original article

The effect of preoperative chest physiotherapy on oxygenation and lung function in cardiac surgery patients: a randomized controlled study

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BACKGROUND: Postoperative pulmonary complications in patients who undergo open heart surgery are serious life-threatening conditions. Few studies have investigated the potentially beneficial effects of preoperative physiotherapy in patients undergoing cardiac surgery.
OBJECTIVES: Assess the effects of preoperative chest physiotherapy on oxygenation and lung function in patients undergoing open heart surgery.
DESIGN: Randomized, controlled.
SETTING: University hospital.
PATIENTS AND METHODS: Patients with planned open heart surgery were randomly allocated into an intervention group of patients who underwent a preoperative home chest physiotherapy program for one week in addition to the traditional postoperative program and a control group who underwent only the traditional postoperative program. Lung function was assessed daily from the day before surgery until the seventh postoperative day.
MAIN OUTCOME MEASURES: Differences in measures of respiratory function and oxygen saturation. Length of postoperative hospital stay was a secondary outcome.
SAMPLE SIZE: 100 patients (46 in intervention group, 54 in control group).
RESULTS: Postoperative improvements in lung function and oxygen saturation in the intervention group were statistically significant compared with the control group. The intervention group also had a statistically significant shorter hospital stay ($P<.01$).
CONCLUSION: Preoperative chest physiotherapy is effective in improving respiratory function following open heart surgery.
LIMITATIONS: Relatively small number of patients.
CONFLICT OF INTEREST: None.
REGISTRATION: ClinicalTrials.gov (NCT04665024).

Coronary artery disease (CAD) is considered one of the most common causes of mortality across the world.[1] In addition to its effects on mortality, CAD also incurs a financial burden accounting for about 169 million Euro annually in Europe (direct cost).[2] Moreover, CAD may cause loss of productivity (indirect cost).[1] In coronary artery bypass grafting (CABG), the main approach for treating CAD, the patient undergoes sternotomy and then is connected to a cardiorespiratory bypass machine.[3] However, this kind of surgery has several postoperative complications. Loss of physical activity and pulmonary impairment are among the most common.[4] These complications could be included with socioeconomic costs such as long stays at hospital, high budgets for treatment, ICU care for most patients, or even could lead to the death if the patient is not appropriately managed.[5]

Several factors can act integrally to impair postoperative pulmonary function after cardiac surgery, including general anesthesia, mechanical ventilation duration, cardiopulmonary bypass, and the sternotomy incision.[6] The use of cardiopulmonary bypass and general anesthesia is a main factor influencing patient outcome in cardiac surgery.[7] Postoperative pulmonary complications (PPCs) have been attributed to several factors related to cardiopulmonary bypass: blood being exposed to artificial materials, variability in body temperature, ischemia-reperfusion of organs, surgical trauma, and endotoxin release; all of these elicit an acute inflammatory response.[8-10] Anesthesia may predispose to PPCs by reducing the functional residual capacity and vital capacity and widening the alveolar-arterial oxygen gradient, with subsequent hypoxemia and atelectasis. In fact, anesthetic drugs predispose to PPCs via immune dysfunction, which subsequently yields to lung injury.[11]

Several postoperative techniques can be used to control lung function and maintain the normal function of organs in CABG patients.[12] These postoperative techniques could therefore reduce the mortality rate among patients. The techniques include mucus suction, exercise producing positive pressure and physiotherapy that could potentially increase the level of respiratory volumes and oxygen saturation.[12] In addition, there has been strong evidence supporting the role of preoperative exercise training in enhancing patient capability for sustaining surgical stress by improving physical fitness. Various physiotherapy strategies have been shown to be effective in improving physical fitness and inducing physiological changes in the diaphragm to improve the overall clinical condition of the patient. These include endurance training (ET) and respiratory muscle training (RMT).[13-15] Hence, these strategies have been applied within the preoperative period to facilitate postoperative recovery.[16]

Few studies have been published on the potential effects of preoperative physiotherapy on cardiorespiratory and musculoskeletal traits after CABG surgery.[1,17] These preoperative techniques can be applied in different ways, such as intensive breathing, muscle training during inspiration, and early mobilization or education. In addition, preoperative physiotherapy could also boost the patient's ability to cope with the major surgery (relaxation and goal setting).[18] The main goal of preoperative techniques is to mitigate potential PPCs after heart surgery. In addition, these techniques could reduce the mortality among those patients.[1,17] Therefore, this study aimed to assess the effects of preoperative chest physiotherapy on oxygenation and lung function in patients undergoing open heart surgery.

