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Ambulation capacity and functional outcome in patients undergoing neuromuscular electrical stimulation after cardiac valve surgery

A randomised clinical trial

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Abstract

Background: Early mobilization and physical exercise are considered fundamental components in cardiovascular surgery rehabilitation; however, occasionally they are inadequate for inhibiting functional decline. Neuromuscular electrical stimulation (NMES) is a promising tool in cardiovascular rehabilitation; however, to date, no randomized clinical trial has measured the effects of NMES on functional capacity and quality of life in patients who undergo routine cardiac surgery with a short intensive care unit (ICU) stay. Therefore, we aimed to investigate the effects of NMES on walking ability, muscle strength, functional independence, and quality of life in cardiac valve surgery patients in the immediate postoperative period.

Methods: A randomized, parallel, controlled, 2-arm clinical trial with assessor blinding was conducted. Fifty-nine adult patients in the preoperative period after cardiac valve reconstruction and/or replacement were randomly assigned to a control or intervention group. The intervention group underwent NMES in the quadriceps and gastrocnemius, bilaterally, for 60 minutes, for up to 10 sessions. The primary outcome was ambulation ability, assessed through the Six-Minute Walk Test and Walking Speed Test at postoperative day 5 (5PO). Secondary outcomes were muscular strength (assessed through the Medical Research Council scale), functional independence measure (assessed through the Functional Independence Measurement Questionnaire), and quality of life (assessed through the Nottingham Health Profile) at baseline (preoperative) and at postoperative days 3 and 5.

Results: The baseline characteristics were similar in both groups, except for body mass index. There was no statistically significant difference, with a small effect size, between both groups regarding the distance walked (95% CI, −64.87 to 65.97) and walking speed (95% CI, −0.55 to 0.57). There was a statistically significant difference in upper-limb muscle strength loss and decline in mobility at postoperative day 3, which had a tendency to recover to initial values at 5PO, in both groups. No significant between-group difference was noted for muscle strength, functional independence, and quality of life.

Conclusions: The use of NMES had no effect on walking ability, strength, quality of life, or functional outcome in the postoperative period for patients that underwent regular valve replacement.

Abbreviations: 3PO = postoperative day 3, 5PO = postoperative day 5, 6MWT = Six-Minute Walk Test, ANOVA = analysis of variance, FIM = Functional Independence Measurement Questionnaire, ICU = intensive care unit, MRC = Medical Research Council score, MV = mechanical ventilation, NHP = Nottingham Health Profile, NMES = neuromuscular electrical stimulation, T10 = 10-meter Walking Speed Test.

Keywords: ambulation, electric stimulation therapy, rehabilitation, thoracic surgery

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1. Introduction

Patients with cardiac conditions tend to present with a decline in their performance of daily life activities because of a reduction in aerobic condition and muscle weakness.[1] This condition is aggravated by postoperative physical inactivity, in which a longer duration of bed rest leads to greater muscle strength loss and deconditioning.[2,3] Previous studies showed that even patients undergoing high-risk elective cardiac surgeries with good clinical outcome and short intensive care unit (ICU) stay commonly presented with acute muscle loss as a result of an imbalance between muscle atrophy and hypertrophy markers.[4] Muscle proteolysis is notably accelerated within 48 hours after cardiovascular surgery due to increased protein catabolism.[3,5] In addition, postoperative physical inactivity stimulates muscle wasting by slowing down protein synthesis, accelerating protein degradation and myonuclear apoptosis in the fibers, and promoting strength reduction and functional decline, which may compromise the quality of life.[6,7] This, and the fact that cardiovascular disease is the main cause of death worldwide suggests that more attention should be given to the rehabilitation of patients after cardiac surgery.[8]

Early mobilization and physical exercise are considered fundamental components in cardiovascular surgery rehabilitation, but occasionally they are inadequate for inhibiting functional decline.[3,9] Among a variety of resources, neuromuscular electrical stimulation (NMES), which is widely used as an adjunct tool in physical training, has been shown to be a promising tool in cardiovascular rehabilitation.

