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Research

Preoperative physiotherapy prevents postoperative pulmonary complications after major abdominal surgery: a meta-analysis of individual patient data

Ianthe Boden [a,b], Julie Reeve [c,d], Anna Jernås [e], Linda Denehy [f,g], Monika Fagevik Olsén [h]

[a] University of Tasmania, Launceston, Tasmania, Australia; [b] Launceston General Hospital, Launceston, Australia; [c] School of Clinical Sciences, Auckland University of Technology, Auckland, New Zealand; [d] Physiotherapy Department, North Shore Hospital, Auckland, New Zealand; [e] Department of Physical Therapy, Sahlgrenska University Hospital, Gothenburg, Sweden; [f] Physiotherapy Department, The University of Melbourne, Melbourne, Australia; [g] Peter McCallum Cancer Centre, Melbourne, Australia; [h] Department of Physical Therapy, Sahlgrenska Academy at Gothenburg University, Gothenburg, Sweden

KEY WORDS

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ABSTRACT

Questions: Among patients having elective abdominal surgery, how much does preoperative physiotherapy education with breathing exercise training reduce the incidence of postoperative pulmonary complications (PPCs), hospital length of stay and 12-month mortality? How stable are the treatment effects across different PPC definitions, including pneumonia? How much do the treatment effects on PPC, hospital length of stay and mortality vary within clinically relevant subgroups? **Design**: Individual participant-level meta-analysis (n = 800) from two randomised controlled trials analysed with multivariable regression. **Participants**: Adults undergoing major elective abdominal surgery. **Interventions**: Experimental participants received a single preoperative session with a physiotherapist within 4 weeks of surgery and educated on PPC prevention with breathing exercises and early mobilisation. They were taught breathing exercises and instructed to start them immediately on waking from surgery. The control group received no preoperative or postoperative physiotherapy, or early ambulation alone. **Outcome measures**: PPC, hospital length of stay and 12-month mortality. **Results**: Participants who received preoperative physiotherapy had 47% lower odds of developing a PPC (adjusted OR 0.53, 95% CI 0.34 to 0.85). This effect was stable regardless of PPC definition. Effects were greatest in participants who smoked, were aged ≤ 45 years, had abnormal body weight, had multiple comorbidities, or were undergoing bariatric or upper gastrointestinal surgery. Participants having operations ≤ 3 hours in duration were least responsive to preoperative physiotherapy. Participants with multiple comorbidities were more likely to have a shorter hospital stay if provided with preoperative physiotherapy (adjusted MD –3.2 days, 95% CI –6.2 to –0.3). Effects on mortality were uncertain. **Conclusion**: There is strong evidence to support preoperative physiotherapy in preventing PPCs after elective abdominal surgery. **[Boden I, Reeve J, Jernås A, Denehy L, Fagevik Olsén M (2024) Preoperative physiotherapy prevents postoperative pulmonary complications after major abdominal surgery: a meta-analysis of individual patient data. *Journal of Physiotherapy* 70:216–223]**

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Introduction

Approximately one-third of all patients develop a postoperative pulmonary complication (PPC) following major abdominal surgery,[1] which significantly impacts patient morbidity, mortality and hospital costs.[2] Considering the severe impact of PPCs, patients in high-income countries commonly receive preoperative and postoperative physiotherapy interventions aiming to prevent this serious complication;[3–6] yet, despite ubiquitous service provision, there is no consensus on which treatment strategy most effectively prevents PPCs.[7,8]

Systematic reviews have conflicting results and provide little clarity on the effectiveness of respiratory-focused physiotherapy interventions to prevent PPC.[9–11] A possible reason for this uncertainty could be the inclusion of highly heterogeneous trials involving different patient populations, various types of interventions, comparators and PPC definitions. Given this, a traditional meta-analysis is unlikely to provide clinicians with a true understanding of the effectiveness of a specific type of physiotherapy treatment to prevent PPCs after abdominal surgery. A method proposed to overcome this limitation is to select homogenous trials and combine the individual participant-level data from each trial.[12] This method allows for robust statistical methods to adjust results for confounding participant-level factors, thus ensuring that the findings are a valid representation of the effect of a specific intervention within a defined patient population.

Clinical trials are also usually powered for a single primary outcome, for example PPC, yet are frequently underpowered for detecting small, yet clinically important, differences in secondary outcomes like hospital length of stay (LOS) and patient mortality. An individual participant-level data meta-analysis improves statistical power to enable exploration of these secondary outcomes, providing

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clinicians and hospitals with information about the value of physiotherapy outside their immediate impacts on preventing or treating postoperative complications. An individual participant-level data meta-analysis also enables exploration of treatment effect modifiers within clinically relevant subgroups,[13] giving clinicians an understanding of for which types of patients a specific treatment may be more or less likely to be effective.

A large multicentre randomised trial with patient and assessor blinding recently reported that a single session of preoperative education and respiratory training with a physiotherapist halved the risk of a PPC following major abdominal surgery[14] and was cost-effective.[15] Effects on secondary outcomes, such as mortality and hospital LOS, and on patients within different subgroups were uncertain. An individual participant-level data meta-analysis combining data from similar trials could confirm whether preoperative physiotherapy prevents PPC after abdominal surgery and provide greater statistical power to analyse the secondary outcomes and treatment effect modifiers. This study aimed to conduct an individual patient data meta-analysis by pooling original data sets from homogenous trials that provided a single preoperative respiratory physiotherapy education and training session to patients awaiting abdominal surgery and assessed PPC outcomes.

