Physiotherapy 105 (2019) 434–441

In-hospital physiotherapy improves physical activity level after lung cancer surgery: a randomized controlled trial

Marcus Jonsson [a,*], Anita Hurtig-Wennlöf [b], Anders Ahlsson [c], Mårten Vidlund [d], Yang Cao [e,f], Elisabeth Westerdahl [a]

[a] Department of Physiotherapy, Faculty of Medicine and Health, Örebro University, SE-70182 Örebro, Sweden
[b] School of Health Sciences, Department of Medical Diagnostics, Faculty of Medicine and Health, Örebro University, SE-70182 Örebro, Sweden
[c] Cardiovascular Division, Karolinska University Hospital, SE-17176 Stockholm, Sweden
[d] Department of Vascular and Cardiothoracic Surgery, Faculty of Medicine and Health, Örebro University, SE-70182 Örebro, Sweden
[e] Unit of Biostatistics, Institute of Environmental Medicine, Karolinska Institutet, SE-17177 Stockholm, Sweden
[f] Clinical Epidemiology and Biostatistics, School of Medical Sciences, Örebro University, SE-70182 Örebro, Sweden

Abstract

Objectives Patients undergoing lung cancer surgery are routinely offered physiotherapy. Despite its routine use, effects on postoperative physical recovery have yet not been demonstrated. The aim of this study was to investigate whether physiotherapy could improve postoperative in-hospital physical activity level and physical capacity.
Design Single-blind randomized controlled trial.
Setting Thoracic surgery department at a University Hospital.
Participants Patients undergoing elective thoracic surgery ($n = 94$) for confirmed or suspected lung cancer were assessed during hospital stay.
Intervention Daily physiotherapy, consisting of mobilization, ambulation, shoulder exercises and breathing exercises. The control group received no physiotherapy treatment.
Outcomes In-hospital physical activity assessed with the Actigraph GT3X+ accelerometer, six-minute walk test, spirometry and dyspnea scores.
Results The treatment group reached significantly more accelerometer counts (2010 (1508) *vs* 1629 (1146), mean difference 495 [95% CI 44 to 1109]), and steps per hour (49 (47) *vs* 37 (34), mean difference 14 [95% CI 3 to 30]), compared to the control group, during the first three postoperative days. No significant differences in six-minute walk test (percent of preoperative 71% *vs* 79%, $P = 0.13$), spirometry (FEV1 percent of preoperative 69% *vs* 69%, $P = 0.83$) or dyspnoea (M-MRC 2 *vs* 2, $P = 0.74$) between the groups were found.
Conclusions Patients receiving in-hospital physiotherapy showed increased level of physical activity during the first days after lung cancer surgery, compared to an untreated control group. However, no effects on the six-minute walk test or spirometric values were found. The clinical importance of an increased physical activity level during the early postoperative period needs to be further evaluated.

Clinical Trial Registration number: NCT01961700.

Keywords: Randomized clinical trial; Physical activity; Physical therapy; Lung cancer

Introduction

Surgical resection, with or without adjuvant chemotherapy, is the primary approach for curative treatment of non-small cell lung cancer [1].

* Corresponding author at: Department of Physiotherapy, L2, Örebro University Hospital, SE 701 85 Örebro, Sweden.
E-mail address: marcus.jonsson@oru.se (M. Jonsson).

https://doi.org/10.1016/j.physio.2018.11.001
0031-9406/

Postoperative complications are common after lung cancer surgery [2]. After lung cancer surgery, limited physical activity is common and associated with increased length of hospital stay [3]. The reasons for low level of physical activity could include altered respiratory mechanics, pain and dyspnoea. Patients with lung cancer who have undergone surgery have a lower daily step count compared to healthy individuals, measured 6–10 weeks after surgery, they also spend more time in prolonged uninterrupted periods of sedentary behaviour, and less time in light-intensity physical activity [4]. One study from USA has reported that at a mean of four years after lung cancer surgery, only 25% of patients are sufficiently active [5] according to the American Cancer Society guidelines for cancer survivors [6].