Studies show that NMES influences the improvement of maximal oxygen uptake,[1] fatigue tolerance, and ambulation ability in patients with heart failure[2] and can be safely applied to patients in the immediate postoperative period of cardiothoracic surgery.[6] NMES may even be used to attenuate muscle proteolysis and strength loss after cardiac surgery. [10]

No randomized clinical trial has measured the effects of NMES on functional capacity and quality of life in patients who undergo routine cardiac surgery with a short ICU stay. Thus, this study aimed to investigate the effects of NMES on walking ability, muscle strength, functional independence, and quality of life in cardiac valve surgery patients in the immediate postoperative period.

2. Material and methods

2.1. Study design

This was a randomized, parallel, 2-arm, controlled trial performed from February 2014 to December 2016. Adult patients in the immediate preoperative period after cardiac valve reconstruction and/or replacement were randomly assigned to an intervention or control group. The randomization was performed in a simple and confidential manner by an independent investigator using the electronic randomization system, http://random.org.

Considering the intervention protocol, it was not possible to blind patients and/or the investigator who performed the NMES. However, the investigator who recruited and assessed patients in the periods determined in the study was blinded. Variables were assessed in the preoperative period, at postoperative day 3 (3PO), and at the end of the NMES protocol at postoperative day 5 (5PO).

This study was approved by the Ethics and Research Committee of Tiradentes University, (approval number: 429.256) and written informed consent was obtained from each participant and/or their next of kin before enrolment in the study. This study was submitted to the Brazilian Registry of Clinical Trials (Registro Brasileiro de Ensaios Clínicos-REBeC; registration number: RBR-8vkw87).

2.2. Participants

Participants were recruited through the Cardiology Service of the Fundação de Beneficência Hospital de Cirurgia. Adult patients of both sexes scheduled to undergo preoperative cardiac valve reconstruction and/or replacement or bioprosthesis replacement were eligible for the research. Patients were excluded if they were <18 and >75 years old and had any psychiatric disorders, cognitive decline or dementia, recent or unresolved musculoskeletal or neuromuscular disorder limit in walking ability, mobility, or functional capacity, haemodynamic instability (mean arterial pressure <60 or >120 mmHg), dyspnoea with oxygen saturation below 90%, tachycardia or bradycardia, cardiac pacemakers, dermatitis, damaged skin or sensitivity changes, or if they refused to participate in the study. Patients were recruited for the research before surgery, and if surgery was canceled or the patient died in the perioperative period, the patient was excluded from the study.

Patients who needed reoperation, had a mechanical ventilation (MV) time longer than 24 hours, were discharged before 5PO, had postoperative cerebrovascular accident (neuromuscular disorder), were in an unstable medical condition that prevented assessment, and refused to continue in the study or died were discharged from the study.

2.3. Intervention

After randomization, participants in the experimental group received NMES, in addition to regular physiotherapy care, in the immediate postoperative period after admission to the ICU until 5PO. They underwent NMES twice a day (morning and evening), for a total of 10 sessions per patient. The 4-channel Neuromed 4082 IFC (Carci, Brazil) device was used, and 3×3-cm silicone-carbon electrodes were attached to the quadriceps and gastrocnemius muscle bellies, bilaterally, and fixed with adhesive tape. Functional electrical stimulation was applied with 50-Hz frequency, 400-ms pulse width, 3-second on-time, and 9-second off-time for 60 minutes.[11] The intensity was adjusted until visible muscle contraction occurred. For doubtful cases, contraction was confirmed by the palpation of the involved muscles. [12]

Participants in the control group received usual physiotherapy care from hospital physiotherapists twice a day, in the morning and evening.

2.4. Outcome measures

Assessments were performed at baseline (preoperative), at 3PO, and at the end of the intervention (5PO). Evaluators were blinded to patient allocation and participants were instructed not to disclose their group allocation. The demographic, physical, and clinical characteristics of patients were evaluated in the preoperative period, and information related to the surgical procedure, length of ICU stay, and time between surgery and hospital discharge was collected throughout the study.

