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Expiratory muscle training versus incentive spirometry after colorectal surgery

Pulmonary rehabilitation after colorectal surgery

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Abstract
Aim: The aim of this study was to compare the effects of expiratory muscle training (EMT) and incentive spirometry (IS) after colorectal surgery.
Material and Methods: Twenty-four individuals (13 were males) undergoing colorectal surgery were included. They were randomly divided into two groups. In addition to conventional chest physiotherapy, Group 1 was performed EMT (n=12), Group 2 was performed deep breathing exercises with IS in postoperative period. Respiratory muscle strength, functional capacity, levels of movement and independence, and postoperative pulmonary complications (PPC) were evaluated. Length of stay in hospital (LOS) was recorded.
Results: Respiratory muscle strength, increased in both groups after treatment ($p<0.05$), but there was no difference between the groups ($p>0.05$). Functional capacity decreased in both groups, and there was no difference between the groups ($p>0.05$). PPC did not develop, and the LOS of the groups was similar ($p>0.05$). Mobility and independence levels improved in both groups at discharge ($p<0.05$), but there was no difference ($p>0.05$).
Discussion: IS and EMT in addition to pulmonary rehabilitation improve respiratory muscle strength, have no side effects, and can be easily used in the clinic as alternatives to each other after colorectal surgery.

Keywords
Colorectal Surgery, Respiratory Muscle, Expiratory Muscle Training, Pulmonary Rehabilitation

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Introduction

Pulmonary complications are one of the most important causes of postoperative morbidity and mortality. Its incidence after surgery is 6-76%, and it depends on the characteristics of anesthesia, the type of surgery, the condition of the patient before surgery, and the type of complication. In abdominal surgeries, this rate varies between 25-80% [1,2].

Pulmonary rehabilitation is frequently used to prevent postoperative pulmonary complications (PPC). It aims to provide deep inspiration after surgery by using breathing exercises or assistive devices, to achieve a normal breathing pattern, to maintain normal muscle tone and to regulate blood circulation with active participation in exercises and to provide early independent mobility. Secretion clearance accumulated in the airways is ensured by coughing, postural drainage, and manual drainage techniques. Thus, atelectasis is prevented and the risk of infection of the lungs reduces [3].

The surgeries with the highest PPC are thoracic and upper abdominal surgeries. There is a direct correlation between the proximity of the incision to the diaphragm and PPC [4, 5]. It takes two weeks for diaphragmatic functions to return to normal after upper abdominal surgery. Insufficient coughing and postoperative pulmonary restriction and the development of PPC are associated with this process. During abdominal surgery, effective coughing is adversely affected, and secretion clearance is impaired due to the severing of the major abdominal muscles [2]. In colorectal surgeries, the integrity of the rectus abdominis, external obliques, internal obliques, and transversus abdominis muscles, which are forced expiratory muscles, is disrupted using a vertical incision [6]. The strength of these muscles has great importance in increasing the quality of coughing and clearing secretions. Therefore, it is necessary to train the respiratory muscles, especially the expiratory respiratory muscles. Previously, respiratory muscle training (RMT) studies on neuromuscular diseases, chronic obstructive pulmonary disease, pre- and post-thoracic surgery, congestive heart failure and abdominal surgeries have been performed. However, postoperative studies have focused on inspiratory muscle training [7].

The aim of this study was to compare the effects of expiratory muscle training (EMT) and incentive spirometry (IS) in addition to conventional pulmonary rehabilitation after colorectal surgery.

Material and Methods

Twenty-four individuals who underwent colorectal surgery at Pamukkale University General Surgery Department were included in the study. The study protocol was approved by Pamukkale University Non-Invasive Clinical Research Ethics Committee (60116787-020/47012) on 10/07/2018 and registered at Clinicaltrials.gov (Identifier: NCT0529480). All individuals were informed, and consent was obtained. The study was designed as a 1:1 parallel group and randomized controlled trial. Participants were divided into two groups using the sealed envelope method. Treatment and evaluation were performed by two different physiotherapists. The assessing physiotherapist was blind to group allocation. In addition to conventional chest physiotherapy postoperatively, Group 1 underwent EMT (n=12), Group 2 underwent deep breathing exercises with IS (n=12).

Subjects aged 18 years and older, hemodynamically stable, able to walk independently, cooperative, and oriented volunteers were included in the study. Subjects who had any contraindication for chest physiotherapy (unstable cardiovascular disease, severe pulmonary hypertension, corrected severe hypoxemia, exercise desaturation, rib fractures, subcutaneous emphysema, advanced osteoporosis, thrombocytopenia, effort dyspnea and vertigo), any metastases, subjects with severe chronic cardiovascular disease, candidates for organ transplantation, requiring abdominal hernia repair, history of surgery more than one year, or orthopaedic or neurological disease that would prevent independent walking were excluded from the study.

