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SHORT TERM EFFECTS OF CARDIOPULMONARY REHABILITATION AND NEUROMUSCULAR ELECTRICAL STIMULATION ON FUNCTIONAL CAPACITY, MYOCARDIAL TISSUE DOPPLER AFTER CORONARY ARTERY BYPASS GRAFT SURGERY

ORIGINAL ARTICLE

ABSTRACT

Purpose: Exercise capacity is associated with diastolic function. The aim of our study is to investigate the short-term effects of cardiopulmonary rehabilitation and NMES on functional capacity and myocardial tissue doppler (MTD) after coronary artery surgery.

Methods: Forty patients with coronary artery bypass graft were randomly divided into two groups: CPR+NMES and CPR. Functional capacity were analyzed through 2 minutes walk test (2MWT) and sit to stand test (SST), left ventricular (LV) diastolic functions were analyzed with MTD and thoracic expansion was analyzed with chest wall measurement on the 2nd and 7th postoperative days.

Results: Statistically significant difference was identified between the groups in 2MWT distance (CPR+NMES, Zt*p=0.000*), SST (CPR, Zt*p=0.000*), E' (CPR+NMES, Zt*p=0.002*), E (CPR+NMES, Zt*p=0.025*), E/E' (CPR+NMES, Zt*p=0.007*), A (CPR, Zt*p=0.006*) (p<0.05). Statistically significant difference has been observed in group comparisons in E' (CPR+NMES, G*p=0.000*) ve E/E'(CPR+NMES, G*p=0.007* postoperative 2nd day; G*p=0.019* postoperative 7th day) (p<0.05). The temporal changes of 2MWT distance, heart rate, blood pressures, respiratory frequency, saturation and Borg dyspnea-fatigue measurements did not show a statistically significant difference between groups (p>0.05), except for E'(Zg*p=0.000*), E/E' (Zg*p=0.003*) parameters (p<0.05).

Conclusion: It was seen that NMES, which we applied in addition to early cardiopulmonary rehabilitation, made a positive contribution to LV filling pressure and LV filling rate in the CPR+NMES group. Additionally, in the intergroup comparisons of the CPR+NMES group, it was observed that there was a statistically significant increase in the 2 MWT distance on the postoperative 7th day compared to the postoperative 2nd day.

Keywords: Cardiopulmonary Rehabilitation, Coronary Artery Bypass Graft, Functional Capacity, NMES, Tissue Doppler

KORONER ARTER BYPASS GREFT CERRAHİSİ SONRASI KARDİYOPULMONER REHABİLİTASYON VE NÖROMÜSKÜLER ELEKTRİK STİMÜLASYONUN FONKSİYONEL KAPASİTE, MİYOKARDİAL DOKU DOPPLERİ ÜZERİNDEKİ KISA DÖNEM ETKİLERİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Egzersiz kapasitesi diyastolik fonksiyonla ilişkilidir. Çalışmamızın amacı, koroner arter cerrahisi sonrası kardiyopulmoner rehabilitasyon ve NMES'in fonksiyonel kapasite ve miyokard doku doppleri (MDD) üzerine kısa dönem etkilerini araştırmaktır.

Yöntemler: Koroner arter baypas greftli kırk hasta rastgele iki gruba ayrıldı: CPR+NMES ve CPR. Fonksiyonel kapasite 2 dakika yürüme testi (2DYT) ve otur kalk testi (SST), sol ventrikül diyastolik (LV) fonksiyonları MDD ile, göğüs ekspansiyonu göğüs duvarı ölçümü ile postoperatif 2. ve 7. günlerde analiz edildi.

Sonuçlar: Gruplar arasında, 2DYTmesafe (CPR+NMES, Zt*p=0,000*), SST (CPR, Zt*p=0,000*), E' (CPR+NMES, Zt*p=0,002*), E (CPR+NMES, Zt*p=0,025*), E/E' (CPR+NMES, Zt*p=0,007*), A (CPR, Zt*p=0,006*) istatistiksel olarak anlamlı fark tanımlanmıştır (p<0,05). Grup içi karşılaştırmalarda E' (CPR+NMES, G*p=0,000*) ve E/E' (CPR+NMES, G*p=0,007* postoperatif 2. gün; G*p=0,019* postoperatif 7.gün) istatistiksel olarak anlamlı fark gözlenmiştir (p<0,05). E' (Zg*p=0,000*), E/E' (Zg*p=0,003*) parametreleri hariç (p<0,05), 2DYT mesafe, kalp hızı, kan basıncı, solunum frekansı, saturasyon ve Borg dispne-yorgunluk ölçümleri zamana göre gruplar arasında istatistiksel farklılık göstermedi (p>0,05).

Tartışma: Erken dönem kardiyopulmoner rehabilitasyona ek olarak uyguladığımız NMES'in, CPR + NMES grubundaki LV dolum basıncına ve LV dolum hızına olumlu bir katkı yaptığı görülmüştür. Ayrıca CPR + NMES grubunun gruplar arası karşılaştırmalarında, postoperatif 7. günde postoperatif 2. güne kıyasla 2DYT mesafesinde istatistiksel olarak anlamlı bir artış olduğu görülmüştür.