The primary outcome was ambulation, which was quantified by measuring the distance traveled (in meters) during the Six-Minute Walk Test (6MWT). 6MWT was performed according to

the recommendations of the American Thoracic Society,[13] with patients instructed to walk at their maximum tolerated speed for 6 minutes, on a 30-meter obstacle-free course, marked every 2 meters and at the end of course. Ambulation was also quantified by measuring the speed (in meters per second) during the 10-meter Walking Speed Test (T10). A 20-meter distance was marked with a straight line on a flat floor, and the patient was instructed to perform fast, non-running ambulation, at a comfortable pace, over 20 meters. The first and last 5 meters, which correspond to the period of gait acceleration and deceleration, respectively, were not measured.

The secondary outcomes were muscle strength, functional independence, and quality of life. Muscle strength was assessed by measuring the peak strength and representative maximum voluntary contraction through manual testing, ranging from 0 (no muscular contraction) to 5 (active movement against complete resistance) for 6 lower and upper limbs movements; thus, obtaining the total Medical Research Council (MRC) score. Functional independence was measured using the Functional Independence Measurement Questionnaire (FIM) and quality of life was assessed using the Nottingham Health Profile (NHP).

2.5. Data analysis

The sample size was calculated from an earlier study performed on the same population,[14] where ambulation ability was assessed in postoperative cardiac patients. Based on the results of this previous study, a sample size of 23 patients per group was derived, with a 2-sided significance level (α) of 0.05 and a power of 95%. The minimum clinically important difference was 20 meters based on the primary outcome variable (distance traveled in 6MWT).

Statistical analyses were performed with SPSS test version 15.0 (IBM Corp., Armonk, NY). All data were analyzed according to the intention-to-treat principle. Normality was assessed with the Shapiro–Wilk test. Normally distributed quantitative variables are expressed as mean (SD). To compare patient characteristics between groups, the chi-square test was used for categorical variables and the *t* test was used for independent samples.

To answer the research question, the distance traveled in 6MWT and the T10 walking speed were compared between groups using the *t* test for independent samples. The comparison of MRC, FIM, and NHP between both groups was performed using a 3×2 (time: preoperative period versus 3PO versus 5PO; group: NMES versus control) analysis of variance (ANOVA), and the Bonferroni post-hoc test was used to determine, when possible, where the differences occurred. The significance level was set at 0.05. All *P* values were 2-tailed. When comparing means between the 2 groups using *t* test, Hedges' g (variation of Cohen's *d*) was used and the effect size was classified as small (>0.20), medium (>0.50) or large (>0.80).[15] When comparing means between the 2 groups using ANOVA, the eta-square was used and the effect size was classified as small (>0.01), medium (>0.06) or large (>0.014).[15]

3. Results

3.1. Flow of participants through the study

The analysis included 59 patients (NMES group, n = 26; control group, n = 33) from February 2014 to December 2016. The flow of participants through the study is summarised in Figure 1. All patients included in the analysis started the study in the NMES or control group; thus, the analysis is not limited to patients who completed the entire protocol. Patients who could not be assessed for any of the outcome measures at the end of the intervention were not included in the analysis. The patients' characteristics are detailed in Table 1, and there was homogeneity between the 2 groups in relation to the studied variables, except for body mass index.

3.2. Compliance with the intervention

The median number of NMES sessions applied to the analyzed patients was 10 (range, 5–10), using an average intensity of 54.9 (range, 22.8–71.2) mA in the quadriceps and 49.5 (range, 17.5–79.1) mA in the gastrocnemius. Regarding adherence, only 20 of the 260 sessions planned were not performed (98.6% completion). Concerning adverse effects, 2 patients presented with hypotension during 1 NMES application and 1 patient reported pain.

3.3. Primary outcome

Eight patients did not undergo ambulation tests (NMES group, n = 4; control group, n = 4) because they presented with clinical contraindications to 6MWT at the time of assessment, such as precordial pain, resting heart rate above 120 beats per minute, systolic blood pressure >180 mmHg, and diastolic blood pressure >100 mmHg. There was no statistically significant difference, with a small effect size, between the groups regarding the distance walked (95% CI, −64.87 to 65.97) and walking speed (95% CI, −0.55 to 0.57), as shown in Table 2.