In several centres in the United Kingdom, Australia and New Zeeland, more than 90% of physiotherapists routinely treat patients that undergo thoracic surgery postoperatively [7,8]. The treatment typically consists of mobilization, shoulder exercises and breathing exercises. In-hospital physiotherapy treatment after lung cancer surgery has been shown to decrease pain [9], increase shoulder mobility [9], and increase quadriceps strength [10]. Despite its routine use, no significant effects on pulmonary complications or the six-minute walk test (6MWT) have been reported [10–12]. Further, no studies with an untreated control group that investigate the effect on physical activity have been found. The aim of this study was to examine whether physiotherapy during hospitalization after lung cancer surgery has any effect on early postoperative physical activity, physical capacity, and lung function. Our hypothesis was that in-hospital physiotherapy would have a positive effect on postoperative physical outcomes.

Material and methods

Patients

All patients undergoing elective thoracic surgery due to suspected or confirmed lung cancer at the Department of Cardiothoracic and Vascular Surgery, Örebro University Hospital, Sweden, during the time period December 2013–January 2017 were eligible for the study. The patients had to be able to participate in required tests, and to read and understand the native language. Patients who had undergone previous thoracic surgery were not included.

Written informed consent was obtained from each patient, and the Regional Ethical Review Board in Uppsala, Sweden, approved the study (2013/199). The study was registered at ClinicalTrials.gov (NCT01961700; URL: www.clinicaltrials.gov).

Randomization

A single-blinded, 1:1 parallel-group, randomized controlled trial was conducted. Information about the study was sent by post to the patients before surgery. On the day of admission, a study-responsible physiotherapist informed patients about the study and asked them to participate. Informed written consent was obtained before inclusion.

A computer-generated randomization list was created by a statistician and administered by an independent secretary in sequentially numbered, sealed, opaque envelopes. After baseline testing, performed during admission day, the envelope was opened by a physiotherapist responsible for patient care at the thoracic surgery department.

Intervention

The treatment group received brief individual preoperative physiotherapy information regarding mobilization and breathing exercises, and, during hospital stay, daily postoperative physiotherapy treatment consisting of individually adapted mobilization and ambulation (day of surgery: sitting up in bed or in a chair; from the first postoperative day: progressive ambulation on the ward, typically from 15 m up to one or two laps around the ward (one lap being approximately 100 m), the patients were instructed to walk as much as possible during the day, with or without a walking aid, according to patient needs), exercises for range of motion (shoulder elevation, shoulder flexion while taking a deep breath, horizontal shoulder abduction with hands at the neck while taking a deep breath, and thoracic rotation, to be performed at least twice daily from postoperative day one, five repetitions per exercise each time), and breathing exercises (three series of 10 deep breaths, with or without positive expiratory pressure, performed every waking hour) with instructions on coughing/huffing techniques. All patients in the treatment group received about the same amount of physiotherapy during the first two postoperative days (20–30 minutes per session), from the third day forward the treatment was individually adapted according to the patients' status (i.e. patients that were feeling well and deemed adequately active received less time). The physiotherapy treatment, delivered by physiotherapists with experience from treating cardiac and thoracic surgery patients, was available all week with the exception of Sundays. The control group received no physiotherapy instructions or specific treatment during the in-hospital phase, neither preoperatively or postoperatively. Both groups were treated the same way by the staff regarding ambulation, pain management and nursing. None of the groups received preoperative pulmonary rehabilitation. The surgeon responsible for the patient was able to override study protocol if deemed necessary, in which case a physiotherapist would treat the patient.

Surgery

Thoracic surgery was performed either by video-assisted thoracoscopy or open antero-lateral muscle-sparing thoracotomy, according to the surgeon's preference. At the end of surgery, a single chest tube was placed in the pleural space and connected to a suction device (Thopaz chest drainage system®, Medela, Switzerland, or Oasis® dry suction water seal drain, Atrium Europe, The Netherlands). A pressure of −15 cm H_2O was applied. The chest drainage was removed when there was no air leak and the volume of pleural effusion per day was below 300–400 ml. Pain management was primarily delivered by continuous epidural infusion, with ropivacaine and sufentanil. Alternatively, locally placed catheters with ropivacaine were used. As a supplement, the patients received intravenous morphine, per-oral non-steroid anti-inflammation drugs and paracetamol for as long as needed.

