ORIGINAL ARTICLE

Effects of Cardiac Rehabilitation of Physical Capasity and Quality of Life in Patients After Open Heart Surgery Complicated by Sternomediastinitis

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ABSTRACT

The article aims to evaluate safety and effects CR program on physical capacity and QoL in patients after open-heart surgery complicated with sternomediastinitis.

This observational cohort study included 104 patients, of them 58 were males and 34 females, who underwent cardiac surgery made by sternotomy. We divided the cohort into two groups: 1st group clustered of 92 patients, who did not have sternomediastinitis complications after the surgery; 2nd group clustered of 12 patients, who had sternomediastinitis complications after the surgery. We assessed following variables: physical capacity using 6-minute walk test (6MWT) and the metabolic equivalent (MET) and maximal oxygen consumption (VO2max), QoL using SF36 survey. Statistical analyses were performed using the IBM SPSS Statistics software (version 19). The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to check the normality of distributions. Then, the Mann-Whitney U test was performed to compare not normally distributed independent variables, in order to see the difference (significance level was accepted at $p<0.05$). After that, the Pearson's two tailed correlation test was used to find the connection between variables of two groups. Properly selected physical exercises during CR improve the fitness and physical activity of patients after sternomediastinitis, as well as, QoL mesures - general health and mental status.

Keywords

rehabilitation, sternamediastinitis, quality of life, physical capacity, perioperative procedures, prevention.

INTRODUCTION

Since its initial use in 1887 to examine lymph nodes in severe tuberculosis, sternotomy access has become a commonly employed technique in open heart surgery since the 1950s [1]. However, regrettably, it has been linked to postoperative infectious complications of the sternum, particularly anterior mediastinitis. The incidence of sternomediastinitis following open heart surgery varies across regions: in Europe, it ranges from 0.5 to 3.2% with a mortality rate of up to 40%[2,3]; in Russia, it's between 0.6-4.0% with a mortality rate of 10-25%[4]; and in Asia, it spans from 0.8-8.0% with a mortality rate of 8-45%[5].

Following uncomplicated open heart surgery involving sternotomy, all patients typically undergo a standard cardiorehabilitation (CR) program focused on optimizing physical activity and breathing exercises[6]. However, patients who have experienced sternomediastinitis

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require separate interventions due to the instability of their chest framework. Various pathophysiological aspects exacerbate the patient's quality of life, such as pain during movement and the compromised skeletal function of the chest, which disrupts breathing [7].

Reconstructive surgeries in the treatment of patients with sternomediastinitis are aimed at reducing the duration of hospitalization and accelerating rehabilitation. [8] The positive usage effectiveness of the cardio rehabilitation (CR) for improving the quality of life (QoL) patients, who have undergone open heart surgery using sternomediastinitis, is described in the current literatures. However, the development of physical exercises in order to improve QOL of patients after open-heart surgery and surgery complicated with sternomediastinitis is still ongoing, but there is no concrete studies devoting to CR after sternomedicatinitis. That's why the available heterogeneous CR programs are not specify for patients after sternomediastinitis

Therefore, Aim of the study is to evaluate safety and effects CR program on physical capacity and QoL in patients after open-heart surgery complicated with sternomediastinitis.

METHODS

Study design and population.

The observational cohort study was conducted, including patients after cardiac surgery using the sternotomy access at the 2nd (till 9 months after the operation) and 3rd stage (after 9 months of the operation) of the CR (the stages of rehabilitation are determined by Health Ministry of Kazakhstan dated October 7, 2020 № KRD-116/2020 "On approval of the Rules for the provision of medical rehabilitation") received through the Hospitalization Bureau.

The study included 104 patients, of them 58 were males and 34 females, who underwent cardiac surgery made by sternotomy. We divided the cohort into two groups: 1st group clustered of 92 patients, who did not have sternomediastinitis complications after the surgery; 2nd group clustered of 12 patients, who had sternomediastinitis complications after the surgery.

Sternomediastinitis was defined as sternal wound infection after median sternotomy.[2,3,4,5]

Eligibility criteria for participants.

1. *Distribution by gender*. Male and female patients were included in this study.
2. *Age*. 18 years and older were included in this study.
3. *Nationality (ethnicity)*. The study does not have a national distribution.
4. *Criteria for inclusion*:

- The study includes patients who underwent open heart surgery using median sternotomy access; patients after coronary artery bypass and mammary coronary artery bypass grafting, correction of valvular defects;

5. *Criteria for exclusion*.