3.4. Secondary outcome variables

Muscle strength was not measured in 1 patient at 5PO and in 2 patients at 3PO because they refused to exert maximum effort. All patients assessed in the preoperative period presented with normal mean upper-limb, lower-limb, and total MRC values, with no significant statistical difference between the 2 groups ($P > .05$ all). We observed a decrease in upper-limb MRC values at 3PO when compared to preoperative values in both groups, with a return to baseline values at 5PO in the control group ($P = .35$) and a statistical tendency to return to baseline values in the NMES group ($P = .01$), without a clinical difference in values in relation to the preoperative period. No significant between-group difference, with only a small effect size, was found for muscle strength in the upper-limb, lower-limb, and total MRC values (Table 3).

All patients were assessed for FIM, both at 3PO and 5PO, which showed no reduction during the study or significant differences between the groups ($P > .05$) (Table 3). This behavior was observed in the evaluation of the motor, cognitive, and total FIM, and their corresponding domains.

Regarding the quality of life, the total NHP and its domains were assessed in all patients at the 3-time points of the study, and no significant difference, with a small effect size, was found between the groups ($P > .05$) (Table 4). The score of the domain corresponding to mobility increased at 3PO (both groups, $P < .01$) and recovered at 5PO (control group, $P = .61$; NMES group, $P = .17$).

4. Discussion

Our results suggest that the use of NMES during the immediate postoperative period in patients who underwent routine cardiac valve surgery and with a short ICU stay did not influence the ambulation ability, muscle strength, quality of life, and functional independence of this cohort. These findings may be associated with the short sedation period, MV, bed rest, and ICU stay, which

