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Research

Preoperative intervention reduces postoperative pulmonary complications but not length of stay in cardiac surgical patients: a systematic review

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KEYWORDS

Cardiac surgical procedures
Coronary artery bypass
Preoperative care
Rehabilitation
Education

CrossMark

ABSTRACT

Question: Does preoperative intervention in people undergoing cardiac surgery reduce pulmonary complications, shorten length of stay in the intensive care unit (ICU) or hospital, or improve physical function? **Design:** Systematic review with meta-analysis of (quasi) randomised trials. **Participants:** People undergoing coronary artery bypass grafts and/or valvular surgery. **Intervention:** Any intervention, such as education, inspiratory muscle training, exercise training or relaxation, delivered prior to surgery to prevent/reduce postoperative pulmonary complications or to hasten recovery of function. **Outcome measures:** Time to extubation, length of stay in ICU and hospital (reported in days). Postoperative pulmonary complications and physical function were measured as reported in the included trials. **Results:** The 17 eligible trials reported data on 2689 participants. Preoperative intervention significantly reduced the time to extubation (MD -0.14 days, 95% CI -0.26 to -0.01) and the relative risk of developing postoperative pulmonary complications (RR 0.39, 95% CI 0.23 to 0.66). However, it did not significantly affect the length of stay in ICU (MD -0.15 days, 95% CI -0.37 to 0.08) or hospital (MD -0.55 days, 95% CI -1.32 to 0.23), except among older participants (MD -1.32 days, 95% CI -2.36 to -0.28). When the preoperative interventions were separately analysed, inspiratory muscle training significantly reduced postoperative pulmonary complications and the length of stay in hospital. Trial quality ranged from good to poor and considerable heterogeneity was present in the study features. Other outcomes did not significantly differ. **Conclusion:** For people undergoing cardiac surgery, preoperative intervention reduces the incidence of postoperative pulmonary complications and, in older patients, the length of stay in hospital. [**Snowdon D, Haines TP, Skinner EH (2014) Preoperative intervention reduces postoperative pulmonary complications but not length of stay in cardiac surgical patients: a systematic review. *Journal of Physiotherapy* 60: 66–77**].

Introduction

Cardiovascular disease is a major cause of death; it accounts for over four million deaths annually in Europe[1] and over half a million deaths per year in the United States.[2] In addition to the health burden, cardiovascular disease poses a significant financial burden, with an estimated annual cost of €169 billion in the European Union[3] and US$109 billion in the United States.[4] Over half of the cost is attributable to inpatient care.[3] With such high mortality and cost it is vital that the services provided to people with cardiovascular disease are effective and cost efficient.

Postoperative hospital and community-based cardiac rehabilitation exercise programs reduce the mortality of individuals with coronary heart disease.[5] In contrast to the body of evidence favouring postoperative rehabilitation programs following cardiac surgery, few reviews have investigated the effects of preoperative interventions in the management of this population. Typical preoperative interventions may be delivered by different disciplines and include interventions targeted at physiological optimisation of the cardiorespiratory and musculoskeletal systems to mitigate the effects of general anaesthesia (eg, deep breathing exercises, inspiratory muscle training, exercise training, early mobilisation or education aimed at promoting these behaviours both preoperatively and postoperatively). Preoperative interventions are also targeted at improving the patient's ability to cope with major surgery (eg, relaxation, goal setting/counselling or education aimed at promoting these behaviours both preoperatively and postoperatively). These interventions typically have the goal of preventing or reducing postoperative complications – in particular, postoperative pulmonary complications, which are associated with morbidity, mortality and prolonged hospital length of stay[6,7] – and hastening postoperative recovery.

Although three systematic reviews have recently been published, which examine rehabilitation before major surgery,[8]

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1836-9553/

Box 1. Example of a definition of postoperative pulmonary complications.[39]

Postoperative pulmonary complications are defined as the presence of four or more of the following criteria:

- Chest radiograph report of collapse/consolidation
- Raised maximal oral temperature > 38°C on more than one consecutive postoperative day
- Pulse oximetry saturation (SpO_2) < 90% on more than one consecutive postoperative day
- Production of yellow or green sputum, different to preoperative assessment
- Presence of infection on sputum culture report
- An otherwise unexplained white cell count greater than 11 x 10^9/l or prescription of an antibiotic specific for respiratory infection
- New abnormal breath sounds on auscultation, different to preoperative assessment
- Physician's diagnosis of postoperative pulmonary complication

Box 2. Inclusion criteria.

Design
- Randomised controlled trials (including quasi-randomised)
- Published in English
- Peer reviewed

Participants
- Adults (≥ 18 years old)
- Undergoing coronary artery bypass grafting and/or valvular surgery

Intervention
- Preoperative intervention (including anaesthetic clinic or pre-admission clinic) targeted at preventing/reducing postoperative pulmonary complications or hastening recovery of function

Outcome measures
- Postoperative pulmonary complications
- Postoperative pulmonary function
- Length of intensive care unit stay, inpatient hospital stay or other measures that related to resource burden
- Time to extubation

preoperative intervention (exercise and education) in abdominal and thoracic surgery[9] and preoperative inspiratory muscle training,[10] they have all grouped multiple surgical populations together. It is possible that intervention effects vary by surgical specialties[6] and it is therefore imperative that reviews focus on intervention effects in specific populations. An earlier review specifically investigating patients undergoing coronary artery bypass graft surgery demonstrated no postoperative benefit of preoperative education,[11] although the included studies were low quality and often omitted clinically meaningful outcomes, such as length of stay or postoperative pulmonary complications. Although the definitions vary widely, postoperative pulmonary complications have been reported to include respiratory infections/pneumonia, respiratory failure and atelectasis.[6] A commonly used tool for diagnosing postoperative pulmonary complications is presented in Box 1.

