EFFECT OF HIGH INTENISTY INTERVAL TRAINING VERSUS NEUROMUSCULAR ELECTRIC STIMULATION ON QUALITY OF LIFE AND BLOOD PRESSUR IN POST-CABG

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ABSTRACT

Background: *Coronary artery disease (CAD) is a significant global health concern. Post-CABG, patients often experience diminished quality of life and elevated blood pressure, necessitating effective rehabilitation strategies. Objective: This research aimed to evaluate the effects of high-intensity interval training (HIIT) and neuromuscular electrical stimulation (NMES) on quality of life and blood pressure following coronary artery bypass graft (CABG).* ***Methods:*** *Ninety post-CABG patients were randomly assigned to one of three groups: (A) the HIIT group, which received high-intensity interval training plus standard physical therapy; (B) the NMES group, which received neuromuscular electrical stimulation plus standard physical therapy; and (C) the control group, which received only conventional physical therapy. Pre- and post-intervention assessments included quality of life measured via the SF-36 questionnaire and blood pressure readings.* ***Results:*** *After six weeks of intervention, significant changes in SF-36 scores were observed across the three groups (P<0.05)%. Additionally, notable improvements in blood pressure, including both systolic and diastolic measures, were seen in all groups (P<0.05)%.* ***Conclusion:*** *Clinically, incorporating HIIT or NMES with conventional therapy may provide the most substantial benefits for post-CABG patients.*

Keywords: HIIT, NEMS, post-CABG

INTRODUCTION

The accumulation of plaque in the coronary arteries, which prevents oxygen-rich blood from reaching the heart, results in coronary artery disease (CAD), a dangerous medical condition. Individuals suffering from this illness may exhibit no symptoms, angina (chest pain), or even heart attacks. This condition is chronic, weakening the heart muscles and increasing the risk of arrhythmias, heart failure, and even unexpected death. As a result, ischemia eventually results from a decrease in blood flow to the distal myocardium in CAD. In recent years, low- and middle-income countries have seen an increase in the prevalence of CAD, the leading cause of death worldwide [1].

Many different factors can lead to CVD. Some things are unchangeable (like age, gender, and genetic heritage), while others are malleable (like smoking, inactivity, unhealthy eating, high blood pressure, type 2 diabetes, dyslipidemia, and obesity) [2].

During coronary artery bypass grafting (CABG), a narrowed or blocked section of the coronary arteries is connected above and below using healthy blood vessels from the patient's leg, arm, or chest. This is an open cardiac procedure. The heart's blood flow is restored by these new blood vessels, also known as grafts. Dr. Vasilii Kolesov performed CABG for the first time in 1964. Currently, CABG is the most frequently performed cardiac surgery globally [3].

One option for treating coronary artery disease (CHD) is a coronary artery bypass graft (CABG). In the US, CABG is performed on over 200,000 patients each year. Even though CABG is widely recognized for its advantages, a number of patients experience side effects that increase morbidity, mortality, and lengthen stays in the intensive care unit (ICU), including dystrophin, pneumonia, atelectasis, anxiety, and fear of dying [4].

Patients who have had coronary artery bypass graft (CABG) surgery frequently have a decline in their cardiopulmonary fitness and capacity during the recovery phase. Regretfully, after CABG, patients' quality of life does not always improve; in fact, for some, the procedure may have worsened their health-related quality of life (HRQOL). Following CABG, patients frequently experience pain, discomfort, hopelessness, impatience, a loss of general wellbeing, and an inability to function at the same level as prior to the procedure. The patient's quality of life may be significantly impacted by these feelings. Because of this, all patients who have had CABG surgery need to take part in a comprehensive rehabilitation program that addresses their physical, nociceptive, mental, and cognitive needs as well as their sleep, mobility, and everyday living skills [5].

