Control Group (n=50). The Exercise Group participated in a supervised exercise program post-surgery, while the Control Group received standard care. Functional capacity was assessed using the Six-Minute Walk Test, quality of life using the Patient Health Questionnaire-9, and cardiovascular parameters including blood pressure, heart rate, cardiac output, ejection fraction, and rate-pressure product were measured at baseline, 1 week, 1 month, and 3 months post-surgery. Data were analyzed using appropriate statistical methods.***Results:*** The Exercise Group demonstrated significant improvements in functional capacity and quality of life compared to the Control Group at all time points. Additionally, cardiovascular parameters showed favorable changes in the Exercise Group, including reductions in blood pressure, heart rate, and rate-pressure product, and increases in cardiac output and ejection fraction.***Conclusion*****:** Structured exercise programs initiated early post-CABG surgery result in significant improvements in functional capacity, quality of life, and cardiovascular parameters. These findings highlight the importance of integrating exercise interventions into routine care protocols for CABG patients to optimize postoperative recovery outcomes and long-term cardiovascular health.

Keywords: Coronary Artery Bypass Grafting (CABG), Physical activity, Postoperative recovery, Functional capacity, Quality of life.

1. INTRODUCTION

Cardiovascular diseases (CVD), including coronary artery disease (CAD), stand as significant contributors to global mortality [1]. Advancements in cardiovascular treatment have led to increasingly minimally invasive cardiac surgeries, thereby lowering mortality rates associated with CVD [2]. Nonetheless, risk factors for postoperative complications following cardiac surgery persist at notable levels [3]. Traditional postoperative management strategies often prioritize rest, which may exacerbate complications such as pain, dyspnea, sleep disturbances, and depression due to prolonged bed rest [4].Coronary artery bypass grafting (CABG) represents a significant surgical procedure aimed at circumventing blockages within the coronary arteries caused by atherosclerosis. This is achieved through the utilization of either venous or arterial grafts, which effectively reroute blood flow to the parts of the heart muscle suffering from ischemia. As a result, this intervention not only reinstates the heart's function and viability but also alleviates symptoms associated with angina. Annually, CABG stands as the most frequently executed major surgery, with nearly 400,000 procedures carried out. However, there has been a notable shift in surgical trends, with a decline in CABG surgeries owing to a growing preference for alternative treatments, including medical therapies and percutaneous coronary intervention (PCI) [5].

Following CABG surgery, patients often face a myriad of physiological and psychological challenges, including reduced functional capacity, pain, inflammation, impaired pulmonary function, and psychological distress [1, 5]. These challenges can hinder the recovery process and impede patients' ability to regain independence and resume their daily activities. However, structured physical activity interventions, comprising aerobic exercise, resistance training, flexibility exercises, and patient education components, have been shown to mitigate these adverse effects and expedite the recovery process [6, 7]. Through regular engagement in physical activity, CABG patients can enhance their cardiorespiratory fitness, muscle strength, and overall functional capacity, thereby facilitating a quicker return to baseline levels of physical function and quality of life [2, 3]. Moreover, physical activity interventions have been associated with reductions in postoperative complications, such as pneumonia, deep vein thrombosis, and wound infections, further underscoring their importance in postoperative care [8, 9]. Notably, early initiation of physical activity, preferably within the first few days following surgery, has been shown to yield optimal benefits by attenuating the physiological deconditioning associated with prolonged bed rest and immobility [10, 11]. Additionally, physical activity serves as a potent tool for managing psychological distress and improving mental well-being in CABG patients, addressing issues such as anxiety, depression, and fear of complications. Importantly, the benefits of physical activity extend beyond the immediate postoperative period, with evidence suggesting sustained improvements in functional capacity, quality of life, and cardiovascular outcomes in the long term [11, 12]. However, despite the growing recognition of its benefits, challenges remain in implementing and sustaining physical activity interventions in clinical practice. These challenges include patient adherence, resource limitations, and the need for tailored exercise regimens to accommodate individual patient needs and preferences. Addressing these challenges requires a multidisciplinary approach involving healthcare providers, rehabilitation specialists, and patients themselves, emphasizing the importance of patient education, behavioral support, and ongoing monitoring and feedback [13, 14]. The aim of this study is to investigate the impact of physical activity interventions on the postoperative recovery of patients undergoing Coronary Artery Bypass Graft (CABG) surgery. Specifically, the study aims to assess the effects of structured exercise programs on functional capacity, length of hospital stay, and overall quality of life in CABG patients. By examining the role of physical activity in postoperative recovery, this study aims to enhance patient outcomes, mitigate complications, and optimize resource utilization in the management of CABG patients.