Therefore, the research questions for this review were:

1. Does preoperative intervention in people undergoing cardiac surgery reduce the time to extubation, the incidence of postoperative pulmonary complications, or the length of stay in ICU or in hospital?
2. Does preoperative intervention in people undergoing cardiac surgery improve postoperative physical function?

Method

Identification and selection of studies

This systematic review sought to identify, and where possible meta-analyse, randomised or quasi-randomised trials of preoperative intervention in people undergoing cardiac surgery. The criteria used to determine eligibility of studies for the review are presented in Box 2.

CINAHL, Medline (1948 to Present with Daily Update), EMBASE (1980 to 2011), PubMed, Proquest, ISI Web of Science, Expanded Academic ASAP, Physiotherapy Evidence Database (PEDro) and Cochrane Central Register of Controlled Trials were searched up to May 24th 2011, inclusively. The search strategy combined terms related to the population (eg, *cardiac, coronary, cardiothoracic, open heart, CABG, preadmission, anaesthetic clinic*) with terms for the intervention (eg, *physiotherapy, education, exercise, mobilization*) and the outcomes (eg, *length of stay, postoperative pulmonary complications*). The full electronic search strategy for Medline and EMBASE is presented in Appendix 1 (See the eAddenda for Appendix 1).

Two reviewers (DS and ES), working independently, assessed papers identified by the search for eligibility. Full-text versions were sought where there was insufficient information in the title or abstract.

Assessment of study characteristics

Data were extracted using a template based on the Cochrane Consumers and Communication Review Group's data extraction template, the PEDro scale[12] and the PRISMA statement.[13] Data were extracted independently by two reviewers (DS and ES); disagreements were adjudicated by the third author (TH). Where insufficient data were reported, first authors were contacted by email to request data.

Quality

The PEDro scale was used to assess trial quality and it is a reliable tool for the assessment of risk of bias of randomised controlled trials in systematic reviews.[14] The PEDro scale consists of 11 items, 10 of which contribute to a total score.[12] In the present review, PEDro scores of 9 to 10 were interpreted as 'excellent' methodological quality, 6 to 8 as 'good', 4 to 5 as 'fair', and < 4 as 'poor' quality.[15] Two reviewers (DS and ES) independently assigned PEDro scores and any disagreements were adjudicated by a third reviewer (TH).

Participants, interventions and outcomes

The number of participants, their ages and genders, and the types of cardiac surgery were extracted for each trial. The country in which each trial was performed was also extracted. To characterise the preoperative interventions, the content of the intervention, its duration and the health professional(s) who administered it were extracted for each trial. The data required for meta-analysis of the outcome measures presented in Box 2 were also extracted wherever available.

Data analysis

Meta-analysis aimed to quantify the effect of preoperative intervention on the relative risk of developing postoperative pulmonary complications, on time to extubation (in days), and on the length of stay in ICU and in hospital (also in days). An iterative analysis plan was used to partition out possible heterogeneity in study results by sub-grouping studies according to independent variables of relevance, eg, age, type of intervention or type of outcome. Due to the differences in clinical populations and therapies being investigated across the studies, random effects meta-analysis and meta-regression models were used. The principal summary measures used were the pooled mean difference (95% CI) and the pooled relative risk (95% CI). Where trials included multiple intervention groups, the meta-analyses were performed using the outcome data of the most-detailed intervention group. Sensitivity analyses were conducted for length of stay using meta-regression to examine: the influence of population differences (age as a continuous variable); study design (randomised versus quasi-randomised); global geographical region (Western versus Eastern); intensity of education (intensive, defined as anything more than an educational booklet, versus non-intensive, defined as a booklet only); and type of intervention (breathing exercises versus other). Thresholds for sensitivity analyses were defined according to median values (eg, age) or defined using investigator judgment and clinical expertise. Two studies could only be included in analyses for outcomes assessable until time to extubation, as they provided postoperative physiotherapy intervention following extubation in ICU.[16,17] To aid interpretation of the effect on postoperative pulmonary complications, the relative risk reduction and number needed to treat were also calculated.

Results

Flow of studies through the review

The searches retrieved 859 citations. After review of abstracts and full-text articles, 17 trials were included in the review. Data from 13 of the trials were included in the meta-analyses. The flow of studies through the review is presented in Figure 1.

Characteristics of included trials

The 17 included trials involved 2689 participants. The characteristics of these trials are presented in Table 1.

Quality

All trials except one[18] satisfied the first item on the PEDro scale, which relates to the eligibility criteria and source of participants and does not contribute to the total score. The remaining PEDro item ratings and total scores for the included trials are presented in Table 2. The median PEDro score of the included trials was 6 (range 3 to 8), indicating that the methodological quality of the included trials varied from poor to good.

Participants, interventions and outcomes

The sample sizes of the included trials ranged from 41 to 406, consisting mainly of male participants. The experimental interventions included exercise training, inspiratory muscle training, education, relaxation, counselling, and complex/multiple interventions. Outcome data from at least one trial were available for postoperative pulmonary complications, time to extubation, length of stay in ICU and the hospital, physical function and costs.

Overall effect of preoperative intervention

Postoperative pulmonary complications

Based on data from six trials (661 participants), there was a significant reduction in the relative risk of developing postoperative pulmonary complications with preoperative intervention, as presented in Figure 2. When the results from trials included in this meta-analysis were pooled, no heterogeneity was present and the pooled relative risk of developing postoperative pulmonary complications was 0.39 (95% CI 0.23 to 0.66). The relative risk reduction was 61% and the number needed to treat was 12 (95% CI 8 to 27).