High-intensity interval training (HIIT) is a type of exercise regimen characterized by alternating short bursts of vigorous activity with periods of lower-intensity exercise or rest. HIIT has become increasingly popular due to its efficiency and effectiveness in enhancing cardiovascular health, metabolic function, and overall physical fitness. Research indicates that HIIT can markedly improve aerobic capacity, decrease body fat, and enhance insulin sensitivity. This form of exercise is especially advantageous for individuals with cardiovascular diseases, as it aids in reducing blood pressure and enhancing heart function [6]. Furthermore, HIIT has been associated with improvements in mental health and quality of life, making it a valuable component of rehabilitation programs for post-CABG patients [7].

Neuromuscular electrical stimulation (NMES) involves the application of electrical impulses to elicit muscle contractions. This technique is widely used in physical therapy to enhance muscle strength, endurance, and functional capacity, especially in patients who may have difficulty performing voluntary exercises. NMES has been effective in improving the physical capabilities of patients with chronic obstructive pulmonary disease (COPD) and other chronic conditions [8]. For cardiac surgery patients, NMES can aid in reducing the loss of muscle mass and strength that often accompanies prolonged hospital stays and inactivity. Although some studies have shown mixed results regarding its impact on quality of life, NMES remains a promising adjunct to conventional rehabilitation methods [9].

Conventional physical therapy programs for post-CABG patients typically include a combination of aerobic exercises, resistance training, and flexibility exercises. These programs are designed to improve cardiovascular health, increase physical strength, and enhance overall mobility. Respiratory exercises are also a critical component, helping to improve lung function and reduce the risk of postoperative complications such as pneumonia and atelectasis. Adhering to the guidelines of phase 2 cardiac rehabilitation, these programs aim to restore the patient’s physical function, alleviate pain, and improve their quality of life. Regular physical therapy sessions, tailored to the patient’s individual needs, are essential for achieving optimal recovery outcomes [10].

In this context, our study hypothesized that incorporating high-intensity interval training (HIIT) exercises or neuromuscular electrical stimulation (NEMS) into conventional physical therapy would improve blood pressure and quality of life. The aim of this study was to compare the effects of adding HIIT exercises or NEMS to conventional physical therapy on blood pressure and quality of life in patients’ post-CABG (coronary artery bypass grafting) by analyzing these parameters.

MATERIALS AND METHODS

Study Design

Randomized controlled trial (RCT)

Participants

The research took place from June 2023 to August 2023. Participants were fully briefed on the study’s objectives and any associated risks. Informed consent was obtained from all participants. The research received approval from the Ethical Committee of the Physical Therapy Faculty at Cairo University (Approval No: P.T.REC/012/004532).

Subjects

A total of 90 patients from both sexes underwent CABG were enrolled at from inpatient of The National Heart Institute, Cairo, Egypt. Their BMI was 25 up to 29.9 kg/m², and their ages were between 55and 65 years. They were recruited after one week of the CABG. The patients were hemodynamically stable, conscious, and capable of performing physical tasks. Patients with the following conditions were excluded from this study: Hemodynamic instability (mean arterial blood pressure "systolic more than 160mmHg and less than 100 mmHg"," diastolic more than 100 mmHg and less than 60mmHg", Large pneumothorax ,pulmonary embolism, Neuromuscular disorders such as (peripheral neuropathy, Myasthenia gravis), Active hemorrhage ,hemoptysis, Poor cognition and mentality, peripheral vascular disorders in the lower limbs, such as (deep vein thrombosis (DVT), intermittent claudication),musculoskeletal disease such as (osteoarthritis, rheumatoid arthritis, osteoporosis, sarcopenia, fibromyalgia),epidermal lesions at the site of NMES application, intolerance to electrical stimulation, any change in skin sensitivity, pacemaker or electrical prosthesis, renal or hepatic diseases and metabolic disorders such as diabetes mellitus. Figure 1 is a flowchart illustrating the selection criteria.