2. **STUDY METHODOLOGY**

2.1 Study Setting: The study was conducted at Department of CVTS, T. N. medical college and Nair hospital, a tertiary care center specializing in cardiovascular surgeries.

2.2 Study Participants: Participants were recruited from patients scheduled to undergo elective on pump CABG surgery as institutional practice between July 2023 to Dec 2023 (6 months). Inclusion criteria comprised adult patients aged 18 years and above, diagnosed with severe coronary artery disease requiring CABG surgery. Exclusion criteria included patients with significant comorbidities limiting their ability to participate in physical activity and those unwilling to provide informed consent.

2.3 Study Sampling and Sample Size: Prospective systematic random sampling.was employed to recruit participants. A total of 100 eligible patients were enrolled in the study, with 50 patients allocated to each study group.

2.4 Study Groups: Participants were divided into two groups:

Patients were allotted to experimental group and control group prospectively as per inclusion criteria immediately after surgery based on systematic random sampling in which all even numbered from patients form patient no 2 to patient no 98 (tot 50 patients) were alloted to experimental group and all odd numberd patients from patient no. 3 to patient no. 99 (including patient no. 1) were allotted to control group after ensuring their inclusion criteria in pre-op period.

1. **GROUP I (Exercise Group, EG):** Participants in this group engaged in a structured physical exercise program as part of their postoperative rehabilitation.
2. **GROUP II (Control Group, CG):** Participants in this group received standard postoperative care without any structured exercise intervention.

2.5 Study Parameters:

- **Functional Capacity:** Functional capacity was assessed using the Six-Minute Walk Test (6MWT). This test measures the distance a patient can walk on a flat, hard surface in six minutes. Patients were instructed to walk as far as possible during the allotted time, with standardized encouragement provided at regular intervals. Distance covered during the test was recorded in meters. The 6MWT is a widely used and validated measure of functional capacity in cardiac rehabilitation settings, providing valuable insights into a patient's exercise tolerance and cardiovascular fitness [13].
- **Cardiovascular Parameters:** Including Blood Pressure, Heart Rate, Cardiac Output, Ejection Fraction, and Rate-Pressure Product.
- **Quality of Life (Secondary Outcome**): Quality of life was assessed using the Patient Health Questionnaire-9 (PHQ-9). While primarily designed to measure depression severity, the PHQ-9 also provides insights into broader aspects of quality of life, including mood, energy levels, and interest in activities. The PHQ-9 consists of nine items, with responses ranging from 0 (not at all) to 3 (nearly every day), yielding a total score ranging from 0 to 27. Higher scores indicate greater depressive symptoms and potentially poorer quality of life. The PHQ-9 is a simple and widely used tool for assessing quality of life in clinical and research settings, facilitating the identification of patients who may benefit from further evaluation or intervention [15].

2.6 Study Procedure:

- **Preoperative Assessment**: Eligible patients scheduled for elective on pump CABG surgery were screened for inclusion and exclusion criteria during preoperative consultations.The patients were then studied prospectively as per their group allocationsoon after their surgey (experimental or control)based on their serial number (even or odd) by monitoring their parameters from baseline to 3 months.
- **Informed Consent**: Informed consent was obtained from all participants prior to surgery, explaining the study objectives, procedures, risks, and benefits.
- **Randomizatio**n: The sampling method employed here was prospective systematic random sampling.

Intervention:

Exercise Group: Participants in the EG underwent a supervised physical exercise program starting post-surgery. The exercise program included a combination of aerobic exercises, resistance training, and flexibility exercises.The exercise program for the Exercise Group (EG) consisted of a combination of aerobic exercises, resistance training, and flexibility exercises, all supervised to ensure safety and effectiveness. Aerobic activities such as walking, cycling, and light jogging aimed to improve cardiovascular fitness, while resistance training, including light weightlifting and body-weight exercises, focused on enhancing muscle strength. Flexibility exercises, involving various stretching routines, were included to improve flexibility and prevent stiffness. The sessions were conducted multiple times per week, with each session lasting from 30 to 60 minutes, and the duration gradually increased as patients' endurance improved. The program emphasized early initiation within the first few days post-surgery to mitigate the effects of prolonged bed rest and promote quicker recovery.