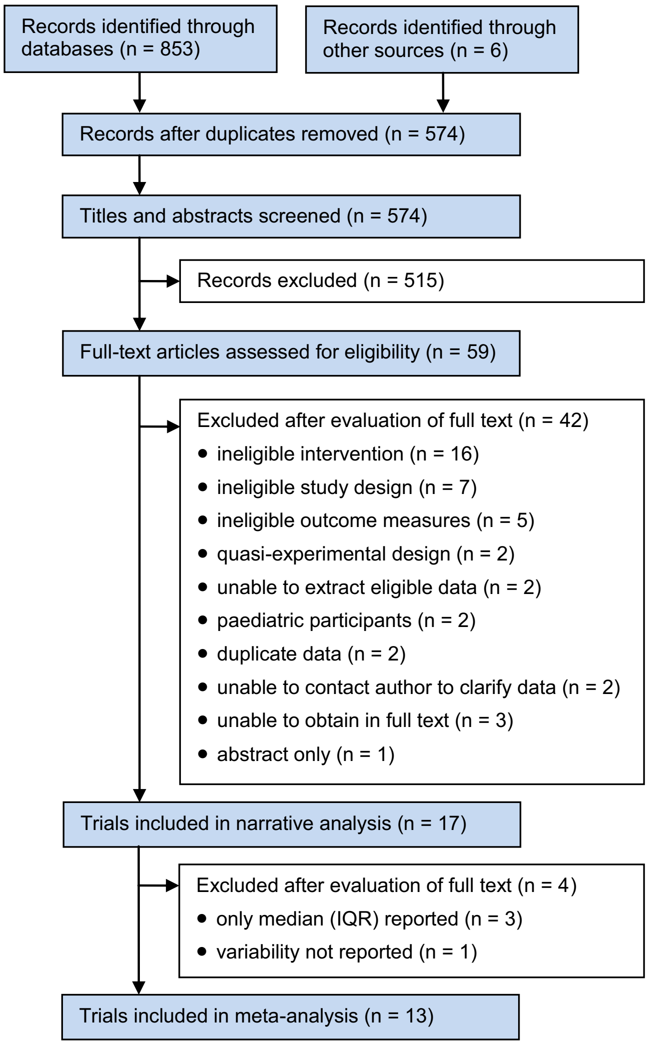

Figure 1. Flow of studies through the review.

Time to extubation

Preoperative intervention shortened the time to extubation by a pooled mean difference of 0.14 days (95% CI 0.01 to 0.26), based on data from four trials (291 participants). There was moderate heterogeneity in the analysis, which is presented in Figure 3.

Length of stay

Meta-analysis of data from three trials (233 participants) indicated a non-significant reduction in ICU length of stay due to preoperative intervention, with a pooled mean difference of -0.15 days (95% CI -0.37 to 0.08) and low heterogeneity, as presented in Figure 4. Data from ten trials (1573 participants) showed no significant effect on hospital length of stay, with a pooled mean difference of -0.55 days (95% CI -1.32 to 0.23) and moderate heterogeneity, as presented in Figure 5. Exploratory meta-regression demonstrated no influence on this outcome by study design, geographical region, or type of intervention (either

Table 1
Characteristics of included studies (n = 17).

Study	Country n	Surgery	Participants[a]	Intervention	Health professional giving intervention	Outcomes
Arthur[21]	Canada 249	Elective first CABG	Age = 62 (8) 88% males	Exp = exercise training 2/wk for 8 wks, education at recruitment and pre-surgery, and monthly telephone call	• Nurse • Kinesiologist • Exercise specialist	• LOS • ICU LOS
			Age = 64 (8) 83% males	Con = education pre-surgery in 1 session		
Christopherson[19]	USA 41	First CABG	Age = 50 (n/s) 100% males	Exp = education booklet 1 to 2 days preoperatively, plus routine nurse education on admission the evening before surgery	• Nurse	• LOS • ICU LOS
			Age = 57 (n/s) 100% males	Exp = education booklet when informed of surgery, plus routine nurse education on admission the evening before surgery		
			Age = 56 (n/s) 100% males	Con = routine nurse education post-admission the evening before surgery		
Deyirmenjian[35]	Lebanon 110	First CABG	Age = 62 (8) 83% males	Exp = education session and unit tour	• Not reported (RA provided education)	• LOS • PPC • Time to extubation
			Age = 59 (12) 86% males	Con = no education		
Furze[24]	England 204	Elective first CABG	Age = 64 (9) 85% males	Exp = education booklet, relaxation, and targeted counselling, administered at 45 to 60 min interview + phone calls at week 1, 3, 6 and monthly till operation	• Nurse	• LOS • Cost utility Mobility scale[b]
			Age = 65 (9) 79% males	Con = pre-admission nurse education and general counselling, administered at 45 to 60 min interview + phone calls at week 1, 3, 6 and monthly till operation		
Goodman[23]	England 188	CABG ± valve surgery	Age = 63 (n/s) 76% males	Exp = preoperative counselling appointments monthly and education booklet	• Nurse	• LOS • Cost • SF-36 • CROQ
			Age = 66 (n/s) 86% males	Con = pre-admission education day and help line		
Herdy[16]	Brazil 84	First CABG	Age = 61 (10) 69% males	Exp = exercise program at least 5 days preoperatively	• Physiotherapist	• ICU LOS • Time to extubation
			Age = 58 (9) 74% males	Con = no intervention unless prescribed		
Hulzebos[26]	Netherlands 279	Elective first CABG	Age = 67 (9) 78% males	Exp = inspiratory muscle training 7/wk for ≥ 2 wks, instruction on deep breathing, cough and early mobilisation	• Physiotherapist	• LOS • PPC • Time to extubation
			Age = 67 (9) 78% males	Con = instruction on deep breathing, cough and early mobilisation, in one session		
Hulzebos[27]	Netherlands 26	Elective CABG	Age = 70 (10) 50% males	Exp = inspiratory muscle training 7/wk for ≥ 2 wk, instruction on deep breathing, cough and early mobilisation	• Physiotherapist	• LOS • PPC
			Age = 71 (10) 50% males	Con = instruction on deep breathing, cough and early mobilisation, in one session		
Mahler[29]	USA 268	Elective first CABG	Age = n/s 100% males	Exp1 = viewed a video of information about surgery narrated by a nurse, plus usual hospital care	• Nurse	• LOS • ICU LOS • Post-operative ambulation
			Age = n/s 100% males	Exp2 = as for Exp1, but the video also included patient interviews showing smooth recovery		
			Age = n/s 100% males	Exp3 = as for Exp1, but the video also included patient interviews showing effortful recovery		
			Age = n/s 100% males	Con = usual hospital care (oral education about deep breathing, cough and ambulation ± video about incentive spirometry)		