Outcomes

The primary outcomes were in-hospital physical activity level and postoperative physical capacity. Secondary outcomes were lung function, pain intensity and subjective degree of dyspnoea. Baseline measurements of 6MWT, lung function, dyspnoea and pain were performed during admission day. The measurements were repeated on the fourth day after surgery for patients who were still at the hospital and able to perform the tests. All measurements were performed by a physiotherapist, blinded to group allocation. Objective measurements of physical activity were conducted by accelerometer during the hospital stay, starting on the morning of the first postoperative day.

Physical activity

Objective measurement of physical activity was performed with the use of an accelerometer (ActiGraph, model GT3X+, Manufacturing Technology Inc., Pensacola, FL, USA). The accelerometer measures change in acceleration while comparing with time. The output variable is counts per time interval, processed by filtering and summarizing procedures and presented as counts per time interval "epoch". The settings used in this study were sample frequency 30 Hz and 10 seconds epoch. The patients were instructed to wear the device at the waist during their hospital stay after surgery, starting the morning of the first postoperative day. Total counts and steps were summarized for the first three postoperative days, and then divided by the hours the patients spent on the ward (some patients were discharged on the third day and did not wear the accelerometer the whole day), thus giving average counts and steps per hour. Assessment with accelerometer has been reported to give a valid estimate of physical activity [13].

Physical capacity

To assess physical capacity, the six-minute walk test was used [14]. The test was performed in a 25-m corridor. The patients were instructed to walk as far as possible in six minutes. The use of a walking aid, if needed, was recorded. The output parameter was distance walked.

Lung function

Lung function was assessed using a spirometer (The MicroLab Cat.No ML3500, MicroMedical, Kent, England), according to the recommendations from the American Thoracic Society/European Respiratory Society [15]. The variables assessed were forced vital capacity and forced expiratory volume in 1 second. The test was performed with the patient in sitting position, wearing a nose clip. The best out of three results was recorded.

Pain

Pain intensity was measured using a numeric rating scale at rest, while taking a deep breath, and when coughing, the scale ranging from 0 (no pain) to 10 (worst imaginable pain).

Dyspnoea

Perceived dyspnoea was measured using the Modified Medical Research Council dyspnoea scale [16], where the patients rate dyspnoea from 0 (no dyspnoea) to 4 (breathless when washing/getting dressed).

Statistical methods

For patients' characteristics, continuous data is summarized as mean ± standard deviation (SD), or median with the corresponding interquartile range (IQR), and categorical data is presented as numbers and percentages. Normality of data was assessed with the Shapiro–Wilk test. Log transformation of skewed distributions was applied if necessary. Differences between the groups were tested using the Student's T-test for normally distributed continuous variables, and the Mann–Whitney U test for continuous variables with skewed distribution. Differences of categorical variables were tested using the χ^2 test. Differences in physical activity during the first three postoperative days between the groups were examined using a general linear regression model with group allocation as fixed factor, adjusting for surgery time and duration of pleural drainage.

The sample size was determined as for a long-term follow-up as follows: a difference between the groups of 60 m from three months after surgery compared to base line, measured by the 6MWT, was considered clinically relevant. The 6MWT was used for sample size calculation since there were no studies available for comparison regarding physical activity. Applying a level of significance of 0.05 and 80% power yielded a number of 47 patients per group. To compensate for loss in follow-up, 53 patients per group were needed. No sample size calculation for the early postoperative period was performed.

For all analyses, a two-sided P-value <0.05 was considered statistically significant. All the analyses were performed using IBM SPSS Statistics 24 (IBM Corporation, Armonk,