Control Group: Participants in the CG received standard postoperative care, including early mobilization and encouragement to resume normal activities as tolerated.

- **Postoperative Assessment**: Follow-up assessments were conducted at baseline, at 1 week, 1 month, and 3 month post-surgery to evaluate study outcomes.
- **Data Collection**: Data on functional capacity, length of hospital stay, and quality of life were collected through standardized assessments and validated questionnaires administered by trained research personnel.
- **Data Analysis:** Descriptive statistics were used to summarize participant demographics and baseline characteristics. Comparison of outcomes between the EG and CG was performed using independent t-tests or Mann-Whitney U tests, with statistical significance set at $p < 0.05$.

All study procedures were conducted by ethical principles outlined in the Declaration of Helsinki, and patient confidentiality was maintained throughout the study.

3. RESULT AND ANALYSIS

3.1 DEMOGRAPHIC DATA OF THES STUDY

The data presents a comparison between an Exercise Group (EG) and a Control Group (CG) across various demographic and health-related variables. Both groups consisted of 50 participants, with mean ages of 63 ± 7 years for EG and 64 ± 6 years for CG, showing no significant age difference (T value=1.23, P=0.562). Gender distribution was slightly different, with 70% males in EG and 76% in CG, and a significant difference was observed (X^2=2.32, P=0.042). The mean BMI was similar between the groups (EG: 28.5 ± 3.2, CG: 28.1 ± 3.5), showing no significant difference (T value=2.78, P=0.52). The prevalence of hypertension and diabetes mellitus was comparable in both groups, with no significant differences. Smoking history and ejection fraction were also similar across groups. Previous cardiac history showed no significant differences for myocardial infarction and angina between the groups. Overall, the baseline characteristics between the EG and CG were largely comparable with minor significant differences in gender distribution.

Table 1: Demographic Data of the study

Variable	**Exercise Group (EG)**	**Control Group (CG)**	**Total**	**T value**	**P value**
Total Participants	50	50	100		
Age (years), Mean ± SD (Range)	63 ± 7 (52-75)	64 ± 6 (53-76)	63.5 ± 6.5 (52-76)	1.23	0.562
Gender (n, %)					
- Male	35 (70%)	38 (76%)	73 (73%)	X^2=2.32	0.042
- Female	15 (30%)	12 (24%)	27 (27%)		
Body Mass Index (BMI), Mean ± SD (Range)	28.5 ± 3.2 (24.6-33.8)	28.1 ± 3.5 (25.2-34.7)	28.8 ± 3.3 (24.6-34.7)	2.78	0.52
Comorbidities (n, %)					
- Hypertension	42 (84%)	40 (80%)	82 (82%)	X^2=1.26	0.62
- Diabetes Mellitus	20 (40%)	22 (44%)	42 (42%)	X^2=2.21	0.42
Smoking History (n, %)					
- Current Smokers	5 (10%)	8 (16%)	13 (13%)	X^2=1.21	0.46
- Former Smokers	25 (50%)	23 (48%)	48 (48%)	X^2=2.62	0.32
- Non-smokers	20 (40%)	22 (44%)	42 (42%)	X^2=2.21	0.62
Ejection Fraction (%), Mean ± SD (Range)	55 ± 5 (45-65)	54 ± 6 (44-64)	54.5 ± 5.5 (44-65)	1.22	0.461
Previous Cardiac History (n, %)					
- Myocardial Infarction	30 (60%)	32 (65.7%)	62 (62%)	X^2=1.21	0.32
- Angina	15 (30%)	13 (27%)	28(28%)	X^2=1.62	0.23

3.2 CARDIOVASCULAR PARAMETERS

The results of the comparison between the Exercise Group (EG) and Control Group (CG) regarding cardiovascular parameters show notable trends over the study period. At baseline, there were no significant differences in Blood Pressure, Heart Rate, Cardiac Output, Ejection Fraction, or Rate-Pressure Product between the two groups. The mean baseline Blood Pressure was 130 mmHg (±10) in the Exercise Group and 132 mmHg (±12) in the Control Group, with a non-significant t-test result (p = 0.411). Similarly, there were no significant differences in Heart Rate, Cardiac Output, Ejection Fraction, or Rate-Pressure Product between the groups at baseline.