Measurements

The respiratory muscle strength of subjects was evaluated preoperatively, postoperatively and before discharge. Maximum inspiratory pressure (PImax) and maximum expiratory pressure (PEmax) were measured using an additional mouth apparatus attached to the portable spirometer 'Pony FX Desktop Spirometry' device [8].

Physical function levels were evaluated with the '6 Minute Walk Test' (6MWT) before surgery and before discharge [9].

The 'Patient Mobility and Observer Mobility Scale' (PMOMS), developed by Heye et al. [10], was used to evaluate patient perceptions and objective observations regarding postoperative mobility and independence levels. The global score of 'patient mobility' and 'observer mobility' was recorded. Evaluation was done in the postoperative and pre-discharge periods.

PPC determination was evaluated with the "Melbourne group scale version-2" in the postoperative period until the patient was discharged [11].

Intervention

Patients who were transferred to the general surgery department after 24 hours of intensive care following surgery were included in the study. On day 2, intervention was started, if the subjects were stable. Preoperatively, the subjects were informed and educated about the postoperative physiotherapy program. Conventional pulmonary physiotherapy (postoperative respiratory control, diaphragmatic breathing, local expansion exercises, bronchial hygiene techniques, effective coughing, posture exercises and early mobilization) was performed once a day by the same physiotherapist until discharge. In addition, EMT was performed with the "Threshold Expiratory Muscle Trainer" (Respironics New Jersey Inc.) device for 3 sets of 10 repetitions, 6 times/per day until discharge in Group 1.

In Group 2, active inspiration was performed with an IS device, 10 repetitions of 3 sets 6 times/per day until discharge. General surgeon, blinded to the groups, decided to discharge.

EMT was performed 5 days a week at 10-30% of the PEmax. The training was continued by increasing 2 cmH2O per day according to the tolerance of the subjects. Participants rested in an upright sitting position for 1-2 minutes after 10 breaths through the Threshold device.

Statistical analysis

Statistical Package for Social Sciences (SPSS, IBM, Armonk, NY, USA) 21.0 program was used for data analysis. The previous study used a large effect size (d= 1.08) for discharge PEmax in independent groups. This effect size was used to calculate sample size; At least 12 individuals were required for each group, with a 95% power and a significance value of 0.05 [11]. In independent group comparisons, when parametric test assumptions are provided, analysis of variance in repeated measures and significance test of the difference between two peers: Friedman and Wilcoxon's tests were used for nonparametric variables. Significance test of the difference between two means in parametric data was used in independent group comparisons; The Mann-Whitney U test was used for nonparametric data. The difference between qualitative variables was examined by chi-square analysis.

Ethical Approval

Ethics Committee approval for the study was obtained.

Results

The flow diagram of the study is shown in Figure 1. Twenty-eight subjects were evaluated in the preoperative period, and 24 patients aged 18 years and older were included in the study. Socio/demographics of the subjects are given in Table 1. There was no significant difference between the two groups at baseline characteristics.

Subjects stayed in the intensive care unit for 1 day after surgery. The surgical characteristics are shown in Table 2.

There was no statistically significant difference between the groups in PImax and PEmax preoperatively, but 2 days after surgery they significantly decreased in both groups. Pre-discharge PImax and PEmax increased significantly in both groups compared to the postoperative period, but no significant difference was observed between the groups (Table 3).

There was no significant difference in preoperative 6MWT distances between the groups. Although the 6MWT distances before discharge decreased significantly in both groups compared to the preoperative period, there was no significant difference between the groups (Table 3).

The mobility and independence levels of the individuals were compared, and no significant difference was found between the two groups in the 'Patient Mobility Score'
and 'Observer Mobility Score' in the postoperative and pre-discharge periods (Table 3).

Any PPC was not observed in both groups. The mean hospital stay was 7.41±2.46 days in the EMT group and 8.33±2.3 days in the IS group. There was no significant difference between the two groups in the length of hospital stay and the percentages of persistence (Table 2).

Discussion

In our study, we compared the effect of expiratory muscle training (EMT) and incentive spirometry (IS) in addition to conventional physiotherapy after colorectal surgery. While there was a significant increase in respiratory muscle strength in both groups compared to the post-operative period, there was no statistically significant difference between the groups. Functional capacity decreased significantly in both groups after colorectal surgery and did not reach the preoperative level at discharge. Although there was a significant increase in the levels of mobility and independence in both groups after the treatment compared to the postoperative period, there was no statistical difference between the groups.