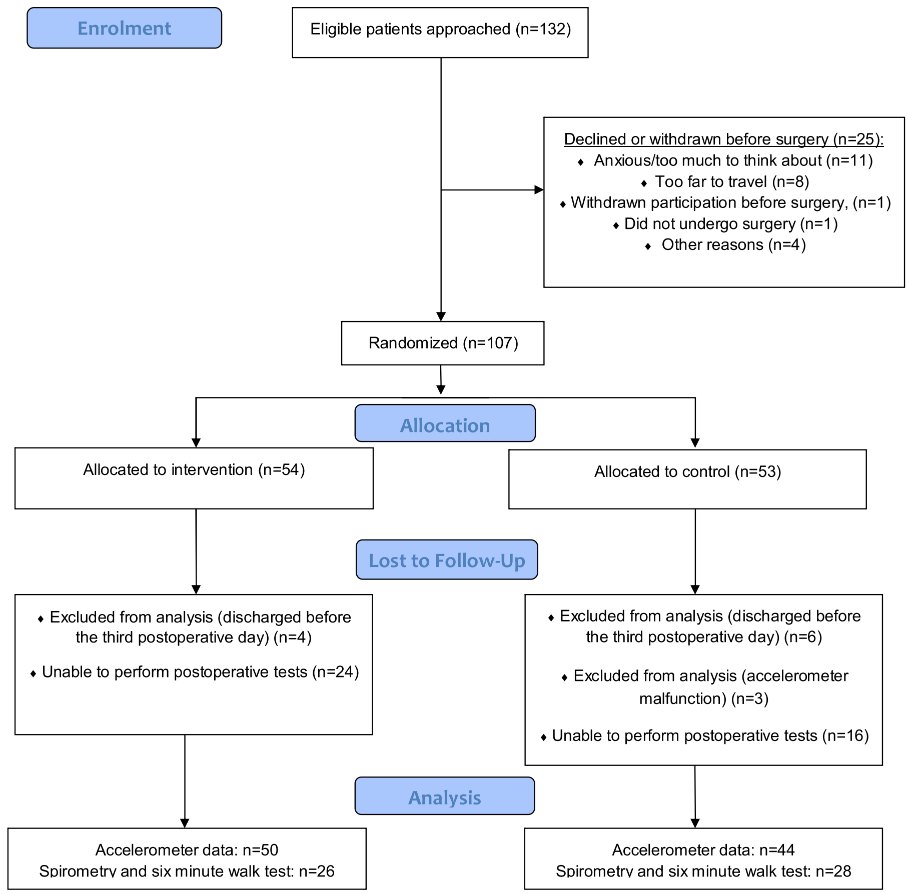

Fig. 1. Study flow chart of the patients in the study.

Table 1
Patient characteristics preoperatively.

Variable	Treatment group ($n = 50$)	Control group ($n = 44$)	*P*-value
Age (years), mean (SD)	69 (8)	68 (8)	0.97
Gender (male/female, male%)	28/22, 56%	17/27, 39%	0.09
BMI (kg/cm^2), mean (SD)	26 (4)	25 (4)	0.46
6MWT (m), median [IQR]	477 [417 to 536]	471 [404 to 534]	0.70
FVC (L), mean (SD)	3.5 (0.8)	3.4 (0.8)	0.44
FVC (% of predicted), mean (SD)	103 (20)	108 (17)	0.18
FEV1 (L), mean (SD)	2.4 (0.7)	2.3 (0.7)	0.60
FEV1 (% of predicted), mean (SD)	87 (17)	90 (17)	0.29
FEV1/FVC (%), mean (SD)	68 (12)	68 (10)	0.96
Dyspnoea (M-MRC), median [IQR]	1 [1 to 1]	1 [1 to 1]	0.49

Data presented as mean (SD), median [IQR], or number (n) of patients. BMI = body mass index. 6MWT = six-minute walk test. FVC = forced vital capacity. FEV1 = forced expiratory volume in one second. M-MRC = modified medical research council dyspnoea scale. The *P*-value refers to the difference between the groups.

New York) and Stata 14.2 (StataCorp LLC, College Station, Texas).

Results

A total of 107 patients were included in the study. Thirteen patients were excluded: discharge before third postoperative day ($n = 10$), technical error in accelerometer data ($n = 3$). The study group consisted of 94 patients (treatment group $n = 50$, and control group $n = 44$) (Fig. 1). Of these, 24 patients in the treatment group (discharged before postoperative day 4 ($n = 8$), unable to perform ($n = 15$), lack of staff ($n = 1$)), and 16 patients in the control group (discharged before postoperative day 4 ($n = 5$), unable to perform ($n = 11$)) did not perform postoperative assessment of 6MWT, spirometry, dyspnoea, or pain, but had accelerometer data and were assessed for physical activity level.

At baseline, the randomization process yielded no major differences between the groups regarding age, gender, body

Table 2
Surgical data.

