

# Decreased cardiorespiratory fitness and slow gait speed in Thai patients after open cardiac surgery: a preliminary prospective observational study

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## Abstract

**Introduction.** The study purpose was to investigate the pulmonary function test, respiratory muscle (RM) strength, functional capacity, and gait speed in Thai patients submitted to open heart surgery.

**Methods.** A prospective observational cohort study was designed with 48 patients who underwent open heart surgery, aged 35–70 years, both males and females. The average duration of follow-up after cardiac surgery was  $16.15 \pm 4.97$  days. Spirometry, RM strength, 6-minute walk test, and 5-meter walk test were performed. ANOVAs were used to compare whether these parameters significantly changed in the preoperative, prior to discharge, and follow-up periods.

**Results.** Overall, 26 female and 22 male patients participated in the initial and follow-up study; the average age was  $55.46 \pm 10.35$  years. There was a significant decrease in lung function (%predicted forced vital capacity [FVC] and %predicted forced expiratory volume in 1 second [FEV<sub>1</sub>]), RM strength (maximal inspiratory pressure [MIP] and maximal expiratory pressure [MEP]), functional capacity, and gait speed compared with preoperative values. Before discharge from hospital, the mean %predicted FVC was dramatically decreased to  $-22.87 \pm 14.93$  and %predicted FEV<sub>1</sub> was  $-22.10 \pm 15.59$  compared with the preoperative period ( $p < 0.05$ ). Furthermore, mean MIP dropped to  $-24.75 \pm 17.08$  cm H<sub>2</sub>O and MEP to  $-20.96 \pm 15.79$  cm H<sub>2</sub>O. These values did not fully recover after discharge from hospital ( $p < 0.001$ ).

**Conclusions.** Decreased lung function, RM, functional capacity, and gait speed were observed during hospitalization and follow-up time.

**Key words:** open heart surgery, pulmonary function, respiratory muscle strength, gait speed, functional capacity

## Introduction

Open heart surgery has been associated with several physical health problems in patients, e.g., decreases in cardiovascular endurance and respiratory function. In addition, an incidence of approximately 7.5% of postoperative pulmonary complications after open heart surgery has been reported and this might lead to a hospital length-of-stay of more than 10 days in 64.3% of all cases [1]. Complications and prolonged hospital admissions increase economic costs [2]. It is well known that cardiac surgery may give rise to a reduction in function of lungs and respiratory muscles. These may result in atelectasis and decreased functional residual capacity, which lead to poor gas exchange and increased ventilation/perfusion mismatch [3].

An early systematic review of 7 studies indicated that cardiopulmonary exercise testing was associated with postoperative morbidity and mortality in non-cardiopulmonary surgery, e.g., abdominal aortic aneurysm repair, hepatic transplantation, oesophagectomy, gastric bypass, and intra-abdominal surgery [4]. Smith et al. [5] reported that low preoperative cardiorespiratory fitness was related to high incidence of postoperative events after coronary artery bypass grafting (CABG), e.g., death during the hospitalization or less than 30 days after CABG, pneumonia, sternal wound infection, reintubation, required treatment for atrial or ventricular arrhythmias. In a statement of the American Heart Association concerning the relationship of cardiorespiratory fitness

and risk of cardiovascular disease, it was suggested that cardiorespiratory fitness was a preoperative predictor of cardiovascular disease and all-cause mortality [6]. In addition, this could be a cardiovascular disease risk assessment factor in patients before heart surgery and patients with CABG [6].

A reduction in pulmonary function and respiratory muscle strength of approximately 30–60% in the 1<sup>st</sup> week after surgery has been reported [7–10]. Cardiac rehabilitation program phase 1, inpatient cardiac rehabilitation, has been suggested to prevent pulmonary complications among patients who underwent cardiac surgery. In addition, phase 2 treatment, outpatient cardiac rehabilitation, usually starts after hospital discharge. Several studies reported the effects of open heart surgery on respiratory function among inpatients. Little is known regarding the cardiorespiratory function and gait speed in Thai patients submitted to open heart surgery during hospital stay and after discharge from hospital. Therefore, the purpose of the present study was to determine the lung function, respiratory muscle strength, functional capacity, and gait speed in patients treated with open cardiac surgery before surgery, before discharge, and at the 1<sup>st</sup> visit after hospital discharge.