Therefore, the research questions for this individual participant-level meta-analysis were:

1. Among patients having elective abdominal surgery, how much do preoperative physiotherapy education and breathing exercise training reduce the incidence of PPC, hospital LOS and 12-month mortality?
2. How stable are the treatment effects across different PPC definitions, including pneumonia?
3. How much do the treatment effects on PPC, LOS and mortality vary within clinically relevant subgroups?

Method

Design

An individual participant-level meta-analysis of two purposively selected randomised controlled clinical trials was conducted. A recent systematic review of trials investigating physiotherapist-directed breathing exercises to prevent PPC in adults after elective abdominal surgery[16] was screened for trials meeting the following criteria: participants were adults having elective abdominal surgery; the intervention was a single session of preoperative physiotherapy education and breathing exercise training alone with minimal postoperative respiratory-focused physiotherapy; the comparator was no preoperative or postoperative physiotherapy, or early postoperative ambulation alone; and the incidence of hypoxaemia and pneumonia was measured during the postoperative hospital stay. Two trials fulfilled these criteria.[14,17]

Trials

LIPPSMAck POP was a prospective, international, placebo-controlled trial with patient and assessor blinding conducted at three government-funded hospitals (a metropolitan tertiary centre, a major regional centre and a rural facility) in Australia and New Zealand.[14] The other trial, referred to here as the Swedish trial, was a prospective, single-centre trial conducted at a metropolitan tertiary hospital in Sweden.[17] Trials received ethical approval and written consent from participants prior to recruitment (Västra Götaland, Sweden, 203-31 T449-18; Human Research Ethics Committee Tasmania, Australia, H0011911; The Health and Disability Ethics Committee, New Zealand, 14/NTA/233). Each trial was granted ethics approval for data sharing, aggregation and analysis. LIPPSMAck POP was prospectively registered (ANZCTR 12613000664741). The Swedish trial was conducted prior to the availability of any clinical trial registry. The methodological quality for LIPPSMAck POP was excellent, with a very low risk of bias, scoring 8 out of 10 on the Physiotherapy Evidence Database (PEDro) scale.[18] The Swedish trial scored 5 out of 10 (eAddenda Table 1 on the eAddenda). The methodology and primary and secondary results have been published.[14,15,17,19–21] Both trials had similar methods, patient cohorts, treatment protocols and outcome measures (Table 2).

Participants

Enrolled participants were adults aged ≥ 18 years and listed for major elective abdominal surgery.

Table 2
Characteristics of the included trials.

Characteristics	The Swedish trial	LIPPSMAck POP
Location	Sweden	Australia and New Zealand
Eligibility criteria	Inclusion: adults aged ≥ 18 years undergoing elective open abdominal surgery admitted to hospital the day prior to surgery.	Inclusion: adults aged ≥ 18 years awaiting elective, open, upper-abdominal surgery attending the hospital pre-admission clinic. Exclusion: organ transplants, hernia repairs, inability to walk > 1 min.
Preoperative experimental intervention	Single session of education on importance of early postoperative mobilisation and self-directed breathing exercises. Participants trained in breathing exercises.	Information booklet and session of education on importance of early postoperative mobilisation and self-directed breathing exercises. Participants trained in breathing exercises.
Postoperative experimental intervention	One to two physiotherapy sessions to confirm breathing exercises. High-risk[a] patients provided with PEP masks for resisted breathing exercises.	A single reminder to perform breathing exercises as per information booklet. Standardised early mobilisation program.
Preoperative control	No preoperative physiotherapy	Information booklet alone
Postoperative control	No postoperative physiotherapy	A single reminder to perform breathing exercises as per information booklet. Standardised early mobilisation.
Participants, n (exp:con)	368 (174:194)	441 (222:219)
Age *(yr)*, mean (SD)	53 (17)	63 (15)
Male, n (%)	158 (43)	266 (62)
BMI *(kg/m^2)*, mean (SD)	27 (8)	28 (6)
Current smoker, n (%)	104 (30)	99 (23)
Respiratory comorbidity, n (%)	42 (11)	97 (22)
ASA > 2, n (%)	48 (13)	156 (36)
Surgery, n (%)		
colorectal	168 (46)	213 (49)
upper GI or HB	125 (34)	106 (25)
renal	0 (0)	98 (23)
bariatric	75 (20)	0 (0)
Surgical time > 3 h, n (%)	243 (66)	316 (73)

ASA = American Society of Anaesthesiologists category, BMI = body mass index, Con = control group, Exp = experimental group, GI or HB = gastrointestinal or hepatobiliary, PEP = positive expiratory pressure.
[a] Aged > 50 years and one of: smoking within prior 12 months, BMI > 30 and respiratory comorbidity.