Variable	Treatment group ($n = 50$)	Control group ($n = 44$)	*P*-value
Type of surgery (thoracotomy/VATS, % VATS)	40/10, 20%	34/10, 23%	0.75
Surgery side (left/right, % left)	14/36, 28%	15/29, 34%	0.52
Wedge resection (*n*)	17	17	0.97
Lobectomy (*n*)	28	23	
Bilobectomy (*n*)	2	1	
Pneumonectomy (*n*)	3	3	
Length of surgery (minute), mean (SD)	144 (50)	110 (37)	<0.01
Duration of pleural drainage (days), median [IQR]	2 [2 to 4]	2 [1.5 to 2.5]	0.11
Length of stay (days), median [IQR]	5 [4 to 6]	4 [3 to 5]	0.04

Data presented as mean (SD), median [IQR], or number (*n*) of patients. VATS = video assisted thoracoscopic surgery. The *P*-value refers to the difference between the groups.

Table 3
Accelerometer data for the entire sample.

	Postoperative day 2	Postoperative day 3
Counts per day, mean (SD)	42,225 (35,424)	40,871 (37,937)
Counts per day, median [IQR]	33,694 [16,312 to 56,229]	33,166 [22,392 to 51,460]
Steps per day, mean (SD)	974 (1035)	1041 (1049)
Steps per day, median [IQR]	659 [280 to 1243]	805 [455 to 1290]

The mean (SD) and median [IQR] number of counts and steps for the entire sample, on the second and third postoperative day.

Table 4
Accelerometer data for the first three postoperative days.

	Treatment group ($n = 50$)	Control group ($n = 44$)	Mean difference [95% CI]
Steps per hour	49 (47)	37 (34)	14 [3 to 30]
Counts per hour	2010 (1508)	1629 (1146)	495 [44 to 1109]

Data presented as mean (SD). Data on steps and counts per hour during the first three postoperative days, adjusted for length of surgery and duration of pleural drainage.

Table 5
Data on postoperative 6MWT, lung function, pain and dyspnoea.

Variable	Treatment group ($n = 26$)	Control group ($n = 28$)	*P*-value
6MWT (% of preoperative), mean (SD)	71 (22)	79 (16)	0.13
FEV1 (% of preoperative), mean (SD)	69 (16)	69 (16)	0.83
Pain at rest (NRS), median [IQR]	1 [0 to 2]	1 [0 to 3]	0.85
Pain while taking a deep breath (NRS), median [IQR]	3 [0 to 4]	3 [1 to 4.5]	0.68
Pain while coughing (NRS), median [IQR]	6 [3 to 7]	5 [2.5 to 7]	0.51
M-MRC, median [IQR]	2 [1 to 3]	2 [1 to 2]	0.74

Data presented as mean (SD) or median [IQR]. 6MWT = six-minute walk test. FEV1 = forced expiratory volume in one second. NRS = numeric rating scale. M-MRC = modified medical research dyspnoea scale.

mass index, physical function (6MWT), lung function, self-reported physical activity, or dyspnoea (Table 1). The groups were comparable regarding type of surgery, but there were significant differences in length of surgery and length of stay (Table 2). There was a positive significant correlation between duration of pleural drainage and length of hospital stay ($r = 0.61$, $P < 0.001$).

Accelerometer data for the entire sample is presented in Table 3.

During the first three postoperative days, patients in the treatment group reached significantly more counts (2010 (1508) *vs* 1629 (1146), mean difference 495 [95% CI 44 to 1109], adjusting for length of surgery and duration of pleural drainage) and steps per hour (49 (47) *vs* 37 (34), mean difference 14 [95% CI 3 to 30], adjusting for length of surgery and duration of pleural drainage) as compared to the control group (Table 4).

For patients available for the follow-up test on the fourth postoperative day (treatment group $n = 26$, control group $n = 28$), there were no significant differences between the groups regarding 6MWT, spirometric values, pain, or dyspnoea (Table 5).

Discussion

The main finding from this trial was that patients who receive physiotherapy during the first postoperative days were significantly more physically active during their hospital stay than patients not receiving physiotherapy. Patients in the treatment group reached significantly more counts and steps per hour than the patients in the control group. To our knowledge, this study is the first to investigate the effect of in-hospital physiotherapy on level of physical activity.