PATIENTS AND METHODS

This randomized controlled study was carried out in the cardiothoracic surgical department, intensive care unit and preoperative outpatient clinic of Pécs Clinical Centre, Heart Institute, Pécs, Hungary between April 2019 and October 2019. The study was approved by the Regional Ethical Committee of Clinical Research (4114. 316-474/KK15/2011). The study is reported according to CONSORT guidelines[19] and the protocol was registered on ClinicalTrials.gov (NCT04665024).

Adult patients scheduled for open heart surgery were eligible for the study. Patients with a history of strokes, musculoskeletal disorders, or psychological disorders were excluded. The minimum required sample size, calculated based on an O_2 saturation estimated a mean difference of 2% (standard deviation of 1.9),[20] was 20 participants in each group. Informed written consent was obtained from each patient. Eligible patients were randomly allocated to the intervention or control during their outpatient visit after being scheduled for cardiac surgery. The study was blinded by an independent hospital employee who prepared opaque sealed envelopes containing either number 1 (intervention group) or number 2 (control group). The patient then chose one of the opaque envelopes and was assigned to that group by the same employee.

The intervention group underwent breathing exercises preoperatively after weaning from the ventilator, while the other group underwent the postoperative exercise only. Both were monitored for seven days after surgery. In the outpatient clinic, all patients received guidance on surgery and possible postoperative conditions. Patients in the intervention group received a standard educational paper about breathing exercise, written in an easily understandable language with pictures and shapes that describe the preoperative program elements. In the outpatient clinic, experienced registered physical therapy specialists explained how to perform chest physiotherapy exercises, and trained patients on the breathing exercise. The breathing exercises were as follows: patients practiced 10 deep breaths with an incentive spirometer (Respiflo FS, *https://www.oxygenium.gr/en/proionta/respiflo-fs-kendall-2/*), with breath holding during inspiration for 2 to 3 seconds, exhaling slowly in 5 deep breaths by incentive spirometer and coughing while exhaling in another 5 breaths. Patients were instructed to repeat this cycle of breathing exercises for 30 minutes daily with 0.5 to 1 minute breaks. Each patient practiced the exercises for one week before surgery. The physiotherapists trained each patient three times: once on the first day, on the third day and one day prior to surgery. In both groups, patients underwent routine postoperative daily chest physiotherapy until discharge.

The primary outcome measures were differences between the groups in respiratory function and oxygen saturation. Forced vital capacity (FVC), forced expiratory volume in the first second (FEV1%) and oxygen saturation (SpO_2) were measured in the outpatient clinic (first measurement), one day before surgery (second measurement) and for 7 consecutive days after surgery. Spirometry was performed using an Otthon 2.0 - Mobile Handheld Spirometer (*https://www.healthcarehk.com/product/thor-2-0-mobile-handheld-spirometer/*). The measurement was performed with the patient in a sitting position according to the American Thoracic Society recommendations.[21] The value recorded was the best of three consecutive attempts. Oxygen saturation was measured by pulse oximeter (FaceLake FL400 Pulse Oximeter, *https://facelake.com/products/fl400-pulse-oximeter*). The secondary outcome measure was the difference in the length of postoperative hospital stay between groups.

Numerical data are presented as mean and standard deviation, while categorical data are presented as number and percentage. The chi-square test was used to compare the categorical data. The *t* test (unpaired) was used to compare differences in FVC, FEV_1 and SPO_2. ANOVA was used to compare differences in repeated measures across the pre- and postoperative days using IBM SPSS version 22.0 program. $P \leq .05$ was chosen as the level of statistical significance.