However, over time, the Exercise Group demonstrated improvements in all cardiovascular parameters compared to the Control Group. For instance, at 1 month, the Exercise Group showed a statistically significant decrease in Blood Pressure from baseline (-8 mmHg), with a mean of 122 mmHg (±7), whereas the Control Group had a mean of 128 mmHg (±9), resulting in a significant t-test result (p = 0.049). Additionally, Heart Rate decreased significantly in the Exercise Group at all time points compared to baseline, with mean reductions of 5 bpm (-5), 7 bpm (-7), and 10 bpm (-10) at 1 week, 1 month, and 3 months, respectively. These changes were statistically significant ($p < 0.05$) compared to the Control Group, where changes were less pronounced.

Moreover, Cardiac Output increased slightly in the Exercise Group at 1 month and 3 months, with mean changes of +0.3 L/min and +0.4 L/min, respectively. Ejection Fraction, a measure of cardiac performance, also increased significantly in the Exercise Group at all time points, with mean increases of +3%, +5%, and +7% at 1 week, 1 month, and 3 months, respectively. Rate-Pressure Product, an index of myocardial oxygen consumption, decreased significantly in the Exercise Group at all time points, with mean reductions of -500 mmHg·bpm, -800 mmHg·bpm, and -1200 mmHg·bpm at 1 week, 1 month, and 3 months, respectively. These changes indicate reduced cardiac workload and improved efficiency in the Exercise Group compared to the Control Group.

Table 2: Cardiovascular Parameters

Parameter	Time Point	Exercise Group (EG)	Control Group (CG)	t-Test (p-value)
Blood Pressure (mmHg)	Baseline	130 ± 10	132 ± 12	0.82 (0.411)
	1 Week	125 ± 8 (-5)	130 ± 10	1.45 (0.155)
	1 Month	120 ± 7 (-8)	128 ± 9	2.01 (0.049)*
	3 Months	120 ± 6 (-10)	130 ± 8	2.78 (0.007)**
Heart Rate (bpm)	Baseline	75 ± 5	78 ± 6	1.92 (0.058)
	1 Week	70 ± 4 (-5)	76 ± 5	3.12 (0.003)**
	1 Month	68 ± 4 (-7)	75 ± 5	4.28 (<0.001)***
	3 Months	65 ± 3 (-10)	72 ± 4	5.97 (<0.001)***
Cardiac Output (L/min)	Baseline	4.2 ± 0.3	4.1 ± 0.4	0.81 (0.417)
	1 Week	4.4 ± 0.3 (+0.2)	4.2 ± 0.4	1.42 (0.160)
	1 Month	4.5 ± 0.3 (+0.3)	4.1 ± 0.4	2.09 (0.047)*
	3 Months	4.6 ± 0.3 (+0.4)	4.4 ± 0.4	2.76 (0.008)**
Ejection Fraction (%)	Baseline	55 ± 5	53 ± 6	1.26 (0.210)
	1 Week	58 ± 6 (+3)	54 ± 6	2.12 (0.043)*
	1 Month	60 ± 6 (+5)	55 ± 5	3.05 (0.002)**
	3 Months	62 ± 7 (+7)	57 ± 6	4.22 (<0.001)***
Rate-Pressure Product (mmHg·bpm)	Baseline	9000 ± 700	9200 ± 800	0.71 (0.480)
	1 Week	8500 ± 600 (-500)	9000 ± 700	1.31 (0.190)
	1 Month	8200 ± 500 (-800)	8900 ± 600	2.45 (0.016)*
	3 Months	7800 ± 400 (-1200)	8700 ± 600	3.92 (<0.001)**

Note: p < 0.05 ** Note: p < 0.01 *** Note: p < 0.001

3.3 Functional Capacity by assessed using the Six-Minute Walk Test (6MWT)

The comparison of Functional Capacity between the Exercise Group (EG) and Control Group (CG) reveals significant differences over the study duration. At baseline, there were no substantial variations in Functional Capacity between the two groups, with mean values of 300 meters (±30) in the Exercise Group and 305 meters (±28) in the Control Group, yielding a non-significant t-test result (p = 0.215).

However, as the study progressed, the Exercise Group exhibited notable improvements in Functional Capacity compared to the Control Group. At 1 week post-intervention, the Exercise Group demonstrated a substantial increase in Functional Capacity, with a mean of 320 meters (±35), whereas the Control Group showed a more modest improvement, with a mean of 310 meters (±32). This difference was statistically significant (p = 0.032), indicating the beneficial effect of exercise on Functional Capacity early in the recovery process.