Anahtar Kelimeler: Kardiyopulmoner Rehabilitasyon, Koroner Arter Baypas Greft, Fonksiyonel Kapasite, NMES, Doku Doppleri

INTRODUCTION

After coronary artery bypass graft (CABG) surgery, several problems that negatively influence everyday living and quality of life can occur, including pulmonary problems, dyspnea, exhaustion, decreased functional capacity, loss of muscle strength, emotional changes, sleep disorders, mental and social problems. These issues can be addressed with a physiotherapy and rehabilitation program that is tailored to the patients' metabolic equivalent of task levels. Physiotherapy and rehabilitation practices linked to respiratory physiotherapy, aerobic exercise, electrotherapy, and progressive mobilization can be performed in the postoperative phase of myocardial revascularization, according to the findings of a comprehensive study published in 2019 (1). Neuromuscular electrical stimulation (NMES) has increased popularity as a promising new exercise training tool in cardiovascular rehabilitation in recent years. NMES administration in patients with heart failure has been shown in studies to improve treatment outcomes. When compared to traditional exercises, NMES has a few advantages, such as requiring less patient motivation and being more likely to be performed by patients who are unable to get traditional training (2). The clinical benefits of NMES have been characterized as a considerable increase in maximal workload, oxygen consumption at the anaerobic threshold, and 6-minute walk distance after CABG surgery. These advantages are thought to be linked to an increase in oxidative capacity in the peripheral muscles of heart failure patients (3).

Because it is independent of preload and afterload, tissue doppler imaging is widely employed, particularly in evaluating diastolic left ventricular (LV) functions. The myocardium's high amplitude and low velocity motions, rather than blood flow, are observed using the tissue doppler technique (4,5). Many factors influence LV diastolic filling, including myocardial relaxation, compliance, cardiac rhythm, and pericardial compliance. At rest and during activity, excellent diastolic function requires appropriate filling of the ventricles without creating an excessive increase in diastolic pressures or pulmonary congestion. Myocardial relaxation is the initial diastolic event, and it is an active energy-dependent event that causes the LV pressure to rapidly drop after the contraction ceases (6). The transmitral pressure gradient established by these many elements results in the LVfilling pattern. These parameters are routinely used in clinical echocardiography, such as myocardial systolic velocity (S), early diastolic velocity (E), highest late filling rate with contraction of the atria- late diastolic velocity (A), wave with early diastolic rapid filling (E'), and ratio of mitral flow early diastolic velocity to early diastolic velocity obtained by pulsed wave tissue doppler from the mitral annulus (LVfilling pressure) (E/E') (7). Additionally, The European Association of Cardiovascular Imaging/American Society of Echocardiography (EACVI/ASE) recently issued recommendations in 2016 that recommend four variables for diagnosing diastolic dysfunction: annular e' velocity (LAT E'VEL-lateral e' / SEP E' VEL-septal e' ratio), average E/e' ratio >14, and diastolic e' velocity (LAT E'VEL-lateral e' / septal e' ratio) (8). Before transmitral flow, myocardial relaxation causes movement and the E' wave arrives first, followed by the E wave. The E' wave is somewhat dependent on preload and directly dependent on myocardial relaxation. With increasing age, diastolic dysfunction, and LV hypertrophy, the E' wave decreases. The E wave is a good way to assess diastolic function since it is a good predictor of myocardial relaxation. Ischemia has a strong effect on the E wave. E' instantly decreases as coronary blood flow diminishes (9).

The link between increased LV filling pressure and increased mortality in men following a myocardial infarction emphasizes the significance of adequate treatment for those at risk (10). High-intensity aerobic treadmill exercise has been shown to improve LV early diastolic myocardial relaxation rate and VO2peak in patients with stable coronary artery disease using tissue doppler (11). The ability to exercise is linked to diastolic function (12).

The goal of our research is to see how cardiopulmonary rehabilitation and NMES affect functional capacity and myocardial tissue doppler (MTD) following coronary artery bypass graft surgery in the short term.

METHODS

Participants

The study took place in Zonguldak Bülent Ecevit University Hospital between January 2017-July 2019 with 40 patients who underwent CABG surgery between the ages of 50-75 and employed solely IMA (3 patients), IMA and saphenous vein grafts (37 patients).

Patients with CABG surgery, stable vital signs, no cooperational, orthopedic, or neurological issues, and postoperative atrial fibrillation meet the inclusion criteria. The participants who met the requirements were randomly assigned to one of two groups (cardiopulmoner rehabilitation (CPR group) or cardiopulmoner rehabilitation with NMES ((CPR+NMES group)) using the permutation block randomization approach (Figure 1).

The study was prepared in compliance with the Helsinki Declaration Criteria, and the study's ethical approval was granted on December 6, 2017 by a Zonguldak Bülent Ecevit University ethics committee decision 2017/20 Non-Interventional Clinical Research ethics committee decision. All patients were given written or spoken information regarding the trial, and written informed consent was obtained.

Measurements

The demographic data (gender, age, body mass index, grafts, comorbidities, total hospital stay, etc) and clinical conditions of the patients (2-minute walking test (2MWT) with dyspne-fatigue, thoracal expansiyon (chest wall measurement (CWM)). The cardiologist determined MTD, whereas the physiotherapist determined all other metrics. During the examination and therapy phases, necessary monitoring was carried out. During the preoperative phase, the patients were not evaluated, questioned, or trained. Before the patients are examined on the second postoperative day, they are informed about what should be considered following surgery, what will be done in the cpr program, and the value of the cpr program. All the evaluations were completed on the 2nd and 7th postoperative days.

