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Inspiratory Muscle Training in High-Risk Patients Following Lung Resection May Prevent a Postoperative Decline in Physical Activity Level

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Abstract

Objectives. To describe postoperative self-reported physical activity (PA) level and assess the effects of 2 weeks of postoperative inspiratory muscle training (IMT) in patients at high risk for postoperative pulmonary complications following lung resection. *Methods*. This is a descriptive study reporting supplementary data from a randomized controlled trial that included 68 patients (mean age = 70 ± 8 years), randomized to an intervention group (IG; n = 34) or a control group (CG; n = 34). The IG underwent 2 weeks of postoperative IMT added to a standard postoperative physiotherapy given to both groups. The standard physiotherapy consisted of breathing exercises, coughing techniques, and early mobilization. We evaluated self-reported physical activity (Physical Activity Scale 2.1 questionnaire) and health status (EuroQol EQ-5D-5L questionnaire), assessed the day before surgery and 2 weeks postoperatively. *Results*. A significant percentage of the patients in the IG reported less sedentary activity 2 weeks postoperatively when compared with the CG (sedentary 6% vs 22%, low activity 56% vs 66%, moderate activity 38% vs 12%, respectively; *P* = .006). The mean difference in EQ-5D-5L between the IG and CG 2 weeks postoperatively was nonsignificant (*P* = .80). The overall preoperative EQ-5D-5L index score for the study population was comparable to a reference population. *Conclusion*. Postoperative IMT seems to prevent a decline in PA level 2 weeks postoperatively in high-risk patients undergoing lung resection. More research is needed to confirm these findings.

Keywords

lung cancer, surgery, activity level, respiratory muscle training, postoperative, physiotherapy, randomized controlled trial

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Background

Lung resection is currently the main curative intervention for patients with early-stage non–small-cell lung cancer (NSCLC).[1] Furthermore, surgery may also be performed to obtain a diagnosis when lung cancer (LC) is suspected. Surgical outcomes have improved because of developments regarding early disease detection,[1] the use of less-invasive surgical techniques such as video-assisted thoracoscopic surgery (VATS),[2] and the optimization of perioperative and postoperative care via fast-track pathways.[3] However, surgery is still associated with a high incidence of postoperative pulmonary complications (PPCs), particularly in patients with comorbid conditions such as chronic obstructive pulmonary disease (COPD) and elderly individuals.[4] Besides being a clinical marker for decreased survival,[5] PPC is associated with a longer length of hospital stay (LOS)[6] and may have a negative influence on the patient's ability to resume usual daily physical activity (PA).[6]

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Descriptive studies have shown a decline in postoperative PA. Novoa et al[7] reported on a decrease in the time and quality of daily ambulatory activity 1 month after major lung resection, whereas Granger et al[8] described a decline in PA in a mixed LC population (surgically and nonsurgically treated) 10 weeks after diagnosis. A postoperative decline in PA may affect early recovery, as demonstrated by Agostini et al,[6] who reported that less-active patients had a longer hospital stay and a higher incidence of PPC (16%) following thoracotomy and lung resection. Bearing in mind that physically active patients after LC surgery survive an average of 4 or more years, compared with those who are not physically active,[9] it could be of value to develop strategies and interventions to mitigate the impact of lung resection on postoperative PA to improve the clinical outcome.

There is general lack of evidence to support the use of routine prophylactic, targeted, postoperative respiratory physiotherapy in the general population following LC surgery.[10] Preoperative inspiratory muscle training (IMT) has been shown to significantly improve respiratory muscle function and decrease PPC and LOS following cardiac, pulmonary, or upper-abdominal surgery.[11,12] However, in some countries, because of the implementation of a fast-track set up for patients referred to LC surgery, resulting in a short time between referral and surgery,[13,14] preoperative IMT[13] or a preoperative exercise training program[14] may not feasible. There is emerging evidence that patients at high risk of PPC may profit from specific breathing exercises, when added to physiotherapy protocols in the postoperative period. It has been suggested that incentive spirometry may decrease the frequency of PPC in a subgroup of patients, defined by ≥2 risk factors (age ≥75 years, American Society Anesthesiologists Score ≥3, COPD, smoking status, and body mass index ≥30 kg/m^2).[15] IMT has also been shown to increase oxygenation up to 5 days after the surgery.[16] However, there is currently no evidence whether improved pulmonary function can influence the recovery of PA postsurgery. Therefore, this study aimed to evaluate the effect of IMT on self-reported PA in patients at high risk of PPC 2 weeks after lung resection. Secondarily, we aimed to identify potential predictors of enhanced recovery of PA level and to assess general health status. We hypothesized that postoperative IMT in addition to standard physiotherapy would mitigate a decline in PA level following hospital discharge, when compared with patients receiving standard physiotherapy alone.

