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Correlation Between Change In Respiratory Muscle Strength And Cough Ability In Patients Submitted To Open-Heart Surgery

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ABSTRACT

The purpose of this study was to determine the correlation between change in respiratory muscle strength and change in cough ability in patients submitted to open-heart surgery. An observational cross-sectional study was conducted among 52 participants. Respiratory muscle strength was assessed by maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) using a respiratory pressure meter. Cough ability was evaluated by voluntary expiratory peak flow (PEF) using a digital spirometer. Evaluations were performed on the day of admission and discharge. Post-operative MIP, MEP, and PEF were significantly lower than those evaluated preoperatively (all $p < 0.001$). The difference of MIP and MEP was substantial positively correlated with the change in PEF in both absolute and predicted values (all $p < 0.001$) with the changes in MIP was highly relation. This study demonstrated that weakness of respiratory muscles, especially inspiratory muscle, was correlated to declining in cough ability in patients who had undergone open-heart surgery.

Key Words: Respiratory muscle strength, Cough ability, Open-heart surgery

Introduction

Postoperative respiratory dysfunction after open-heart surgery is a leading cause of a reduction in respiratory muscle strength that was presented by a decrease in maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) postoperatively (1-3). These changes may be related to surgical manipulation, cardiopulmonary bypass, anesthetic agents, thoracotomy pain, and immobilization (4, 5).

In addition to the importance of ventilation, inspiratory and expiratory muscles are also necessary to produce an effective cough (6). The sequence of a productive cough is classified as deep inspiration, compression, and forced expulsion by contraction of the respiratory muscles (7). Hence, the attenuation of respiratory muscle strength can affect the ability to generate peak cough flow. According to previous study, it was revealed that the voluntary expiratory peak flow (PEF) was diminished in patients who had undergone coronary artery bypass graft (2) and cardiac valve surgery (8).

Although the reduction of maximal respiratory pressure and PEF after open-heart surgery have been demonstrated, the association of its deterioration has not been elucidated. Therefore, this study aims to determine whether respiratory muscle weakness would correlate with a decrease in PEF in patients submitted to open-heart surgery.

Materials and Methods

Participants and Procedures: This observational cross-sectional study was accomplished in 52 participants including males and females who were undergoing coronary artery bypass graft, cardiac valve surgery or combined surgery at Thammasat Hospital, Thailand within the age of 35-65 years. The participants who had a body mass index more than 35 kg/m^2, pulmonary diseases, neurological diseases, chronic heart failure, uncontrolled diabetes mellitus and using a mechanical ventilator more than 24 hours after surgery were excluded. This study was approved by the human research ethics committee of Thammasat University No.3 (066/2558), and all participants have signed a written informed consent.

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Table 1. Characteristics of the participants

Variables	Values
Age (years)	56.38 ± 10.21
Male (N, %)	28 (53.85)
Body mass index (kg/m²)	23.68 ± 3.93
Echocardiography	
Left ventricular ejection fraction (%)	60.72 ± 9.89
Diagnosis	
Valvular heart disease (N, %)	25 (48.08)
Coronary artery disease (N, %)	32 (61.54)
Underlying diseases	
Hypertension (N, %)	33 (63.46)
Diabetes mellitus (N, %)	13 (25.00)
Dyslipidemia (N, %)	15 (28.85)
Length of hospital stay (days)	7 (6-8)

Values presented as mean ± standard deviation, median (interquartile range), or number of participants (%)

Respiratory muscle strength was assessed by maximal respiratory pressure (MIP and MEP) using a respiratory pressure meter RPM 01 (Micro Medical Ltd., United Kingdom). The MIP was measured during a maximum inspiratory effort from residual volume, and the MEP was measured during a maximum expiratory effort from total lung capacity. The participants were asked to breathe as much effort and maintained for at least one second. Three satisfactory attempts with an acceptable by no leakage of air and met the reproducible with the variation less than 20% were used for analysis (9). The absolute values of maximal respiratory pressure were expressed as a percentage of predicted values according to sex and age following the equations of Neder et al. (10).

Cough ability was assessed by voluntary PEF using a digital spirometer (Micro Medical Ltd. (ML2525), United Kingdom). The measurement of PEF was obtained during a maximal inspiration, followed by a maximal and rapid explosive expiration. The values of the three satisfactory attempts with no difference between them more significant than 10% were used in the analysis (11). The absolute values were expressed as a percentage of predicted value proposed by Dejsomritrutai et al. (12) according to sex, age, and height.

