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Active cycle of breathing techniques and incentive spirometer in coronary artery bypass graft surgery

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Research Report

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Purpose: The purpose of this study was to evaluate the efficacy of incentive spirometer (IS) and active cycle of breathing techniques (ACBT) following coronary artery bypass graft (CABG) surgery. **Material and methods:** Sixty male patients (41-75 years) with CABG were included in this prospective randomized study. Thirty patients underwent ACBT and 30 patients underwent IS combined with mobilization. Patients were evaluated using pulmonary function tests, arterial blood gases, 6-minute walk test (6MWT), chest radiography, and a 10-cm visual analogue scale for pain perception. **Results:** Fifth day post-operatively, pulmonary function variables were similarly but significantly decreased in both groups compared to pre-operative values (vital capacity decreased 15% and 18% in ACBT and IS, respectively, $p<0.05$). First day post-operatively, there was significant increase in oxygen saturation after the treatments in both groups. Incidence of atelectasis and pain perception was similar between the groups ($p>0.05$). No significant difference was found in 6MWT distance obtained before and on the fifth day following CABG surgery within and between ACBT and IS groups ($p>0.05$). **Conclusion:** Both treatments improved arterial oxygenation from the first day post-operatively. After a 5-day treatment, functional capacity was well preserved with the usage of ACBT or IS. Both physiotherapy methods had similar effects on the rate of atelectasis, pulmonary function, and pain perception.

Key words: Physiotherapy, Coronary artery bypass surgery, Lung function tests, Exercise.

Koroner arter bypass greft cerrahisinde aktif solunum teknikleri döngüsü ve insentif spirometre

Amaç: Bu çalışmada koroner arter bypass greft (KABG) cerrahisinden sonra insentif spirometre (İS) ve aktif solunum teknikleri döngüsünün (ASTD) etkinliğinin değerlendirilmesi amaçlandı. **Gereç ve yöntem:** Bu prospektif randomize çalışmaya 60 erkek hasta (41-75) alındı. Mobilizasyonla kombine olarak 30 hastaya ASTD ve 30 hastaya İS uygulandı. Hastalar solunum fonksiyon testleri, arteryel kan gazları, 6 dakikalık yürüme testi (6DYT), göğüs radyografi ve ağrı algılaması için 10 cm'lik görsel analog skalası ile değerlendirildi. **Sonuçlar:** Postoperatif beşinci günde her iki grupta da solunum fonksiyonları preoperatif değerlerle karşılaştırıldığında anlamlı olarak azaldı (vital kapasite ASTD'de % 15, İS'de % 18 azaldı, $p<0.05$). Her iki grupta da postoperatif birinci gün oksijen satürasyonu tedaviyi takiben arttı ($p<0.05$). İki grupta atelektazi insidansı ve ağrı algılaması benzerdi ($p>0.05$). ASTD ve İS gruplarında KABG'den önce ve beşinci günde elde edilen 6DYT mesafesi arasında anlamlı bir farklılık saptanmadı ($p>0.05$). **Tartışma:** Her iki tedavi de postoperatif birinci günden itibaren arteryel oksijenasyonu artırdı. Beş günlük tedaviden sonra, ASTD veya İS'nin kullanımı ile fonksiyonel kapasite iyi bir şekilde korundu. Her iki fizyoterapi yöntemi atelektazi insidansı, pulmoner fonksiyon ve ağrı algılamasını benzer şekilde etkiledi.

Anahtar kelimeler: Fizyoterapi, Koroner arter bypass cerrahisi, Akciğer fonksiyon testleri, Egzersiz.

Post-operative pulmonary complications after coronary artery bypass graft (CABG) surgery are still a major cause of morbidity and mortality.[1,2] Impairment of pulmonary function,[3] and post-operative atelectasis[4] are common in patients with CABG.

Respiratory physiotherapy is routinely used in the prevention and treatment of post-operative pulmonary complications after cardiac surgery. The goals of physiotherapy are to improve ventilation–perfusion matching, increase lung volume, enhance mucociliary clearance, and decrease pain.[5] Post-operative physiotherapy techniques include early mobilization, change of position, breathing exercises, cough, huffing, active cycle of breathing techniques (ACBT) and various mechanical devices such as incentive spirometer (IS), positive expiratory pressure mask therapy and continuous positive airway pressure.[6-11] Early mobilization has been accepted as the most important therapy after surgery in the prevention and treatment of pulmonary impairment.[6,12] However, there is no absolute consensus for the most effective respiratory physiotherapy regime after CABG surgery.