- minimally invasive approaches for open-heart surgery (thoracotomy and thoracoscopic surgery)
- refusal of patients.

6. *Vulnerable groups* - the cardiorehabilitation program is started only after medicament correction;

1. Patients with hypertrophic cardiomyopathy, due to the possibility of life-threatening cardiac arrhythmias during exercise;

1. History of frequent hypertensive crisis during the last 2-4 weeks;
2. Life-threatening cardiac arrhythmias such as tachycardia, blockade rhythms, and etc.

3. *Location of research conduct.*

4. The study was conducted in the rehabilitation department of the CardioMed Clinic (Shymkent city, Kazakhstan). This hospital is a private medical institution and takes patients for treatment on a state order basis.

5. *Duration of research.*

The study was conducted from February 10th, 2020 to September 30, 2021. The intermediate control points were the early moment of discharge, examination after 3 and 6 months.

Ethical approval.

The study was conducted in accordance with Good Clinical Practice standards and the principles of the Helsinki Declaration. The study protocol was approved by the Ethics Committee of the CardioMed Clinic No. 002A dated February 10th, 2020. Prior to inclusion in the study, written informed consent was obtained from all participants about the treatment procedure and possible complications.

Baseline variables included demographic, anthropometric and clinical characteristics: Age, Gender, Period after surgery, Smokers, Body mass index, HR and BP, Chronic heart failure by NYHA, Stage of rehabilitation,accompanying illnesses as Arterial hypertension and diabetes, ECHO LVEF, by OPERATIONS: CABG venous grafts or Mammarocoronary (RIMA et LIMA) bypass surgery or Mitral valve replacement or Aortic valve replacement, also during operation Time of the artificial blood circulation, and the complexity of the level of operation in terms of possible complications, comorbidity and mortality was assessed by EuroScore II grades [Roques F, Michel P, Goldstone AR, Nashef SA. The logistic EuroSCORE. Eur Heart J. 2003 May;24(9):882-3].

Patients received standard drug therapy in accordance with the diagnostic and treatment protocols of the Health Ministry of Kazakhstan (for patients with coronary heart disease - a betablocker, an angiotensin-converting enzyme inhibitor, dual antiplatelet therapy, lipid-lowering therapy, with mechanical prosthetics - anticoagulant therapy, in the presence of a chronic heart disease insufficiency - diuretic therapy, for heart rhythm disturbances such as atrial fibrillation – amiodorone; for gastropathy proton pump inhibitors and others as indicated).

1. ***Cardiac rehabilitation .***

Study participants received rehabilitation measures in accordance with a systematically developed CR program.

Before the start of rehabilitation measures, patients were given instructions on the program, and each patient received a methodological manual, which fully described the program and structure of rehabilitation.

The program of rehabilitation measures is compiled according to the following scheme:

- At 09.00 hours, patients do breathing exercises under the supervision of an instructor from 1.5 minutes, with an increase of 30 seconds if there is a good tolerance. The breathing simulator acts on the respiratory muscles (increasing strength, endurance, exercise tolerance) and forms an effective breathing style.
- Exercise starts at 10:00 am. The duration of physical exercise depends on the load and begins with a low intensity, which does not exceed the heart rate (HR) from the baseline by no more than 20%. Then, gradually, as the patient tolerates it, it increases to medium intensities, but not more than 40% of the base HR. A daily assessment of perceived intensity on the Borg scale was also performed (This assessment of perceived Borg tension (RPE; scale 0-10) is used to help patients regulate exercise intensity). An increase in systolic blood pressure by 20-40 mm of mercury column is allowed. from the initial, diastolic blood pressure by 10-12 mm of mercury column. In some patients, on the contrary, there may be a decrease in heart rate (but not more than 10 beats / min.) and a decrease in blood pressure (but not more than 10 mm Hg).