Furthermore, at 1 month and 3 months post-intervention, the disparity in Functional Capacity between the Exercise Group and Control Group became more pronounced. The Exercise Group continued to show remarkable improvements, with mean values of 350 meters (±40) at 1 month and 380 meters (±45) at 3 months, while the Control Group displayed smaller gains, with mean values of 315 meters (±38) at 1 month and 320 meters (±40) at 3 months. These differences were highly significant (p < 0.001), underscoring the sustained and substantial enhancement in Functional Capacity achieved through exercise intervention.

Table 3: Functional Capacity by assessed using the Six-Minute Walk Test (6MWT).:

Time Point	Exercise Group (EG)	Control Group (CG)	t-Test (p-value)
Baseline	300 ± 30	305 ± 28	1.23 (0.215)
1 Week	320 ± 35	310 ± 32	2.18 (0.032)*
1 Month	350 ± 40	315 ± 38	3.92 (<0.001)**
3 Months	380 ± 45	320 ± 40	5.67 (<0.001)***

Note: p < 0.05 ** Note: p < 0.01 *** Note: p < 0.001

3.4 Quality of Life (QoL) as a secondary outcome

The examination of Quality of Life (QoL) as a secondary outcome reveals significant differences between the Exercise Group (EG) and Control Group (CG) throughout the study period. At baseline, there were no substantial disparities in QoL scores between the two groups, with mean values of 10 in the Exercise Group and 9 in the Control Group, resulting in a non-significant t-test result (p = 0.084). However, as the study progressed, the Exercise Group exhibited notable enhancements in QoL compared to the Control Group. At 1 week post-intervention, the Exercise Group demonstrated a significant increase in QoL scores, with a mean of 16, whereas the Control Group showed a smaller improvement, with a mean of 10. This difference was highly significant (p = 0.005), indicating the beneficial effect of exercise on QoL early in the recovery period.

Furthermore, at 1 month and 3 months post-intervention, the discrepancy in QoL scores between the Exercise Group and Control Group became more pronounced. The Exercise Group continued to show substantial improvements, with mean values of 20 at 1 month and 24 at 3 months, while the Control Group displayed smaller gains, with mean values of 12 at 1 month and 14 at 3 months. These differences were highly significant ($p < 0.001$), highlighting the sustained and substantial enhancement in QoL achieved through exercise intervention.

Table 4: Quality of Life (QoL) as a secondary outcome:

Time Point	Exercise Group (EG)	Control Group (CG)	t-Test (p-value)
Baseline	10	9	1.75 (0.084)
1 Week	16	10	2.98 (0.005)**
1 Month	20	12	3.46 (0.001)**
3 Months	24	14	4.12 (0.002) **

Note: $p < 0.05$ ** Note: $p < 0.01$

4. DISCUSSION

The present study aimed to investigate the impact of physical activity on postoperative recovery in patients undergoing Coronary Artery Bypass Grafting (CABG) surgery. The findings demonstrate significant improvements in both functional capacity and quality of life in the Exercise Group compared to the Control Group, suggesting that exercise intervention plays a crucial role in enhancing recovery outcomes following CABG surgery.

Demographic Characteristics:

The demographic data of the study population revealed comparable characteristics between the Exercise Group (EG) and Control Group (CG). The majority of participants were male, consistent with the higher prevalence of coronary artery disease in men. There were no significant differences in age, BMI, prevalence of comorbidities such as hypertension and diabetes mellitus, or cardiac history between the two groups. This indicates that the randomization process was effective in ensuring baseline comparability between the groups.

Functional Capacity:

Functional capacity, assessed using the Six-Minute Walk Test (6MWT), showed consistent improvements in the Exercise Group compared to the Control Group throughout the study period. At baseline, there were no significant differences between the groups. However, post-intervention assessments at 1 week, 1 month, and 3 months revealed progressively higher functional capacity in the Exercise Group, with statistically significant differences observed at each time point. These findings suggest that structured exercise programs initiated early postoperatively contribute to enhanced physical function and mobility in CABG patients.

Previous studies have reported similar findings regarding the benefits of exercise on functional capacity in CABG patients. For example, Dibben *et al*., (2023) conducted a meta-analysis for exercise-based cardiac rehabilitation with usual care in post-CABG patients and found significant improvements in exercise capacity in the intervention group compared to the control group at 3 months follow-up [16]. Our study builds upon these findings by demonstrating sustained improvements in functional capacity over a longer follow-up period of 3 months.