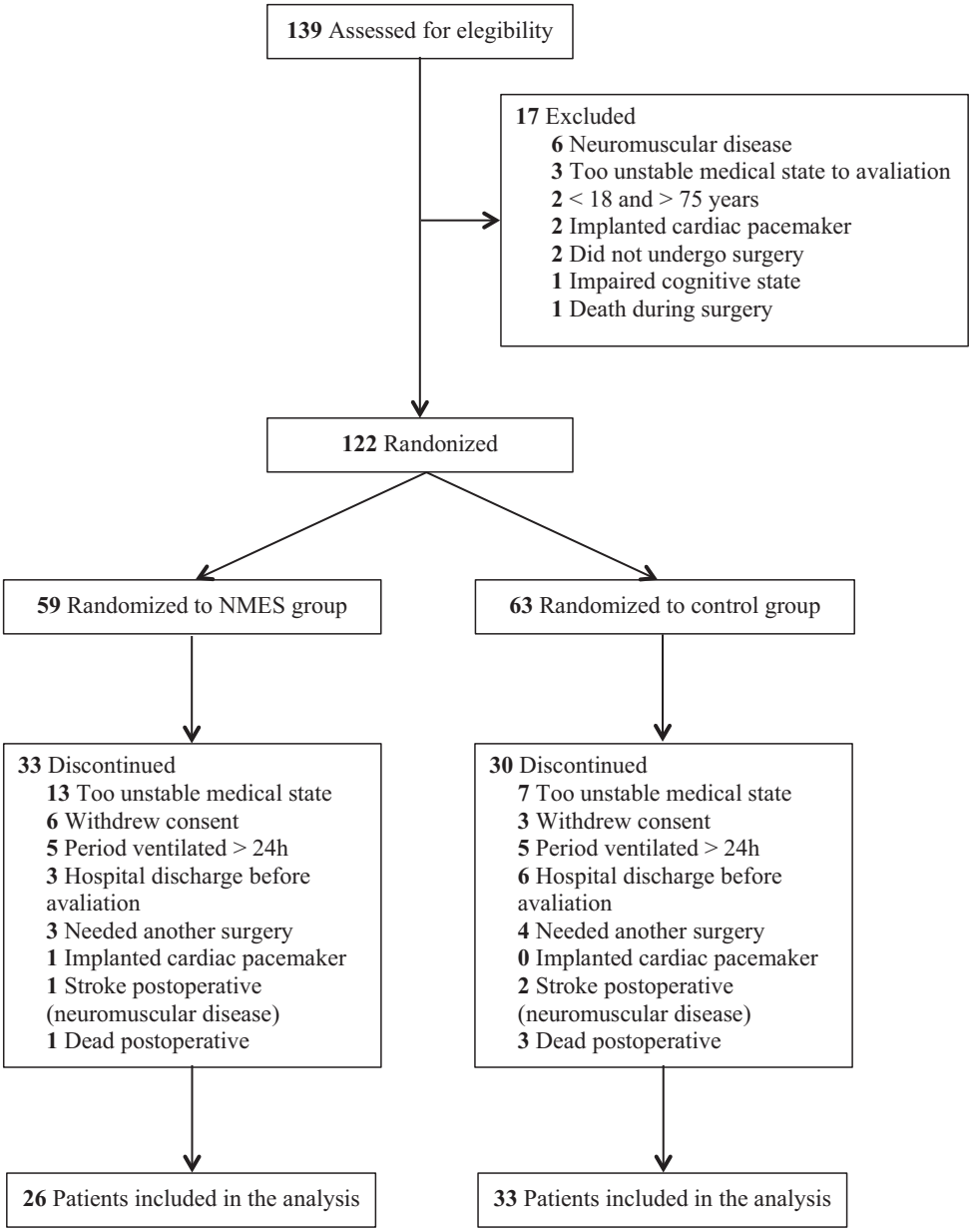

Figure 1. Flow of participants through the trial.

favour the early active engagement of these patients in rehabilitation interventions, leading to better functional outcomes[16,17] and decreased vulnerability to atrophy and muscle weakness secondary to immobilization, for which NMES could provide greater benefits.[16]

The postoperative patients in this study showed maintenance of functional independence, quality of life, and overall muscle strength, confirming their lower vulnerability to functional decline. The decrease in the upper-limb MRC score and physical ability noted at 3PO in both groups, as shown by the increase in the score of this NHP domain and a tendency to recover to initial values at 5PO, was possibly related to sternotomy. Sternotomy limits the mobilization and evaluation of upper-limb muscle strength during the first postoperative days, suggesting that a longer time might be needed for better recovery.

NMES has shown its best results in patients who underwent longer sedation, MV, bed restriction, and ICU stays and in patients who could not engage in active rehabilitation interventions because of disease severity, deep sedation, delirium, and coma.[16] Muscular weakness acquired in the ICU affects 24% to 77% patients with an ICU stay >1 week, which was not seen in the present study population, whose average length of ICU stay was 2 to 3 days.[18]

Some studies indicate that NMES shows greater benefits when the stratification of certain diagnoses is taken into consideration. These benefits were noted in patients admitted to the ICU for respiratory complications such as chronic obstructive pulmonary disease, where NMES reduced the number of days needed to transfer the patient from bed to chair,[19] and showed an increase in the distance walked[20], as well as in cases of neurological complications.[21] Some publications have demonstrated the effectiveness of NMES in non-hospitalised cardiac patients with chronic heart failure in terms of exercise capacity,[22,23] distance traveled,[22–24] muscular strength, fatigue tolerance,[25] decreased

Table 1

Baseline participants characteristics.