IS and ACBT are commonly used techniques for the prophylaxis and treatment of respiratory complications in post-surgical patients.[13-15] Studies evaluating the effectiveness of IS following cardiac surgery have been unable to demonstrate the superiority of IS over breathing exercises, early mobilization, and intermittent positive pressure breathing.[6,11] Oulton et al.[16] compared the use of physiotherapy and two ISs and found that the group using a device requiring a preset volume goal had superior results.

ACBT can be adapted easily to a patient with different states. It can be used independently with or without the inclusion of manual techniques. It is an effective treatment in improving pulmonary function, airway clearance, and oxygenation.[17] The effectiveness of the ACBT has been evaluated in stable cystic fibrosis,[18] chronic obstructive pulmonary disease,[19] and acute respiratory failure.[20] However, there is no report related to its use in patients with CABG surgery. The purpose of this study was to evaluate the efficacy of ACBT and IS performed following CABG surgery. Lung function, radiographic changes, functional capacity, and pain perception were evaluated.

Material and methods

The study was conducted in a military academy hospital, for a 1-year period between May 2003 and May 2004. The institutional review board approved the study protocol. Inclusion criteria were elective CABG procedure, age of greater than 18 years, and an ejection fraction above 50%. Exclusion criteria were current smoking, a history of a cerebrovascular accident, renal dysfunction requiring dialysis, use of immunosuppressive treatments during the 30-day period before surgery, the presence of neuromuscular disorders or chronic obstructive pulmonary disease, or a history of previous open heart or pulmonary surgery, cardiovascular instability or an aneurysm. Eligible patients were randomly allocated to receive either ACBT or IS.

The following pre-operative risk factors were assessed: patient age, sex, body mass index, history of smoking, lung function, and functional capacity. Peri and post-operative characteristics including number of arteries that have been changed, amount of transfusion, total amount of drainage, duration of the drains, duration of intubation, perfusion, and aortic clamping were recorded. The Acute Physiology and Chronic Health Evaluation II (APACHE II) score was calculated in the first 24 hours of surgery.[21]

Pulmonary function tests were performed pre-operatively and on the fifth post-operative day using a spirometer (Minolta Autospiro AS-500, Japan). The vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and peak expiratory flow rate (PEF) were recorded. The highest value from at least three technically acceptable manoeuvres was expressed as the percentage of predicted value.[22]

To evaluate functional capacity, a 6-minute walk test (6MWT) was performed on level ground in an enclosed continuous hospital corridor 80 m long. Standardized phrases of encouragement were given in every 1-minute.[23] Patients were instructed to walk as far as possible in six minutes. The distance covered in six minutes was recorded as nearest meter at the end of the test. The percentage of predicted distance according to age, height, and weight was calculated for each patient.[24] Heart rate using Polar heart rate monitor (PF 3000 Polat Electro, Finland) and oxygen saturation were measured before and immediately after the walking test. The 6MWT was repeated on the fifth post-operative day.

Anteroposterior chest radiography was taken in the standing position pre-operatively and on the fourth post-operative day. Presence or absence of atelectasis, infiltration, pneumothorax, pleural effusion, and pulmonary edema were recorded. A radiologist who was unaware of the patient's randomization performed the evaluation. Size of the atelectasis seen on the chest radiograph was scored in the right and left lung separately. An arbitrary scale was used for scoring of atelectasis: 0: no abnormality, 1: unilateral plate like atelectasis, 2: unilateral lobar atelectasis, 3: bilateral plate like atelectasis, and 4: bilateral lobar atelectasis.[25]

Pain intensity was evaluated using a visual analogue scale (VAS). It was a line of 10 cm length representing the continuum of pain. The patients marked the line at a point corresponding to their estimate of pain (from the median sternotomy incision while taking a deep breath). The distance from zero reflected the intensity.[26]

The acute effects of the ACBT and IS were evaluated using arterial blood gases taken before and immediately after physiotherapy on the first post-operative day. Partial arterial oxygen pressure (PaO_2), partial arterial carbon dioxide pressure ($PaCO_2$), oxygen saturation (SaO_2), bicarbonate level (HCO_3), and arterial pH were analyzed with a blood gas analyzer (Nova Stad Profile, USA).