Methods

This study reports on supplementary data from a randomized controlled trial (Trial registration: Clinicaltrials.gov: NCT01793155) performed in the Department of Cardiothoracic Surgery, Aalborg University Hospital, Denmark, between November 2012 and April 2014. The study design, randomization procedures, methods, and potential harms have been described previously.[16] Briefly, those eligible to participate were patients at high risk for developing PPC following lung resection as a result of LC or diagnostic lung resections, who met one of the following criteria: forced expiratory volume in 1 s (FEV_1) or carbon monoxide diffusion capacity (D_{LCO}) ≤70%, age ≥70 years, or scheduled pneumonectomy. Exclusion criteria were physical or mental deficits adversely influencing physical performance, inability to understand the written and spoken Danish language, previous ipsilateral lung resection, verified tumor activity in other sites or organs, Pancoast tumor, or major surgery within 1 year.

Perioperative Management

Lung resections were performed either by VATS or through a muscle-sparing lateral or posterolateral thoracotomy (preserving musculus latissimus dorsi and serratus anterior). The choice of surgical approach was at the discretion of the surgeon. A single chest tube connected to a suction system (Thopaz digital chest drainage system, Medela, Baar, Switzerland), with negative pressure of 5 to 10 cm H_2O was placed in the pleural space at the end of the surgery. Pain management was in general achieved by continuous epidural infusion of bupivacaine/sufentanil for 3 days together with tablets (T) of paracetamol 1 g ×4. Following discontinuation of the epidural infusion, treatment was continued with T ibuprofen 800 mg ×2, T pantoprazole 40 mg ×1, and T paracetamol for 2 weeks following discharge.

Physiotherapy

Postoperative physiotherapy was given to all patients according to institutional practice for the first 2 days after the surgery. The outpatient clinic does not routinely include access to physiotherapy services. One working day before surgery, patients received instructions in breathing exercises using a positive expiratory pressure device, with 3 × 10 breaths every waking hour after surgery, coughing and huffing technique. Postoperatively, patients were sitting at the bedside on the day of surgery and walked 15 m or more the first day after surgery. Additionally, the intervention group (IG) performed IMT twice daily, using the POWERbreathe K3 (HaB Ltd, Southam, UK). IMT started 1 working day before surgery and continued for 2 weeks after the surgery. Each session consisted of 2 sets of 30 breaths on a start intensity of 15% of the preoperative value of maximal inspiratory pressure (MIP), incrementally increased by 2 cm H_2O daily, according to the patient's capability of training with the targeted training load. The training load was targeted on moderate exertion (level 3 on a 0-10 Borg Scale). Most training sessions were supervised during the hospital stay and unsupervised after discharge. Patients were coached once by telephone after discharge.

Outcomes

Outcomes were assessed 1 working day before surgery and again 2 weeks postoperatively by assessors unaware of the participant's randomization allocation.