## Subjects and methods

The longitudinal prospective cohort study investigated 65 consecutive patients scheduled for elective cardiac operation at the Thammasat University Hospital. The participants,

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both male and female volunteers, were aged 35–70 years. All underwent valve replacement (e.g., aortic, mitral, tricuspid or pulmonic valve replacement) or CABG. Patients with known congestive heart failure, blood pressure higher than 180/100 mm Hg or uncontrollable blood pressure, or high heart rate (more than 100 beats per minute) were excluded from the study. In addition, participants who had unstable angina, uncontrolled cardiac arrhythmia, chronic cough, high temperature within 48 hours prior to the test, or other operative treatments such as thoracotomy were also excluded. Individuals with a severe heart dysfunction (defined as left ventricular ejection fraction less than 30%) were not recruited. Further, participants with a rate of perceived exertion higher than 13 of 20, chest pain, dyspnoea during or after the test were terminated from the study.

Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were tested with an RPM01 respiratory pressure meter (Micro Medical Ltd., United Kingdom). Lung function tests measured the forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV<sub>1</sub>). The measurements of respiratory muscle strength and lung function were performed in upright position in accordance with the American Thoracic Society/European Respiratory Society [11]. A 6-minute walk test, which is a functional capacity test, was conducted. The participants were instructed to walk 30 m straight along a corridor in 6 minutes [12]. All were requested to walk faster for 5 m 3 times and then the mean duration was calculated. All evaluations were performed in patients scheduled for open heart surgery: prior to surgery (within 48 hours), prior to discharge (within 48 hours), and at the 1<sup>st</sup> follow-up visit after discharge from the hospital.

### Statistical analysis

Descriptive data are presented as percentage, mean, and standard deviation. Changes in respiratory muscle strength, lung function, functional capacity, and gait speed were cal-

culated by subtracting the parameter values before discharge from the baseline ones and the follow-up values from the baseline ones. All data were converted to percentages. A normality of distribution test (Kolmogorov-Smirnov goodness-of-fit test) was performed to verify the data distribution. Separate repeated measures ANOVA test and Bonferroni post-hoc tests were conducted to compare physical health conditions, i.e., respiratory muscle strength, lung function, functional capacity, and gait speed, at the different time points: before the open heart surgery, after the surgery, and at the 1<sup>st</sup> visit after hospital discharge. The SPSS version 21.0 (IBM Corporation, United States) software was used for all analyses, and the level of statistical significance was considered as  $p < 0.05$ .

### Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee Board of Thammasat University and Thammasat University Hospital. The study has been approved for registration in the Thai Clinical Trials Registry (identification number: TCTR 20151215002).

### Informed consent

Informed consent has been obtained from all individuals included in this study.

### Results

A total of 65 patients eligible for the study were evaluated for cardiorespiratory health prior to cardiac surgery. Of these, 8 did not proceed to the postoperative assessments owing to surgery cancellation ( $n = 1$ ), postoperative complications, e.g., sepsis, ischemic stroke ( $n = 2$ ), or discharge from hospital before the tests ( $n = 5$ ). During the 1<sup>st</sup> visit after discharge, 48 patients were considered (Figure 1).