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Interventions

Participants randomised to the experimental arms of both trials were provided with a single preoperative face-to-face session of education and breathing exercise training from a physiotherapist. Participants were educated about their risk of a PPC and the need to perform their own breathing exercises and participate in early ambulation after surgery as methods to prevent PPC. Participants were coached on how to perform deep breathing exercises and given instructions to start these independently immediately after surgery and ongoing every hour. Postoperatively, patients in the experimental group were provided with early mobilisation and a brief physiotherapy review to check that breathing exercises were being performed as instructed preoperatively. Control group participants received no coaching or prophylactic respiratory physiotherapy, either before or after surgery. In both trials, a protocol endpoint was reached if a trial participant was diagnosed with a PPC, at which point physiotherapy of breathing exercises and early ambulation was provided.

Outcomes

Primary outcome

In LIPPSMAck POP, PPCs were assessed with the Melbourne Group Score, an eight-factor diagnostic score tool with patients assessed daily for the first 14 postoperative hospital days. The Swedish trial diagnosed a PPC when peripheral oxyhaemoglobin saturation (SpO_2) was $< 92\%$, or a participant had at least two of the following: radiological evidence of pneumonia or atelectasis, temperature $> 38.2°C$ or abnormal lung auscultation. Participants were screened daily for the first 6 postoperative hospital days. It was not possible to retrospectively apply the Melbourne Group Score to the Swedish trial because some required criteria were not originally collected and it was impossible to extract these from the historical case records, whereas the comprehensive data collection methods within LIPPSMAck POP allowed cases to be reanalysed with the PPC definition used by the Swedish trial; therefore, this was selected as the primary outcome for this individual participant-level data meta-analysis with incidence census set at 6 postoperative days.

A sensitivity analysis of treatment effect stability was conducted using different PPC definitions able to be assessed using the available data: a single incidence of hypoxaemia ($SpO_2 < 92\%$); repeated hypoxaemia over two consecutive days; and pneumonia as diagnosed with collapse and/or consolidation or infiltrates on chest X-ray accompanied by temperature $> 38°C$ or abnormal auscultation.

Secondary outcomes

Acute hospital LOS calculated from the day of surgery until the day of separation from the acute care facility, and all-cause mortality within 12 months of surgery.

Data analysis

The principal investigators met together in person with their trial's anonymised individual participant-level data to define and harmonise common variables, outcomes and coding for the aggregated database. Variables and outcomes were assessed for definition consistency between trials. Where grossly dissimilar, the variable was excluded from aggregation. Variables documented in both trials and available for adjusting for independent influence on outcomes and for treatment effect modification analysis were age, gender, body mass index (BMI), existing respiratory disease, smoking history, American Society of Anaesthesiologists (ASA) category, surgical category, surgery duration, and years of experience of the treating preoperative physiotherapist. Years of physiotherapy experience were categorised into novice < 2 years, intermediate 2 to 5 years, senior 5 to 10 years, and expert > 10 years.[22] New variables were created for each participant's source trial and for a combined master set identifier. For the Swedish study, participant date of death and experience grade of treating physiotherapists were retrospectively extracted from the hospital's medical information system specifically for this individual participant-level data meta-analysis. All other data were collected prospectively. Data sets were converted to the same format and combined. The data dictionary for the aggregated meta-database is provided in Table 3 on the eAddenda.

This individual participant-level data meta-analysis was synthesised with a one-stage multi-level model. Trial clustering effects were managed by treating original trial status as a separate random effect within all analyses. Binomial outcomes (PPC definitions and mortality) were reported unadjusted in risk ratios and 95% confidence intervals (CI) and adjusted via multivariable robust random effects generalised linear logistic regression modelling reported with odds ratios and 95% CI. Time to event was calculated using Cox proportional hazards regression analysis with adjustments, reported as hazard ratios and graphically represented using Kaplan-Meier methods. Hospital LOS was logarithmically transformed due to positive skewness and analysed using linear mixed modelling and reported as mean difference in days with 95% CI. The PPC outcomes were adjusted for covariates independently related to PPC (age, ASA category, current smoking, respiratory comorbidity, upper gastrointestinal surgery, bariatric surgery and duration of surgery) or imbalanced between groups. Mortality and hospital LOS outcomes were adjusted for age, ASA category and surgery category. Analyses were conducted using intention-to-treat principles according to participants' original trial group assignment. Multiple imputation was not required as missing data were minimal (see Table 3 on the eAddenda).

Modulation in treatment effects was explored in nine clinically relevant factors (age, gender, BMI, smoking status, respiratory disease, ASA category, surgical category, operation duration and treating physiotherapist experience) and divided into independent subgroups. Each subgroup was analysed separately for effects on PPC, LOS and 12-month mortality, with statistical models and adjustments described above. Odds ratios and mean difference with 95% CI were represented graphically via forest plots. Interaction between subgroups within each factor was assessed using methods described by Christensen et al.[23] Analyses were performed and graphed using commercially available software[a,b].

Results

Flow of participants through the study

Data pooled from the two trials involved 800 participants (392 patients in the experimental group and 408 in the control group) recruited from four hospitals across three countries. Figure 1 presents the flow of participants through the study. Table 4 describes the baseline characteristics of all included participants in the experimental and control groups. Small imbalances between groups in ASA category or surgical category were managed by including these as covariates within statistical analyses.