Primary Outcome. Activity levels were assessed by the Physical Activity Scale 2.1 (PAS 2).[17] This questionnaire is an easy-to-use and valid self-administered instrument comprising 9 activity levels measuring the amount of leisure time and PA as daily hours and minutes of sleep, sitting, TV viewing/reading, standing or walking, heavy physical work, and transportation to and from work. In addition, PAS 2 measures weekly hours and minutes of light PA, moderately strenuous activities, and strenuous activities. The metabolic equivalent (MET) intensity level used is according to the *Compendium of Physical Activity*,[18] defined as inactivity (≤2 METs), light activity (3-4 METs at least 4 h/wk), moderate activity (5 METs at least 4 h/wk), strenuous activity (≥6 METs once a week). Any unaccounted for hours of PA in the questionnaire were weighted with a value of 2 METs. The minimum national recommendations for moderate-intensity PA during leisure time is at least 3.5 h/wk of, for example, brisk walking.[19]

Secondary Outcome. The EuroQol EQ-5D-5L questionnaire was used to assess general health status. The questionnaire comprises 5 dimensions (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression), each with 5 levels (no problem, slight problems, moderate problems, severe problems, and extreme problems).[20] The EQ-5D-5L has been validated in Danish, including the construction of reference values based on a general Danish population.[21] The minimal clinically important difference for the EQ-5D index in a healthy population ranges from 0.037 and 0.069.[22]

Statistical Analysis

Results were reported either as mean (±SD), median (interquartile range [IQR]), or numbers of patients (%). For comparison between the 2 groups for continuous variables, we used the Mann-Whitney *U*-test; for categorical variables, the Mantel-Haenszel χ^2 test or Fisher's exact test was used. For analysis of within-group changes over time, we used the Wilcoxon signed rank test. The independent samples *t*-test was used for comparison in mean scores of EQ-5D-5L between the study population and a weighted average reference Danish population, stratified for gender. Activity levels were dichotomized (inactive/low activity and moderate/high activity) and used as a dependent variable in a univariate logistic regression analysis to detect associations with demographic, surgical, and outcome variables. All statistical tests were 2-sided and conducted at the 5% significance level with SAS System version 9 (SAS Institute, Cary, NC). The analyses were performed considering that the participants maintained their originally assigned groups.

The sample size calculation was performed for the original study[16] based on a difference in MIP between the IG and control group (CG) of 15 ± 20 cm H_2O. Considering 80% power and a 0.05 significance level, we needed to include 35 participants in each group, taking into account an anticipated drop-out rate of 15%.

Results

A total of 66 patients were available for analysis 2 weeks postoperatively (IG, n = 34; CG, n = 32; Figure S1, online supplement, available at http://journals.sagepub.com/home/ict/supplemental-data). Both groups were comparable regarding demographic and surgical characteristics (Table 1) and for baseline outcome measurements (Tables 2 and 3). The overall median LOS was 6 days (IQR 4;10); thoracotomy was performed in 48% of the cases.

Self-reported Physical Activity

We found that a significant percentage of participants in the IG reported less sedentary activity 2 weeks postoperatively when compared with the CG (sedentary 6% vs 22%, low activity 56% vs 66%, moderate activity 38% vs 12%, respectively; $P = .006$; Table 2). On a weekly basis, the decline in moderate activity (3-4 METs) was significantly lower in the IG when compared with the CG (IG −1 ± 6 vs CG −5 ± 7; $P = .016$; Table 3). Preoperatively, 53% of participants met the minimum national recommendations for moderate-intensity PA during leisure time.

Secondary Outcomes

Preoperatively, we found no statistically significant difference in the overall mean EQ-5D-5L score between the overall study sample and a reference population: 0.855 ± 0.11 versus 0.862 for male participants ($P = .767$) and 0.803 ± 0.151 versus 0.831 ± 0.185 ($P = .412$) for female participants, respectively. The overall values for EQ-5D-5L were significantly lower 2 weeks postoperatively (mean difference of −0.127; 95% CI = [−0.168; −0.085]; $P < .0001$) without any differences between the IG and the CG (mean difference of −0.016; 95% CI = [−0.091; 0.060], $P = .80$); Figure S2 illustrates descriptive data on EQ-5D-5L's Mobility Scale. In a univariate logistic regression analysis, we found that D_{LCO} was the single variable positively associated with moderate to high activity level 2 weeks postoperatively (odds ratio = 1.54, 95% CI = 1.01-2.37, $P = .047$; Table S1, supplementary material).