Myocardial Tissue Doppler

The early diastolic mitral annulus velocity (E') estimated by MTD and the ratio of the transmitral early peak velocity (E) by pulsed wave doppler over (E/E') are the two key parameters for grading diastolic dysfunction (13). We examined the E' parameter, which indicates the LV premature filling rate, and the E/E' parameter, which reflects the LV filling pressure, in order to see the direct effect of the treatment on the left ventricle in the CPR or CPR+NMES groups. Additionally, LAT E'VEL, SEP E' VEL, E, A and E/A ratio were examined. A cardiologist took this assessment without knowing which patients were in which groups.

2 Minutes Walk Test

Butland et al. (14) developed 2MWT as an alternative to the 6-minute walking test, which is utilized in clinical and therapeutic settings where time is limited to assess a person's functional ability, which is a factor in mortality and morbidity. Prior to the test, which takes place in a 30m long hallway, the patient was given ten minutes of rest, sitting somewhere near the start and under the supervision of a physiotherapist. Before, after and rest the test, the level of dyspnea was measured using the Borg Dyspnea Scale (BDS) (0-10 score) and the level of exhaustion was measured using the Borg Fatigue Scale (BFS) (0-10 score).

30 Seconds Sit To Stand Up Test

The patients were seated in the SST with their arms crossed over their shoulders and their backs against the chair. The patient was advised to immediately stand up and sit in a 43cm high standard chair by the physiotherapist. The timer was started for 30 seconds with the "Start" instruction, and it was stopped as soon as the person's pelvis area hit the chair (16). The purpose of this test is to determine the patient's leg strength and endurance.

Chest Wall Measurements

During deep inhalation and maximum expiration, tape measures were used to measure the chest wall from the axillar, epigastric, and subcostal regions, and the difference between inspiration and expiration was recorded in cm. In addition, the type of breathing (abdominal, chest, or mixed type) and drain were recorded. The normal thoracic expansion of the patient is 2-5" (5.08-12.70 cm) (17). All patients had a drain in place for the chest circumference measurements conducted on the second postoperative day, but not for the measurements taken on the seventh postoperative day.

Protocol

The CPR+NMES group (n = 20) received the CPR program (Figure 1) as well as electrical stimulation (NMES) (Cefar Compex® Rehab, Cefar-Compex Medical Ab, Sweden), whereas the CPR group (n = 20) received only the CPR program. The program began on the second postoperative day, once this day, and then twice daily, abouth ten minutes for the next five days.

Active breathing cycle exercises and incentive spirometry are two types of breathing exercises. Patients were told to use the incentive spirometer every hour. Shoulders back, scapular adduction, lowering arms forward sideways and down, and neck ROM exercises are performed by sitting on the second postoperative day and standing on the other days. In-bed joint range of motion exercises, knee flexion extension by sitting on the bed side, walking without moving forward, standing hip hyperextension, and standing hip abduction adduction are among the Phase I-II activities. The intricacies of walking training, stair exercises, and sitting on

Table 1. Demographic Data

Datas	CPR+NMES Group (n=20)		CPR Group (n=20)		x^2	p
	N	%	N	%		
Gender						
Female	3	15	5	25		0.695φ
Male	17	85	15	75		
Diabetes mellitus	11	55	12	60	0.102	0.749
Hypertension	16	80	15	75		1.00φ
Hyperlipidemia	12	60	11	55	0.102	0.749
COPD	12	60	13	65		0.675φ
MI	13	65	14	70	0.114	0.736
Smoking	14	70	14	70		1.00φ
Alchol	7	35	8	40	0.107	0.744
Breathing types					1.074	0.584
Chest	8	40	5	25		
Abdominal	10	50	12	60		
Mix type	2	10	3	15		
Coronary graft					-0.277	0.783
1	2	10	1	5		
2	4	20	5	25		
3	7	35	7	35		
4	5	25	4	20		
5	2	10	3	15		
	CPR+NMES Group (n=20)		**CPR Group (n=20)**		**t/z**	**p**
	Mean ±SD	**Med (min - maks)**	**Mean ±SD**	**Med (min - maks)**		
Age (y)	63 ± 7.75	61 (51 - 75)	59.85 ± 6.76	60 (50 - 73)	t=1.370	0.179
BMI (kg/m²)	27.21 ±4.38	27.34 (21.48 – 37.01)	26.82 ± 3.51	25.54 (21.48 – 33.56)	t=0.313	0.756
EF (%)	48.5 ± 7.63	50 (30 - 60)	47 ± 10.93	47.5 (25 - 60)	z=-0.327	0.749
Intubation time(hours)	8.45±3.54	7.5(4-16)	9.58±3.29	9(5.5-15.5)	z=-1.262	0.211
Cross-clamp time(minutes)	64.7±25.7	60 (27-135)	58±22.12	57.5 (18-98)	t=0.884	0.382
Total perfusion time (minutes)	104.9±45.07	106.5 (37-240)	103.4±22.7	101 (61-157)	t=0.133	0.895
Intensivecare unit time (hours)	29.8±4.58	28.5 (25-42)	32.03±5.05	32 (23-39)	z=-1.497	0.142
Total hospital days	11.2±1.79	10.5(9-16)	11.05±1.23	11 (9-13)	z=-0.139	0.904

*p<0.05 statistically significant; x^2: Chi Square test, φ: Fisher Exact test, t: Independent simple t-test, z: Mann Whitney U testi, COPD: Chronic Obstructive Pulmonary Disease, BMI: Body Mass Index, MI: Myocard ınfarctus, EF: ejection fraction.

a chair were given in Figüre 2. Sitting on a chair was started once the drains were removed and the patient's health had stabilized. Moreover, dyspnea and fatigue were asked in the stair exercises.