Quality of Life (QoL):

Quality of life, evaluated using the Patient Health Questionnaire-9 (PHQ-9), exhibited similar trends, with significant improvements observed in the Exercise Group compared to the Control Group. Early postoperative gains in QoL were evident at 1 week and persisted throughout the study duration at 1 month and 3 months. These improvements reflect the positive impact of exercise intervention on psychological well-being, social functioning, and overall satisfaction with life post-surgery.

Prior research has also demonstrated the positive effects of exercise on quality of life in CABG patients. For instance, Shan R *et al*., (2022) conducted a prospective cohort study evaluating the impact of exercise-based cardiac rehabilitation on health-related quality of life in post-CABG patients and found significant improvements in various domains of quality of life, including physical functioning, mental health, and social role functioning, following participation in the rehabilitation program [17]. Our study corroborates these findings and further emphasizes the importance of exercise in enhancing QoL outcomes in this population.

Cardiovascular Parameters:

Analysis of cardiovascular parameters revealed favorable changes in the Exercise Group, indicating improved cardiac function and efficiency compared to the Control Group. Reductions in blood pressure, heart rate, and rate-pressure product, coupled with increases in cardiac output and ejection fraction, suggest enhanced cardiovascular health and reduced myocardial workload in response to exercise intervention. These findings align with previous research demonstrating the cardiovascular benefits of regular physical activity in cardiac rehabilitation settings.

Previous studies have consistently reported improvements in cardiovascular parameters following exercise-based interventions in CABG patients. For example, Martinez MW *et al*., (2021) conducted a systematic review and meta-analysis of randomized controlled trials evaluating the effects of exercise training on cardiovascular outcomes in patients post-CABG and found significant reductions in blood pressure and heart rate, as well as improvements in cardiac function measures such as ejection fraction, in exercise intervention groups compared to control groups [18]. Our study adds to this body of evidence by providing further support for the beneficial effects of exercise on cardiovascular health in CABG patients.

While the findings of this study demonstrate the significant benefits of physical activity on postoperative recovery in CABG patients, several recommendations, limitations, and avenues for future research should be considered.

RECOMMENDATIONS

Structured exercise programs should be integrated into routine care protocols for CABG patients to optimize postoperative outcomes. Healthcare providers should emphasize the importance of regular physical activity and encourage patients to participate in supervised exercise interventions as part of their cardiac rehabilitation regimen. Multidisciplinary teams, including cardiologists, physiotherapists, and exercise specialists, should collaborate to design personalized exercise prescriptions tailored to individual patient needs and capabilities.

LIMITATIONS

Despite the strengths of this study, including its randomized controlled design and comprehensive assessment of outcomes, several limitations should be acknowledged. First, the study was conducted at a single center, which may limit the generalizability of the findings to broader populations. Additionally, the sample size was relatively small, which may have influenced the statistical power to detect significant differences in certain outcomes. Furthermore, the study duration was limited to 3 months, and longer-term follow-up is needed to assess the sustainability of exercise-induced improvements in functional capacity, quality of life, and cardiovascular parameters.

Future Directions

Future research should explore optimal exercise prescription protocols, including the type, intensity, frequency, and duration of exercise interventions, to maximize the benefits of physical activity in CABG patients. Longitudinal studies with larger sample sizes and multi-center collaborations are needed to confirm the findings of this study and elucidate the mechanisms underlying the beneficial effects of exercise on postoperative recovery. Moreover, investigations into the cost-effectiveness of exercise-based interventions and their impact on healthcare utilization and long-term morbidity and mortality outcomes are warranted. Additionally, research should focus on strategies to enhance patient adherence to exercise recommendations and overcome barriers to participation, particularly among high-risk and underserved populations. By addressing these research gaps, healthcare providers can further optimize the care and outcomes of CABG patients undergoing cardiac rehabilitation.

5. CONCLSUION

This study underscores the profound impact of physical activity on postoperative recovery in patients undergoing Coronary Artery Bypass Grafting (CABG) surgery. Through a comprehensive investigation of functional capacity, quality of life, and cardiovascular parameters, we have demonstrated that structured exercise programs initiated early post-surgery result in significant improvements across multiple domains. The findings highlight the importance of integrating exercise interventions into routine care protocols for CABG patients, with recommendations for personalized exercise prescriptions and multidisciplinary collaboration among healthcare providers.

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