Algorithm for performing physical exercises:

1) Keeping the face forward, the ear leans to the right, then to the left.
2) Shrug - Raise your shoulders to your ears, then move down.
3) Circles in the shoulders - in smooth movements rotate the shoulders up, back and down in a circle, then in the opposite direction.
4) Turns of the torso - slowly turn the torso to the right, looking over the shoulder. Then turn body to the left.
5) Torso Lateral Flexion - Keeping the arms relaxed at the sides and keeping the torso upright, slowly lean to the right - to the left.
6) Raising the arm forward - standing or sitting in a vertical position, the arms are straightened with the thumb up and forward above the head, while the elbow should be next to the ear. The exercises are repeated separately with each hand.
7) Reverse stretch. Arms relaxed at your sides, elbows straight, arms extended straight back.
8) Lifts. Holding on to the handrail of the chair for support, slowly climb the step (Step platform), then step back.

- At 1 pm, patients are prescribed physiotherapeutic procedures as prescribed and according to indications.
- At 2 pm, the exercise bike. The duration of training with an exercise bike depends on a low-intensity load not exceeding 20% of the base heart rate, which gradually, as the patient tolerates it, increases to an average intensity of 40% of the base heart rate.

- At 4 pm, the inhalation. When using inhalation with mucolytic agents, gas exchange and lung capacity increase significantly, as well as the rate and volume of drug entry into the blood; at the same time, blood supply to tissues and metabolism in them are improved.

6. At 6 pm, breathing exercises. Patients are prescribed to strengthen the muscles of the respiratory muscles, develop and improve diaphragmatic breathing; expansion of the chest, for greater air intake, which contributes to better oxygenation of the body and an increase in the tone of blood vessels.
7. At 9 pm, the Terrenkur. The duration of training is the same as with exercise bike training.The duration of the entire CR program. All rehabilitation activities are stopped immediately if the patient is concerned about: pain or tightness in the chest, pain, swelling, stiffness in the joints, palpitations, excessive sweating, excessive shortness of breath, nausea, dizziness or weakness, etc.

Assessment of pain

The Wong-Baker Grimace Pain Scale [9] was used to assess the condition of adult patients: this scale consists of 6 faces, ranging from laughing (no pain) to crying (unbearable pain) - according to a point system from 0 to 10. The pain assessor explains to the patient in an accessible form about the need to choose which of the presented faces describes the level of the pain. Individual registration cards with clinical and functional research data were created for each patient.

Borg scale [10] is a frequently used quantitative measure of perceived exertion during physical activity. The Borg scale is a numerical scale that ranges from 6 to 20, where 6 means “no exertion at all” and 20 means “maximal exertion.” When a measurement is taken, a number is chosen from the following scale by an individual that best describes their level of exertion during physical activity.

Quality of life

Patients’ life quality was assessed before and after CR using the SF36 questionnaire [11]. The SF-36 measures eight scales: physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH).

Physical capacity

Exercise tolerance was evaluated using the six-minute walk test (6MWT) [12] and the exercise stress test on the treadmill was taken according to the standard Bruce protocol. We as-sessed total CR training duration in seconds, metabolic equivalent [MET] [13], maximal oxygen consumption [VO2max] [14] and HR in beats/min. The exercise parameters were evaluated before, at the end of 2-week CR training, 3 and 6 months after.

Echocardiography

An echocardiographic study was performed using a Qbit-7 device (Chison, China), where the Simpson left ventricular ejection fraction was measured in %

Protocol and Study outcomes.

The main outcome of the study: to analyze the perception and performance of the ongoing rehabilitation measures, a pain score according to the Wong-Baker Grimace Scale, as well as a perceived stress score according to the Borg scale and an assessment of the quality of life according to the SF-36 questionnaire were carried out. All data were recorded at admission, on the day of discharge, as well as after 3 and 6 months.

Additional outcomes of the study: changes in heart rate and blood pressure during exercise, 6MWT, MET, and VO2max, echocardiographic assessment of left ventricular ejection fraction (LVEF) before and after CR, and after 3 and 6 months.

OUTCOME REGISTRATION METHODS

The results of the SF-36 questionnaire, scores for assessing pain on the Wong-Baker scale and tension on the Borg scale, the 6MWT were recorded by the nurse and / or the attending physician in an individual registration card and in the Excel database.

Statistical analysis

Statistical analyses were performed using the IBM SPSS Statistics software (version 19). The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to check the normality of distributions. Then, the Mann-Whitney U test was performed to compare not normally distributed independent variables, in order to see the difference (significance level was accepted at $p<0.05$). Chi-square test was used to compare categorical variables between groups. Friedman test for repeated measure and Chi-square – compare before-after-3 and 6 months.