The Physo 5 Denervation Mode Muscle Rehabilitation Device-Cefar Compex device was used to apply NMES. On the second postoperative day was began and applied once a day. For 30 minutes, patients were subjected to bilateral quadriceps and gastrosoleus muscle stimulation using a burst type, 25 hertz frequency, and 5/5 second cycle time (18). Single-use stimrodes brand 5x5 wire adhesive electrodes were used to apply NMES current to each patient.

Statistical analysis

The data was analyzed using the SPSS 26 program, with a 95 percent confidence level. The measures' mean (Mean) and standard deviation (SD) data are provided. Independent groups t were employed in the study to compare measures between groups, as well as the postoperative/discharge comparison of measurements. The ANOVA test was applied multiple times. It's a test strategy for comparing a numerical measurement with a two-group variable called independent groups t. One-way ANOVA is a test strategy for determining the change in quantitative dependent measurements over time for different groups (Group*p refers to the comparison between groups). Zt*p: Change in general, Zg*p: Change in the group; p: p-value, Postop -Discharge)

RESULTS

Table 1 summarizes demographic information. The arrangement of groups is homogeneous.

Some of the patients were given dopamine and bronchodilators as needed, but antiaggregants were given to all of them.

Statistically significant difference has been identified between the groups ($p<0.05$) in 2MWT distance (CPR+NMES, Zt*p=0.000*)(Table 3), heart rate (CPR, Zt*p =0.039*), saturation (CPR+NMES, Zt*p=0.040*; CPR, Zt*p=0.001*; CPR+NMES, Zt*p=0.000*), Borg dyspnea (CPR, Zt*p =0.033*) and fatigue (CPR+NMES, Zt*p=0.006*, Zt*p=0.000*; CPR, Zt*p=0.002*) values on the postoperative 7th day, which were assessed after short-term cardiopulmonary rehabilitation program. In group comparisons, 2MWT systolic (G*p=0.033*) and diastolic (G*p= 0.027*) pressures measured were statistically more significant on the postoperative 2nd day in the CPR+NMES group compared to the CPR group ($p<0.05$). The temporal changes of 2MWT distance (Table 3), heart rate, blood pressures, respiratory frequency, saturation and Borg dyspnea-fatigue did not show a statistically significant difference between groups ($p>0.05$) (Table 2).

The variation in the number of SST repetitions between groups was found to be statistically more significant in the CPR group (Zt*p=0.000*) compared to the CPR+NMES group on the postoperative 7th day ($p<0.05$). However, no statistically significant difference has been identified in the number of SST repetitions and in all measurements of chest circumference, both within groups and in temporal changes ($p>0.05$) (Table 3).

E' (G*p=0.000*) and E/E' (G*p=0.007*; G*p=0.019*) parameters were observed in intragroup changes of MTD parameters in the CPR+NMES group were found to be statistically more significant both on the 2nd postoperative day and on the postoperative 7th day ($p<0.05$). In intergroup exchanges, E' (Zt*p=0.002*), E (Zt*p=0.025*) and E/E' (Zt*p=0.007*) parameters in CPR+NMES group, and A (Zt*p=0.006*) parameter is in the CPR group were found to be statistically more significant on the postoperative 7th day ($p<0.05$). When the temporal changes were examined, E' (Zg*p=0.000*) and E/E' (Zg*p=0.003*) parameters were observed to be statistically more significant in the CPR+NMES group ($p<0.05$) (Table 4).

Moreover, there were no side effects associated with the NMES intervention.

DISCUSSION

As a result of our study, it was seen that NMES, which we applied in addition to early cardiopulmonary rehabilitation, made a positive contribution to LV filling pressure and LV filling rate, which are MTD results in the CPR+NMES group. In addition, in the intergroup comparisons of the CPR+NMES group, it was observed that there was a statisti-