All patients received basic post-operative respiratory physiotherapy including breathing exercises, instructions in huffing and coughing techniques, mobilization, and active exercises of the upper limbs and thorax. Patients were mobilized as early as possible by the nursing staff and physiotherapists according to the ordinary routines. The patients were instructed to sit out of bed and stand up on the first post-operative day (2-3 times). They walked 30 m in the intensive care unit in the morning and 80 m on the ward in the afternoon on the first post-operative day. The patients walked in the room or short distance in the corridor on the second day (a 5-minute walk in 2-hour intervals from morning [8:00] to evening [20:00]). On the third post-operative day, they walked freely in the corridor. Active range of motion exercises were performed twice a day starting from the first post-operative day. They were repeated 10 times hourly if the patient could not walk due to continuous drug infusion or complications.

ACBT consisted of 1-2 breathing control breaths, three thoracic expansion exercises followed by a 3-second breath hold at the end of deep inspiration, and the forced expiration technique including 1-2 breathing control breaths combined with 1-2 huffs. Manual techniques were not included in ACBT. Sitting or high sitting positions were used during the treatment.[17] IS was applied as three deep breaths followed by a 3-second breath hold at the end of the deep inspiration. Afterwards, 1-2 huffing was performed with 1-2 breathing control.[7] On the first and the second post-operative days, treatment was applied twice a day, 15 minutes per session. From the third day following surgery, it was applied once a day for 15 minutes.

Statistical analysis:

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 10.0.[27] Data were presented as frequency distribution, percentages, and calculation of means and related standard deviations (mean±SD). Between group comparison was performed using Student t test. Paired t test was used to perform within group comparisons. Kruskal-Wallis test was used to compare the rate of atelectasis on the first, on the third, and on the fifth days following surgery. Pain perception on the post-operative days was analyzed using repeated measurement of analysis of variance. Statistical significance was defined as a value of $p<0.05$.

Results

Sixty male patients (41-75 years) with CABG were included in this study. All patients had left internal mammarian artery grafts. All patients were discharged from the hospital on the fifth post-operative day according to the hospital protocol. Thirty patients were in the ACBT group and 30 patients were in the IS group. Demographics and operative variables are presented in Table 1.

On the first post-operative day, both groups had mild arterial hypoxemia in the arterial blood gases. As an acute response to the treatment; pH, PaO_2 and SaO_2 increased and $PaCO_2$ decreased significantly in ACBT group and SaO_2 significantly improved in IS group ($p<0.05$). There were no significant differences in arterial blood gas values immediately after physiotherapy on the first post-operative day between the ACBT and IS groups ($p>0.05$) (Table 2).

Pre-operative pulmonary function test results were in the normal range. Five days post-operatively, all pulmonary function variables were significantly decreased in both groups compared to pre-operative values ($p<0.05$) (Table 3). The mean VC decreased significantly from pre-operative value by -15.01% (95% CI –18.75 to –11.26, p<0.001) in the ACBT group and by -17.95% (95% CI –20.98 to –14.92, p<0.001) in the IS group. The FVC reduced significantly by a mean of –16.73% (95% CI –20.57 to –12.88, p<0.001) in the ACBT group and by –21.85% (95% CI –26.49 to –17.21, p<0.001) in the IS group. The mean FEV_1 decreased significantly by –19.69% (95% CI –23.38 to –16.01, p<0.001) in the ACBT group and by –21.50% (95% CI –25.65 to –17.35, p<0.001) in the IS group. The PEF reduced significantly by a mean of –1.08 L/min (95% CI –1.74 to –0.42, p=0.002) in the ACBT group and by –1.33 L/min (95% CI –1.70 to –0.97, p<0.001) in the IS group on the fifth post-operative day.

Pre-operatively, during the 6MWT, the patients walked an average of 472.15 m (range, 260 to 690 m), which was 84.82% of their predicted values according to the regression equation proposed by Enright and Sherrill[24] in healthy subjects. On the fifth post-operative day, the patients walked an average of 462.13 m (range, 290 to 624 m), which was 83.18% of their predicted values. The mean 6MWT distance reduced –3.40 m (95% CI –18.17 to 11.37, p=0.64) in the ACBT group and by –16.63 m (95% CI –39.29 to 6.02, p=0.14) to the fifth day following CABG surgery. The mean percentage of predicted distance decreased by –0.55% (95% CI –3.09 to 2.00, p=0.67) in the ACBT group and by –2.73% (95% CI –6.70 to 1.23, p=0.17) in the IS group. No significant differences were found in 6MWT distance, percentage of predicted distance, heart rate, and oxygen saturation performed before and on the fifth day following CABG surgery between the groups ($p>0.05$) (Table 3).