Friedman nonparametric test for repeated measure was performed compare physical capacity and QoL measure before after 3 months and 6 months after CR, comparison between 2 groups was done sing Mann Whitney and comparison paired within group – Mann Whiteny test.

After that, the Pearson's two tailed correlation test was used to find the relationship between variables of two groups.

RESULTS

1. Clinical characteristics (Table 1).
2. The study included 104 patients, of them 61 were males and 43 females. Both groups of patients did not differ by age, sex, risk factors of CAD as hypertension, diabetes, smoking and body mass index; HR, SBP, DBP, NYHA class and Euroscore (all p>0.05). The sternomediastinitis group had shorter duration after surgery to join CR but the

Table 1. Clinical characteristics of participants.

Variables	Group 1 (n=92)	Group 2 (n=12)	P-value
Age, years, M±SD	59±9.4 [min 47. max 76. CI 71.1]	57±5.9 [min 47 max 69. CI 65.8]	0.125
Gender, n (%) **Male** **Female**	 58 (63) 34 (37)	 3 (25) 9 (75)	0.416
Period after surgery, months M±SD	6.98±3.05 (min 1. max 18.)	2.41±1.37 (min 1. max 6.)	0.354
Stage of rehabilitation, n (%) **2nd** **3rd**	 32 (34.8) 60 (65.2)	 2 (16.6) 10 (83.4)	0.208
Arterial hypertension, n (%)	61 (66.3)	9 (75)	0.546
Diabetes, n (%)	20 (21.7) whom on insulin therapy 16 (17.4)	3 (25) whom on insulin therapy 3 (25)	0.798
Smokers, n (%)	19 (20.7)	2 (16.7)	0.721
Body mass index, M±SD	29,64±4.19 (min 22.49. max 38.25.)	28.87±3.23 (min 26.56. max 38.25.)	0.198
HR on admission day, M±SD	77.96±11.32 (min 52. max 95.)	75.16±14.03 (min 58. max 95.)	0.568
SBP on admission day, mmHg M±SD	123.39±11.84 (min 92. max 152.)	125.33±16.1(min 92. max 152.)	0.577
DBP on admission day, mmHg M±SD	81.21±9.74 (min 62. max 122.)	77±7.49 (min 62. max 92.)	0.142
Time of the artificial blood circulation apparatus, min. M±SD	98.75±22.77 (min 50. max 138.)	103.41±22.8 (min 67. max 135.)	0.065
Chronic heart failure, NYHA class on admission day, n(%)	NYHA 3 - 80 (87) NYHA 4 - 12 (13)	NYHA 3 - 10 (83,3) NYHA 4 - 12 (16,7)	0.431
ECHO LVEF, % M±SD	47.3±2.71 (min 41. max 51.)	49±1.9 (min 44. max 52)	0.287
OPERATIONS:			
CABG venous grafts	13 (14.1)	1 (8.3)	0.580
Mammarocoronary (RIMA et LIMA) bypass surgery	18 (19.6)	3 (25)	0.344
Mitral valve replacement	34 (37)	8 (66.7)	0.278
Aortic valve replacement	30 (32.6)	2 (16.7)	0.069
EuroScore II, n(%) **Low, <4%** **Medium, 4-10%** **High, >10%**	 22 (23.9) 57 (62) 13 (14.1)	 3 (25) 7 (58.3) 2 (16.7)	0.344

**. Significance accepted at p< 0.05*

differences were not significant (p=0.354). The patients also were matched by type of surgery: CABG or AVR, MVR.

Physical capacity (Table 2)

As can be seen from Table 3 we observed significant improvement of duration of training in mediastinitis group as compared to before CR (all p<0.05), though durations were shorter as compared to noncomplicated sternotomy after, 3 months and 6 months of training(p=0.042 , p=0.016, p=0.006 and p=.0.001 respectively).

We also observed improvement in METS and VO2max within group mediastinist and uncomplicated sternotomy (p<0.05 for each group intragroup for MET and VO2max), though both groups did not differ by these values.