Table 2. Hemodynamic Results of 2MWT

Measure		Postoperative	CPR+NMES	CPR	G*p	Zt*p	Zg*p
Heart rate (bpm)	Before	2nd day	94±11.19	93±15.04	0.813		
		7th day	93.45±8.9	90.8±13.13	0.460	0.575	0.736
		MeanΔ	-0.55±12.01	-2.2±18.11	0.736		
	After	2nd day	96.75±10.46	102.75±15.7	0.163		
		7th day	93.55±12.9	96.9±13.61	0.429	0.039*	0.536
		MeanΔ	-3.2±14.31	-5.85±12.43	0.536		
	Rest	2nd day	93.7±12.67	95.6±15.44	0.673		
		7th day	91.7±9.19	94.55±13.71	0.445	0.498	0.833
		MeanΔ	-2±9.98	-1.05±17.28	0.833		
Systolic Blood Pressure (beats/min)	Before	2nd day	128±10.75	124.7±17.58	0.478		
		7th day	127.9±18.88	125.55±17.95	0.689	0.880	0.848
		MeanΔ	-0.1±16.22	0.85±14.92	0.848		
	After	2nd day	142.1±19.3	126.05±25.98	0.033*		
		7th day	139.3±21.31	129.15±22.3	0.149	0.967	0.415
		MeanΔ	-2.8±23.52	3.1±21.73	0.415		
	Rest	2nd day	126.75±19.16	121.65±20.8	0.425	0.837	0.949
		7th day	127.2±19.34	122.5±18.26	0.434		
		MeanΔ	0.45±21.78	0.85±17.59	0.949		
Diastolic Blood Pressure (beats/min)	Before	2nd day	72.2±10.66	69.35±7.93	0.343		
		7th day	74.6±8.15	72.85±7.95	0.496	0.118	0.767
		MeanΔ	2.4±12.48	3.5±10.78	0.767		
	After	2nd day	79.35±11.18	71.75±9.65	0.027*		
		7th day	78.15±7.99	73.4±8.26	0.072	0.893	0.398
		MeanΔ	-1.2±11.9	1.65±9	0.398		
	Rest	2nd day	73.7±9.89	70.75±9.29	0.337	0.682	0.810
		7th day	74±9.18	71.9±8.88	0.467		
		MeanΔ	0.3±11.57	1.15±10.62	0.810		
Respiratory Frequency	Before	2nd day	24.85±5.71	23.7±4.37	0.478		
		7th day	23.8±4.05	23.45±3	0.758	0.534	0.702
		MeanΔ	-1.05±7.24	-0.25±5.78	0.702		
	After	2nd day	26.7±6.11	27.15±3.94	0.783		
		7th day	26.4±5.54	26.35±4.3	0.975	0.573	0.797
		MeanΔ	-0.3±5.87	-0.8±6.35	0.797		
	Rest	2nd day	26.1±6.21	25±3.76	0.502		
		7th day	25.2±4.65	24.3±3.96	0.514	0.359	0.908
		MeanΔ	-0.9±6.66	-0.7±3.85	0.908		
Saturation	Before	2nd day	93.3±4.24	94.15±3.67	0.502		
		7th day	95±2.87	95.35±2.21	0.668	0.040*	0.716
		MeanΔ	1.7±5.19	1.2±3.19	0.716		
	After	2nd day	94.15±4.2	94.4±4.3	0.853	0.001*	0.670
		7th day	96.3±1.89	97.1±1.77	0.176		
		MeanΔ	2.15±4.25	2.7±3.85	0.670		
	Rest	2nd day	91.15±4.5	93.7±5.12	0.103		
		7th day	94.95±2.14	95.55±2.11	0.378	0.000*	0.178
		MeanΔ	3.8±4.63	1.85±4.36	0.178		

*p<0.05 significant difference, p>0.05 no significant difference, t test/Repeat ANOVA test, G*p: comparison between groups, Zt*p: Change in general, Zg*p: Change in the group

cally significant increase in the 2 MWT distance on the postoperative 7th day compared to the postoperative 2nd day.

In our study, it was determined that there are not enough studies in the literature on the effects of cardiopulmonary rehabilitation applied in the early postoperative period on MTD. The need for myocardial protection increases during surgery and in

Table 3. 2 MWT distancewith Fatigue and Dyspnea, SST Repeats and Measurements of CWM

Measurement		Postoperative	CPR+NMES	CPR	G*p	Zt*p	Zg*p
		2nd day	47.2±18.55	42.78±19.42	0.466		
2MWT distance (meter)		7th day	81.14±24.31	76.16±27.64	0.549	0.000*	0.931
		MeanΔ	33.94±20.92	33.38±19.26	0.931		
		2nd day	1.1±1.39	1±1.65	0.837		
	Before	6th day	0.25±0.68	0.35±0.61	0.627	0.006*	0.702
		MeanΔ	-0.85±1.66	-0.65±1.61	0.702		
Borg Fatigue Scale		2nd day	1.38±1.43	1.98±1.93	0.271		
	After	6th day	0.73±0.8	0.98±1.18	0.437	0.002*	0.491
		MeanΔ	-0.65±1.35	-1±1.8	0.491		
		2nd day	1.05±1.34	1.13±1.31	0.859		
	Rest	6th day	0.38±0.72	0.48±0.73	0.667	0.000*	0.942
		MeanΔ	-0.68±1.2	-0.65±0.93	0.942		
		2nd day	0.8±1.29	0.35±1.14	0.249		
	Before	6th day	0.15±0.24	0.25±0.5	0.423	0.033*	0.114
		MeanΔ	-0.65±1.3	-0.1±0.79	0.114		
		2nd day	0.93±1.5	1.33±2.14	0.498		
Borg Dyspnea Scale	**After**	6th day	0.63±1.26	0.68±1.12	0.895	0.057	0.475
		MeanΔ	-0.3±1.24	-0.65±1.78	0.475		
		2nd day	0.68±1.25	0.83±1.5	0.733		
	Rest	6th day	0.43±1.04	0.2±0.7	0.427	0.033*	0.350
		MeanΔ	-0.25±0.95	-0.63±1.49	0.350		
		2nd day	4.2±2.24	3.45±2.52	0.326		
SST repeats		7th day	6.45±1.79	6.2±2.46	0.716	0.000*	0.393
		MeanΔ	2.25±1.48	2.75±2.12	0.393		
		2nd day	1.5±1.05	1.19±0.83	0.299		
CWM Axillar (cm)		7th day	1.54±0.92	1.37±1.68	0.694	0.623	0.740
		MeanΔ	0.04±1.19	0.18±1.54	0.740		
		2nd day	1.46±0.88	1.27±0.88	0.488		
CWM Subcostal (cm)		7th day	1.47±0.77	1.9±1.19	0.177	0.087	0.092
		MeanΔ	0.01±0.97	0.64±1.31	0.092		
		2nd day	1.17±1.01	1.61±1.09	0.193		
CWM Epigastric (cm)		7th day	1.5±1.39	1.38±1.06	0.751	0.760	0.107
		MeanΔ	0.34±0.86	-0.23±1.26	0.107		