Table 1. Baseline characteristics

Variables	EMT (n = 12)	IS (n = 12)	p
	Mean ± SD	Mean ± SD	
Age (year)	61.75 ± 7.49	56.41 ± 12.54	0.222*
Height (cm)	161 ± 9.14	167.16 ± 7.84	0.912*
Weight (kg)	75.83 ± 16.83	72.41 ± 10.98	0.554*
BMI (kg/m²)	29.14 ± 5.29	26 ± 4.31	0.131*
Smoke (box/year)	0	6.08 ± 15.32	0.149**
Smoke history	n (%)	n (%)	
Yes	0	2 (16.6)	0.239***
No	12 (100)	10 (83.4)	
Gender			
Male	6 (50)	7 (58)	0.512***
Female	6 (50)	5 (42)	
ASA			
1	3 (25)	6 (50)	0.227***
2	9 (75)	6 (50)	

EMT: expiratory muscle training, IS: Intensive spirometry, BMI: Body mass index,
*: independent t-test, **: Mann-Whitney U test, ***: Chi-Square test

Table 2. Surgery characteristics of both group.

Variables	EMT (n = 12) n (%)	IS(n = 12) n (%)	p
Preoperative diagnosis			
Rectum tumor	3 (25)	3 (25)	
Colon tumor	9 (75)	7 (58)	0.327***
Anal fistula	0	2 (17)	
Surgery type			
Hemicolectomy	5 (42)	4 (33.3)	
Total colectomy	1 (8)	1 (8.7)	0.910***
Rectum low anterior resection	6 (50)	7 (58)	
	Mean ± SD	Mean ± SD	
Anesthesia duration (min)	165.33 ± 48.31	172 ± 48.21	0.738*
Length of hospital stay (day)	7.41 ± 2.46	8.33 ± 2.3	0.66**
Treatment participation (%)	84.41 ± 18.9	87.33 ± 12.3	0.811**

*: independent t- tes, **: Mann-Whitney U test, ***: Chi-square test

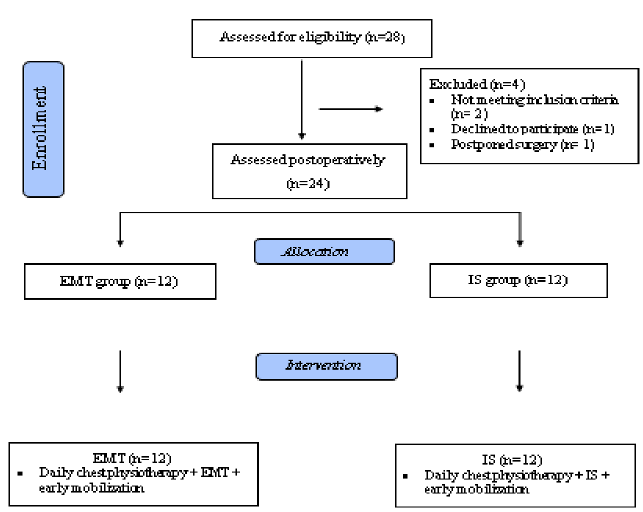

Figure 1. Study flow diagram

Table 3. Preoperative values of both group, change of discharge and postoperative values compared to the preoperative period.

Variables	EMT (n = 12)			IS (n = 12)				p
	Preoperative Mean±SD	Postoperative (compare to preoperative) Mean±SD	Discharge (compare to preoperative) Mean±SD	Preoperative Mean±SD	Postoperative (compare to preoperative) Mean±SD	Discharge (compare to preoperative) Mean±SD	Change between groups (%95 CI) Mean±SD	
PImax (cmH2O)	73.25 ± 20.7	-34.33±4.7***	-15.75±14.6**	67.5 ± 34.3	-33.66±6.8***	-14.16 ± 19.8*	1.59 (-13.1; 16.3)	0.826
PEmax (cmH2O)	77 ± 24.17	-42.16 ± 6.4**	-27.20±20.63**	69.75±28.93	-42.5 ± 6.9***	-28.83 ± 21.6**	1.63 (-19.7; 16.08)	0.834
6MWT (m)	437 ± 78.4		-88.43 ± 43	439.47±80.6		-120.23 ± 60.19	31.8 (76.08;12.4)	0.456
		Postoperative	Discharge (compare to postoperative)		Postoperative	Discharge (compare to postoperative)		
Patient mobility score (cm)		21.04 ± 10.3	-10.4 ± 12.49*		32.13 ± 16.6	-20.67 ± 16.23**		0.97
Observer mobility score		6.58 ± 2.5	-1.75 ± 0.49*		8.33 ± 2.7	-3.41 ± 0.77**		0.155

EMT: Expiratory muscle training, IS: Incentive spirometer, 6MWT: 6 Minute walk test, PImax: maximum inspiratory pressure, PImax: maximum expiratory pressure, ***: p <0.05, **: p <0.01, ***: p <001 (significance within groups).