Two studies have earlier reported on in-hospital physical activity after lung cancer surgery [3,17]. Agostini *et al*. [3] reported a low physical activity level; the patients took a median of 170 steps on the second postoperative day, and 233 steps on the third postoperative day. This is somewhat lower than the patients in our study, who took a median of 659 and 805 steps on the second and third day respectively. In contrast, the patients in the study by Esteban *et al*. [17] were remarkably active during hospitalization, taking a mean of 7275 and 8943 steps on the second and third day. The corresponding results from our patients were 974 and 1041 steps. There are differences in methodology between these three studies; Esteban *et al*. [17] used a pedometer placed at the waist, Agostini *et al*. [3] used Sensewear, a motion sensor placed on the upper arm, and in the current study, the Actigraph GT3X+ accelerometer placed at the waist was used. Patients in the other two studies were all treated by physiotherapists, like the patients in our treatment group. Esteban *et al*. [17] excluded patients undergoing pneumonectomy; these patients were included in Agostini's and our study. These differences in methodology and patient selection could probably explain some, but not all, of the disparity in reported physical activity. More studies are needed to describe in-hospital physical activity after lung cancer surgery.

In our study, there were no significant differences between the groups in 6MWT, spirometric values or pain, measured on the fourth postoperative day. A lack of difference in 6MWT between patients receiving physiotherapy and a control group has been reported earlier, supporting our results [10]. The supervised walking at the ward might have been at to low intensity to show an effect on exercise capacity, measured with the 6MWT. However, adding early postoperative exercise to routine physiotherapy did not improve exercise tolerance [18]. Further, the four days of treatment might not be enough to give results of the 6MWT. Considering the internal missing data due to early discharge or inability to perform the tests, the small sample size contributes to uncertainty regarding these results. Pleural drainage has been shown to have a negative impact on 6MWT, lung function and pain [19,20], but this was not further evaluated in this study.

The group receiving physiotherapy had an increased length of stay. The reason for this remains unclear, but it seems unlikely that the physiotherapy treatment would have an impact on the length of stay. In the clinical setting, length of stay is dependent on factors other than the patient's physical status. Length of stay is an important outcome, but hard to evaluate due to many contributing factors. In our study, there was a significant correlation between duration of pleural drainage and length of stay. Differences in length of stay after lung surgery have also been linked to older age, male gender, and comorbidities such as chronic obstructive pulmonary disease [21]. In our study, there was a significant difference between the groups in length of surgery which could potentially affect the length of stay. Length of surgery has been associated with postoperative complications after pulmonary lobectomy [22], and postoperative complications have been associated with length of stay [23].

Medical patients admitted to hospital spend more than 80% of the time lying in bed [24], and patients who have undergone lung cancer surgery spend the majority of their time in hospital being sedentary [3]. The patients in our sample were also quite inactive. Physical activity in lung cancer surgery patients has been described from six weeks up to six months after surgery, and the data shows that, according to recommendations for cancer survivors, only about 25% of patients are sufficiently active after lung cancer surgery [5], and these patients are more sedentary and less active than healthy controls [4]. Physical activity has been positively associated with control of symptom burden [25].

The patients in our study experienced a low level of physical activity, nevertheless they were deemed fit for discharge. This could indicate a need for outpatient physiotherapy. Post discharge pulmonary rehabilitation may potentially increase exercise capacity [26]. Despite the potential benefits of pulmonary rehabilitation, referral to such rehabilitation is rare [7]. One important role the physiotherapist could play during the in-hospital phase could be informing patients about the benefits of, and refer interested patients to, pulmonary rehabilitation. It is not clear whether or not it is important to be physically active in the early postoperative period after lung cancer surgery, but it seems likely that it would be beneficial to get a good start. Our results indicate that physiotherapists could play an important part in helping patients to be physically active early in the postoperative period. Our research group is currently conducting a long-term follow-up to investigate the effects of in-hospital physiotherapy, with the aim of providing evidence-based treatment for patients undergoing lung cancer surgery.

Limitations

First, for postoperative measurements of 6MWT, lung function and pain, some internal data was missing due to either early discharge or inability to perform the tests. Another limitation is the fact that the study is not double blinded. However, the nature of physiotherapy treatment makes it impossible to conduct a double-blinded design. To minimize the potential bias, the assessments were made by a physiotherapist who was blinded to group allocation. Another limitation is the lack of assessment of preoperative level of physical activity. The optimal design would be to have the patients wear an accelerometer preoperatively. Unfortunately, this was not possible due to the fact that the patients presented at the thoracic surgery department at short notice, making it hard to reach the patients in time for objective preoperative assessment of physical activity. Further, there was a significantly longer surgery time in the treatment group, how much it affected the outcome is not known. When this study was planned, there were no studies that could be used for power analysis regarding physical activity. Since then, one study has been presented suggesting a minimal clinical important difference in 6MWT to be between 22 and 42 m [27], thus, our study could be under-powered to detect differences in 6MWT. There is also a risk of contamination, meaning that patients in the control group could be influenced by other patients, both patients in the treatment group but also other patients treated at the thoracic surgery ward, i.e. patients undergoing cardiac surgery, who followed a clinical pathway with early mobilization. Despite this risk of bias, the patients in the treatment group were more active than the patients in the control group.