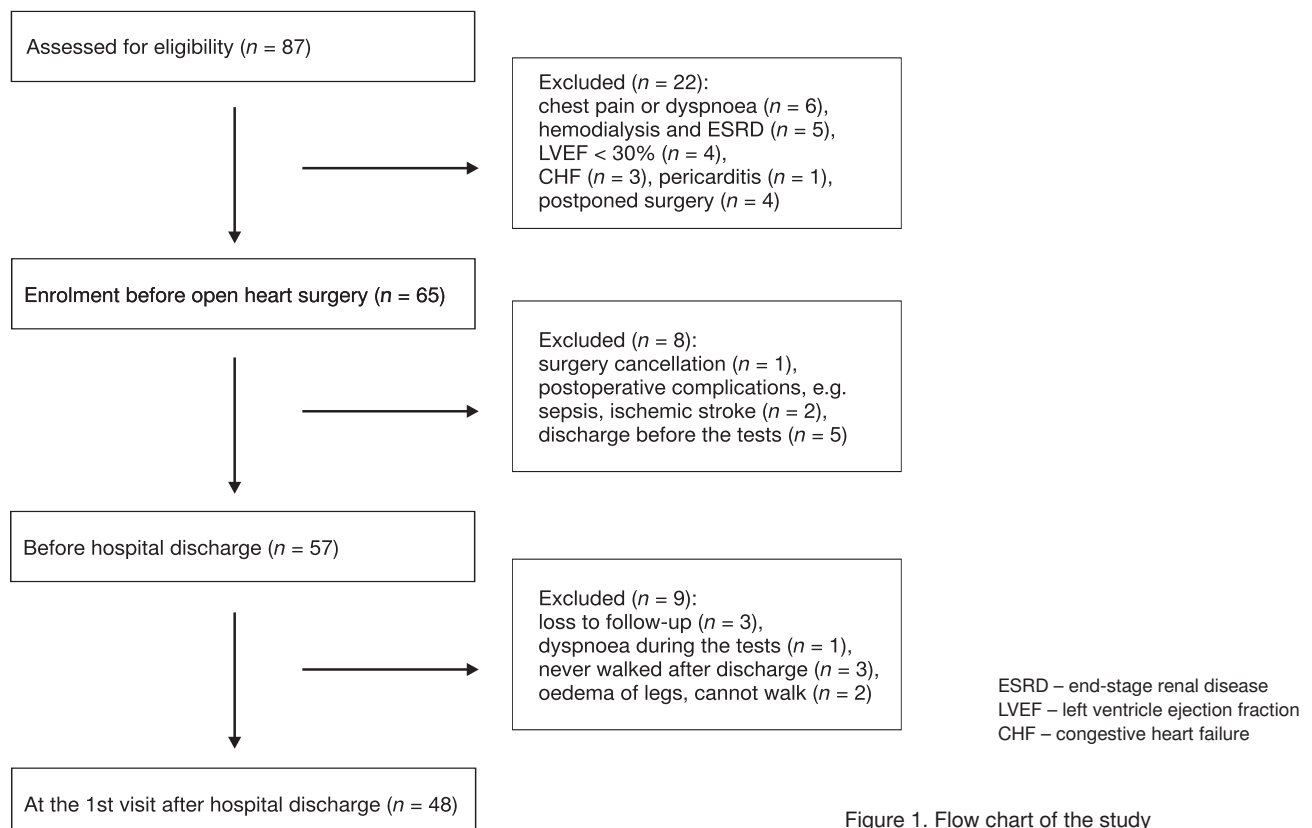


Figure 1. Flow chart of the study

The characteristics of the study participants are presented in Table 1. The patients' mean age was  $55.46 \pm 10.35$  years. There were 22 males and 26 females. Airflow obstruction was defined as  $FEV_1/FVC$  less than 0.7; therefore, only 4 patients (8.33%) were regarded as having airflow obstruction in the preoperative period. A total of 27 (56.25%) overweight participants, with a body mass index of  $\geq 23.0$  kg/m<sup>2</sup>, were noted in the study. In addition, there were no significant differences in these parameters between those who were involved in the follow-up and those who were not ( $p > 0.05$ ). The mean length of hospital stay after the cardiac surgery was  $7.77 \pm 2.85$  days and the postoperative study period equalled  $16.15 \pm 4.97$  days.

One-way ANOVA and Bonferroni post-hoc tests were performed to determine whether there was a difference of cardiorespiratory function in the preoperative, postoperative, and 1<sup>st</sup> follow-up periods (Table 2).

Patients who had median sternotomy showed a reduction of pulmonary volumes and respiratory muscle strength of approximately 20–34% compared with the preoperative time point (–30.25% for FVC, –28.78% for  $FEV_1$ , –33.65% for MIP, and –26.31% for MEP). In addition, 2 weeks after surgery, i.e., on the 1<sup>st</sup> visit after hospital discharge, the rate of recovery was not improved (–16.85% for FVC, –15.83% for  $FEV_1$ , –26.84% for MIP, and –23.30% for MEP). Likewise, functional capacity and gait speed were also reduced: by –20.01% and –25.16%, respectively, compared with the preoperative time point. Similarly, 2 weeks after the open heart surgery, the walking distance was shown to be decreased by –4.78% and gait speed remained decreased by –6.47%. Subgroup analysis by sex found no significant differences in these values (Table 3).

In sum, significant pulmonary impairment and decreased respiratory muscle strength, functional capacity, and gait speed were observed in patients up to 2 weeks after cardiac surgery.