Table 1. Demographic and Surgical Data for the Intervention and Control Groups.[a]

Variable	Intervention Group (n = 34)	Control Group (n = 34)	*P* Value
Age (years)	70 ± 8	70 ± 8	.69
Gender (male)	20 (59%)	19 (56%)	1.00
BMI	26 ± 4	28 ± 6	.07
COPD, n (%)	13 (38%)	17 (50%)	.46
Mild FEV_1 ≥80% predicted	2 (6%)	6 (17%)	
Moderate 50% ≤ FEV_1 < 80% predicted	7 (20%)	9 (26%)	
Severe 30% ≤+ FEV_1 < 50% predicted	4 (12%)	2 (6%)	.13
D_{LCO} percentage predicted	63 ± 16	63 ± 14	.97
ASA 2/3, n (%)	26/8, 77 (23%)	26/8, 77 (23%)	1.00
ECOG 0/1, n (%)	21/13, 62 (38%)	18/16, 53 (47%)	.47
VATS/thoracotomy	20/14, 59 (41%)	15/19, 44 (56%)	.23
Duration of surgery (hours)	2 ± 1	2 ± 1	.41
Wedge resection/segmentectomy	11 (32%)	10 (29%)	
Lobectomy	20 (59%)	18 (53%)	
Bilobectomy/pneumonectomy	2/1, 6 (3%)	1/5, 3 (15%)	.52
Length of hospital stay[b] (days)	8 ± 5	8 ± 6	.97
NSCLC	27 (79%)	25 (74%)	
Metastatic tumor/other type	4/3, 12 (19%)	4/5, 12 (15%)	.75
FEV_1, l	2.2 ± 0.8	2.1 ± 0.7	.53
MIP, cm H_2O	83 ± 27	78 ± 29	.51
6MWT (m)	495 ± 112	450 ± 110	.22

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease; FEV_1, forced expiratory volume in 1 s; D_{LCO}, carbon monoxide diffusion capacity; ASA, American Society of Anesthesiologists; ECOG, Eastern Cooperative Oncology Group performance status; VATS, video-assisted thoracoscopic surgery; NSCLC, non–small-cell lung cancer; MIP, maximal inspiratory pressure; 6MWT, six-minute walk test.
[a]Values are presented as means ± SD or n (%).
[b]Total length of hospital stay (includes transfer to other units).

Table 2. Categories of Physical Activity Levels Before Surgery and 2 Weeks After Surgery, From Self-reported PAS 2 Questionnaire.[a]

Level of Physical Activity	Before Surgery			Two Weeks Postoperatively		
	IG, n = 34	CG, n = 34	*P* Value	IG, n = 34	CG, n = 32	*P* Value
Inactive, n (%)	0 (0%)	2 (6%)		2 (6%)	7 (22%)	
Light activity	13 (38%)	14 (41%)		19 (56%)	21 (66%)	
Moderate activity	18 (53%)	18 (53%)		13 (38%)	4 (12%)	
Strenuous activity	3 (9%)	0 (0%)	*P* = .12	0 (0%)	0 (0%)	*P* = .0063

Abbreviations: PAS 2, Physical Activity Scale 2.1; IG, intervention group; CG, control group; MET, metabolic equivalent.
[a]Classification of activity level, according to MET intensity on a weekly basis: inactive ≤2 METs; light activity 3-4 METs ≤4 h/wk; moderate 5 METs ≤4 h/wk), strenuous (≥6 METs at least once a week). Statistics: Mantel-Haenszel χ^2 test.

The number of participants from the CG who were available at 2 weeks postsurgery differs from the number reported in the published randomized controlled trial[16] (n = 32 vs n = 31, respectively) because 1 participant from the CG who declined the 2-week follow-up returned the questionnaires postsurgery.

Discussion

This study reports on the effect of 2 weeks of postoperative IMT on self-reported PA level among high-risk patients undergoing lung resection. Patients who underwent IMT in addition to standard postoperative physiotherapy reported significantly less sedentary activity 2 weeks postoperatively compared with patients receiving standard postoperative physiotherapy alone. The overall preoperative health status was comparable to that in a general reference population.