Effect of preoperative physiotherapy on PPCs

Pooled individual patient data from two homogenous randomised controlled trials found that participants were 33% less likely to develop a PPC if they received preoperative physiotherapy education and breathing exercise training before abdominal surgery (unadjusted RR 0.67, 95% CI 0.53 to 0.83; Table 5) with a number needed to treat of 8 (95% CI 5 to 18). Following adjustments for confounding effects of trial, age, ASA category, current smoking status, respiratory comorbidity, surgery category and duration, the effect of preoperative physiotherapy remained clinically significant, independently reducing the odds of contracting a PPC by 47% (OR 0.53, 95% CI 0.34 to 0.85; Table 5).

Effect of preoperative physiotherapy on alternative diagnostic versions of PPCs

The beneficial treatment effect of preoperative physiotherapy remained stable regardless of the PPC diagnostic criteria applied.

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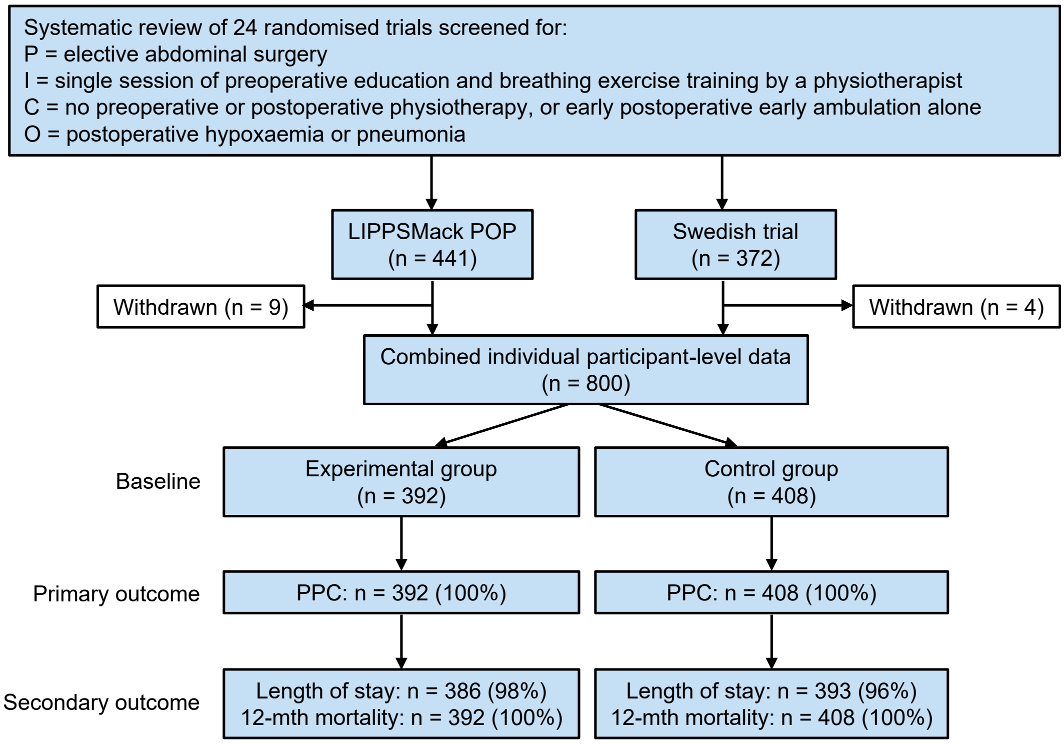

Figure 1. Flow of participants through study.
C = comparator, I = intervention, LIPPSMAck POP = Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy, O = outcome, P = population, PPC = postoperative pulmonary complication.

Specifically, the risk of developing pneumonia after surgery was halved in participants provided with preoperative physiotherapy (Table 5).

Effect of preoperative physiotherapy on hospital length of stay and 12-month mortality

A crude 1-day reduction in hospital LOS (experimental group 10 days (SD 7.2) versus control group 11 days (SD 8.9)) resulted in an unclear estimate when adjusted for trial, age, ASA and surgery category (adjusted MD –0.8 days, 95% CI –1.9 to 0.3). Although the point estimate of effect suggested a reduction in LOS by a day in participants provided with preoperative physiotherapy, the chance that the intervention could be associated with a small increase in LOS cannot be excluded in this sample.

All-cause mortality at 30 days was low (< 1%) and no different between groups (six in experimental group, seven in control group).

Table 4
Characteristics of the participants.

Characteristic	Exp (n = 392)	Con (n = 408)
Age *(yr)*, mean (SD)	58 (16)	59 (17)
BMI *(kg/m²)*, mean (SD)	27.6 (6.6)	28.1 (7.3)
Male, n (%)	204 (52)	219 (54)
Smoking status, n (%)		
current smoker	105 (27)	98 (24)
ex-smoker	125 (32)	142 (35)
Respiratory comorbidity, n (%)	61 (16)	78 (19)
ASA category 3 to 4, n (%)	84 (22)	120 (30)
Surgery, n (%)		
colorectal	198 (51)	183 (45)
hepatobiliary or upper gastrointestinal	104 (27)	127 (31)
renal or urology	51 (13)	47 (12)
bariatric	29 (7)	46 (11)
other	10 (3)	5 (1)
Duration anaesthesia *(hr)*, n (%)		
< 3	121 (31)	113 (28)
3 to 5	180 (46)	193 (47)
> 5	86 (22)	100 (25)

ASA = American Society of Anaesthesiologists, BMI = body mass index, Con = control group, Exp = experimental group.