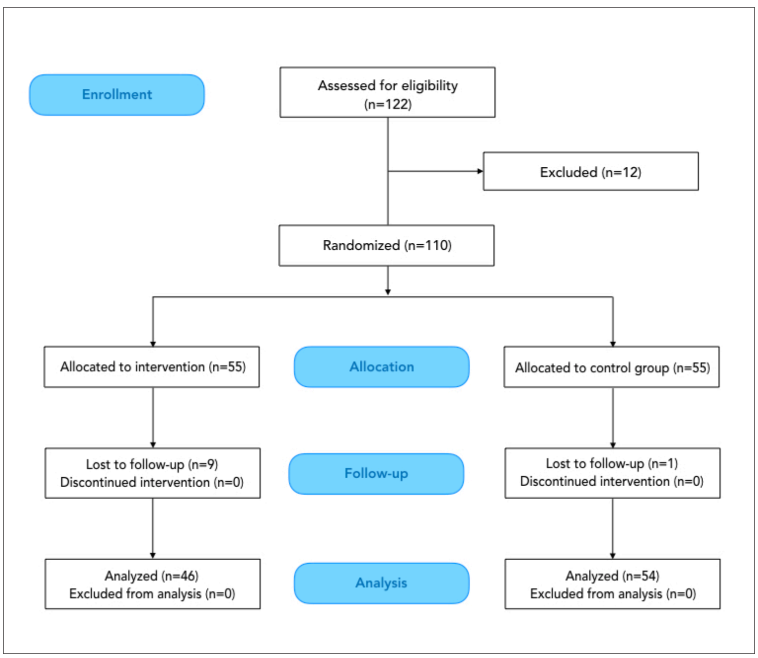

Figure 1. CONSORT flow diagram.

Table 1. Clinical and demographic characteristics (n=100).

Characteristics	Intervention (n=46)	Control (n=54)	Chi-square statistic	*P*
Age (years)				
40-<51	2 (4.4)	3 (5.5)	.15	.99
51-<62	10 (22.2)	11 (20.0)		
62-<73	20 (44.4)	24 (43.6)		
73-83	13 (28.9)	17 (30.9)		
Gender				
Male	28 (62.2)	33 (60.0)	.05	.82
Female	17 (37.8)	22 (40.0)		

RESULTS

Of 122 patients enrolled, 12 patients were excluded based on eligibility criteria, leaving 110 patients in the study population; 55 in each group. Nine patients from the intervention group and 1 patient in the control group did not complete the study, leaving 100 patients, 46 in the intervention group and 54 in the control group (**Figure 1**). Ages ranged from 40 and 83 years, and males comprised 61% with no statistically significant differences between groups in clinical and demographic characteristics (**Table 1**). The most common operation was coronary artery bypass graft (64%). There were no significant differences between groups in respiratory function or O_2 saturation in the preoperative outpatient clinic or day 0, while differences in these measures were found for the postoperative 7 day measurements were evident (**Tables 2, 3, Figures 2-4**). The postoperative hospital stay length ranged from 7 to 20 days, with statistically significant longer stay in the control group (**Table 4**).

DISCUSSION

Postoperative pulmonary complications are a principal contributor to morbidity and mortality in patients undergoing major surgery despite advances in perioperative care. PPCs are disorders of the respiratory system such as atelectasis and respiratory failure that occur within the first postoperative week.[22] Interventions used for prevention of postoperative PPCs include preoperative measures to support the respiratory system, and intraoperative or postoperative measures to eliminate anesthesia-associated adverse events.[23] Compared with measures taken to minimize postoperative cardiovascular complications, interventions for respiratory disorders are outdated and clinical practices are not standardized.[24,25]