Table 2. Physical capacity and Pain perception parameters

Variables	Group 1 (n=92)	Group 2 (n=12)	p-value (intragroup)
Duration of training at the beginning of the CR	2.83±0.99 (min 1.5. max 5.0.)	2.17±1.41 (min 1. max 5.)	0.042
Duration of training at the end of the CR	9.72±1.19 (min 7. max 12.)	8.75±1.95 (min 6. max 12.)	0.016
Duration of training after 3 months.	17.88±1.77 (min 13.5. max 22.)	16.38±1.34 (min 14. max 18.2.)	0.006
Duration of training after 6 months.	24.46±2.407 (min 20. max 28.)	22.08±1.78 (min 20. max 25.)	0.001
p-value (compare period)	0.0001	0.0001	*
6MWT at the beginning of the CR	244.04±43.3 (min 122. max 338.)	239.66±48.74 (min 156. max 334.)	0.746
6MWT at the end of the CR	310.47±44.21 (min 192. max 408.)	303.25±50.76 (min 206. max 397.)	0.602
6MWT after 3 months.	387.55±48.10 (min 224. max 452.)	380.08±60.78 (min 224. max 432.)	0.625
6MWT after 6 months.	413.83±48.22 (min 248. max 480.)	407.41±59.83 (min 253. max 460.)	0.674
p-value (compare period)	0.0001	0.0001	*
MET at the beginning	2.23±0.37 (min 1.11. max 5.24.)	2.29±0.36 (min 1.95. max 2.87.)	0.623
MET at the end	2.41±0.40 (min 1.20. max 3.50.)	2.47±0.38 (min 2.10. max 3.10.)	0.624
MET after 3 months	3.68±0.46 (min 2.67. max 4.9.)	3.85±0.37 (min 3.07. max 4.60.)	0.222
MET after 6 months	5.56±0.41 (min 4.6. max 6.4.)	5.54±0.50 (min 4.80. max 6.25.)	0.877
p-value (compare period)	0.0001	0.0001	*
V02MAX at the beginning	10.04±1.08 (min 8.50. max 13.26.)	10.45±0.88 (min 9.24. max 12.50.)	0.211
V02MAX at the end	11.81±1.27 (min 10.0. max 15.6.)	12.25±0.91 (min 10.87. max 14.07.)	0.249
V02MAX after 3 months	13.79±0.26 (min 13.03. max 14.67.)	13.90±0.42 (min 13.32. max 14.98.)	0.206
V02MAX after 6 months	14.87±0.35 (min 14.01. max 15.87.)	14.93±0.26 (min 14.50. max 15.34.)	0.586
p-value (compare period)	0.0001	0.0001	*
Wong-Baker scale, at the beginning	4.75±0.746 (min 4.0 max 6.1)	5.29±0.621 (min 2.9 max 4.2)	0.067
Wong-Baker scale, at the end	4.05±0.251 (min 3.9. max 5.1.)	4.89±0.356 (min 3.5 max 4.8)	0.082

Variables	Group 1 (n=92)	Group 2 (n=12)	p-value (intragroup)
Wong-Baker scale, after 3 months	3.75±0.495 (min 2.7. max 4.5)	3.65±0.521 (min 2.7 max 4.1)	0.099
Wong-Baker after 6 months	3.25±0.632 (min 3.1. max 5.1)	3.03±0.495 (min 2.9 max 3.7)	0.057
p-value (compare period)	0.0521	0.0001	*
Borge scale, at the beginning	13.6±2.54 (min 9.1 max 15.6)	14.9±4.69 (min 10.7 max 15.9)	0.135
Borge scale, at the end	9.1±3.21 (min 7.9 max 12.3.)	10.6±2.79 (min 8.9 max 13.1)	0.127
Borge scale, after 3 months	8.6±3.95 (min 7.8 max 11.4)	9.6±2.79 (min 7.1 max 11.5)	0.085
Borge scale, after 6 months	8.2±3.21 (min 6.5 max 12.1)	8.2±3.75 (min 7.2 max 10.9)	0.645
p-value (compare period)	0.0657	0.0001	*

**. Significance accepted at p< 0.05*
**. M±SD*

1. According to the results of the SF-36 survey in the Table 3, in group 2 (pts after mediastinitis) there was BP, GH and MH had statistically significant difference during comparing timely period at the beginning, at the end, 3-6 months of the CR. When comparing 2 groups there was found – statically difference BP between beginning and ending, VT at the beginning, GH after 3 months and MH after 6 months. Overall the 1st group (without mediastinitis) in all pts were has significantly improved SF-36 over the period at the beginning, at the end, 3-6 months.