A 2.7% absolute risk difference in 12-month mortality favoured the experimental group, but the confidence interval showed considerable uncertainty in this estimate (experimental 6.9% versus control 9.6%; adjusted HR 0.72, 95% CI 0.42 to 1.24; Figure 2).

Treatment effect modifiers

The effect of preoperative physiotherapy on PPCs within different subgroups is shown in Figure 3. Preoperative physiotherapy was more effective in participants with low body weight (OR 0.08, 95% CI 0.01 to 0.62), those aged < 45 years (OR 0.13, 95% CI 0.04 to 0.48) and those having open bariatric surgery (OR 0.11, 95% CI 0.02 to 0.47) with the odds of a PPC reduced by approximately 90%. Obese participants, smokers, those with an ASA category of 3 or 4, or having upper gastrointestinal or hepatobiliary surgery also had a heightened response to preoperative physiotherapy, with the odds of a PPC reduced by approximately 60% (Figure 3). Participants least responsive to the effect of preoperative physiotherapy were those having operations lasting < 3 hours (OR 1.56, 95% CI 0.76 to 3.23).

Regarding hospital LOS, obese participants, those with multiple comorbidities (ASA category > 2) or those having prolonged procedures were most responsive to preoperative physiotherapy, with clinically significant reductions in LOS (1 to 3 fewer days in hospital) (see Figure 4 on the eAddenda). The treatment response in participants with an ASA category > 2 was associated with a large 3-day reduction in LOS, even following multilevel robust statistical models to account for within-subgroup and between-subgroup interactions (adjusted MD –3.25 days, 95% CI –6.23 to –0.27). Treatment effects on mortality remained uncertain, with wide variation in responses within subgroups (see Figure 5 on the eAddenda).

Discussion

Pooling patient-level data from two homogenous trials involving patients recruited in Australia, New Zealand and Sweden showed that preoperative physiotherapy respiratory education and breathing exercise training prior to major abdominal surgery reduces the risk of a

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Table 5
Estimate of treatment effect of preoperative physiotherapy on postoperative pulmonary complications.

Outcome	Control (n = 408)	Intervention (n = 392)	Crude analysis RR (95% CI)	Adjusted analysis[a] OR (95% CI)
Primary comparison				
Single episode $SpO_2 < 92\%$ or two of: temp > 38.2°C, auscultation changes or CXR changes	147 (36%)	94 (24%)	0.67 (0.53 to 0.83)	0.53 (0.34 to 0.85)
Sensitivity analysis				
Single episode $SpO_2 < 92\%$	126 (31%)	75 (19%)	0.62 (0.48 to 0.80)	0.58 (0.41 to 0.83)
Two consecutive daily episodes of $SpO_2 < 92\%$	67 (16%)	40 (10%)	0.62 (0.43 to 0.90)	0.61 (0.39 to 0.96)
Pneumonia	67 (16%)	36 (9%)	0.56 (0.38 to 0.82)	0.53 (0.34 to 0.85)

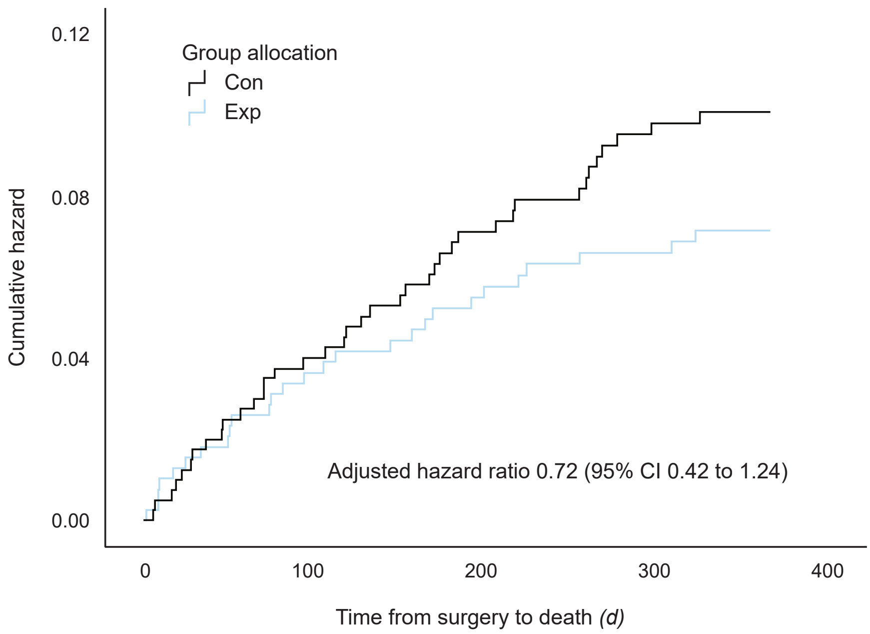
CXR = chest x-ray; SpO_2 = peripheral oxyhaemoglobin saturation, temp = temperature.
[a] Adjusted for trial, age, American Society of Anaesthesiologists category, respiratory comorbidity, smoking status, operation duration, and surgery category.

patient developing a PPC. The treatment effect was large and clinically relevant with a 30 to 50% reduction in risk across multiple PPC definitions, including pneumonia. This highlights the consistent and reliable physiological effect on signs and symptoms of postoperative gas exchange abnormalities and airway infection by simply teaching patients to perform self-directed lung expansion exercises and airway clearance immediately on waking from surgery. These findings are particularly remarkable because the only respiratory physiotherapy that participants in the experimental group received was delivered preoperatively. There was minimal to no respiratory physiotherapy on the surgical ward following the operation other than early ambulation alone.