Table 1 (*Continued*)

Study	Country n	Surgery	Participants[a]	Intervention	Health professional giving intervention	Outcomes
Rajendran[28]	India 45	CABG	Age = 55 (7) Gender n/s	Exp = multi-disciplinary training package including relaxation, respiratory training, and breathing exercises for 1 wk	• Multidisciplinary team (not specified)	• LOS • PPC • Time to extubation
			Age = 59 (7) Gender n/s	Con = no intervention		
Rice[20]	USA 55	Elective first CABG	Age = 60 (8) 84% males	Exp = pre-admission exercise booklet	• Nurse	• LOS • ICU LOS • Physical activity performance
			Age = 60 (7) 80% males	Con = post-admission nurse instruction and exercise booklet		
Rosenfeldt[22]	Australia 117	Elective CABG and/or valve surgery	Age = median 63 (range 59 to 69) 78% males	Exp = gentle exercise program, stress management and relaxation, for 2 wks	• Physiotherapist • Occupational Therapist	• LOS • SF-36
			Age = median 68 (range 58 to 77) 70% males	Con = no intervention		
Shuldham[11]	England 256	First CABG	Age = 63 (7) 90% males	Exp = group education (written and video), ward visit, and 1:1 education in 1 session	• Multidisciplinary team[c]	• LOS
			Age = 62 (8) 85% males	Con = 1:1 education in 1 session on admission		
Stiller[17]	Australia 127	Elective CABG	Age = 63 (8) 80% males	Exp1 = education and instruction (DB and cough) in 1 session	• Physiotherapist	• PPC • Time to extubation
			Age = 61 (9) 83% males	Exp2 = education and instruction (DB and cough) in 1 session [d]		
			Age = 62 (11) 83% males	Con = no intervention		
Watt-Watson[46]	Canada 50	Elective	Age = 57 (10) 88% males	Exp1 = interview, pain relief booklet, and routine education, including booklet and video, in 1 session	• Nurse	• LOS • BPI-Interference
			Age = 64 (7) 87% males	Exp2 = pain relief booklet with advice to read it preoperatively, and routine education, including booklet and video, in 1 session		
			Age = 60 (11) 94% males	Con = routine education, including booklet and video, provided in 1 session		
Watt-Watson[47]	Canada 406	Elective first CABG	Age = 61 (9) 87% males	Exp = pain relief booklet, interview and routine education, including booklet and video, in 1 session	• Nurse	• LOS • BPI-Interference
			Age = 62 (9) 83% males	Con = routine education, including booklet and video, in 1 session		
Weiner[18]	Israel 84	CABG	Age = 59 (n/s) Gender n/s	Exp = daily 30-min sessions of inspiratory muscle training with resistance, 6 sessions/wk for 2 to 4 wks	• Physician	• PPC
			Age = 64 (n/s) Gender n/s	Con = daily 30-min sessions of inspiratory muscle training with no resistance, 6 sessions/wk for 2 to 4 wks		

Con = control group, Exp = experimental groups, LOS = length of stay, n/s = not stated, PPC = postoperative pulmonary complication, SF-36 = Short Form 36, CROQ = Coronary Revascularisation Outcome Questionnaire, BPI = Brief Pain Inventory.
[a] Age is mean (SD) unless otherwise stated.
[b] Mobility scale of the cardiovascular limitations and symptoms profile (M-CLASP).
[c] This multidisciplinary team consisted of nurse, doctor, physiotherapist, occupational therapist, pharmacist and dietician.
[d] Exp1 and Exp2 differed in postoperative management.

intensive education versus booklet only, or breathing exercises versus no breathing exercises). Age, however, had a significant effect (I^2 = 26%, co-efficient = -0.08 (SE 0.03), p = 0.04). When the mean differences were pooled and dichotomised by age (<> 63), as presented in Figure 5, preoperative intervention reduced length of stay in trials where the population was older, with a pooled mean difference of -1.32 days (95% CI -2.36 to -0.28). However, in younger patients, preoperative intervention had no significant effect, with a pooled mean difference of 0.07 days (95% CI -0.99 to 0.84), although significant heterogeneity was present in this analysis (I^2 = 77%, p = 0.001).

Other outcomes

Meta-analysis of physical function was unable to be performed due to insufficient data and a lack of consistency in the selection of outcome measures. The results of individual trials are discussed below. Cost effectiveness was only reported for trials of counselling, so these data are discussed in that section below.

Table 2
PEDro item ratings and total scores for included papers (n = 17).