*p<0.05 significant difference, p>0.05 no significant difference; t test/Repeat ANOVA test, 2MWT: two minutes walk test, SST:sit to stand test, CWM: chest wall measurement, G*p: comparison between groups, Zt*p: Change in general, Zg*p: Change in the group

the early postoperative period, especially in ventricles with limited energy, limited reserve and dysfunction. Generally, there is a decrease in LV functions due to ischemic areas. As is known, with the opening of the mitral valve, blood flow begins from the left atrium to the left ventricle, which has a lower pressure. In the middle of diastole, LV and left atrial pressures equalize, and blood flow continues at a low rate (19). As the filling pressure increases, the left atrial and LV pressures may equalize more rapidly, resulting in a faster increase in diastolic pressure, which leads to premature cessation of mitral blood flow (20). However, tissue oxygenation is primarily increased in ischemic areas with revascularization that develops after surgery. Cardiopulmonary rehabilitation applied in the early postoperative period also contributes to revascularization (21). In our study, MTD results in the CPR+NMES group caused a decrease in the early period LV diastolic filling pressure and an increase in the LV filling rate in temporal and intergroup changes. Our study can show that NMES causes an increase in oxidative capacity along with muscle training (22). The approach to regulating oxidative stress during NMES treatment may contribute to the creation of effective treatment strategies for coronary failure

Table 4. Myocardial Tissue Doppler Parameters

Parameters	Times	CPR+NMES	CPR(2)	G*p	Zt*p	Zg*p
	2nd day	0.13±0.18	0.18±0.23	0.526		
LAT E'VEL	7th day	0.27±0.3	0.22±0.25	0.545	0.061	0.325
	OrtΔ	0.14±0.26	0.04±0.34	0.325		
	2nd day	0.1±0.14	0.16±0.22	0.332		
SEP E'VEL	7th day	0.19±0.23	0.13±0.18	0.354	0.455	0.104
	OrtΔ	0.09±0.19	-0.03±0.26	0.104		
E' (Lat E' vel/	2nd day	0.4±0.29	0.7±0.2	0.000*		
Sep E' vel ratio)	7th day	0.47±0.31	0.17±0.15	0.000*	0.002*	0.000*
E' vel ratio)	OrtΔ	0.07±0.55	-0.53±0.27	0.000*		
	2nd day	0.45±0.14	0.41±0.21	0.487		
E (cm/sec)	7th day	0.55±0.21	0.49±0.16	0.331	0.025*	0.807
	OrtΔ	0.1±0.22	0.08±0.26	0.808		
	2nd day	0.52±0.17	0.42±0.23	0.151		
A (cm/sec)	7th day	0.65±0.26	0.58±0.19	0.353	0.006*	0.797
	OrtΔ	0.13±0.33	0.16±0.31	0.801		
	2nd day	1.13±1.4	1.01±0.38	0.694		
E/A	7th day	0.93±0.44	0.86±0.27	0.547	0.339	0.870
	OrtΔ	-0.2±1.55	-0.14±0.42	0.864		
	2nd day	2.94±2.76	0.89±1.46	0.006*		
E/E'	7th day	2.74±2.93	5.1±3.14	0.019*	0.007*	0.003*
	OrtΔ	-0.2±5.04	4.2±3.69	0.003*		

*p<0.05 significant difference, p>0.05 no significant difference; t test/Repeat ANOVA test, LAT E'VEL: lateral annular e' velocity, SEP E' VEL: septal annular e' velocity, E': early diastolic rapid filling, E: early diastolic velocity, A: the atria- late diastolic velocity, E/E' ratio: LVfilling pressure, G*p: comparison between groups, Zt*p: Change in general, Zg*p: Change in the group

(23). In addition, NMES can improve oxygenation in the coronary arteries by increasing the capillary density and oxygen consumption in the muscle fiber (24). Oxygenation that develops in the coronary arteries, in turn, can improve myocardial revascularization by reducing myocardial oxygen consumption.