The early timing of commencing breathing exercises after surgery could be the crucial factor driving the success of this low-cost single-session preoperative intervention.[8] The primary aim is to equip patients with the knowledge and skills to perform effective deep breathing exercises and airway secretion clearance techniques as soon as possible on waking from surgery. This enables much earlier commencement of breathing exercises than if a physiotherapist sees the patient for the first time the day after surgery.[4–6] It is hypothesised that early initiation of breathing and coughing exercises reverses mild atelectasis and clears stagnating airway secretions in the first 24 hours after abdominal surgery, thus preventing the progression to severe atelectasis, bacterial contamination and a PPC.[8]

Previous systematic reviews and meta-analyses of lung expansion exercises to prevent PPC after abdominal surgery have had conflicting findings, with some finding that they are effective[9,11] and others not.[10] The most recent review included 12 trials and reported a halving of PPC incidence (RR 0.55, 95% CI 0.32 to 0.92).[9] However, the authors acknowledged the significant limitation of including studies with different interventions and timings (preoperative, postoperative or both). Where systematic reviews combine data from trials with a variety of interventions (including breathing exercises, early mobilisation, incentive spirometry, positive expiratory pressure devices and non-invasive ventilation) and at different timings, this can lead to results that are difficult to interpret, may have little clinical relevance and could be misleading. In the current study, patient-level data from two trials with highly similar methods, patient cohorts, interventions, controls and outcomes were merged to obtain a sample of 800 patients. Conducting a patient-level data meta-analysis of these studies provides clinicians with a true understanding of the effect of a single specific physiotherapy intervention delivered at a defined time point, unconfounded by the additional effects of other interventions or timing of delivery. This improved certainty of the specific effects of preoperative physiotherapy can aid in accelerating widespread implementation.

Clinicians and hospitals can be confident that preoperative physiotherapy provided broadly to all patients listed for major



Number of cases alive					
Days	0	100	200	300	365
Con	408	380	380	370	369
Exp	392	378	370	367	365

Figure 2. 12-month mortality between groups. Data adjusted for trial, age, ASA category and surgical category.
Con = control group, Exp = experimental group.

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	Con	Exp	Adjusted OR (95% CI)
Overall	147/408 (36%)	94/392 (24%)	0.53 (0.34 to 0.85)
Age *(y)*			
< 45	20/89 (23%)	4/84 (4.8%)	0.13 (0.04 to 0.48)
45 to 65	50/130 (39%)	40/149 (27%)	0.46 (0.26 to 0.81)
65 to 75	41/104 (39%)	34/96 (35%)	0.89 (0.47 to 1.66)
> 75	35/84 (42%)	16/61 (26%)	0.71 (0.31 to 1.60)
Gender			
female	60/189 (32%)	37/188 (20%)	0.49 (0.29 to 0.83)
male	87/219 (40%)	57/204 (28%)	0.69 (0.44 to 1.10)
BMI *(kg/m^2)*			
< 20	9/26 (35%)	2/34 (5.9%)	0.08 (0.01 to 0.62)
20 to 25	38/156 (24%)	28/139 (20%)	0.97 (0.51 to 1.86)
25 to 30	31/93 (33%)	27/91 (30%)	0.95 (0.46 to 1.96)
> 30	68/126 (54%)	36/122 (30%)	0.35 (0.20 to 0.61)
Smoking status			
non-smokers	46/168 (27%)	35/162 (22%)	0.79 (0.45 to 1.37)
ex-smokers	61/142 (43%)	42/125 (34%)	0.60 (0.34 to 1.05)
current	40/98 (41%)	17/105 (16%)	0.35 (0.16 to 0.74)
Respiratory disease			
no	107/330 (32%)	71/330 (22%)	0.60 (0.41 to 0.89)
yes	40/78 (51%)	22/61 (36%)	0.59 (0.27 to 1.26)
ASA category			
1 to 2	83/280 (30%)	67/305 (22%)	0.66 (0.44 to 0.99)
3 to 4	61/120 (51%)	27/84 (32%)	0.40 (0.21 to 0.78)
Surgery			
colorectal	46/183 (25%)	34/198 (17%)	0.72 (0.42 to 1.26)
UGI or HB	53/127 (42%)	27/104 (26%)	0.34 (0.17 to 0.67)
renal/urology	21/47 (45%)	25/51 (49%)	1.35 (0.56 to 3.22)
bariatric	26/46 (57%)	4/29 (14%)	0.11 (0.02 to 0.47)
Operation duration *(h)*			
< 3	20/113 (18%)	26/121 (22%)	1.56 (0.76 to 3.23)
3 to 5	70/193 (36%)	34/180 (19%)	0.39 (0.23 to 0.67)
> 5	57/100 (57%)	34/86 (40%)	0.44 (0.22 to 0.86)
Physiotherapist experience			
novice	21/66 (32%)	14/64 (22%)	1.08 (0.37 to 3.14)
intermediate	33/100 (33%)	23/89 (26%)	0.86 (0.42 to 1.76)
senior	13/52 (25%)	5/45 (11%)	0.47 (0.30 to 0.73)
expert	80/190 (42%)	52/194 (27%)	0.48 (0.30 to 0.79)