IMT aims to strengthen the respiratory muscles by applying resistance during inspiration. In the surgical setting, preoperative IMT for at least 2 weeks in adults undergoing cardiac, pulmonary, and major abdominal surgery has been found to be associated with reduction of PPC and LOS.[11,12]

Table 3. Percentage of Time Used on Different MET Levels on a Weekly Basis for IG and CG, Based on the PAS 2 Self-reported Physical Activity Questionnaire.[a]

	Before Surgery			Two Weeks Postoperatively, Within-Group Mean Changes		Between Groups *P* Value
MET	IG, n = 34	CG, n = 34	*P* Value	IG, n = 34	CG, n = 32	
≤2	87% ± 7%, 87% [73; 98]	87% ± 8%, 88% [67; 98]	.97	3.3 ± 6.4,* 3.7 [−11.3; 16.9]	7.0 ± 8.3,*** 6.1 [−9.5; 28]	.065
3-4	9% ± 5%, 8% [2; 21]	10% ± 7%, 11% [2; 33]	.62	−0.7 ± 5.7, −1.3 [−12.5; 15.4]	−4.9 ± 7.2,**** −4.2 [−29.2;9.5]	.016
≥5	4% ± 5%, 4% [0; 24]	3% ± 4%, 2% [0; 15]	.24	−2.6 ± 4.1,** −1.8 [−15.5; 2.4]	−2.1 ± 4.4,*** −1.2 [−15.5; 11.9]	.910

Abbreviations: MET, metabolic equivalent; IG, intervention group; CG, control group; PAS 2, Physical Activity Scale 2.1.
[a]Values are presented as mean ± SD and medians [minimum; maximum]. METs: ≤2 = inactivity; 3-4 = light activity; ≤5 moderate to high activity level. *P* value for within-group changes in METs (**P* = .004; ***P* = .0002; ****P* = .0003; *****P* < .0001). Statistics: between-group comparisons, Mann-Whitney *U* test; within-group comparisons, Wilcoxon signed rank test.

Meanwhile, the effects of preoperative or postoperative IMT on surgical outcomes following lung surgery have scarcely been evaluated.[23] To our knowledge, no RCT has assessed the effects of postoperative IMT on PA following lung resection. We have previously reported that additional IMT in patients at high risk of PPC significantly improved oxygenation up to 5 days after the surgery when compared with standard physiotherapy alone; no differences between groups in respiratory muscle strength or walked distance were detected.[16] The additional findings reported in the present study suggest that IMT may also mitigate the postoperative decline in PA in patients at high risk of PPC. A plausible explanation may be that applying an inspiratory resistance is likely to facilitate lung expansion, consequently helping maintain patency of the small airways.[24] A similar rationale may be applied for the use of breathing exercises, the standard intervention for all study participants. Additional IMT may thus help patients take deeper breaths during activity. More research is needed to confirm our findings and to investigate the underlying mechanisms related to the role of the respiratory muscles under activity following lung resection. In particular, research could cover patients' experience with IMT and their perception of breathing and symptoms during activity.

In recent years, attention has been drawn to the negative effects of excessive sedentary behavior (activities that require very low energy expenditure such as sitting or reclining) on health outcomes and death in both health and disease.[25] We reported that, before surgery, only 53% of the participants met the minimum national recommendations for moderate-intensity PA during leisure time, compared with 67% of all healthy adults meeting this recommendation.[19] Early after the surgery, patients present with symptoms such as dyspnea, fatigue, and pain, which may preclude resumption of daily living activities and delay recovery. This could be a plausible explanation for the findings of a significant increase in sedentary behavior in both groups 2 weeks after surgery in the present study. These results are in line with the findings of Cavalheri et al,[26] who reported that patients accumulated a greater percentage of time in sedentary behavior activities 6 to 10 weeks after lobectomy when compared with healthy controls. In this context, it may be of importance not only to motivate and support patients in achieving sufficient and adequate PA levels early after the surgery, but also to screen and target high-risk patients for specific interventions aimed at early recovery of PA. In an observational study performed on low-risk patients following minimally invasive LC resection, Esteban et al[27] reported that supervised aerobic exercise and encouragement to walk along the hospital ward's corridor during hospital stay improved PA, except for those patients having any postoperative cardiopulmonary complication. The latter group had a significantly inferior walking capability, both preoperatively and postoperatively, than their peers without complications.[27] Agostini et al[6] have also reported that poor preoperative activity, together with age ≥75 years and predicted FEV_1 <70% were independent predictors of low postoperative PA. The findings from the present study suggesting that D_{LCO} was positively associated with moderate to high PA add to the knowledge regarding predictors of postoperative PA. D_{LCO} reflects the lungs' capability for alveolar oxygen exchange, which may be of particular importance with increasing demand on ventilation, such as during exercise.[1] Apart from its usefulness in assisting clinicians in the assessment of the lung resection candidates, we suggest D_{LCO} as an element in screening patients at high risk of postoperative sedentary activity in order to refer those patients for tailored interventions aimed at preventing decline in postoperative PA level.[28]