	NMES group	Control group	*P* value
Male sex, n (%)	18 (69.2)	23 (69.7)	.96
Age (yr), mean (SD)	41.80 (13.17)	42.21 (14.36)	.91
Weight (kg), mean (SD)	66.12 (13.29)	61.85 (12.69)	.22
Height (m), mean (SD)	1.60 (0.06)	1.65 (0.08)	.08
Body mass index, mean (SD)	25.80 (4.72)	21.96 (4.20)	.02*
Left ventricular ejection fraction, mean (SD)	58.75 (9.20)	56.37 (10.64)	.40
Type surgery			
Mitral valve replacement, n (%)	12 (46.2)	14 (42.4)	.85
Aortic valve replacement, n (%)	8 (30.8)	5 (15.2)	.15
Mitral valve reconstruction, n (%)	2 (7.7)	2 (6.0)	.82
Aortic valve reconstruction, n (%)	1 (3.8)	0 (0)	.25
Mitral valve replacement + aortic valve reconstruction, n (%)	2 (7.7)	7 (21.2)	.15
Mitral valve replacement + aortic valve reconstruction, n (%)	1 (3.8)	5 (15.2)	.15
Cardiopulmonary bypass time (min), mean (SD)	92.61 (32.38)	107.96 (44.19)	.14
ICU length of stay (d), mean (SD)	2.57 (0.53)	2.66 (0.51)	.75
Time between surgery and hospital discharge (d), mean (SD)	10.96 (7.63)	12.39 (7.98)	.48
Comorbidities, n (%)	18 (69.2)	18 (54.5)	.25
Rheumatic fever, n (%)	12 (46.2)	10 (30.3)	.21
Hypertension, n (%)	4 (15.4)	2 (6.1)	.23
Diabetes, n (%)	1 (3.8)	1 (3.0)	.59
Gastritis, n (%)	1 (3.8)	1 (3.0)	.86
Hyperthyroidism, n (%)	1 (3.8)	1 (3.0)	.86
Epilepsy, n (%)	0 (0)	2 (6.1)	.20
Pulmonary hypertension, n (%)	1 (3.8)	1 (3.0)	.86
Lymphoma, n (%)	0 (0)	1 (3.0)	.37
Dyslipidaemia, n (%)	0 (0)	1 (3.1)	.36
Asthma, n (%)	0 (0)	1 (3.0)	.37

Values are mean (SD) or n (%).

NMES = neuromuscular electrical stimulation, SD = standard deviation, ICU = intensive care unit. Chi-square test and independent sample test.

* $P < .05$.

levels of anaerobic enzymes, and transition from fast to slow fibers.[26,27]

A study reported that NMES, performed twice daily for 60 minutes and for an average of 16 days, promoted an increase in the distance travelled in 6MWT compared to the control group, in patients hospitalized for clinical compensation of heart failure.[11] This outcome differs from that of the present study, where the studied population included patients in the immediate postoperative period of cardiac surgery with a 5-day protocol of NMES application.

NMES has been reported as a useful tool for reducing protein catabolism in postoperative patients, but few studies show which molecular changes are accompanied by changes in strength, muscle mass, and functional outcome.[3,5,28]

In another randomized clinical trial, NMES did not promote any significant effect on muscle thickness and strength at the time of hospital discharge.[29] However, the MRC scores showed that patients in the NMES group regained strength 4.5 times faster than patients in the control group. In addition, patients did not recover their mobility levels, and their FIM score at the time of hospital discharge did not depend on the allocated group. The study only applied NMES to critically ill patients who had a median ICU stay of 6 to 7 days and longer MV periods, while those with ICU stays shorter than 48 hours were excluded. This is in contrast with our study where participants had a regular postoperative period and a mean ICU stay of 2 to 3 days, with NMES showing no impact on strength and functional independence.

Finally, NMES has been the subject of several published studies, including a wide variety of protocols. However, there is no consensus on parameters, which makes comparison difficult. Further, many authors found positive correlations between fluid balance and muscle mass change during the first 3 postoperative days, suggesting that edema, which is predominant during this initial phase in surgical patients, may affect current dissipation and decrease muscle contraction quality[29,30]. This may also

Table 2

Ambulation ability outcome in both NMES and Control group.

Outcomes	Groups			Difference between groups	
	NMES (n = 22)	Con (n = 29)	*P* value*	CI (95%)	Effect size†
6MWT (m)	293.68 (122.11)	293.58 (114.46)	.99	0.10 (−64.87 to 65.97)	0.002
Gait speed (m/s)	1.05 (0.46)	1.02 (0.25)	.76	0.01 (−0.55 to 0.57)	0.084

Values are mean (SD) of groups, mean (95% CI) difference between groups and overall effect size.

NMES = neuromuscular electrical stimulation group, Con = control group, 6MWT = Six-Minute Walking Test.

* *P* value intergroup, independent sample test, significant *P* value < .05.