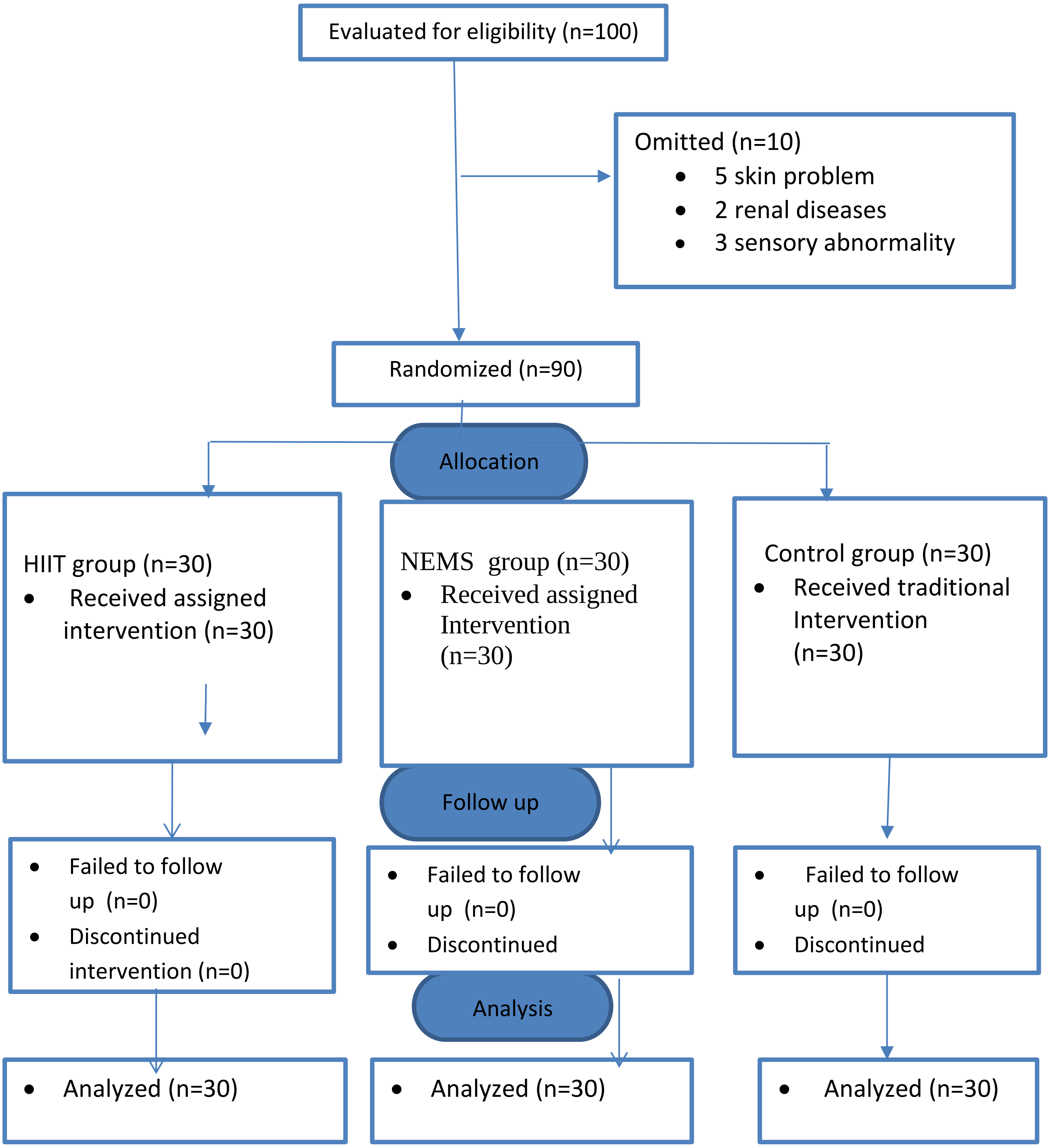

Figure 1. study flow chart

Procedures

At the start of the trial, all participants underwent a physical evaluation by a qualified physiotherapist to ascertain their eligibility for participation. Demographic information was collected through a survey. The height (in centimeters) and weight (in kilograms) of each participant were recorded, and the body mass index (BMI) was subsequently calculated.