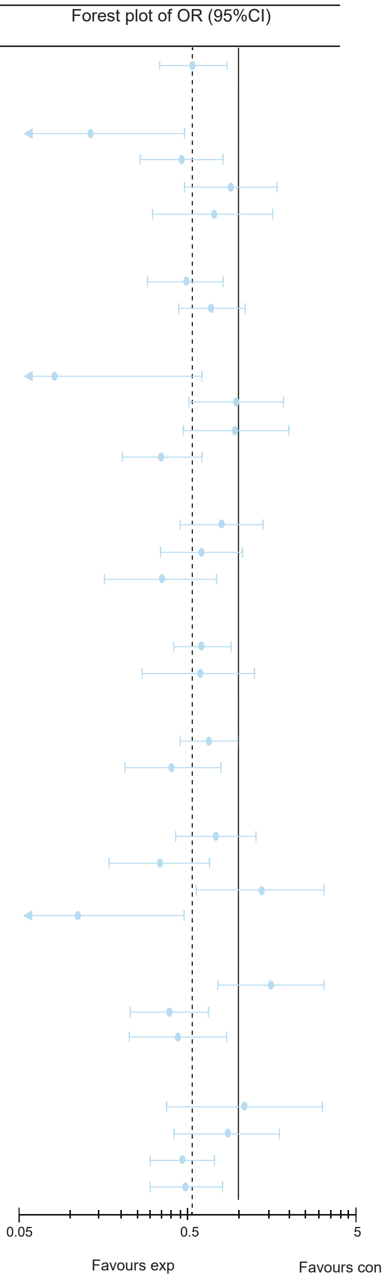

Figure 3. Subgroup effects on incidence of postoperative pulmonary complications. Adjusted for trial, age, ASA category, respiratory disease, smoking, operation duration and surgery category.
ASA = American Society of Anaesthesiologists, BMI = body mass index, Con = control group, Exp = experimental group, HB = hepatobiliary, UGI = upper gastrointestinal.

abdominal surgery is a cost-effective method[15] in reducing the overall PPC rate by approximately half. Despite this intervention being effective across the general abdominal surgery population, understanding subgroups that may or may not benefit to a greater extent than others can assist in critically analysing hypotheses of mechanisms of action for breathing exercises to prevent PPCs. In a time-poor or resource-limited environment, knowledge of subgroups in whom the intervention is particularly beneficial could guide physiotherapists to target their preoperative services and give researchers valuable information to consider other interventions to better reduce the risk of PPCs in these patients. A pooled patient-level data meta-analysis provides greater power to conduct these types of analyses.

The very large 90% reduction in the odds of contracting a PPC seen in participants with low BMI may be related to the complex relationship between low BMI, malnutrition, sarcopenia and poor respiratory muscle strength.[24] Compared with matched controls, malnourished patients without respiratory disease have low respiratory muscle strength, poorer maximal voluntary ventilation,[25] less chest wall expansion and a higher risk PPCs.[26] It is plausible that early initiation of postoperative breathing exercises increases the total dosage of voluntary deep breaths above tidal volumes over the first 24 postoperative hours enough to offset the impact of weak respiratory muscles and poorer maximal lung volumes on atelectasis development. Similarly, the very large treatment effect of preoperative physiotherapy in obese participants and those having bariatric surgery could be explained by early postoperative breathing exercises ameliorating the inevitable dependent atelectasis during tidal volumes, due to excessive thoracic and abdominal adipose tissue, and lower functional residual capacity and lung unit closing capacity. Patients with high BMI are also prone to prolonged duration of neuromuscular blockade used to induce muscle paralysis during surgery,[27] leading to poor inspiratory muscle strength and an increased likelihood of a PPC.[28] It may be that self-directed deep breathing exercises are enough to overcome these physiological deficits and reverse atelectasis in the early postoperative period.

The greater benefit observed in younger participants could be explained by the physiological responsiveness of more compliant

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elastic lung tissue to simple deep breathing exercises and increased inspiratory muscle strength, thus more easily re-expanding collapsed lung tissue compared with older patients. Other subgroups in whom the intervention is particularly beneficial (ie, those with an ASA category > 2, smokers and those having upper gastrointestinal surgery) are prone to significantly more postoperative atelectasis[29] and a higher risk of contracting a PPC.[1] Early breathing exercises may be most effective in patients with significant postoperative atelectasis and, conversely, less effective in patients with very little atelectasis. The subgroups that were less responsive to preoperative physiotherapy were those having short procedures. Increasing duration of anaesthesia has consistently been found to be strongly associated with risk of a PPC, with every hour increase in length of anaesthesia associated with an additional 14% increase in PPC risk.[1] Conversely, patients having short anaesthetic times have less atelectasis[30] and breathing exercises may not be needed in patients with no other risk factors.