† Hedges' g (variation of Cohen's *d*): small > 0.20, medium > 0.50, large > 0.80.

Table 3

Strength muscle and independence functional outcome in both groups NMES and Control: Medical Research Council and Functional Independence Measure Questionnaire score.

	Groups							Difference within groups				Difference between groups			
	Pre		3PO		5PO			3PO minus Pre		5PO minus Pre		3PO minus Pre	5PO minus Pre	Overall effect*	
Outcome	NMES (n=26)	Con (n=33)	NMES (n=26)	Con (n=33)	NMES (n=26)	Con (n=33)	P value†	NMES	Con	NMES	Con	NMES minus Con	NMES minus Con	P value‡	Effect size§
Upper limb	29.57 (1.13)	29.06 (1.81)	27.25 (3.52)	27.20 (3.24)	28.32 (2.23)	28.51 (2.81)	<.01‖ .02¶	−2.3 (3.28)	−1.80 (2.9)	−1.15 (1.99)	−0.54 (3.06)	−0.5 (−2.10 to 1.10)	−0.61 (−1.90 to 0.68)	.54	0.014
Lower limb	29.46 (1.24)	29.45 (1.14)	28.54 (2.75)	28.26 (2.97)	29.08 (1.68)	28.72 (1.94)	.26‖ .08¶	−1.0 (2.48)	−1.20 (3.35)	−0.30 (1.56)	−0.72 (2.21)	0.2 (−1.29 to 1.69)	0.42 (−0.54 to 1.38)	.67	0.004
MRC Total	58.26 (6.39)	57.60 (5.68)	53.65 (12.32)	55.51 (5.63)	57.24 (4.52)	57.24 (4.52)	.11‖ .25¶	−2.53 (8.80)	−2.0 (8.03)	−0.69 (7.04)	−0.36 (6.85)	−0.53 (−4.88 to 3.82)	−0.33 (−3.90 to 3.24)	.57	0.014
Motor	92.11 (17.59)	100.06 (28.83)	87.30 (53.60)	92.53 (64.25)	77.15 (12.79)	78.56 (24.49)	.26‖ .13¶	−4.80 (43.10)	−7.53 (54.75)	−14.96 (19.80)	−21.50 (29.72)	2.73 (−22.23 to 27.69)	6.54 (−6.13 to 19.21)	.55	0.005
Cognitive	33.34 (2.80)	33.34 (1.72)	34.00 (2.36)	34.43 (2.04)	33.88 (2.21)	34.43 (1.54)	.67‖	0.57 (3.42)	0.093 (2.55)	0.46 (2.08)	0.093 (1.85)	0.47 (−1.09 to 2.05)	0.36 (−0.65 to 1.38)	.76	0.002
FIM Total	125.53 (18.5)	134.40 (28.99)	121.30 (25.04)	126.96 (64.73)	111.03 (13.79)	113.00 (25.04)	.29‖ .14¶	−4.23 (44.28)	−7.43 (55.75)	−14.50 (20.09)	−21.40 (29.78)	3.20 (−22.32 to 28.72)	6.69 (−5.86 to 19.66)	.51	0.002

Values are mean (SD) of groups, mean (95% CI) difference between groups and overall effect size.

NMES = neuromuscular electrical stimulation group, Con = control group.

* 3 × 2 analysis of variance (ANOVA).

† *P* value intragroup, ANOVA, representing interaction effect of time by group on dependent variable, significant *P* value < .05.

‡ *P* value intergroup, ANOVA, significant *P* value < .05.

§ Eta-square: small > 0.01, medium > 0.06, large > 0.14

‖ ANOVA reported for the intervention group

¶ ANOVA reported for the control group.

Table 4

Quality of life outcome in both groups NMES and Control: Nottingham Health Profile.