Participants were randomly assigned to receive either HIIT plus conventional physical therapy, NMES plus conventional physical therapy, or only conventional physical therapy. The randomization process was performed by a staff member who was not involved in the specifics of the experiment, ensuring equal likelihood for each participant being placed in any group. The assignments were made using a sealed envelope method.

Blood pressure measurements:

Brachial systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using a standard mercury sphygmomanometer (ALPK2, Japan). The first and fifth Korotkoff sounds were used to determine SBP and DBP, respectively. Blood pressure readings were taken twice, and if the values were within 5 mmHg of each other, the average was calculated for analysis. Measurements were repeated until two readings within 5 mmHg were achieved. After a 5-minute seated rest, blood pressure was measured three times across two separate laboratory visits. Participants were excluded if the average of the last two readings for SBP exceeded 139 mmHg or for DBP exceeded 89 mmHg during each visit. Blood pressure and heart rate were assessed immediately before (pre) and after (post), as well as approximately 15 minutes (post-15) and 30 minutes (post-30) after each exercise session [12].

Outcome measures

Quality of life (QOL):

The Short Form 36 Quality of Life Questionnaire is a widely recognized instrument for evaluating health-related quality of life (HRQL). It comprises 36 items categorized into eight domains: Physical Functioning, Vitality, Bodily Pain, Physical Role Functioning, General Health Perceptions, Social Role Functioning, Emotional Role Functioning, and Mental Health. These items are rated using various scales, including a 2-point scale (yes/no), a 3-point scale, and predominantly a 5-point scale, reflecting experiences from the previous month. Scores for each section range from 0 (worst QOL) to 100 (best QOL). Additionally, a physical composite score (PCS) and a mental composite score (MCS) are calculated, both ranging from 0 (worst QOL) to 100 (best QOL) [11].

Interventions

High intensity exercise training group

The HIIT group participated in high-intensity interval training (HIIT) alongside a conventional physical therapy program. Each HIIT session began with a 5-minute active warm-up, followed by 3 minutes of exercise at 60% to 70% of heart rate reserve (HRR). This was followed by four high-intensity intervals, each lasting 4 minutes at 80% to 90% of HRR. Each high-intensity interval was succeeded by a 3-minute active recovery period at 60% to 70% of HRR. The session concluded with a 4-minute active cool-down period [6].

Neuromuscular electrical stimulation group

In addition to conventional physiotherapy, patients in this group received neuromuscular electrical stimulation (NMES) administered by researchers three times a week. The device used was the Geko™ from the United Kingdom, featuring four channels and silicon-carbon electrodes (3 × 3 cm), secured to the motor points of the quadriceps muscle bilaterally with adhesive tape. A functional electrical stimulation current of 25 Hz frequency, 400 μs pulse width, 10 s on-time, and 30 s off-time was applied for 20 minutes. The intensity was adjusted to ensure visible muscle contraction, confirmed by palpation if needed. The quadriceps muscles were targeted due to their crucial role in ambulation, making them a key treatment focus for critical and cardiac patients [13].

Conventional physical therapy program:

Participants in Groups A, B, and C engaged in a conventional physical therapy cardiac rehabilitation program. Each session started with a 5-minute warm-up of gentle walking and arm circles, followed by a 20-minute aerobic exercise phase, including stationary cycling or brisk walking at 50-70% of maximum heart rate [14].

A 10-minute strength training segment with light resistance exercises was next, performed in 2-3 sets of 10-15 repetitions. This was followed by 10 minutes of flexibility and balance exercises to improve flexibility and prevent falls [15].

The session ended with a 5-minute cool-down involving slow walking and gentle stretching to reduce heart rate and blood pressure, along with diaphragmatic and pursed-lip breathing exercises to enhance respiratory efficiency and relaxation [14]. These respiratory exercises followed phase 2 cardiac rehabilitation guidelines, focusing on diaphragmatic breathing, incentive spirometry, and pursed-lip breathing.