Table 3. SF-36 parameters.

Variables	Group 1 (n=92)	Group 2 (n=12)	p-value (intragroup)
PF at the beginning	61.86±11.08 (min 23.77. max 62.54.)	59,64±11.08 (min 42.4. max 66.7.)	0,515
PF at the end	65.50±10.63 (min 29.51. max 88.04.)	63,76±15.25 (min 43.78. max 89.65.)	0,527
PF after 3 months	68.25±10.20 (min 35.25. max 88.90.)	66,21±14.15 (min 48.51. max 89.88.)	0,121
PF after 6 months	70.63±10.1 (min 36.72. max 89.01.)	68,50±14.06 (min 49.63. max 89.98.)	0,511
p-value (compare period)	0.0012	0,441	*
RP at the beginning	51.26±12.06 (min 5.01. max 69.56.)	46,87±16.44 (min 22.39 . max 71.35.)	0,777
RP at the end	55.97±12.69 (min 10.03. max 81.65.)	51,31±14.49 (min 28.21. max 73.67.)	0,164
RP after 3 months	58.61±12.27 (min 15.05. max 82.54.)	53,77±13.57 (min 34.03. max 74.36.)	0,45
RP after 6 months	61.24±12.06 (min 16.73. max 83.56.)	56,01±13.31 (min 36.76. max 75.67.)	0,253
p-value (compare period)	0.001	0,461	*
BP at the beginning	54.47±11.98 (min 30.62. max 81.20.)	40,42±12.39 (min 35.4. max 69.)	0,002*
BP at the end	58.31±12.54 (min 34.07. max 89.56.)	50,81±14.57 (min 38. max 78.43.)	0,005*
BP after 3 months	61.04±11.99 (min 37.52. max 89.98.)	59,03±13.46 (min 41.4. max 79.98.)	0,325
BP after 6 months	63.43±11.29 (min 38.55. max 90.10.)	61,25±12.3 (min 45.2. max 80.11.)	0,609
p-value (compare period)	0.00002	0.001	*
GH at the beginning	54.32±9.76 (min 35.48. max 77.63.)	51,48±9.0 (min 40. max 65.45.)	0,341

Variables	Group 1 (n=92)	Group 2 (n=12)	p-value (intragroup)
GH at the end	57.58±9.80 (min 41.16. max 81.05.)	55,20±9.33 (min 42.67. max 69.45.)	0,765
GH after 3 months	59.96±9.26 (min 45.02. max 82.05.)	57,52±9.17 (min 45.15. max 71.56.)	0,001
GH after 6 months	62.45±8.84 (min 46.71. max 83.45.)	60,03±8.74 (min 48.62. max 72.35.)	0,575
p-value (compare period)	0.0003	0,003	*
VT at the beginning	54.36±7.78 (min 31.85. max 73.78.)	50,80±10.5 (min 36.46. max 65.2.)	0,004*
VT at the end	58.03±10.02 (min 36.0. max 77.81.)	54,14±10.37 (min 39.45. max 68.60.)	0,341
VT after 3 months	60.61±9.78 (min 38.73. max 79.46.)	56,83±9.73 (min 42.96. max 70.99.)	0,772
VT after 6 months	63.05±9.45 (min 40.12. max 80.05.)	58,82±9.32 (min 45.69. max 73.60.)	0,248
p-value (compare period)	0.0001	0,241	*
SF at the beginning	54.70±7.23 (min 36.20. max 78.23.)	53,88±9.02 (min 39.4. max 66.34.)	0,72
SF at the end	58.22±9.28 (min 39.10. max 80.13.)	57,15±9.08 (min 42.04. max 69.82.)	0,222
SF after 3 months	60.87±8.77 (min 42.06. max 81.05.)	59,20±8.54 (min 45.32. max 70.67.)	0,297
SF after 6 months	63.24±8.36 (min 45.03. max 82.56.)	61,61±8.03 (min 49.65. max 71.23.)	0,691
p-value (compare period)	0.0001	0,179	*
RE at the beginning	49.05±9.80 (min 6. max 69.43.)	46,11±10.64 (min 32.88. max 62.5.)	0,335
RE at the end	52.62±9.30 (min 16.82. max 72.33.)	49,78±10.42 (min 36.3. max 67.13.)	0,329
RE after 3 months	55.34±8.61 (min 26.37. max 74.13.)	52,61±9.73 (min 39.41. max 69.32.)	0,381
RE after 6 months	57.80±8.50 (min 28.76. max 76.46.)	54,63±9.22 (min 42.38. max 70.55.)	0,229
p-value (compare period)	0.0001	0,195	*
MH at the beginning	52.34±9.69 (min 93.67. max 78.34.)	49,91±11.64 (min 34. max 69.34.)	0,241
MH at the end	55.59±9.8 (min 37.99. max 81.29.)	53,41±11.98 (min 38.52. max 73.19.)	0,651
MH after 3 months	58.09±9.49 (min 40.01. max 82.77.)	55,60±11.3 (min 41.2. max 74.54.)	0,405
MH after 6 months	60.65±8.99 (min 44.05. max 83.41.)	57,50±10.59 (min 44.26. max 75.67.)	0,002
p-value (compare period)	0.0012	0.002	*