Physical training for the prevention of PPCs include endurance training (ET), respiratory muscle training (RMT) or both. Preoperative RMT strengthens inspiratory muscles by improving neural control and increasing the diaphragm thickness with enhancement of the aerobic mechanical performance.[26,27] Strengthening the respiratory muscles sustains an elevated ventilation workload in the early postoperative period. It also helps in atelectasis prevention and gas exchange improvement.[16] ET has been shown to improve early cardiovascular adaptation by means of an increase in blood volume and enhanced vasodilatation, sympathetic neural drive relief and improved ventricular relaxation. All these factors facilitate the delivery and uptake of oxygen to accommodate the demand of energy within active skeletal muscle.[28,29] In addition, ET elevates ventilation load and physiological adaptive alterations within the respiratory muscles, which may confer higher strength and resistance to fatigue.[16] Chest physiotherapy is one of the procedures applied to eliminate PPCs after cardiac surgery, although there is no evidence to confirm the efficacy of these techniques.[30] No consensus has been reached on the most appropriate and effective treatment.[31] Therefore, this study was an attempt to investigate the role of preoperative chest physiotherapy on pulmonary function and length of stay in patients undergoing open heart surgery.

In our study, respiratory physiotherapy was effective in improving lung function and oxygenation of the blood. There were statistically significant differences in measures of respiratory function in the postoperative days, suggesting that preoperative chest physiotherapy

Table 1 (cont.). Clinical and demographic characteristics (n=100).

Characteristics	Intervention (n=46)	Control (n=54)	Chi-square statistic	*P*
Weight (kg)				
47-<70	13 (28.9)	16 (29.1)		
70-<93	23 (51.1)	27 (49.1)	.06	.97
93-114	9 (20.0)	12 (21.8)		
Height (cm)				
150-<162	11 (24.4)	13 (23.6)		
162-<174	22 (48.9)	27 (49.1)	.01	.99
174-185	12 (26.7)	15 (27.3)		
BMI				
Normal weight	11 (24.5)	11 (20.0)		
Overweight	22 (48.8)	25 (45.5)	2.02	.57
Obese	8 (17.9)	16 (29.1)		
Extreme obese	4 (8.8)	3 (5.5)		
Previous diseases				
Hypertension	25 (55.6)	36 (64.5)	1.02	.31
Diabetes	15 (33.4)	16 (29.1)	.12	.74
COPD	5 (11.1)	10 (18.2)	.97	.32
Pulmonary fibrosis	2 (4.4)	1 (1.8)	.59	.44
Chronic bronchitis	3 (6.7)	10 (18.2)	2.9	.09
Smoking				
Current smokers	9 (20.0)	17 (30.9)		
Ex-smokers	3 (6.7)	6 (10.9)	2.49	.11
Non-smokers	33 (73.4)	32 (58.2)		
Type of surgery				
CABG				
On-pump	25 (62.2)	30 (65.5)		
Off-pump	3 (6.7)	6 (10.9)		
Valve surgery	13 (29.0)	13 (23.6)	.4	.82
CABG + valve surgery	4 (8.8)	6 (10.9)		

Data are number (%).

expanded the lungs, promoted circulation of air to all pulmonary regions, increased the expiratory volume, improved the movement of the rib cage, and increased vital capacity. An increase in inspiratory muscle strength that occurred in the preoperative period could be responsible for higher functional capacity compared to individuals with weak muscles before surgery.[32,33] The findings of our study are consistent with previous studies.[1,17,18,34,35] Nardi et al reported improved physical and respiratory conditions in patients who underwent preoperative respiratory exercises.[17] These findings have also been confirmed.[32] A systematic review of these studies showed improvements in functional capacity and decreased PPC in postoperative outcome in cardiac surgery patients.[36] Moreover, the breathing exercise alone demonstrated efficiency in decreasing PPCs after cardiac surgery.[37]

The postoperative hospital stay length in our study ranged from 7 to 20 days, but most did not exceed 12 days of hospital stay (84%). There was a statistically significant difference between groups in the length of hospital stay. Nardi et al also reported shorter lengths of hospital stay in the group treated preoperatively, but without statistical significance.[4] The association of

Table 2. Lung function measures.