Pain perception from the sternotomy measured using VAS while the patient took a deep breath was decreased significantly throughout the post-operative days in both groups ($p<0.05$) (Figure 1). The mean VAS score decreased significantly from the first post-operative day by –4.37 cm (95% CI –4.68 to –4.07, p<0.001) in the ACBT group and by –4.17 cm (95% CI –4.37 to –3.98, p<0.001) to the fifth day following CABG surgery. However, no significant difference in pain perception was found between the ACBT and IS treatment ($p>0.05$) (Figure 1).

No patients showed signs of atelectasis before the operation. On the first post-operative day atelectasis was found in 22 (73.3%) patients in the ACBT group and 23 (76.7%) patients in the IS group (p=0.77). On the third post-operative day, atelectasis was found in 18 (60.0%) patients in the ACBT group and 19 (63.3%) patients in the IS group (p=0.79). On the fifth post-operative day, atelectasis was found in 10 (33.3%) patients in the ACBT group and 9 (30.0%) patients in the IS group (p=0.78, Table 4). There were no significant differences in the distribution of the atelectasis throughout the post-operative days ($p>0.05$) (Figure 2). There was no infiltration, pneumothorax or pulmonary edema on chest x-ray.

Discussion

We showed that ACBT and IS combined with early mobilization had similar effects on lung function, rate of atelectasis, pain perception, and functional capacity after coronary artery bypass surgery. Although lung function decreased, functional capacity was well preserved after a 5-day treatment program consisting of ACBT or IS combined with mobilization.

Table 1. Demographics and operative variables.

	ACBT (N=30)	IS (N=30)	
Age (years)	55.2±8.5	57.2±8.9	*
Height (cm)	170.6±5.9	168.8±5.7	*
Body weight (kg)	76.7±9.9	74.9±10.5	*
Body mass index (kg/m^2)	26.3±3.1	26.2±3.3	*
Smoking (pack-years)	24.9±27.1	20.4±21.2	*
Duration of intubation (hours)	7.6±2.9	9.0±2.9	*
Duration of drains (hours)	20.2±2.1	20.4±2.0	*
Amount of transfusion (cc)	771.7±193.3	761.0±166.1	*
Aortic occlusion time (hours)	35.5±12.8	33.8±16.2	*
APACHE II	6.9±1.9	7.6±2.5	*

* p>0.05. ACBT=Active Cycle of Breathing Techniques, IS=Incentive Spirometer, APACHE II=Acute Physiology and Chronic Health Evaluation II.

Table 2. Arterial blood gases before and immediately after the active cycle of breathing techniques and incentive spirometer on the first day following coronary artery bypass surgery.

	ACBT (N=30)			**IS (N=30)**		
	Preoperative	**Postoperative**		**Preoperative**	**Postoperative**	
pH	7.50±0.03	7.52±0.03	*	7.50±0.03	7.50±0.02	
$PaCO_2$ (mmHg)	35.78±4.83	35.12±5.02	*	35.33±4.33	34.81±4.83	
HCO_3 (mEq/L)	28.85±3.37	28.98±3.64		28.92±4.81	28.64±4.69	
PaO_2 (mmHg)	75.66±20.13	79.69±18.26	*	73.33±14.07	76.08±13.69	
SaO_2 (%)	93.03±5.39	94.59±4.33	*	94.47±1.92	95.74±2.13	*

ACBT: active cycle of breathing techniques, IS: incentive spirometer, $PaCO_2$: arterial carbondioxide pressure, HCO_3: bicarbonate level, PaO_2: arterial oxygen pressure, SaO_2: oxygen saturation. * p<0.05, between pre and postoperative.

Table 3. Pulmonary function and 6-minute walk test data before and on the fifth day following coronary artery bypass surgery.

	ACBT (N=30)			**IS (N=30)**		
	Preoperative	**Postoperative**		**Preoperative**	**Postoperative**	
Lung function test						
VC (% pred)	72.77±12.54	57.76±9.47	*	71.13±12.90	53.18±13.60	*
FVC (%)	79.90±12.62	63.17±11.65	*	79.45±13.82	57.60±14.17	*
FEV_1 (%)	84.67±10.08	64.98±12.95	*	78.76±17.27	57.26±14.60	*
PEF (L/min)	6.98±2.04	5.90±1.96	*	5.87±1.54	4.54±1.44	*
6-min walk test						
Δ Heart rate (beats/min)	3.70±5.56	4.30±3.22	*	3.20±2.28	4.13±2.19	*
Distance (m)	472.40±134.67	469.00±114.36	*	471.90±81.29	455.27±56.85	*
% Predicted distance	83.06±22.61	82.52±19.53	*	86.57±15.78	83.84±13.78	*
Δ Oxygen saturation (%)	0.13±2.11	0.30±2.17	*	0.73±1.86	0.53±2.08	*

ACBT: active cycle of breathing techniques, IS: incentive spirometer, VC: vital capacity, FVC: forced vital capacity, FEV_1: forced expiratory volume in one second, PEF: peak expiratory flow rate. * p<0.05, between pre and postoperative.