Statistical analysis

All statistical analyses were conducted using SPSS version 22. The demographic characteristics of the subjects in the three groups were analyzed using one-way ANOVA, while the Kruskal-Wallis test was used to compare sex differences between the groups. Additionally, MANOVA was employed to assess the differences between the groups before and after the intervention, and multiple comparisons were performed to identify significant variations between each group. The significance level for all statistical tests was set at $P < 0.05$.

RESULTS

Typically, 90 participants were enrolled in this investigation and distributed randomly in three groups (30 patients per group). Demographic data analysis was conducted and indicated that there were no significant differences between the three groups regarding their age, weight, height, BMI, and sex, as the P-values were (0.656, 0.776. 0.123, 0.567, and 0.845, respectively) **(Table 1).**

Table 1. Comparison of characteristics between groups A, B, and C.

		Group A	Group B	Group C	F-value	P-value
		$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SD		
Age (years)		58.4±3.7	59.2±3.6	59±3.6	0.424	0.656
Weight (kg)		73.7±6.4	74.8±6.3	74.1±6.1	0.254	0.776
Height (cm)		166.1±6.8	169.2±5.4	167.9±5.5	2.149	0.123
BMI (kg/m²)		26.9±1.2	26.8±0.9	26.6±1.4	0.570	0.567
		N (%)	N (%)	N (%)		
Sex	**Male**	22(73.3%)	23(76.7%)	21(70%)		0.845
	Female	8(26.7%)	7(23.3%)	9(30%)		

$\bar{X}$: Mean, SD: Standard deviation, p-value: Probability value, *: significance

Our investigation indicated that all interventions had a significant impact on the SF 36 questionnaire score; however, according to the outcomes, no statistical variation was observed between the three groups before intervention. Furthermore, The results indicated a significant difference between all groups following treatment (Table 2). Multiple comparisons showed significant variations between groups A and B, as well as between groups A and C (P-values of 0.010 and 0.001, respectively). However, no significant difference was observed between groups B and C (P-value of 0.650) **(Table 2)**. According to the percentage of change within every group, the intervention that was conducted in group B (11.1%) was more effective than in groups A (9.9%) and C (10.3%) **(Table 2).**

Table 2. SF 36 Questionnaire results comparison within and between groups A, B, and C.

	Group A $\overline{X}$ ± SD	Group B $\overline{X}$ ± SD	Group C $\overline{X}$ ± SD	Comparison between Groups	
				F-value	P-value
Pre-Treatment	2.5±0.3	2.4±0.1	2.4±0.14	2.330	0.103
Post-Treatment	2.8±0.1	2.7±0.1	2.6±0.06	9.025	P<0.05*
Change %	9.9%	11.1%	10.3%		
Comparison within Group	P<0.05*	P<0.05*	P<0.05*		

Multiple Comparisons (post-treatment)

	MD	P-value
Group A vs. Group B	0.08	0.010*
Group A vs. Group C	0.097	0.001*
Group B vs. Group C	0.022	0.650

$\overline{X}$: Mean, SD: Standard deviation, MD: mean difference, p-value: Probability value, *: significance, change%: percentage of change

The outcomes indicated that all treatment procedures had a significant effect on the systolic and diastolic blood pressure; however, no statistical variation was detected between the three groups before treatment. Furthermore, the findings exhibited that there was a significant difference between all groups post-treatment regarding the systolic blood pressure, but no significant difference was detected regarding the diastole **(Table 3).** The multiple comparisons revealed that significant variation in the systolic blood pressure was detected between groups A and C as well as between groups B and C (P-value, 0.010 and 0.014, respectively); however, no significant difference between groups A and B (p-value was 0.991). Based on the percentage of change regarding systolic blood pressure, the intervention that was performed for individuals in group C (3.2%) was more effective than in groups A (2.3%)or B (2.4%) **(Table 3).**

Table 3. Systolic and diastolic blood pressure comparison within and between groups A, B, and C.