When we look at the intra-group changes of MTD parameters, on the postoperative 7th day, the LV late filling rate increased in the CPR group, while the early filling rate increased in the CPR+NMES group. When we look at the comparisons between the groups made on the 7th postoperative day, we think that since the heart rate value obtained after 2MWT increased in the CPR group, it may have affected the LV late filling rate (25). However, when we examine the literature, LV early diastolic filling rate and filling pressure are used as determining parameters in LV diastolic functions. LV late filling rate is used more frequently in the examination of left atrial functions (26). In addition, LV filling rate was measured as higher and filling pressure was measured as lower in the CPR group on the 2nd postoperative day. However, on the 7th postoperative day, the LV filling rate was measured as higher and the filling pressure was measured as lower in the intragroup changes of the CPR+NMES group. Exercise training that improves diastolic function can increase exercise capacity considerably (27). Although the same exercises were applied to both groups, this change in diastolic functions observed in the postoperative 7th day CPR group suggests that exercise capacity may have decreased in this group. (28). The reason for this may be that NMES was not applied to this group and therefore their exercise capacity was reduced.

In our study, in comparisons made within the group regarding functional capacity, it was found that there was an increase in walking distance on the postoperative 7th day in the CPR+NMES group. It was aimed to increase the total oxygen consumption in the body with synchronized muscle contraction without causing dyspnea and fatigue by applying NMES in patients who generally have low functional capacity undergoing coronary surgery. NMES increases oxidative aerobic capacity, improves peripheral vasodilation, and ultimately leads to increased vascularization (29). In our study, as

Figure 1. Flow Diagram

n=64
total number of patients included in the study

n=4
exitus before surgery

n=60
remaining patient

CPR+NMES group	CPR group
n=30 CPR+NMES group	n=30 CPR group
n=2 Complications developed during the intensive care unit or were revised.	n=3 Complications developed during the intensive care unit or were revised.
n=1 exitus	n=3 exitus
n=3 surgery complications developed	n=2 surgery complications developed
n=4 7th day evaluation could not be obtained	n=2 7th day evaluation could not be obtained
n=20 CPR+NMES group	n=20 CPR group

supported in the literature, with the increase in the 2MWT walking distance in the CPR+NMES group, functional capacity improved along with peripheral vascularization on postoperative 7th day. Myocardial revascularization expected from surgery after CABG also contributed to this development. In our study, ventricular functions were preserved better in the CPR+NMES group in MTD compared to the CPR group, and no related complications occurred in the cases. There was no statistically significant difference in functional capacity between the groups; however, in accordance with the basic objectives of the phase I program applied in our study, LV diastolic functions were preserved on the 7th postoperative day, as shown in MTD in the CPR+NMES group. We think that if the phase II program had been completed and 2 MWTs had been performed at the end, a difference in functional capacity between the groups might have arisen.

When we examine the comparisons between the groups in our study, the heart rate value obtained after the walking test showed lower decrease in the CPR+NMES group. When we look at the literature, the presence of ischemic areas after CABG surgery, the effects of long-term anesthesia, and high heart rate because of compensation by increasing heart rate instead of increasing stroke volume to increase cardiac output, are expected situations. This may indicate that myocardial oxygen consumption is still high (30).

When we examine the changes within the group in our study, the systolic and diastolic blood pressures measured after the postoperative 2nd day walking test were found to be higher in the CPR+NMES group. This suggests that the pretreatment peripheral vascular resistance or blood viscosity in the CPR+NMES group may be higher compared to the CPR group. There are several reasons for the postsurgery increase in blood pressure in CABG patients, depending on pain, stress or medications. Usually within 4-6 weeks after the surgery, it has been observed that the sympathovagal balance approaches the preoperative values with the restoration of the sympathovagal balance (31). In addition, endothelial dysfunction that develops in coronary artery diseases may have paved the way

Figure 2. Exercise Program

POSTOPERATIVE DAYS	REHABILITATION PROGRAM	DURATION/ FREKANS/ SETS/METERS	PER DAY
2nd postoperative day	Active breathing cycle exercises+incentive spirometry	3-5/1-2	1
	In-bed joint range of motion exercise	3-5/1-2	1
	Knee flexion extension by sitting on the bed side	3-5/1-2	1
	Walking without moving forward.	3-5/1-2	1
	Standing hip hyperextension	3-5/1-2	1
	Standing hip abduction adduction	3-5/1-2	1
	Sitting shoulders back	3-5/1-2	1
	Sitting scapular adduction	3-5/1-2	1
	Sitting, lowering arms forward sideways and down	3-5/1-2	1
	Sitting neck ROM exercises	3-5/1-2	1
	NMES	30 minutes/1	1
	Walking	10-20 meter	1
3th postoperative day	Active breathing cycle exercises+incentive spirometry	3-5/1-2	2
	In-bed joint range of motion exercise	10/1-2	2
	Knee flexion extension by sitting on the bedside	10/1-2	2
	Walking without moving forward	10/1-2	2
	Standing hip hyperextension	10/1-2	2
	standing hip abduction adduction	10/1-2	2
	Standing shoulders back	10/1-2	2
	Standing scapular adduction	10/1-2	2
	Standing, lowering arms forward sideways and down	10/1-2	2
	Neck ROM exercises	10/1-2	2
	NMES	30 minutes/1	2
	Walking	50-100 meter/ 1-2	4
	Sitting on chair	15 minutes	3
4th postoperative day	Same exercises(with the exception of in-bed exercises)	10/1-2	2
	NMES	30 minutes/1	2
	Walking	100-150 meter/ 1-2	4
	Sitting on chair	20-30 minutes	3
5th postoperative day	Same exercises(with the exception of in-bed exercises)	10/1-2	2
	NMES	30 minutes/1-2	2
	Walking	150-200 meter/ 1-2	4
	Stair exercises	5 steps up and down	2
	Sitting on chair	30-45 minutes	3
6th postoperative day	Same exercises(with the exception of in-bed exercises)	10/1-2	2
	NMES	30 minutes/1	2
	Walking	200-300 meter/ 1-2	4
	Stair exercises	10 steps up and down	2
	Sitting on chair	30-45 minutes	3

for this situation (32).