	Groups							Difference within groups				Difference between groups			
	Pre		3PO		5PO			3PO minus Pre		5PO minus Pre		3PO minus Pre	5PO minus Pre	Overall effect*	
Outcome	NMES (n=26)	Con (n=33)	NMES (n=26)	Con (n=33	NMES (n=26)	Con (n=33)	P value†	NMES	Con	NMES	Con	NMES minus Con	NMES minus Con	P value‡	Effect size§
Energy	36.70 (6.8)	42.85 (6.49)	42.27 (5.80)	36.80 (5.75)	24.55 (5.42)	27.90 (6.36)	.11‖ .24¶	5.56 (48.56)	−6.05 (35.56)	−12.15 (41.12)	−14.95 (35.35)	11.61 (−10.65 to 33.87)	2.8 (−17.08 to 22.68)	.49	0.013
Pain	25.67 (4.56)	21.48 (5.11)	35.38 (5.85)	34.98 (5.34)	37.72 (6.03)	32.48 (5.19)	.27‖ .16¶	9.70 (34.48)	13.49 (37.02)	12.04 (38.61)	10.99 (32.28)	−3.79 (−22.09 to 14.51)	1.05 (−13.13 to 15.03)	.76	0.003
Emotional reactions	37.52 (5.67)	36.52 (5.60)	21.25 (6.03)	30.26 (5.40)	37.02 (5.15)	31.07 (4.71)	.05‖ .16¶	−16.26 (29.73)	−6.26 (32.09)	−16.38 (39.95)	−14.12 (23.31)	−10.0 (−25.82 to 5.82)	−2.26 (−19.55 to 15.03)	.41	0.015
Sleep	27.43 (6.10)	36.97 (6.15)	46.42 (6.91)	47.07 (6.15)	43.70 (6.87)	50.28 (6.61)	.10‖ .30¶	18.99 (35.77)	10.10 (32.05)	16.27 (36.06)	13.31 (33.35)	8.89 (−8.67 to 26.45)	2.96 (−14.97 to 20.89)	.60	0.009
Social isolation	22.50 (5.23)	22.37 (6.29)	13.83 (3.95)	17.63 (4.85)	16.76 (3.74)	13.04 (4.08)	.36‖ .44¶	−8.67 (25.54)	−4.73 (29.49)	−5.73 (25.43)	−9.32 (30.76)	−3.94 (−17.99 to 10.11)	3.59 (−10.75 to 17.93)	.50	0.010
Mobility	26.86 (5.24)	27.95 (4.08)	49.41 (4.35)	46.48 (4.20)	37.02 (5.15)	31.07 (4.71)	<.01‖ <.01¶	22.54 (29.60)	18.53 (28.98)	10.15 (35.94)	3.10 (25.17)	4.01 (−11.06 to 19.08)	7.05 (−9.21 to 23.31)	.68	0.008
Total	176.70 (26.37)	188.16 (26.49)	208.58 (20.63)	213.24 (22.75)	180.89 (23.29)	177.18 (23.90)	.58‖ .57¶	31.87 (134.35)	25.08 (144.85)	4.19 (154.08)	−10.97 (130.28)	6.79 (−64.69 to 78.27)	15.16 (−59.12 to 89.44)	.90	0.002

NMES = neuromuscular electrical stimulation group, Con = control group.

* 3 × 2 analysis of variance (ANOVA).

† *P* value intragroup, ANOVA, representing interaction effect of time by group on dependent variable, significant *P* value < .05.

‡ *P* value intergroup, ANOVA, significant *P* value < .05.

§ Eta-square: small > 0.01, medium > 0.06, large > 0.14.

‖ ANOVA reported for the intervention group.

¶ ANOVA reported for the control group.

have influenced our results, although visualization or palpation of muscle contraction during NMES sessions was possible.

This study was limited by the absence of a preoperative evaluation of the distance covered in 6MWT and T10 because the patients were in a serious health state, debilitated, and with preoperative restrictions. Other methods for measuring muscle strength, such as dynamometry, could have been more sensitive in assessing small muscle strength losses, and electromyography could have been used to better investigate NMES effects. Future studies should perform further follow-up NMES and patient evaluation to better investigate the effects of NMES.

In conclusion, the use of NMES showed no effect on ambulation ability, strength, quality of life, and functional outcome in patients in the regular postoperative period of cardiac valve surgery.

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