Variables		Group A $\bar{X}$ ± SD	Group B $\bar{X}$ ± SD	Group C $\bar{X}$ ± SD	Comparison between Groups	
					F-value	**P-value**
Systole	**Pre-Treatment**	126.6±3	126.7±3.1	125.4±2.8	1.770	0.176
	Post-Treatment	123.7±2.3	123.6±2.9	121.4±3.1	6.248	0.003*
	Change %	2.3%	2.4%	3.2%		
	Comparison within Group	P<0.05*	P<0.05*	P<0.05*		
Diastole	**Pre-Treatment**	88.6±0.6	88.7±0.5	88.8±0.8	0.333	0.718
	Post-Treatment	88.2±0.37	88.1±0.4	88.3±0.5	1.274	0.285
	Change %	0.5%	0.64%	0.56%		
	Comparison within Group	P<0.05*	P<0.05*	P<0.05*		

Multiple Comparisons (post-treatment)

	Post-Treatment Systole	
	MD	**P-value**
Group A vs. Group B	0.10	0.991
Group A vs. Group C	2.27	0.010*
Group B vs. Group C	2.17	0.014*

$\bar{X}$: Mean, SD: Standard deviation, MD: mean difference, p-value: Probability value, *: significance, change%: percentage of change

DISCUSSION

The primary finding of our research over the course of the 6 week training session, was that the three groups showed a notable improvement in their quality of life and blood pressure. The results of this study had shown there was no significant difference in all parameters between the three groups before treatment (p<0.05).

Effects of HIIT

The implementation of high-intensity interval training (HIIT) in phase 2 rehabilitation post-CABG demonstrated significant improvements in both blood pressure and quality of life. Specifically, the systolic blood pressure of participants decreased from 126.6±3.1 mmHg to 123.6±2.3 mmHg, reflecting a 2.3% reduction (P≤0.05). The diastolic blood pressure showed a slight decrease from 88.7±0.6 mmHg to 88.2±0.3 mmHg, amounting to a 0.6% reduction (P≤0.05). Additionally, the quality of life, as measured by the SF-36 questionnaire, improved by 10%, with scores increasing from 2.5±0.3 to 2.8±0.1 (P≤0.05). These outcomes indicate that HIIT is effective in reducing blood pressure and enhancing overall well-being in post-CABG patients.

Supporting studies

Heidari (2021) conducted a study demonstrating that high-intensity interval training (HIIT) significantly reduces both systolic and diastolic blood pressure post-exercise in post-CABG patients. The study highlighted immediate post-exercise improvements, indicating the efficacy of HIIT in managing blood pressure [16].

Attarbashi et al. (2008) demonstrated that phase II cardiac rehabilitation, which can include HIIT, significantly improved health-related quality of life (HRQoL) in Iranian patients after CABG [17].

Contradicting Studies

Keteyian et al. (2014) found that while HIIT could be successfully integrated into standard cardiac rehabilitation and improved peak exercise capacity, it did not show a significant difference in blood pressure changes compared to moderate-intensity continuous training [18].

Gjellesvik et al. (2020) conducted a study on stroke patients which found that HIIT did not result in superior improvements in blood pressure or blood profile compared to standard care, indicating similar outcomes might be expected in post-CABG patients [19].

Dall et al. (2015) compared HIIT and continuous moderate training in heart transplant recipients and found no significant changes in arterial stiffness and biomarkers, including blood pressure, suggesting that HIIT might not significantly impact these parameters in post-CABG patients [20].

Effects of NMES

Neuromuscular electrical stimulation (NMES) also yielded significant benefits in the rehabilitation process. Participants in the NMES group experienced a reduction in systolic blood pressure from 126.7±3.1 mmHg to 123.5±2.9 mmHg, which corresponds to a 2.4% decrease (P≤0.05). Diastolic blood pressure dropped from 88.7±0.5 mmHg to 88.1±0.4 mmHg, indicating a 0.64% change (P≤0.05). The quality of life improvements were notable, with SF-36 scores rising from 2.4±0.1 to 2.6±0.1, an 11.2% improvement (P≤0.05). These findings underscore the efficacy of NMES in managing blood pressure and enhancing quality of life in individuals undergoing post-CABG rehabilitation.