	Intervention (n=46)	Control (n=54)	*t* test statistic	*P* value
FVC (% predicted)				
Outpatient clinic	93.6 (17.7)	91.9 (18.4)	2.22	.05
Day 0	96.8 (17.5)	91.3 (15.8)	3.67	.07
Day 1	37.0 (6.9)	29.7 (6.0)	6.04	<.001
Day 2	48.8 (13.3)	35.3 (8.2)	5.65	<.001
Day 3	64.0 (16.2)	36.6 (5.5)	5.56	.011
Day 4	68.5 (22.4)	45.4 (10.7)	3.06	.02
Day 5	72.2 (14.5)	50.0 (11.1)	6.37	<.001
Day 6	78.8 (11.5)	60.1 (9.4)	9.58	<.001
Day 7	87.9 (11.1)	65.0 (10.3)	11.9	<.001
ANOVA test (within group)	78.7	229.7		
P value	<.001	<.001		
FEV_1 (% predicted)				
Outpatient clinic	96.3 (18.15)	95.3 (16.6)	2.94	.07
Day 0	98.7 (18.0)	96.6 (17.36)	3.89	.06
Day 1	40.3 (9.1)	31.3 (7.5)	5.41	<.001
Day 2	52.7 (15.2)	39.3 (9.044)	4.58	<.001
Day 3	68.4 (17.9)	38.4 (6.4)	5.18	.011
Day 4	65.1 (20.4)	47.7 (6.3)	6.00	<.001
Day 5	74.0 (11.2)	53.2 (10.0)	7.47	<.001
Day 6	82.3 (12.8)	62.8 (8.1)	9.02	<.001
Day 7	91.0 (11.9)	67.2 (9.4)	11.74	<.001
ANOVA test (within group)	75.11	269.36		
P value	<.001	<.001		

Data are number (%) or mean (standard deviation).

Table 3. Oxygen saturation (%).

O_2 saturation (%)	Intervention (n=46)	Control (n=54)	*t* test statistic	*P* value
Outpatient clinic	97.3 (1.2)	97.2 (1.4)	.69	.49
Day 0	97.4 (0.9)	97.4 (1.1)	.56	.91
Day 1	96.7 (1.6)	96.5 (1.0)	0.47	.64
Day 2	97.7 (1.7)	96.3 (1.0)	4.57	<.001
Day 3	97.3 (1.8)	96.1 (0.8)	2.23	<.05
Day 4	96.2 (1.6)	95.4 (0.8)	1.98	<.05
Day 5	97.4 (1.0)	96.1 (1.1)	4.76	<.001
Day 6	98.1 (0.9)	95.7 (1.4)	8.45	<.001
Day 7	98.4 (0.88)	95.6 (1.0)	13.97	<.001
ANOVA test (within group)	11.41	43.35		
P value	.01	.01		

Data mean (standard deviation).