Perceived health status is an important outcome measure when evaluating the impact of disease and treatment on daily lifestyle. Quality of life is also a critical independent prognostic factor for predicting survival in the NSCLC population.[29] Our findings that health status was similar between the study sample and a reference population are contradictory to those of Brunelli et al,[30] who reported an impaired quality of life before surgery as well as when compared with the general population. In the study performed by Brunelli et al, the SF-36 was used, whereas the EQ-5D was used in the present study. Both questionnaires are generic and provide national reference values. We chose the EQ-5D because this questionnaire is very easy to administer, although it is not commonly used within the LC population. We found a significant overall decline in EQ-5Q index value of 0.127 2 weeks postoperatively, which is beyond the reported threshold values for minimal important clinical difference ranging from 0.037 and 0.069.[21] One can reason that this decline is expected because patients may still experience pain at the surgical site 2 weeks after the surgery,[6] which may in turn negatively influence resumption of normal daily living activities early after the surgery.

Study Limitations

This study involves consecutive patients at high PPC risk undergoing lung resection, with a relatively small number of participants, which may limit the generalizability of results to the general population undergoing LC surgery. Meanwhile, the participants were comparable to national data for LC surgery regarding age, gender, and surgery type.[31] Conversely, a higher proportion of participants underwent major resections (13% vs 3%), developed pneumonia (13% vs 5%), and had a longer median LOS (6 vs 4 days) when compared with the national data.[31] This difference can be explained by the inclusion criteria of high-risk patients (FEV_1/D_{LCO} ≤70%, age ≥70 years or scheduled for pneumonectomy). Also, the study performed by Sommer et al[14] had an inclusion rate of 32%, whereas in the present study, the inclusion rate was 52%. Second, the initial training load in the study was 15% of the preoperative MIP, incrementally increasing according to patient's perception of exertion (Borg level 3). Because we expected that MIP would decrease postsurgery, we assumed that an initial load of 15% postsurgery would correspond to 30% of the preoperative MIP. We did not access respiratory muscle strength (RMS) until the fifth postoperative day because the measurement requires a maximum voluntary effort and the results could be more influenced by pain, rather than an actual decline in RMS early after the surgery. Meanwhile, as we previously reported, respiratory muscle strength 2 weeks postsurgery was not decreased. Yet the actual IMT load varied between 15% and 43% of the preoperative MIP value.[16] Third, we did not collect objective data on PA by use of activity monitors. It is recommended that both performance-based and patient-reported measurements of PA should be undertaken when feasible,[32] but the use of activity monitors was not possible within the scope of the present study. We chose to use the PAS 2 questionnaire because it is a validated questionnaire for assessing PA in the average population of sedentary to moderately active adults.[17] The questionnaire has gone through construct validation by cognitive interviewing and was found suitable for differentiating levels of intensity through well-known examples of activities in the Danish population (walking for pleasure, bicycling, raking the lawn, carrying loads upstairs). Granger et al[33] have validated a similar self-reporting PA questionnaire (Physical Activity Scale for the Elderly [PASE]) against movement sensors in a mixed LC population, of whom 39% of participants had undergone surgery. Their group found a significant decline in the PASE score from the time of diagnosis to the 2-month postsurgery follow-up, which was consistent with data from movement sensors, meaning a fall in activity levels during the follow-up period.[33] Still, a validation of PAS 2 against activity monitors is warranted. In the present study, the surgical approach was not found to be associated with PA, but that could be a type 2 error because of a lack of power to perform subgroup analysis. In particular, postoperative pain,[28] especially following thoracotomy, could be an issue negatively influencing PA. Future research using activity monitors and with sufficient power is warranted to objectively assess factors associated with a minimum clinically important difference in changes in PA following NSCLC surgery. Although the results of less decline in PA following 2 weeks of IMT may be promising from a clinical point of view, they should be considered hypothesis generating and need to be evaluated in future studies.