Supporting Studies

Demircioğlu et al. (2015) demonstrated that neuromuscular electrical stimulation (NMES) significantly improved functional status and quality of life in patients post-knee arthroplasty. Although this study focused on knee arthroplasty, it underscores the potential benefits of NMES in rehabilitation settings, highlighting improvements in pain, walking distance, and quality of life [21].

Lee et al. (2012) conducted a study on healthy adults to evaluate the effects of NMES on cardiopulmonary function and quality of life. The study involved applying NMES to the quadriceps muscles over two weeks. The SF-36 questionnaire was used to assess quality of life changes, and the results showed significant improvements in maximum oxygen consumption (VO2 max), maximal heart rate (MHR), exercise tolerance, and resting systolic blood pressure. These improvements were reflected in higher scores in various SF-36 domains, indicating better overall quality of life [22].

Contradicting Studies

Lo Re et al. (2023) found that adding NMES to standard rehabilitation care in post-CABG patients did not significantly increase serum levels of neuroprotective myokines or improve long-term cognitive performance compared to standard care alone. Although there were some functional connectivity improvements in the brain, these did not translate to significant clinical benefits [23].

Sumin et al. (2020) assessed the effects of neuromuscular electrical stimulation (NMES) on patients experiencing postoperative complications following cardiovascular surgery. Their findings indicated no significant improvements in quadriceps cross-sectional area, or the distance covered during a 6-minute walk test at discharge when compared to standard rehabilitation alone [24].

Effects of the Conventional Physical Therapy Program

The conventional physical therapy program demonstrated the highest reductions in blood pressure among the three interventions. Systolic blood pressure decreased from 125.4±2.9 mmHg to 121.4±3.2 mmHg, a significant reduction of 3.2% ($P \leq 0.05$). Diastolic blood pressure showed a decrease from 88.8±0.8 mmHg to 88.3±0.5 mmHg, a 0.56% reduction ($P \leq 0.05$). In terms of quality of life, the SF-36 scores improved by 10.4%, with an increase from 2.4±0.2 to 2.7±0.06 ($P \leq 0.05$). These results highlight the conventional physical therapy program's effectiveness in lowering blood pressure and improving quality of life in post-CABG patients.

Supporting Studies

Masoumi et al. (2017) demonstrated that cardiac rehabilitation, which includes conventional physical therapy, significantly improved the quality of life in patients post-CABG. The study reported improvements in physical functioning, emotional well-being, and general health [25].

Patil et al. (2020) compared conventional therapy with closed kinetic chain exercises in post-CABG patients. They found that conventional therapy significantly reduced systolic and diastolic blood pressures, improved respiratory rate, heart rate, and quality of life as measured by the SF-36 questionnaire [26].

Sagar et al. (2012) found that both supervised and home-based phase II cardiac rehabilitation programs, which include conventional physical therapy, significantly improved exercise capacity and quality of life in post-CABG patients [27].

Contradicting Studies

Smith et al. (2004) found that while home-based cardiac rehabilitation was as effective as hospital-based programs in improving physical and psychosocial outcomes in the short term, the sustainability of these effects over 12 months was less clear, with physical HRQL remaining higher in the home-based group [28].

Ashok and Soman (2018) explored the efficacy of music therapy in addition to cardiac rehabilitation and found that while it significantly reduced anxiety and improved quality of life, conventional rehabilitation alone also produced significant benefits, suggesting complementary therapies might enhance conventional outcomes [29].

Limitations

The present study has several limitations. The primary limitation is the lack of an extended follow-up period for the use of neuromuscular electrical stimulation or the HIIT. Additionally, due to the nature of the intervention, it was not feasible to blind the participants to the procedure.

Conclusion

It was concluded that early rehabilitation after CABG surgery via adding HIIT or NEMS to conventional cardiac rehabilitation program could improve blood pressure and quality of life. As they are viewed as a safe and non-invasive therapeutic option that could be implemented as a routine practice in post CABG patients.

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