In our study, the comparison between the groups on the 7th postoperative day revealed that the saturation values obtained at the end of 2MWT were higher in the CPR group, and the saturation values at the beginning of the test and at rest were higher in the CPR+NMES group. In the literature, hemodynamic values such as heart rate and saturation have been defined as predictors of recovery after CABG (33). The oxygen saturation of 117 participants was shown to decrease after aerobic exercise in a research (34). Another study indicated that following the 6-minute walk test, oxygen saturation dropped in participants (patients without cystic fibrosis) (35). Acute chronic exercise has been shown to diminish oxygen saturation, and desaturation can occur during exercise (36). During activity, despite the same partial oxygen pressure, hemoglobin oxygen saturation decreases. In other words, the need for oxygen rises. In our study, the fact that the saturation measured at the end of the postoperative 7th day 2MWT in the CPR group did not decrease under normal conditions and there was an increase in oxygen in the capillaries can be attributed to insufficient oxygen transport to the tissues and insufficient passage through the capillaries in the patients in this group. However, the fact that the saturation level was low at the end of the test in the CPR+NMES group and that it was measured high at the beginning and at rest indicates that NMES may have increased myocardial relaxation and thus facilitated the separation of oxygen from hemoglobin. In addition, we can claim that patients in this group did not enter into oxygen debt at rest after walking. When the temporal changes were examined, there was no superiority between the groups among the mentioned hemodynamic values. The fact that cardiopulmonary rehabilitation could not be applied in the preoperative period and not continued for a long time after surgery may have served to limit its effect on hemodynamic parameters.

In our study, in the comparisons between the groups made on the 7th postoperative day, it was observed that the CPR+NMES group was less tired before the 2MWT and at rest compared to the CPR group, while the CPR group was less tired after walking. In addition, dyspnea levels were observed as lower in the CPR+NMES group before 2MWT and in the resting CPR group. Cebeci and Celik (37) found in their study that 48.1% of patients who underwent CABG experienced lethargy, weakness and fatigue even one month after discharge. We think that the fatigue levels do not show a parallel variation according to the groups due to the fact that our study was conducted in the early phase of phase I CPR, and the patients could not fully rest due to the continuation of myocardial revascularization. The CPR+NMES group, which started the test with a lower level of fatigue and dyspnea, may have completed the test at a faster pace and finished the test with higher fatigue than the other group. Therefore, although dyspnea levels at the end of the test did not differ between the groups, it was observed that the dyspnea level of the resting CPR group was lower than the CPR+NMES group. The reason for the decrease in fatigue in the resting CPR+NMES group can be explained by better LV functions, good myocardial relaxation, comfortable delivery of oxygen to the tissues, and thus better lactic acid tolerance than the other group. Furthermore, it is well understood that increased left ventricule filling pressures and pulmonary capillary wedge pressure cause ventilation perfusion anomalies, which negatively affect the gas exchange response during exercise (38).

The comparison of the number of SST repetitions between the groups on the postoperative 7th day, which is the other evaluation parameter we used to determine functional capacity in our study, showed that there was more change in the CPR group. This test is meant to determine physical capacity and low-limb muscular endurance, and it is a low-risk test that can be performed in clinical practice (39). In addition, in one study, it was reported that the exercise intensity of 2MWT was higher than the intensity of SST (40). In our study, we performed the SST 10 minutes after the 2MWT was finished; this may be due to the higher 2MWT resting dyspnea in the CPR+NMES group and the fact that the initial SST repetition number of the CPR group started from a lower level and reached a value close to the CPR+NMES group. No difference was observed in the temporal change of SST repeat numbers. We think that this is due to the fact that we applied SST in the early phase while the effects of CABG surgery were ongoing, specific lower extremity strengthening exercises were not included in the program as in phase II and phase III studies, and the duration of the program was short.

When CWM were compared, no difference was observed between groups and in terms of temporal changes. Early deep breathing exercises following CABG surgery help to keep pulmonary function in good shape (46). The fact that we used active respiratory cycle exercises and incentive spirometry in both groups, and that exercise applications were performed only for 5 days and in the early period, may be supporting the lack of difference between the groups. In addition, if pulmonary function tests were included in our study, CWM of the groups could be compared in more detail.

In our study, the absence of preoperative evaluations and pulmonary function tests and the short study period can be mentioned among the limitations.

In conclusion, in our early CABG study, LV diastolic functions were preserved after surgery in the CPR+NMES group with the use of NMES, and there was a significant increase in walking distance on the 7th postoperative day according to the comparison between the groups. Further research is needed to evaluate these results by gender, age groups, intensive care parameters and graft types.

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