Table 4. The rate of roentgenological signs of atelectasis in the left or right lung on post-operative days after coronary artery bypass surgery (n).

	ACBT (N=30)			IS (N=30)		
	Day 1	Day 3	Day 5	Day 1	Day 3	Day 5
No abnormality	8	12	20	7	11	21
Unilateral plate atelectasis	19	16	9	19	18	9
Bilateral plate atelectasis	3	2	1	4	1	0

ACBT: active cycle of breathing techniques, IS = incentive spirometer.

Figure 1. Visual analogue scale (VAS) scores for pain due to sternotomy between active cycle of breathing techniques and incentive spirometer.

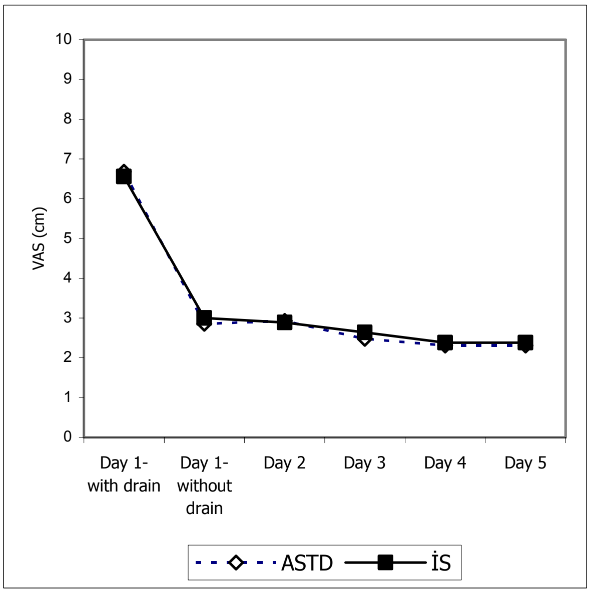
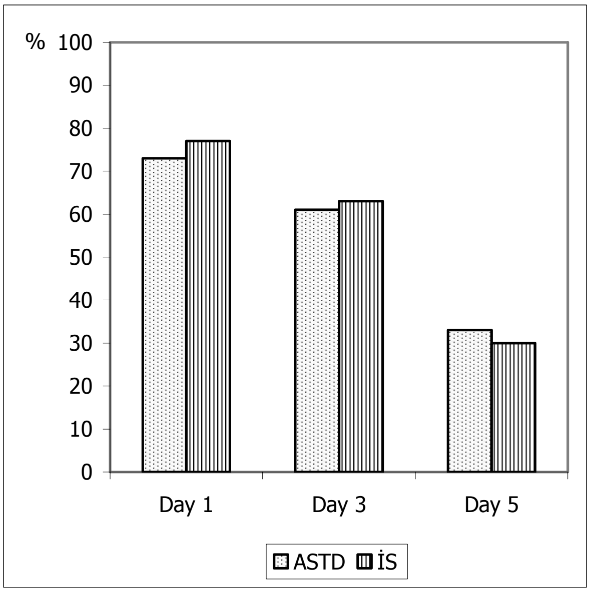


Figure 2. Incidence of atelectasis throughout the post-operative days in the active cycle of breathing techniques and incentive spirometer.



Some studies have shown that the addition of breathing exercise or IS to early mobilization program has no extra benefit following uncomplicated CABG.[5,6,12] In a recent study, Westerdahl et al.[28] have found that performance of 30 deep breaths performed as deep breathing exercises, inspiratory resistance-positive expiratory pressure or blow bottle, decreased atelectatic area and increased aerated lung area in computerized tomography after cardiac surgery in 61 patients. They also showed a small increase in PaO_2 after deep breathing exercises. Blaney et al.[29] found a significant increase in diaphragmatic displacement when deep breathing exercises were performed with tactile stimulation over subject's lower costal margin in addition to verbal instruction. In addition, deep breathing exercises are advocated to improve tidal volume and facilitate secretion removal.[17,29] In this study, we found that arterial oxygenation increased and $PaCO_2$ decreased significantly after a single ACBT, and SaO_2 increased significantly after a single IS session on the first post-operative day of CABG surgery. This finding revealed that both ACBT and IS had a similar and favourable effect on alveolar ventilation. Probably, deep-breathing exercises may allow air to flow via collateral channels, and air behind secretions may assist in mobilizing them.[30] Also, 3-second hold at full inspiration may decrease collapse of lung tissue.[31]