Evaluations were performed in two times point, the day of admission and the day of discharge that nearly recovered from the surgical pain. All participants have received physiotherapy intervention once a day throughout the post-operative period, which is followed to the standard cardiac rehabilitation protocol that composed of breathing exercises, airway clearance techniques, early mobilization, exercise training, and ambulation training (13).

Statistical Analysis: The collected data were analyzed using SPSS (version 23). Paired t-test was used to compare the parameters between time points. Pearson's correlation was used to investigate the relationship between maximal respiratory pressure and PEF differences. Statistical significance was set at $p<0.05$.

Results

Characteristics of the participants are shown in Table 1. Out of 52 participants, the mean aged was 56.38±10.21 years with equally approximate numbers of males and females. The average body mass index and echocardiography were presented within normal ranges. The participants were diagnosed with valvular heart disease or coronary artery disease that had one or more, underlying with hypertension, diabetes mellitus, and dyslipidemia. The duration of hospital stay was approximately 6-8 days. The comparisons of maximal respiratory pressure and PEF between admission and discharge periods are shown in

Table 2. Comparison of MIP, MEP, and PEF between admission and discharge periods

	Admission	Discharge	p
MIP (cmH_2O)	71.12 ± 24.36	49.63 ± 20.45	< 0.001
MIP (%predicted)	82.01 ± 25.64	57.26 ± 22.55	< 0.001
MEP (cmH_2O)	76.02 ± 22.95	56.69 ± 18.75	< 0.001
MEP (%predicted)	72.35 ± 21.67	53.49 ± 16.26	< 0.001
PEF (L/min)	318.35 ± 98.95	244.75 ± 87.48	< 0.001
PEF (%predicted)	74.72 ± 19.24	57.18 ± 17.83	< 0.001

Data analyzed by Paired t-test
Values presented as mean ± standard deviation
MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; PEF: peak expiratory flow

Table 3. Correlation between change in MIP, MEP, and PEF

		ΔMIP (cmH2O)	ΔMIP (%predicted)	ΔMEP (cmH2O)	ΔMEP (%predicted)
ΔPEF (L/min)	r	0.891	0.877	0.588	0.473
	p	< 0.001	< 0.001	< 0.001	< 0.001
ΔPEF (%predicted)	r	0.805	0.843	0.573	0.546
	p	< 0.001	< 0.001	< 0.001	< 0.001

Data analyzed by Pearson's correlation; r: correlation coefficient; p: significance value
ΔMIP: difference of maximal inspiratory pressure; ΔMEP: difference of maximal expiratory pressure; ΔPEF: difference of peak expiratory flow

Table 2. Post-operative actual and predicted values of MIP, MEP, and PEF were lower than those evaluated preoperatively (all p<0.001). Table 3 summarizes the correlation between admission to discharge change (Δ) in respiratory muscle strength and PEF. There were significant positive correlations between ΔMIP and ΔPEF, and between ΔMEP and ΔPEF in both absolute and predicted values (all p<0.001). ΔMIP was more closely relative to ΔPEF than ΔMEP.

Discussion

The finding of this study was showed the correlation of MIP and MEP alteration with the change in PEF indicates that decreased the respiratory muscle strength after open-heart surgery was associated with the attenuated of cough ability.

In our results, respiratory muscle strength and PEF were significantly reduced in the post-operative period, which is similar to a study by Gimenes et al. (14). These reductions are related to intra-operative factors such as surgical manipulation, anesthesia, cardioplegic agents, thermal damage, cardiopulmonary bypass, and mechanical ventilation used. Also, post-operative pain is an essential factor responsible for a decrease of respiratory functions and cough ability by inducing immobilization and restrictive pulmonary pattern (4, 5).

This study demonstrated the significant correlation between the change in respiratory muscle strength and cough ability which is reaffirmed with the previous study that showed a significant association in neuromuscular (6, 15) and stroke patients (16). The reduction in PEF was more highly related to decrease in MIP than to fallen in MEP. To be an ineffective defense mechanism is caused by the insufficient volume of air inhaled during the deep inspiration phase of cough as a result of inspiratory muscle weakness. As well as the reduction of expiratory muscle strength leads to decrease intrathoracic pressures and expiratory flows during the compression and expulsion phases of cough by changed in the length-tension relationship of the expiratory muscles (7). Thus, it is necessary to conduct respiratory muscle training to improve respiratory muscle strength and cough ability. In particular, the increase in inspiratory muscle strength is highly relative to the improvement of an effective cough in these patients.

In conclusion, this study revealed that the patients who had undergone open-heart surgery with decreased maximal respiratory pressure would correlate with reducing voluntary expiratory peak flow. This finding could provide the potential rehabilitation target by respiratory muscle training to restore respiratory muscle strength and cough ability.

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Conflict of Interest Statement: None.

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