Study	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total (0 to 10)
Arthur[21]	Y	Y	Y	N	N	N	Y	N	Y	Y	6
Christopherson[19]	Y	N	N	N	N	N	N	N	Y	Y	3
Deyirmenjian[35]	N	N	Y	N	N	Y	Y	N	Y	Y	5
Furze[24]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Goodman[23]	Y	N	Y	N	N	N	Y	Y	Y	Y	6
Herdy[16]	Y	N	N	N	N	Y	N	Y	Y	Y	5
Hulzebos[26]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Hulzebos[27]	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Mahler[29]	Y	N	N	N	N	Y	Y	N	Y	Y	5
Rajendran[28]	Y	N	Y	N	N	N	Y	Y	Y	Y	6
Rice[20]	Y	N	N	N	N	N	Y	N	Y	Y	4
Rosenfeldt[22]	Y	Y	Y	N	N	N	Y	N	Y	Y	6
Shuldham[11]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Stiller[17]	Y	N	Y	N	N	N	Y	Y	Y	Y	6
Watt-Watson[46]	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Watt-Watson[47]	Y	N	Y	N	N	N	Y	Y	Y	Y	6
Weiner[18]	Y	N	Y	Y	N	N	N	N	Y	Y	5

Y = yes, N = no.

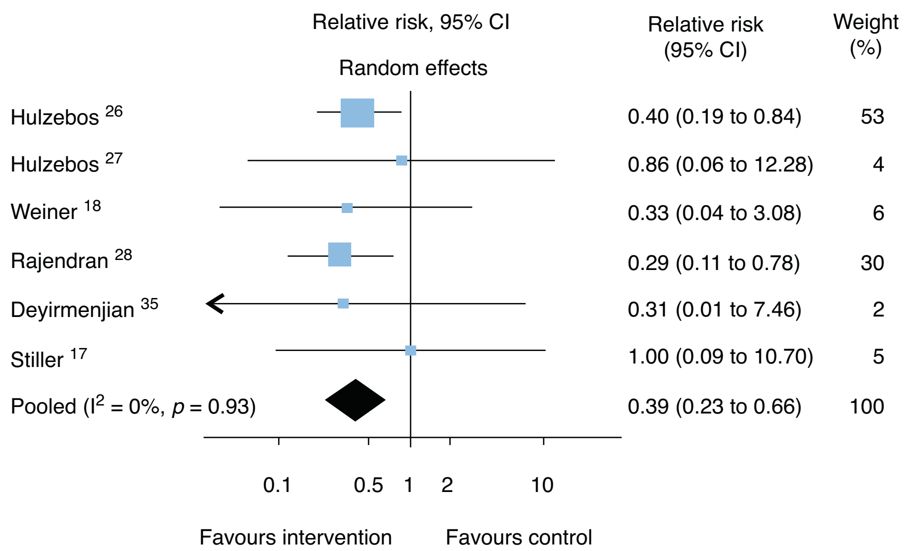

Figure 2. Relative risk (95% CI) of the effect of preoperative intervention on postoperative pulmonary complications in six studies (n = 661).

Effect of education

Postoperative pulmonary complications

Preoperative education did not significantly change the pooled relative risk of developing postoperative pulmonary complications, 0.66 (95% CI 0.10 to 4.40). This was based on meta-analysis of data from two trials, as presented in Figure 6. See the eAddenda for Figure 6.

Time to extubation

Meta-analysis of two trials reporting time to extubation gave a pooled mean difference of 0.07 days in favour of the education, which was not statistically significant (95% CI -0.17 to 0.03), as presented in Figure 7. See the eAddenda for Figure 7.

Length of stay

Meta-analysis of three trials reporting length of stay in hospital gave a pooled mean difference of 0.20 days in favour of usual care, but this difference was not statistically significant (95% CI -0.58 to 0.98), as presented in Figure 8. See the eAddenda for Figure 8.

Two trials[17,19] were unable to be included in this meta-analysis due to limited reporting of the data. Christopherson and Pfeiffer[19] reported a mean reduction of 0.4 days, which could be considered clinically significant. Only two trials reported on length of stay in ICU,[19,20] with conflicting results. Rice et al[20] reported that providing patients with a preoperative educational booklet did not significantly affect length of stay in ICU. Christopherson and Pfeiffer[19] reported that only one of their two intervention groups had a significantly shorter length of stay in ICU (the group who received the booklet 1 to 2 days pre-surgery). It must be noted that the average length of stay in this trial was 2.8 to 4.7 days, which is considerably longer than the majority of trials included in this review.

Physical function

Rice et al[20] reported a statistically significant increase in ambulation on the fifth postoperative day in the intervention group.

Costs

Costs were not reported by any trials that examined education.

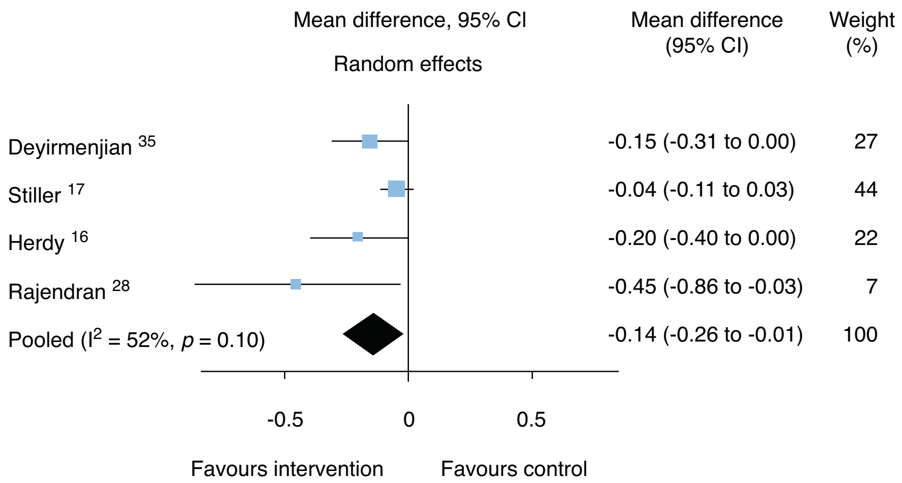

Figure 3. Mean difference (95% CI) of the effect of preoperative intervention on time to extubation (days) in four studies (n = 291).