Despite preoperative physiotherapy being cost-effective[15] and highly valued by patients,[20] the most common payer of the service – the hospital – may still be reluctant to pay for implementation. Demonstrating that preoperative physiotherapy can impact surgical ward bed flow by reducing LOS is a factor that hospitals highly value and could improve the chance of implementation. PPCs have been shown to be associated with prolonged LOS,[1] yet clinical trials have failed to conclusively demonstrate that an intervention that prevents PPCs can also impact LOS.[8] There are complex multifactorial reasons that influence LOS and hospital discharge; this is highlighted by wide statistical variances and standard deviations for LOS in major abdominal surgery populations. Clinical trials would require thousands of participants to be powered to detect small but clinically important differences of spending 1 day less in hospital. Understandably, this meta-analysis of pooled data from 800 patients was therefore insufficient to demonstrate that preoperative physiotherapy effected a 1-day reduction in LOS. However, this patient-level meta-analysis allowed for robust subgroup analyses, which found that participants with an ASA category > 2 provided with preoperative physiotherapy had an estimated 3-day reduction in LOS, although with some inherent uncertainty in the confidence interval. This is a large and clinically relevant impact on a highly valued hospital outcome; with a third of all participants in this study presenting with multiple comorbidities, the significance of reducing LOS by 3 days in these complex high-risk patients with a single once-off preoperative intervention is powerful.

This study had some limitations. The purposeful selection of two highly similar trials through a non-systematic selection process could have introduced potential biases in study selection, sampling and transparency of reporting. The gold standard method would be to conduct a pre-registered systematic review with an integrated individual patient data meta-analysis of all discovered studies, although the feasibility of obtaining and amalgamating original datasets from many clinical trials would need to be considered. Diagnostic tools used to measure both PPC and pneumonia differed between the two included studies, albeit with some commonality and overlap. For the purposes of this meta-analysis, the raw data were re-evaluated to fit to a common diagnosis from data available in both trials. Universally in the literature, there is ongoing difficulty in reaching consensus on defining PPCs and pneumonia, which may lead to the overestimation or underestimation of clinically significant pulmonary complications. Recently the Standardised Endpoints in Perioperative Medicine collaboration derived an agreed diagnostic framework for PPC,[31] including imaging evidence of atelectasis and the United States Centers for Disease Control and Prevention's definition of pneumonia. It was not possible to apply these to this study's cohort retrospectively due to unavailable data fields. Regardless, the effect of preoperative physiotherapy was consistent, despite the PPC diagnostic definition used to measure the difference between groups.

A strength of this individual patient meta-analysis was the inclusion of patients from four hospitals in three countries, with a large variety of abdominal surgical procedures and interventions undertaken by 18 physiotherapists with different levels of clinical experience. Additionally, data were collected across a 20-year period, with major changes in surgical and anaesthetic techniques occurring over this time. The consistency of response to preoperative physiotherapy regardless of time and the diversity of surgical differences across sites and countries demonstrated that the beneficial effect of preoperative physiotherapy has high generalisability. In both studies included in this meta-analysis, similar physiotherapy interventions were used: all received an individualised preoperative education intervention plus a written booklet where the required postoperative physiotherapy treatment was summarised. Whilst the specifics of this intervention varied (eg, the booklet in LIPPSMAck POP was more detailed and the postoperative ambulation protocol varied in frequency), the preoperative physiotherapy intervention contained the same components of education on PPC risk, the need to be involved in early postoperative mobilisation, and teaching of deep breathing and coughing exercises to perform on waking from surgery.

This study found that a single preoperative physiotherapy session delivered any time within 4 weeks of major abdominal surgery is highly effective in reducing PPCs and is likely to reduce LOS in patients with multiple comorbidities. This effective, simple, once-off, low-cost, face-to-face physiotherapy intervention with no known side effects and requiring no specialist equipment improves patient experience, knowledge, self-management and quality of care. It should become a routine part of preoperative care for all patients, regardless of risk, undergoing major open abdominal surgery.

What was already known on this topic: Pulmonary complications are common after major abdominal surgery. Systematic reviews have conflicting results regarding the effectiveness of respiratory-focused physiotherapy interventions to prevent such complications.
What this study adds: Pooling patient-level data from two randomised trials with 800 participants confirmed that preoperative physiotherapy respiratory education and breathing exercise training prior to major abdominal surgery reduces the risk of a patient developing a PPC by 30 to 50%. Effects were greater in participants who smoked, were aged ≤ 45 years, had abnormal body weight, had multiple comorbidities, or were undergoing bariatric or upper gastrointestinal surgery. Furthermore, it reduces length of stay in hospital among those patients with multiple comorbidities.

Footnotes: [a] SPSS Statistics Version 24, IBM Corp, Armonk, USA.
[b] Excel, Microsoft, Washington, USA.

eAddenda: Tables 1 and 3, Figures 4 and 5 can be found online at https://doi/org/10.1016/j.jphys.2024.02.012.

Ethics approval: Västra Götaland, Sweden, 203-31 T449-18; The Tasmanian Human Research Ethics Committee, Australia (H0011911) and Health and Disability Ethics Committee, New Zealand (14/NTA/233) approved this study. All participants were provided with written and verbal information about the study. Those willing to be involved provided signed consent prior to randomisation into the trials.

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The corresponding author had full access to all data in the study and had final responsibility of the decision to submit for publication.

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Correspondence: Ianthe Boden, School of Health Sciences, University of Tasmania, Launceston, Australia. Email: Ianthe.boden@utas.edu.au

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