In our study, the pulmonary function after CABG reduced in both treatment groups on the fifth post-operative day, with a mean 53-65% of the pre-operative values. Crowe and Bradley[11] investigated effects of physiotherapy (mobilization, sustained maximal inspiratory manoeuvres, secretion removal manoeuvres, and supported/assisted coughing) combined with IS which showed that FEV_1 and FVC decreased 50% of the pre-operative values on the second and third post-operative days of CABG surgery. Westerdahl et al.[25] found that pulmonary function reduced on the fourth post-operative day of CABG with 60-75% of the pre-operative values. In a recent systematic review, Pasquina et al.[32] reported that VC was 37-72% of pre-operative values in 11 trials and FEV_1 were 34-72% in eight trials of pre-operative values for cardiac surgery. The reduction in pulmonary function in our study is similar to what have been shown in previous studies investigating the effects of physiotherapy treatment programs on the fifth post-operative day after open-heart surgery.

Westerdahl et al.[25] have found atelectasis in 67% of their patients on the fourth post-operative day, and found no difference in atelectasis rate among three different physiotherapy techniques, including deep breathing exercises, inspiratory resistance-positive expiratory pressure or blow bottle. Crowe and Bradley[11] showed 95% on the second post-operative day, and 58% on the third post-operative day in their high risk patients with the application of IS combined with physiotherapy (mobilization, sustained maximal inspiratory manoeuvres, secretion removal manoeuvres, and supported/assisted coughing). Jenkins et al.[6] found atelectasis in 74% of their patients in deep breathing or IS group and in 74% of their patients in mobilization group on the first post-operative day. In their systematic review of 14 studies, Pasquina et al.[32] reported a 15-98% atelectasis rate in 1266 patients. In our study, we found atelectasis in 75% of our patients on the first post-operative day, 62% on the third, and 32% on the fifth post-operative days. The discrepancy in the incidence of atelectasis is probably due to different days of measurement,[6,11,25,28] presence or absence of other post-operative complications[6,11,13] and the methodological differences in the applications of physiotherapy techniques or programs.[6-12,25]

Usage of anesthesia, intraoperative conditions, usage of internal mammarian artery graft, changes in thorax mechanics, and pain are the factors causing restrictive pulmonary dysfunction and atelectasis in patients with CABG. Sternal pain affects the performance in coughing and deep breathing after surgery.[5,33] In the present study, we found that pain perception during ACBT and IS application was similar. In addition, we showed a similar decrease in sternal pain perception from the first to the fifth post-operative days.

Early post-operative mobilization has been shown to increase lung volume, improve ventilation/perfusion matching, and mobilize secretion.[34] In post-acute and chronic cardiopulmonary dysfunction, impaired oxygen transport results in a deteriorated functional work capacity,[35] and exercise capacity is one of the major concerns in post-operative recovery.[36] Maximal oxygen uptake measured during a standard treadmill or bicycle test is the best available method to assess aerobic exercise capacity. Because these tests require significant effort or special skills from the patients, timed walked tests have become a common method to determine functional capacity.[23] To our knowledge, only one study used 6MWT after cardiac surgery to provide reference values for defining disability.[37] In this study, we used 6MWT to assess the efficacy of the ACBT and IS intervention combined with mobilization after CABG in terms of effectiveness of functional capacity. Pre- and post-operative 6MWT distances were 84% and 83%, respectively, of predicted distances according to the reference equation by Enright and Sherill.[24] They were in the normal range because a walking distance <82% of predicted is considered abnormal.[38]

In conclusion, we found that ACBT and IS improved arterial oxygenation from the first day of the CABG surgery. In addition, we showed that ACBT and IS combined with mobilization could be used safely from the early period after cardiac surgery. After a 5-day treatment, both physiotherapy methods similarly decreased the rate of atelectasis, and they had similar effects on pulmonary function, and pain perception; and functional capacity was well preserved. Characteristics of the patients who need intensive physiotherapy, and effects of specific methods on these patients need to be determined.

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