Conclusion

Patients receiving in-hospital physiotherapy showed increased level of physical activity during the first days after lung cancer surgery, as compared to an untreated control group. However, no effects on the six-minute walk test or spirometric values were found. The clinical importance of an increased physical activity level during the early postoperative period needs to be further evaluated.

Key messages

- Patients are physically inactive after lung cancer surgery.
- Physiotherapy increases physical activity the first days after lung cancer surgery.
- There was no significant effect of physiotherapy on spirometric values, exercise capacity or dyspnoea.

Ethical approval: The Regional Ethical Review Board in Uppsala, Sweden, approved the study (Ref 2013/199).

Funding: This work was supported by grants from the Research Committee of Örebro County Council [OLL-363321, OLL-686781], the Swedish Heart and Lung Patients National Association [E o86/13], and the Swedish Cancer Society [CAN 2015/721].

Conflict of interest: None declared.

References

[1] Howington JA, Blum MG, Chang AC, Balekian AA, Murthy SC. Treatment of stage I and II non-small cell lung cancer: diagnosis and management of lung cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. Chest 2013;143(5 Suppl):e278S–313S, http://dx.doi.org/10.1378/chest.12-2359.

[2] Kim ES, Kim YT, Kang CH, Park IK, Bae W, Choi SM, *et al.* Prevalence of and risk factors for postoperative pulmonary complications after lung cancer surgery in patients with early-stage COPD. Int J Chron Obstruct Pulmon Dis 2016;11:1317–26, http://dx.doi.org/10.2147/COPD.S105206.

[3] Agostini PJ, Naidu B, Rajesh P, Steyn R, Bishay E, Kalkat M, *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, http://dx.doi.org/10.1186/1749-8090-9-128.

[4] 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(1):82–5, http://dx.doi.org/10.1177/1479972315616931.

[5] Philip EJ, Coups EJ, Feinstein MB, Park BJ, Wilson DJ, Ostroff JS. Physical activity preferences of early-stage lung cancer survivors. Support Care Cancer 2014;22(2):495–502, http://dx.doi.org/10.1007/s00520-013-2002-5.

[6] Rock CL, Doyle C, Demark-Wahnefried W, Meyerhardt J, Courneya KS, Schwartz AL, *et al.* Nutrition and physical activity guidelines for cancer survivors. CA Cancer J Clin 2012;62(4):243–74.

[7] Cavalheri V, Jenkins S, Hill K. Physiotherapy practice patterns for patients undergoing surgery for lung cancer: a survey of hospitals in Australia and New Zealand. Intern Med J 2013;43(4):394–401, http://dx.doi.org/10.1111/j.1445-5994.2012.02928.x.

[8] Agostini P, Reeve J, Dromard S, Singh S, Steyn RS, Naidu B. A survey of physiotherapeutic provision for patients undergoing thoracic surgery in the U.K. Physiotherapy 2013;99(1):56–62, http://dx.doi.org/10.1016/j.physio.2011.11.001.

[9] Reeve J, Stiller K, Nicol K, McPherson KM, Birch P, Gordon IR, *et al.* A postoperative shoulder exercise program improves function and decreases pain following open thoracotomy: a randomised trial. J Physiother 2010;56(4):245–52.

[10] Arbane G, Tropman D, Jackson D, Garrod R. Evaluation of an early exercise intervention after thoracotomy for non-small cell lung cancer (NSCLC), effects on quality of life, muscle strength and exercise tolerance: randomised controlled trial. Lung Cancer 2011;71(2):229–34, http://dx.doi.org/10.1016/j.lungcan.2010.04.025.