Table 1. Demographic data of patients undergoing open heart surgery who completed baseline and follow-up study sessions ( $n = 48$ )

Characteristics	Number (%)	Mean	SD
Gender			
Female	26 (54.17)		
Male	22 (45.83)		
Type of operation			
CABG	19 (39.58)		
Valve replacement/repair	27 (56.25)		
Combined	2 (4.17)		
Age (years)		55.46	10.35
BMI (kg/m <sup>2</sup> )		23.80	3.85
Length of hospitalization (days)		7.77	2.85
Duration of follow-up (days)		8.38	3.96
Duration after surgery (days)		16.15	4.97
6MWD (m)		337.55	122.40
Gait speed (m/s)		1.18	0.33
MIP (cm H <sub>2</sub> O)		72.69	24.32
MEP (cm H <sub>2</sub> O)		74.67	25.23
Predicted FVC (%)		74.85	16.30
Predicted $FEV_1$ (%)		74.94	16.87

SD – standard deviation, CABG – coronary artery bypass grafting, BMI – body mass index, 6MWD – 6-minute walk distance, MIP – maximal inspiratory pressure, MEP – maximal expiratory pressure, FVC – forced vital capacity,  $FEV_1$  – forced expiratory volume in 1 second

Table 2. Differences in cardiorespiratory function results before the open heart surgery, before discharge from hospital, and at follow-up ( $n = 48$ )

Parameter	Mean difference Before surgery & before hospital discharge ( $p$ )	Mean difference Before surgery & at 1 <sup>st</sup> follow-up ( $p$ )	Mean difference At 1 <sup>st</sup> follow-up & before hospital discharge ( $p$ )
MIP (cm H <sub>2</sub> O)	$24.75 \pm 2.47$ ( $< 0.001$ )	$21.04 \pm 2.64$ ( $< 0.001$ )	$3.71 \pm 2.09$ ( $= 0.83$ )
MEP (cm H <sub>2</sub> O)	$20.96 \pm 2.28$ ( $< 0.001$ )	$19.67 \pm 2.92$ ( $< 0.001$ )	$1.29 \pm 2.24$ ( $= 0.567$ )
Predicted FVC (%)	$22.88 \pm 2.15$ ( $< 0.001$ )	$13.08 \pm 1.80$ ( $< 0.001$ )	$9.79 \pm 2.17$ ( $< 0.001$ )
Predicted $FEV_1$ (%)	$22.10 \pm 2.25$ ( $< 0.001$ )	$12.19 \pm 1.97$ ( $< 0.001$ )	$9.92 \pm 1.92$ ( $< 0.001$ )
6MWD (m)	$102.28 \pm 16.10$ ( $< 0.001$ )	$43.50 \pm 16.95$ ( $= 0.014$ )	$58.78 \pm 10.45$ ( $< 0.001$ )
Gait speed (m/s)	$0.36 \pm 0.04$ ( $< 0.001$ )	$0.18 \pm 0.05$ ( $< 0.01$ )	$0.19 \pm 0.03$ ( $< 0.001$ )

MIP – maximal inspiratory pressure, MEP – maximal expiratory pressure, FVC – forced vital capacity,  $FEV_1$  – forced expiratory volume in 1 second, 6MWD – 6-minute walk distance

## Discussion

The present study evaluated the effect of open heart surgery on cardiorespiratory function and gait speed of patients in 3 periods: before surgery, before discharge from hospital, and on the 1<sup>st</sup> visit after discharge. In the 1<sup>st</sup> week post-surgery, impaired lung function, reduced respiratory muscle strength, and slow gait speed were observed in the patients. In addition, the recovery rates were not improved after the

2<sup>nd</sup> postoperative week. This suggests that cardiorespiratory function requires more than 2 weeks for full recovery.

Riedi et al. [13] investigated patients who underwent sternotomy before surgery and on the 5<sup>th</sup> day post-surgery. They found an approximate 14% reduction in MIP and 25% reduction in MEP on the 5<sup>th</sup> postoperative day. Morsch et al. [14] reported that patients who underwent heart surgery showed an approximate 41% reduction in  $FEV_1$  and FVC together with 34–35% reduction in MIP and MEP 6 days

Table 3. Differences in cardiorespiratory function results before the open heart surgery, before discharge from hospital, and at follow-up depending on sex