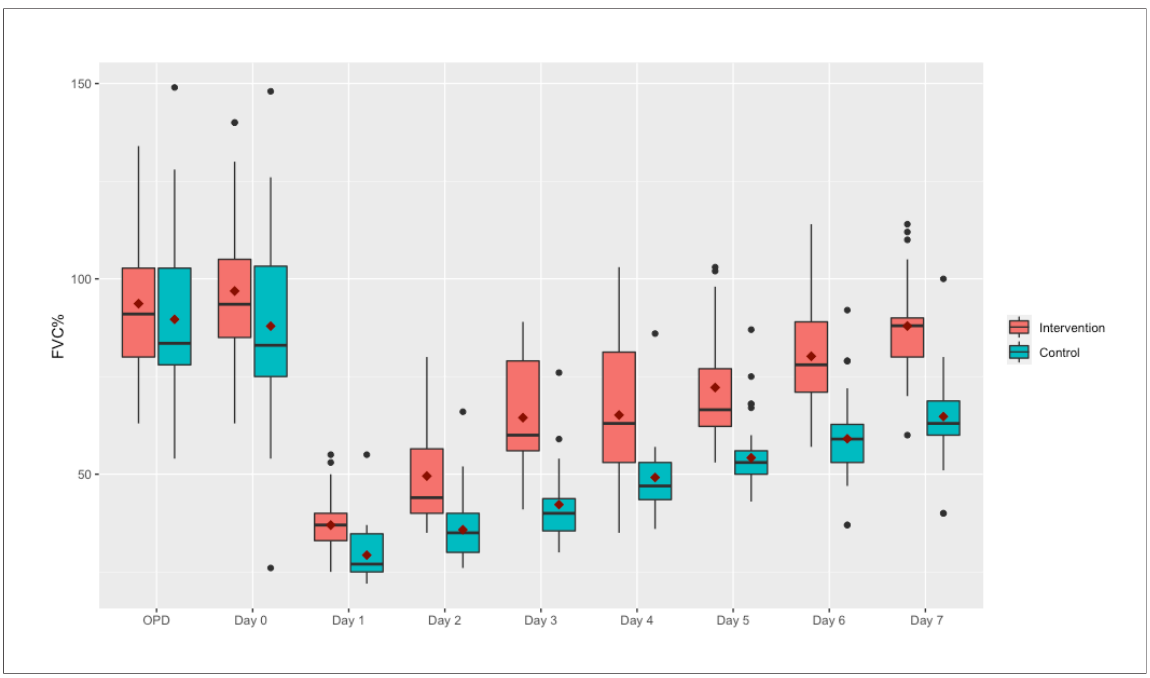

Figure 2. Median, interquartile range and mean (red diamond) of forced vital capacity (FVC%) in the intervention and control groups.

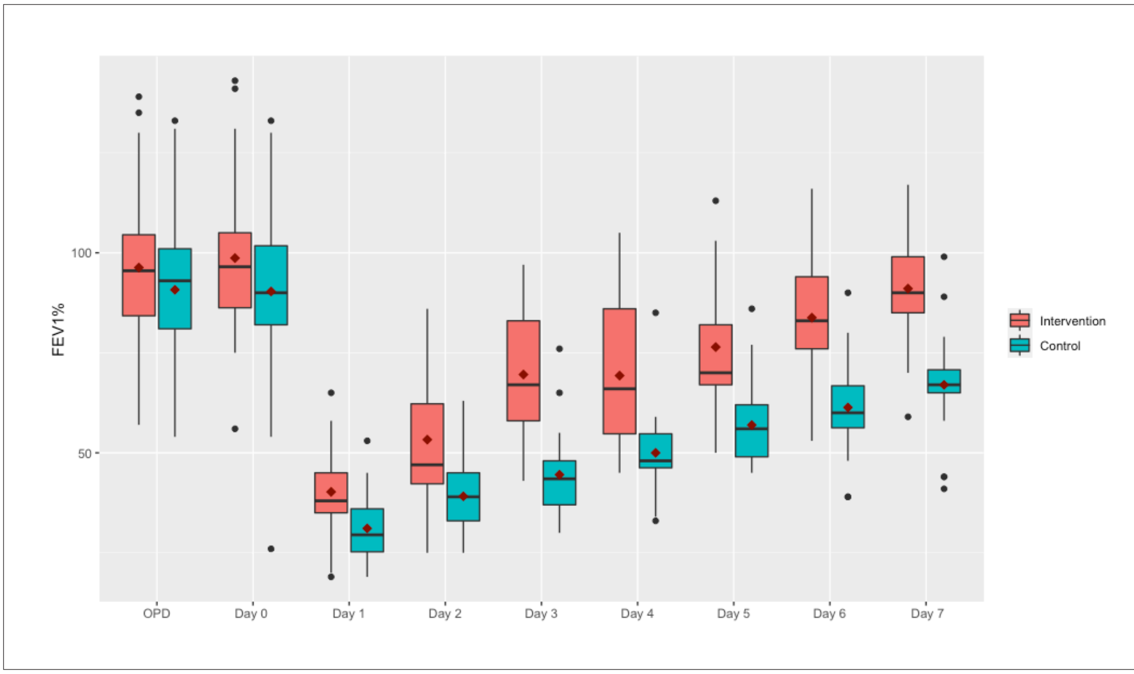

Figure 3. Median, interquartile range and mean (red diamond) of forced expiratory volume in first second (FEV1%) in the intervention and control groups.