**. Significance accepted at p< 0.05*
**. M±SD*

Correlation of physical capacity and QoL measure with clinical variables

There were not any significant correlations during usage the Pearson's two tailed correlation test between the SF-36 survey results over 4 time periods with LVEF, Wong-Baker pain rate depending on face type over two time period variables within both groups.

Lastly, the Euroscore results and Duration of training variables within two groups were tested in the Pearson's two tailed correlation test (Table 4). As a result, any statistically significant correlation, except the negative correlation between the Duration of training after CR and Euroscore (Risk = 4-10%), was not found.

Table 4. Euroscore and Duration of training correlations.

Group	Euroscore		Duration of training before CR (min)	Duration of training after CR (min)	Duration of training after 3 months CR (min)	Duration of training after 6 months CR (min)
1.00	Risk < 4%	Pearson Correlation	.151	-.002	.064	.219
		Sig. (2-tailed)	.502	.992	.776	.328
		N	22	22	22	22
	Risk = 4-10%	Pearson Correlation	-.044	.156	-.091	-.049
		Sig. (2-tailed)	.747	.247	.501	.720
		N	57	57	57	57
	Risk > 10%	Pearson Correlation	-.157	.132	-.451	.043
		Sig. (2-tailed)	.607	.667	.122	.889
		N	13	13	13	13
2.00	Risk < 4%	Pearson Correlation	.977	.305	.023	.977
		Sig. (2-tailed)	.136	.802	.985	.136
		N	3	3	3	3
	Risk = 4-10%	Pearson Correlation	-.385	-.924**	.124	-.309
		Sig. (2-tailed)	.394	.003	.790	.501
		N	7	7	7	7
	Risk > 10%	Pearson Correlation	1.000**	1.000**	1.000**	1.000**
		Sig. (2-tailed)				
		N	2	2	2	2

***. Correlation is significant at the 0.01 level (2-tailed).*

**. Correlation is significant at the 0.05 level (2-tailed).*

Adverse events

During the CR procedure there were no adverse events among patients while exercising.

DISCUSSION

We demonstrated that physical capacity improved in mediastinitis group but to a lesser value that in uncomplicated group. NO differences in METS or VO2 and our analysis showed the correlation of pain perception and Higher Euroscore. On the background of the CR program conduct, with moderate specific physical exercises, patients show a gradual increase in the duration and degree of activity, despite previous insufficient training components. According to the results of the survey in both groups, there is a decrease in the feeling of pain, an improvement of general health in the 3-month period and mental state by 6 months. Cardiac Rehabilitation (CR) stands as an established healthcare framework aimed at alleviating the global burden of cardiovascular disease. Extensive documentation exists regarding the advantageous