Post-operative PPC did not occur in any of the participants

In the literature, studies on respiratory muscle training focused on inspiratory muscle training. Although there are studies on expiratory muscle training in diseases such as stroke, cardiac surgery, and multiple sclerosis, there is no study that specifically applied expiratory muscle training in colorectal surgeries [13-16]. Onerup et al. [17] applied inspiratory muscle training (IMT) in the preoperative period in colorectal surgery and only informed the subjects about use of PEP device together with respiratory exercises in the postoperative period, but did not apply progressive expiratory muscle training. In our study, EMT was performed progressively according to the measured PEmax and patient tolerance until discharge. In the previous studies on respiratory training, exercise intensity was generally performed by starting with 30-60% of PImax and PEmax values and increasing it daily or weekly [7,16]. In our study, it was started at 10-30% of the PEmax and increased by 2 cmH2O daily. Respiratory muscle training applied in cardiac surgery, neurological diseases and abdominal surgeries has been reported to increase PImax and PEmax [13, 18-20]. In major abdominal surgeries, including colorectal surgeries, RMT was usually limited to IMT only and was performed in the preoperative period. It has been reported as the reason of the previous studies that the inspiration can be made actively by the respiratory muscles, while the expiration can be done passively. As a result of these studies, it was reported that respiratory muscle strength increased after RMT [15,17]. In our study, expiratory muscle training was applied for active expiration and effective coughing, better secretion clearance and less PPC. As a result, expiratory muscles strength improved.

Intensive spirometry is frequently used in clinics after surgery. Previous studies have reported that IS increases respiratory muscle strength after surgery [21,22]. In our study, IS was used in addition to conventional physiotherapy, and it was found that it increased respiratory muscle strength as well as EMT. Our results were similar to previous studies. However, no significant difference was found between the two groups. Based on this result, it can be thought that IS and EMT have similar effects. In addition, this study showed that EMT can significantly increase PImax without the need for inspiratory muscle training.

Functional capacity measured with the 6MWT decreased in both groups and did not reach the preoperative level. Savcı et al. [23] reported that 6MWT distance decreased in the postoperative period compared to the preoperative period in the IS group. When the studies that included RMT were examined, it was focused on the effect of IMT on functional capacity. Studies on EMT after surgery are limited. There is no previous study examining the effect of postoperative EMT on functional capacity. In our study, the reason for the decrease in functional capacity may be the inadequacy of the short-term effects of the trainings during the hospital stay. In addition, it has been reported in the literature that 2/3 of the subjects did not reach their preoperative functional capacity levels even 9 weeks after the abdominal surgery [24]. We think that the surgical operation has a negative effect on the functional capacities of the participants.

The 'Patient Mobility and Observer Mobility' scale was used to determine the postoperative independence and mobility levels of the participants. Within the group, observer mobility and patient mobility scores decreased before discharge compared to the postoperative period in both groups. But no significant difference was found between the groups. Gürler and Yılmaz [25] reported that 390 participants were evaluated after surgery and reported that subjects had difficulties in behaviours such as coughing, breathing, getting out of bed, and moving due to pain, and therefore their independence during movement decreased. Savcı et al. [23] reported that after coronary artery bypass graft surgery, the pain decreased in the IS group, Crisafulli et al. [14] reported that the pain decreased in the EMT group compared to the sham group in their study of cardiothoracic surgery. In our study, it was found that the pain felt during the movements of turning in the bed, sitting on the side of the bed, standing up and walking in the hospital room in all participants in the post-surgical period decreased significantly and no PPC were observed. The improvement in movement and independence scores at discharge may be associated with a decrease in pain levels and the absence of PPC. These results are similar to previous studies.

The strength of our study, in which we examined the effectiveness of EMT after colorectal surgery, is that it is one of the few studies in which respiratory muscle training was applied after colorectal surgeries. Most studies provided training in the preoperative period. Contrary to the previous studies that focused on inspiratory muscle training, we applied EMT in postoperative period. Our study was a randomized controlled study. To our knowledge, there is no study in which EMT has been applied after colorectal surgery. Our study is pilot work on this topic. The limitations of the study are that physical therapy is routine and there is no group that was not applied any physical therapy due to ethical reasons. This should be considered when planning further studies.

Conclusion

Expiratory muscle training in addition to conventional chest physiotherapy after colorectal surgery increased respiratory muscle strength, improved mobility, and independence levels, prevented postoperative pulmonary complications, did not affect functional capacity, and did not have any superiority in these parameters compared to the incentive spirometry. We think that both interventions do not have any side effects and can be used as alternatives to each other. We recommend that clinicians add expiratory muscle training to the treatment program after colorectal surgery. We think that more studies are needed due to the limited number of studies on expiratory muscle training after colorectal surgery, and the studies are focused on inspiratory muscle training. Not only respiratory muscle training, but also endurance training should be investigated before and after colorectal surgery. Long-term follow ups will also be advisory.

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Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest
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