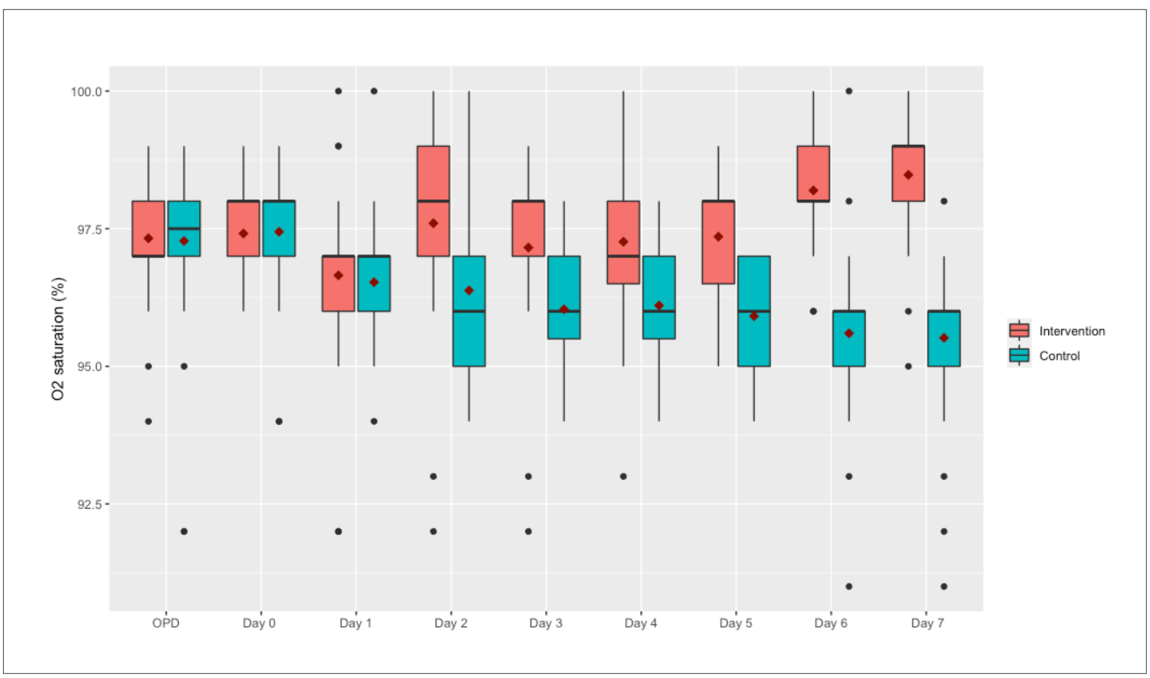

Figure 4. Median, interquartile range and mean (red diamond) of O_2 saturation (%) in the intervention and control groups.

breathing exercise with less hospital stay length has also been documented in other studies.[35,38-40]

A recent meta-analysis analyzed a total of 12 randomized controlled trials (RCTs) involving the application of respiratory physiotherapy in patients undergoing abdominal and thoracic surgery.[25] Physiotherapy protocols included both preoperative and postoperative interventions. They concluded that physiotherapy protocols reduced the incidence of PPCs. The largest and best quality RCT that included both preoperative and postoperative physiotherapy exercises revealed a statistically significant difference in developing PPCs postoperatively. The strength of our study is that it was a prospective RCT that emphasizes the effect of preoperative and postoperative physiotherapy on patients needing cardiac surgery. A limitation of this study is that it may be difficult to generalize the findings of the present study due to the relatively small number of subjects. The different types of surgery is also a limitation of the present study. This study concluded that preoperative chest physiotherapy is effective in improving respiratory functions following the open heart surgery.

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