[11] Reeve JC, Nicol K, Stiller K, McPherson KM, Birch P, Gordon IR, *et al.* Does physiotherapy reduce the incidence of postoperative pulmonary complications following pulmonary resection via open thoracotomy? A preliminary randomised single-blind clinical trial. Eur J Cardiothorac Surg 2010;37(5):1158–66, http://dx.doi.org/10.1016/j.ejcts.2009.12.011.

[12] Agostini P, Naidu B, Cieslik H, Steyn R, Rajesh PB, Bishay E, *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(6):580–5, http://dx.doi.org/10.1136/thoraxjnl-2012-202785.

[13] Chomistek AK, Yuan C, Matthews CE, Troiano RP, Bowles HR, Rood J, *et al.* Physical activity assessment with the ActiGraph GT3X and doubly labeled water. Med Sci Sports Exerc 2017;49(9):1935–44.

[14] ATS Committee on Proficency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med 2002;166(1):111–7.

[15] Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, *et al.* Standardisation of spirometry. Eur Respir J 2005;26(2):319–38.

[16] Fletcher CM, Elmes PC, Fairbairn AS, Wood CH. The significance of respiratory symptoms and the diagnosis of chronic bronchitis in a working population. Br Med J 1959;2(5147):257–66.

[17] Esteban PA, Hernandez N, Novoa NM, Varela G. Evaluating patients' walking capacity during hospitalization for lung cancer resectiondagger. Interact Cardiovasc Thorac Surg 2017;25(2):268–71, http://dx.doi.org/10.1093/icvts/ivx100.

[18] Arbane G, Douiri A, Hart N, Hopkinson NS, Singh S, Speed C, *et al.* Effect of postoperative physical training on activity after curative surgery for non-small cell lung cancer: a multicentre randomised controlled trial. Physiotherapy 2014;100(2):100–7.

[19] Lima VP, Bonfim D, Risso TT, Paisani Dde M, Fiore Jr JF, Chiavegato LD, *et al.* Influence of pleural drainage on postoperative pain, vital

capacity and six-minute walk test after pulmonary resection. J Bras Pneumol 2008;34(12):1003–7.
[20] Refai M, Brunelli A, Salati M, Xiume F, Pompili C, Sabbatini A. The impact of chest tube removal on pain and pulmonary function after pulmonary resection. Eur J Cardiothorac Surg 2012;41(4):820–2, http://dx.doi.org/10.1093/ejcts/ezr126.
[21] Giambrone GP, Smith MC, Wu X, Gaber-Baylis LK, Bhat AU, Zabih R, *et al.* Variability in length of stay after uncomplicated pulmonary lobectomy: is length of stay a quality metric or a patient metric? Eur J Cardiothorac Surg 2016;49(4):e65–71, http://dx.doi.org/10.1093/ejcts/ezv476.
[22] Palleschi A, Privitera E, Lazzeri M, Mariani S, Rosso L, Tosi D, *et al.* Prophylactic continuous positive airway pressure after pulmonary lobectomy: a randomized controlled trial. J Thorac Dis 2018;10(5):2829–36.
[23] Agostini PJ, Lugg ST, Adams K, Smith T, Kalkat MS, Rajesh PB, *et al.* Risk factors and short-term outcomes of postoperative pulmonary complications after VATS lobectomy. J Cardiothorac Surg 2018;13(1):28.
[24] Brown CJ, Redden DT, Flood KL, Allman RM. The underrecognized epidemic of low mobility during hospitalization of older adults. J Am Geriatr Soc 2009;57(9):1660–5, http://dx.doi.org/10.1111/j.1532-5415.2009.02393.x.
[25] Solberg Nes L, Liu H, Patten CA, Rausch SM, Sloan JA, Garces YI, *et al.* Physical activity level and quality of life in long term lung cancer survivors. Lung Cancer 2012;77(3):611–6, http://dx.doi.org/10.1016/j.lungcan.2012.05.096.
[26] Cavalheri V, Tahirah F, Nonoyama M, Jenkins S, Hill K. Exercise training for people following lung resection for non-small cell lung cancer—a Cochrane systematic review. Cancer Treat Rev 2014;40(4):585–94.
[27] Granger CL, Holland AE, Gordon IR, Denehy L. Minimal important difference of the 6-minute walk distance in lung cancer. Chron Respir Dis 2015;12(2):146–54, http://dx.doi.org/10.1177/1479972315575715.