Conclusion

Postoperative IMT in addition to standard physiotherapy, including early mobilization, may prevent a decline in PA level 2 weeks postoperatively in high-risk patients undergoing lung resection. More research is needed to confirm these findings.

Authors' Note

Preliminary findings of this study were presented as a poster at the World Physical Therapy Congress, WCPT, Cape Town, 2017.

Declaration of Conflicting Interests

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Supplemental Material

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References

1. Brunelli A, Charloux A, Bolliger CT, et al. ERS/ESTS Clinical Guidelines on fitness for radical therapy in lung cancer patients (surgery and chemo-radiotherapy). *Eur Respir J*. 2009;34:17-41.
2. Agostini P, Lugg ST, Adams K, et al. Postoperative pulmonary complications and rehabilitation requirements following lobectomy: a propensity score matched study of patients undergoing video-assisted thoracoscopic surgery versus thoracotomy. *Interact Cardiovasc Thorac Surg*. 2017;24:931-937.
3. Fiore JF Jr, Bejjani J, Conrad K, et al. Systematic review of the influence of enhanced recovery pathways in elective lung resection. *J Thorac Cardiovasc Surg*. 2016;151:708-715.
4. Lugg ST, Agostini PJ, Tikka T, et al. Long-term impact of developing a postoperative pulmonary complication after lung surgery. *Thorax*. 2016;71:171-176.
5. Simonsen DF, Søgaard M, Bozi I, Horsburgh CR, Thomsen RW. Risk factors for postoperative pneumonia after lung cancer surgery and impact of pneumonia on survival. *Respir Med*. 2015;109:1340-1346.
6. Agostini PJ, Naidu B, Rajesh P, et al. Potentially modifiable factors contribute to limitation in physical activity following thoracotomy and lung resection: a prospective observational study. *J Cardiothorac Surg*. 2014;9:128.
7. Novoa N, Varela G, Jiménez MF, Aranda JL. Influence of major pulmonary resection on postoperative daily ambulatory activity of the patients. *Interact Cardiovasc Thorac Surg*. 2009;9:934-938.
8. Granger CL, McDonald CF, Irving L, et al. Low physical activity levels and functional decline in individuals with lung cancer. *Lung Cancer*. 2014;83:292-299.
9. Sloan JA, Cheville AL, Liu H, et al. Impact of self-reported physical activity and health promotion behaviors on lung cancer survivorship. *Health Qual Life Outcomes*. 2016;14:66.
10. Rodriguez-Larrad A, Lascurain-Aguirrebena I, Abecia-Inchaurregui LC, Seco J. Perioperative physiotherapy in patients undergoing lung cancer resection. *Interact Cardiovasc Thorac Surg*. 2014;19:269-281.
11. Katsura M, Kuriyama A, Takeshima T, Fukuhara S, Furukawa TA. Preoperative inspiratory muscle training for postoperative pulmonary complications in adults undergoing cardiac and major abdominal surgery. *Cochrane Database Syst Rev*. 2015;(10):CD010356. doi:10.1002/14651858
12. Kendall F, Oliveira J, Peleteiro B, Pinho P, Bastos PT. Inspiratory muscle training is effective to reduce postoperative pulmonary complications and length of hospital stay: a systematic review and meta-analysis. *Disabil Rehabil*. 2018;40:864-882.
13. Brocki B, Andreasen J, Langer D, de Souza D, Westerdahl E. Feasibility of inspiratory muscle training in connection with lung cancer surgery. *Eur Respir J*. 2013;42(suppl 57):P1372.
14. Sommer MS, Trier K, Vibe-Petersen J, et al. Perioperative rehabilitation in operable lung cancer patients (PROLUCA): a feasibility study. *Integr Cancer Ther*. 2016;15:455-466.
15. Agostini P, Naidu B, Cieslik H, et al. Effectiveness of incentive spirometry in patients following thoracotomy and lung resection including those at high risk for developing pulmonary complications. *Thorax*. 2013;68:580-585.
16. Brocki BC, Andreasen JJ, Langer D, Souza DS, Westerdahl E. Postoperative inspiratory muscle training in addition to breathing exercises and early mobilization improves oxygenation in high-risk patients after lung cancer surgery: a randomized controlled trial. *Eur J Cardiothorac Surg*. 2016;49:1483-1491.
17. Andersen LG, Groenvold M, Jørgensen T, Aadahl M. Construct validity of a revised Physical Activity Scale and testing by cognitive interviewing. *Scand J Public Health*. 2010;38:707-714.
18. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 Compendium of physical activities: a second update of codes and MET values. *Med Sci Sports Exerc*. 2011;43:1575-1581.
19. Rasmussen L, Andersen L, Borodulin K, et al. *Nordic Monitoring of Diet, Physical Activity and Overweight: First Collection of Data in All Nordic Countries 2011*. Copenhagen, Denmark: Nordic Council of Ministers; 2012. http://urn.kb.se/resolve?urn=urn%3Anbn%3Ase%3Anorden%3Aorg%3Adiva-1149. Accessed August 11, 2018.
20. EuroQol Group. EuroQol—a new facility for the measurement of health-related quality of life. *Health Policy*. 1990;16:199-208.
21. Sørensen J, Davidsen M, Gudex C, Pedersen KM, Brønnum-Hansen H. Danish EQ-5D population norms. *Scand J Public Health*. 2009;37:467-474.
22. McClure NS, Sayah FA, Xie F, Luo N, Johnson JA. Instrument-defined estimates of the minimally important difference for EQ-5D-5L Index scores. *Value Health*. 2017;20:644-650.
23. Kendall F, Abreu P, Pinho P, Oliveira J, Bastos P. The role of physiotherapy in patients undergoing pulmonary surgery for lung cancer: a literature review. *Rev Port Pneumol (2006)*. 2017;23:343-351.
24. Lumb A. *Nunn's Applied Respiratory Physiology*. 8th ed. London, England: Elsevier; 2017.
25. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med*. 2015;162:123-132.
26. Cavalheri V, Jenkins S, Cecins N, Phillips M, Sanders LH, Hill K. Patterns of sedentary behaviour and physical activity in people following curative intent treatment for non-small cell lung cancer. *Chron Respir Dis*. 2016;13:82-85.