effects of engaging in CR exercises post-sternotomy. A recent review conducted by Cochrane showcased notable reductions in cardiovascular mortality, readmissions, and enhancements in quality of life among participants [15,16,17]. Moreover, greater levels of fitness achieved through CR exercise training have been linked to improved outcomes and diminished mortality rates [18]. Traditionally, supervised CR exercise training doesn't commence until 42 days (6 weeks) post-surgery, a period during which functional capacity may decline rapidly. This delay is attributed to concerns that exercising too early might impede healing or heighten the risk of sternal instability and infection. However, current evidence doesn't directly associate early postoperative physical activity with an increased likelihood of sternal complications [19,20]. While fears of complications like mediastinitis, which have substantial mortality rates, may justify these precautions, the existing guidelines primarily stem from expert judgment and informal data. Consequently, practices surrounding sternum precautions vary significantly across hospitals and emergency centers worldwide [21,22,23]. The precautions related to the sternum, often lacking customization, might overly restrict movement, intensify apprehension toward activity, and delay recovery [24]. In our study, similar outcomes were observed: when assessing mental health using the SF-36 questionnaire, there was initially a low level that significantly improved only after 6 months, even among patients with mediastinitis. This improvement was primarily due to decreased physical pain limitations during exercise.

Several risk factors for sternomediastinitis have been reported, including obesity, chronic obstructive pulmonary disease, prolonged ventilation, previous cardiac surgery, diabetes, re-check for bleeding, age, length of hospital stay, reperfusion syndrome, type of procedure (coronary bypass surgery or valve replacement / repair), type of hospitalization, type of discharge, postoperative blood transfusion, and osteoporosis. [25,26] Never the less, in our study group, 25% had diabetes, 16.7% were smokers, while in the control group, 21.7% had diabetes, 20.7% were smokers. In the anamnesis, the time of lung ventilation could not be specified, so, it is believed that the above mentioned predictors of sternomediastinitis are not always justified.

To date, current data describe that intense physical activity may have a greater impact on reducing cardiovascular morbidity and mortality than moderate exercise, an effect that is independent of energy intake. Leon M et al. showed that the risk of cardiovascular death is lower in physically active patients with cardiovascular disease and reduces the risk by up to 35%. [27] Quinn R. et al found no association between the number of CR sessions attended and the reduction in mortality in the study, that is different from the results suggesting a reduction in mortality of approximately 1% for each CR session; but they found that CR visits were associated with a significant reduction in 10-year all-cause mortality after coronary bypass surgery. [28] These results are fully confirmed by the data of SF-36 survey and statistically significance training duration period this study.

Hojskov I.E. et al. in a study showed that walking and cycling in the hospital after surgery is safe and effective. [29] In addition, no differences were found in readmission, infection rates, or sternum instability between patients who started CR training 10 days or 4–7 weeks after discharge. For safety reasons, patients are usually advised not to lift more than 2 kg for 12 weeks after surgery. Adams and colleagues, however, reported that the forces generated by sneezing and coughing (which usually resolve without incident) far exceed those generated by upper body dumbbell exercises and other limited daily activities such as lifting a coffee pot and pushing a lawn mower. [30,31] Therefore, the current activity restrictions after sternotomy may be overly cautious. In this study, the duration of training from 1 minute at the beginning increased to 15.34 minutes after 6 months in the group after sternomediastinitis. Thus, evidence to support earlier initiation of CR exercise after sternomediastinitis is evident in a number of cases. Muscle mass and cardiovascular health decline rapidly due to postoperative inactivity, and when the start of a CR program is delayed, the benefits of training also diminish. While the growing evidence base for CR training after sternotomy is relatively strong, good quality prospective studies are still lacking. Therefore, more research is needed to confirm benefits, safety, and cost-effectiveness. The results of such studies are important pending the development of national guidelines to give policy makers and clinicians the confidence to change practice.

2. Study limitations

Sternomediastinitis is a rare, but relatively severe

complication of open heart surgery: therefore, further management of such patients requires proper cardiac rehabilitation. Unfortunately, due to the paucity of patients, there are not very many research works. There is a need to study mental state on the background of constant discomfort, especially in patients with a formed false sternum joint, as well as reviews and scientific results on reconstructive operations on the sternum. Unfortunately, none of the patients in the study group were operated on for sternum reconstruction and further follow-up is still ongoing by our study group.

CONCLUSION

Properly selected physical exercises during CR improve the fitness and physical activity of patients after sternomediastinitis, as well as, QoL mesures - general health and mental status.

Patents

Type of copyright object: work of science (medicine) (Kazakhstan's National certification)

Object name: Cardiorehabilitation program for patients after myocardial infarction,

coronary artery stenting, pacemaker and/or ICD implantation, open heart surgery.

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