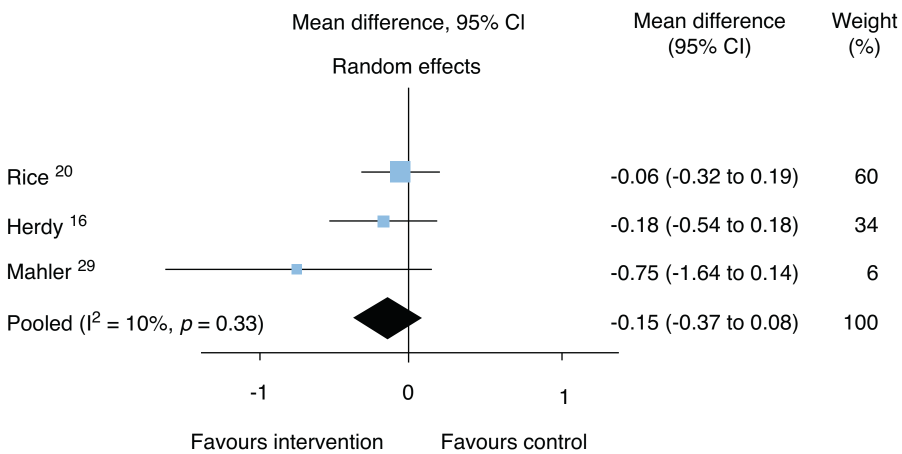

Figure 4. Mean difference (95% CI) of the effect of preoperative intervention on length of stay in ICU (days) in three studies (n = 233).

Effect of exercise

Time to extubation

Herdy et al[16] reported that preoperative exercise resulted in a shorter time to extubation with a mean of 0.73 days (SD 0.26) versus 0.93 days (SD 0.46), $p = 0.04$.

Length of stay

There were conflicting findings from the two trials that examined hospital length of stay and meta-analysis was not possible due to the format of data reporting. Arthur et al[21] delivered a twice weekly, eight-week supervised exercise program and reported a significant reduction in length of stay of one day. Rosenfeldt et al[22] reported no significant difference in length of stay after a two-week exercise and stress reduction program. Two trials reported data about length of stay in ICU following preoperative exercise training, again with conflicting results. Arthur et al[21] reported a statistically significant reduction in ICU length of stay (median of two hours less) due to preoperative exercise, whereas Herdy et al[16] reported no significant difference.

Physical function

The two-week program demonstrated no postoperative benefit to physical function at six weeks (measured using the Short Form 36 Physical Component Summary score) and this trial was the only trial to examine physical function outcomes postoperatively.[22]

Other outcomes

Outcome data for postoperative pulmonary complications and costs were not reported by any trials that examined exercise.

Effect of counselling

Length of stay

There were no significant differences in hospital length of stay between groups in either trial examining counselling or goal setting as their primary intervention.[23,24]

Costs

Both of the trials above concluded that the programs were cost effective when compared to usual care, although they used different metrics. Goodman et al[23] reported that a preoperative support program lowered total costs by £2293, which was statistically significant (95% CI -3743 to -843). Furze et al[24] reported that the incremental cost effectiveness ratio per quality-adjusted life year was £288.83, well below the thresholds for acceptability in the United Kingdom.[25]

Other outcomes

None of the included trials reported data about postoperative pulmonary complications, physical function, time to extubation or length of stay in ICU.