27. Esteban PA, Hernandez N, Novoa NM, Varela G. Evaluating patients' walking capacity during hospitalization for lung cancer resection. *Interact Cardiovasc Thorac Surg*. 2017;25: 268-271.
28. Granger CL, Connolly B, Denehy L, et al. Understanding factors influencing physical activity and exercise in lung cancer: a systematic review. *Support Care Cancer*. 2017;25: 983-999.
29. Yun YH, Kim YA, Sim JA, et al. Prognostic value of quality of life score in disease-free survivors of surgically-treated lung cancer. *BMC Cancer*. 2016;16:505.
30. Brunelli A, Socci L, Refai M, Salati M, Xiumé F, Sabbatini A. Quality of life before and after major lung resection for lung cancer: a prospective follow-up analysis. *Ann Thorac Surg*. 2007;84:410-416.
31. Danish Lung Cancer Group. Årsrapport 2016. http://lungecancer.dk/documents/B5F266A7-A049-4947-802C-D384A668720C.pdf. Accessed October 3, 2017.
32. Edbrooke L, Denehy L, Parry SM, Astin R, Jack S, Granger CL. How is physical activity measured in lung cancer? A systematic review of outcome measures and their psychometric properties. *Respirology*. 2017;22:263-277.
33. Granger CL, Parry SM, Denehy L. The self-reported Physical Activity Scale for the Elderly (PASE) is a valid and clinically applicable measure in lung cancer. *Support Care Cancer*. 2015;23:3211-3218.