Parameter	Females (n = 26)			Males (n = 22)		
	Mean difference Before surgery & before hospital discharge (p)	Mean difference Before surgery & at 1 <sup>st</sup> follow-up (p)	Mean difference At 1 <sup>st</sup> follow-up & before hospital discharge (p)	Mean difference Before surgery & before hospital discharge (p)	Mean difference Before surgery & at 1 <sup>st</sup> follow-up (p)	Mean difference At 1 <sup>st</sup> follow-up & before hospital discharge (p)
MIP (cm H <sub>2</sub> O)	21.42 ± 2.39 (< 0.001)	19.31 ± 2.67 (< 0.001)	2.12 ± 2.64 (= 0.43)	28.68 ± 4.50 (< 0.001)	23.09 ± 4.85 (< 0.001)	5.59 ± 3.36 (= 0.111)
MEP (cm H <sub>2</sub> O)	21.15 ± 3.17 (< 0.001)	19.92 ± 3.67 (< 0.001)	1.23 ± 2.72 (= 0.654)	20.73 ± 3.35 (< 0.001)	19.36 ± 4.78 (= 0.001)	1.36 ± 3.76 (= 0.720)
Predicted FVC (%)	22.23 ± 2.87 (< 0.001)	10.54 ± 2.15 (< 0.001)	11.69 ± 2.61 (< 0.001)	23.64 ± 3.33 (< 0.001)	16.09 ± 2.91 (< 0.001)	7.55 ± 3.61 (= 0.049)
Predicted FEV <sub>1</sub> (%)	20.54 ± 3.04 (< 0.001)	9.69 ± 2.49 (= 0.001)	10.85 ± 2.73 (= 0.001)	23.96 ± 3.38 (< 0.001)	15.14 ± 3.08 (< 0.001)	8.82 ± 2.72 (= 0.004)
6MWD (m)	113.42 ± 24.13 (< 0.001)	41.50 ± 27.11 (= 0.138)	71.92 ± 16.32 (< 0.001)	89.11 ± 20.75 (< 0.001)	45.86 ± 19.20 (= 0.026)	43.25 ± 11.71 (= 0.001)
Gait speed (m/s)	0.40 ± 0.06 (< 0.001)	0.18 ± 0.07 (= 0.013)	0.22 ± 0.05 (< 0.001)	0.32 ± 0.06 (< 0.001)	0.17 ± 0.06 (= 0.011)	0.15 ± 0.04 (= 0.001)

MIP – maximal inspiratory pressure, MEP – maximal expiratory pressure, FVC – forced vital capacity, FEV<sub>1</sub> – forced expiratory volume in 1 second, 6MWD – 6-minute walk distance

after surgery. In contrast, Urell et al. [15] measured respiratory muscle strength and pulmonary function in 36 patients before and after cardiac surgery and revealed that only FEV<sub>1</sub> and inspiratory capacity were decreased, which can be perceived as impaired lung function. It should be noted that the study used a time period of 2 months after heart surgery, which might have affected recovery. Several studies observed that changes in pulmonary function might persist for over 3 months after cardiac surgery [16, 17]. Likewise, Westerdahl et al. [18] reported a 6–13% decrease in post-operative lung function, i.e., vital capacity, inspiratory capacity, FEV<sub>1</sub>, and peak expiratory flow rate, 4 months after heart operation. Therefore, pulmonary impairment remained up to 4 months after cardiac surgery.

Reduced respiratory muscle strength and pulmonary function in the early postoperative period after cardiac surgery might be due to sternal pain that affects performance in the respiratory fitness tests. Pain intensity is linked to an increased poor cardiopulmonary function. Poor pain control is manifested by an ineffective breathing pattern, resulting in poor mobility and leading to prolonged hospital stays [19]. However, the study did not report pain scales. Thus, sternal pain should be considered for cardiopulmonary recovery in patients with cardiac surgery.

Previous studies reported that increased respiratory abnormalities and impairment of lung function in patients who underwent CABG might be attributed to internal mammary artery grafting [20, 21]. However, the present study included patients subjected to both internal mammary artery and saphenous grafting. It cannot discriminate between the results for different types of grafting.