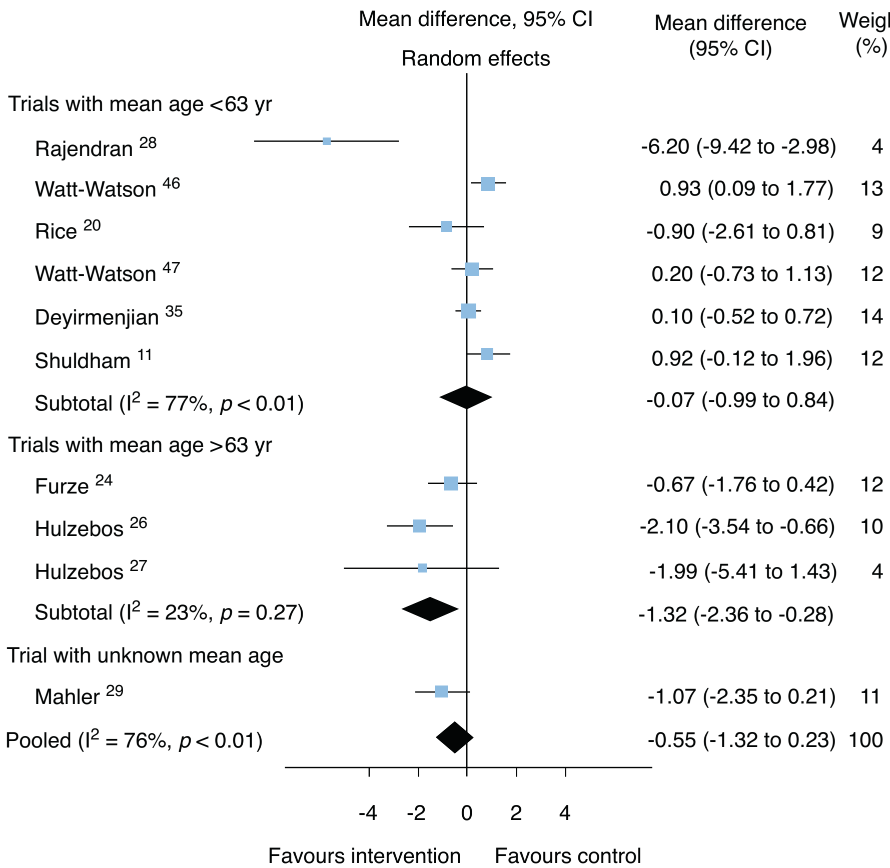

Figure 5. Mean difference (95% CI) of the effect of preoperative intervention on length of stay in hospital (days) in ten studies (n = 1573), with subgroup analysis by age dichotomised at 63 years. Weights shown relate to weighting the overall pooled analysis.

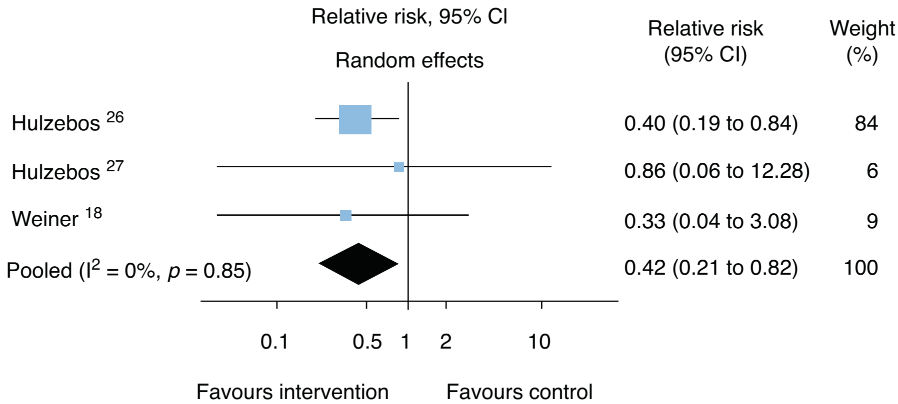

Figure 9. Relative risk (95% CI) of the effect of preoperative inspiratory muscle training on postoperative pulmonary complications in three studies (n = 386).

Effect of inspiratory muscle training

Postoperative pulmonary complications

Meta-analysis of data from three trials showed that inspiratory muscle training caused a significant reduction in the relative risk of developing postoperative pulmonary complications, as presented in Figure 9. No heterogeneity was present (I^2 = 0%) and the pooled relative risk was 0.42 (95% 0.21 to 0.82). The relative risk reduction was 58% and the number needed to treat was 13 (95% CI 7 to 48).

Time to extubation

Only the large randomised controlled trial by Hulzebos et al[26] investigated the effectiveness of preoperative inspiratory muscle training on time to extubation. They reported a statistically significant reduction in the time to extubation with a median of 0.17 days (range 0.05 to 53.6) in the intervention group and 0.21 days (range 0.05 to 3.3) in the control group, *p* = 0.01.

Length of stay

Meta-analysis of two trials by Hulzebos et al[26,27] showed that inspiratory muscle training reduced length of stay in hospital significantly, with a mean difference of 2.1 days (95% CI -3.41 to -0.76) and no heterogeneity present in the analysis, as presented in Figure 10.

Other outcomes

Outcome data for length of stay in ICU, physical function and costs were not reported by any trials that examined preoperative inspiratory muscle training.

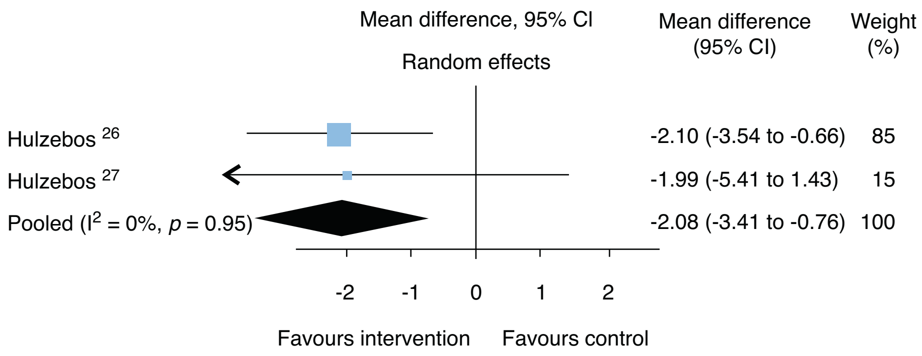

Figure 10. Mean difference (95% CI) of the effect of preoperative inspiratory muscle training on length of stay in hospital (days) in two studies (n = 302).

Effect of complex interventions

Postoperative pulmonary complications

Rajendran et al[28] compared preoperative breathing exercises and multi-disciplinary education to a no-treatment control. The intervention group had a significantly lower incidence of postoperative pulmonary complications (RR 0.29, 95% CI 0.11 to 0.78). While this finding supports the use of breathing exercises in reducing the incidence of postoperative pulmonary complications, it is difficult to determine its clinical relevance because the authors did not sub-group the pulmonary complications. In addition, this trial was conducted in patients with COPD who were determined to be a high-risk population, and so the findings may not be generalisable to other patients.

Time to extubation

Rajendran et al[28] reported that participants who received both preoperative breathing exercises and multi-disciplinary education had a significantly shorter mean time to extubation compared to participants randomised to the control group (mean difference 0.45 days, 95% CI 0.06 to 0.84).