Recovery might depend on the cardiovascular surgery type, e.g., CABG vs. valve replacement/repair, or prosthesis type for valve replacement. Previous studies reported that patients who underwent valvular surgery had lower pulmonary function values compared with CABG patients [22, 23]. El-Sobkey and Gomaa [22] claimed that patients with rheumatic heart disease commonly developed left ventricular dysfunction that led to reduced lung compliance, decreased

gas exchange, and decreased pulmonary function. However, the study found no difference between types of open heart surgery, i.e., CABG or valve replacement, in terms of pulmonary function or respiratory muscle strength. Fino et al. [24] compared functional capacity, i.e., 6-minute walk test, in patients with ischemic mitral regurgitation who received bioprosthesis and mechanical prosthesis. They found that the mean 6-minute walk distance (6MWD) improved from 242 ± 43 m at baseline to 290 ± 50 m at follow-up in mechanical prosthesis whereas it decreased in patients with bioprosthesis from 250 ± 40 m at baseline to 220 ± 44 m at follow-up. Consequently, the type of prosthetic valve might be another factor related to functional capacity. However, the study did not report any difference in prosthetic valves or intraoperative factors, e.g., cardiopulmonary bypass time or aortic cross-clamping time. Therefore, the mechanisms linking postoperative pulmonary function and respiratory muscle strength with open heart surgery may not only involve types of surgery but also pain scale [2, 10, 25] and anaesthetic techniques [26]. Several studies reported that prolonged intubation and cardiopulmonary bypass time were associated with the risk of postoperative cardiopulmonary complications including intraoperative factors [24, 27, 28]. However, these variables have not been noted in the present study and should be addressed in future research.

Similarly, decreases in walking performance, i.e., functional capacity and gait speed, were observed on the 7<sup>th</sup> and 14<sup>th</sup> day post-surgery. The mean 6MWD before heart surgery was 339.64 ± 118.33 m, which is consistent with data obtained by Stewart et al. [29], who reported a walking distance for 6 minutes of 340 ± 117 m in patients submitted to CABG surgery. Furthermore, the present study revealed that the mean 6MWD was 237.35 ± 117.92 m at hospital discharge. Correspondingly, Oliveira et al. [30] found that the mean 6MWD at hospital discharge (11.3 ± 6 days after open cardiac surgery) was 260.20 ± 89.20 m in patients with a mean age of 51 ± 13 years. Also, Demir et al. [31] observed that the mean 6MWD in CABG patients was 349 m before surgery and 284 m at discharge from hospital. Wojtkowska et al. [32]

revealed that the mean 6MWD before CABG was  $437.2 \pm 54.06$  m and showed an improved walking distance of  $43.17 \pm 104.41$  m at the 12<sup>th</sup> month after surgery. In the present study, 6MWD and gait speed were improved at the 1<sup>st</sup> visit after discharge from hospital. However, the values were still lower than before the surgery. Therefore, longer duration of follow-up may, in part, account for cardiorespiratory function recovery. Further, Stein et al. [33] observed that pulmonary function and respiratory muscle strength were reduced on the 7<sup>th</sup> postoperative day of CABG; they concluded that pulmonary function and functional capacity after CABG could recover with a cardiac rehabilitation program within 30 days after CABG. Therefore, cardiac rehabilitation phase 2 should be encouraged in patients who underwent open heart surgery.

Several studies reported that hormones and biochemistry affected the risk of developing cardiovascular disease [34–36]. However, in subgroup analysis, cardiorespiratory values were decreased after heart surgery and were not fully recovered at the 1<sup>st</sup> follow-up after hospital discharge in both males and females. This suggests that recovery from open heart surgery is not related to sex differences and that other factors might be associated with the rate of recovery of cardiorespiratory function. However, the relatively small number of participants, 22 males and 26 females, should be noted. A larger number of male and female subjects should be enrolled in future research.

## Limitations

Several limitations might have affected the results of the present study. Firstly, there was a relatively small sample size ( $n = 48$ ). However, owing to the repeated measures design, the current study had sufficient power to detect effects with a relatively large effects size, e.g., for 6MWD, the respective statistical power was 0.99 for the 2-tailed alpha of 0.05. Furthermore, pain scale, prolonged intubation, and cardiopulmonary bypass time might be associated with postoperative respiratory function and may contribute to its decreased level. Thus, postoperative pain perception and intraoperative factors should be assessed. In addition, physical activity and daily life activity were not recorded after patients were discharged from hospital. These activities might add to improved cardiorespiratory fitness and gait speed.

## Conclusions

In patients with open heart surgery, significant reductions in respiratory muscle strength, pulmonary function, functional capacity, and gait speed were observed before discharge, and these cardiorespiratory values did not fully recover after discharge from hospital. Therefore, focus should be given to patient participation in cardiac rehabilitation program phase 2 (i.e., after discharge from hospital).

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## Disclosure statement

No author has any financial interest or received any financial benefit from this research.

## Conflict of interest

The authors state no conflict of interest.

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