Length of stay

Meta-analysis of four trials reporting length of stay in hospital gave a pooled mean difference of 0.86 days in favour of complex intervention, but this difference was not statistically significant (95% CI -2.53 to 0.81), as presented in Figure 11. See the eAddenda for Figure 11. Only one trial of complex intervention reported data about length of stay in ICU,[29] reporting that individuals who viewed any of three different videotapes had a significantly shorter stay in ICU. (Details of the tapes are presented in Table 1.) However, this trial had a high risk of bias and differences between the intervention and control groups were only significant for those participants who were treated in the public hospital setting.

Physical function

A single trial investigated postoperative ambulation activity (using an activity monitor) and found no statistically significant differences between the three groups who viewed different videotapes, although the device was only worn for a mean (SD) of 7.55 (0.92) hours per day.[29]

Costs

Costs were not reported by any trials that examined complex interventions.

Discussion

The key finding that preoperative intervention reduces the incidence of postoperative pulmonary complications is important because these complications have been associated with a prolonged length of stay in hospital for people undergoing cardiac surgery.[30] It could also be expected that fewer postoperative pulmonary complications would reduce hospital length of stay, particularly as preoperative intervention has been found to reduce length of stay in ICU. However, this review found evidence that preoperative intervention reduced hospital length of stay only in trials where the mean age of participants was over 63 years of age. It is possible that the effect of preoperative intervention is larger in the elderly due to the presence of co-morbidity,[31,32] which increases hospital length of stay[33,34] particularly in post-surgical patients.[34] The relationship between postoperative pulmonary complications and hospital length of stay could be non-existent, not as prominent as first thought or it is possible that latent unobserved variables have a greater influence on hospital length of stay. Potential candidates for these variables include age, co-morbidity or variables not yet identified in the literature to date. Further observational research into the factors associated with hospital length of stay in people undergoing cardiac surgery is required in order to optimise hospital resource use for this population. It is also possible that other factors affect the efficacy of preoperative education, as evidenced by the findings of a Middle Eastern study that demonstrated higher anxiety levels in the group receiving preoperative education.[35] The authors suggested that contextual and cultural factors may be influential and it is important that health professionals consider this point with the prevalent cultural diversity within the western world.

There was no clear effect of preoperative intervention on ICU length of stay, although a few studies reported this. These findings are unsurprising when it is considered that people undergoing cardiac surgery usually have a short duration of mechanical ventilation and ICU stay. Hulzebos et al[26] found a significant reduction in time to extubation in people who performed preoperative inspiratory muscle training, although these results were unable to be included in the meta-analysis as the data were presented as median (range). This, if supported in future work, could be an important outcome because a shorter duration of mechanical ventilation reduces the patient's risk of ventilator-associated pneumonia, prolonged length of stay and mortality.[36] Future studies may be required to quantify the effects of intervention on length of ventilation. However, since the majority of people post cardiac surgery do not undergo prolonged ventilation, there may be little cost saving in shortening this period with intervention.

Given the disparity of reporting and analysis across studies with regard to the primary interventions and outcomes, and the small numbers of studies examining the benefits of individual interventions, pooled analyses were primarily conducted to improve the rigor of the present review's conclusions. This is arguably a clinically relevant way to analyse the data, given that often in public healthcare, policy decisions around service provision may primarily concern whether the service should be provided or not, rather than whether a specific intervention should be delivered or not. For example, many physiotherapy departments face the decision as to whether they should staff a preoperative assessment/clinic session and consideration of the global benefit or absence of benefit should be taken into account with this decision-making. At the individual clinician level, however, it is critically important that decision-making considers individual interventions and takes into account details such as intensity, dosage and frequency. Preoperative education shows a trend toward reduced time to extubation (by 0.07 days or 1.7 hours), obtained by a single session of education on either deep breathing and coughing or pain management, early mobilisation and demonstration of respiratory and leg exercises.

The effects of inspiratory muscle training were more robust, with significant reductions in hospital length of stay (by a mean of 2.1 days) and risk of postoperative pulmonary complications (by 58%). To obtain these benefits, clinicians should deliver inspiratory muscle training as follows: 6 to 7 times a week for two to four weeks (supervised once a week by a physiotherapist); starting at a resistance of 15 to 30% of maximal inspiratory pressure and increasing by 5% each session (or if the Borg scale < 5). It should be noted, however, that these findings were primarily from trials with participants at high risk of pulmonary complications. Thirteen patients would need to be treated with inspiratory muscle training to prevent one postoperative pulmonary complication. In addition, shortening hospital length of stay by two days would be of considerable significance to the public healthcare system in Australia, particularly where earlier discharge frees up beds to allow hospitals to meet emergency department treatment time targets. In addition, whether treating 13 patients preoperatively to reduce postoperative pulmonary complications is worthwhile depends on the cost-effectiveness of treatment and healthcare resource allocation, and the cost of the postoperative pulmonary complications. The resources required to prevent one postoperative pulmonary complication may be better utilised in other health areas if they generate better health outcomes. Furthermore, this review did not take into account unobserved or unreported benefits that may stem from avoiding a postoperative pulmonary complications, for example, avoiding patient discomfort and the risk and cost of investigations or treatment (eg, chest radiograph, antibiotics). None of the studies investigating inspiratory muscle training reported on costs, but both studies of counselling/goal setting reported that their intervention was cost-effective. More research is therefore needed to ascertain whether the specific health benefits applicable to each intervention are worthwhile and cost-effective, despite their statistically significant effect.

Two studies[26,27] used a validated model to identify the risk of cardiac surgery patients developing a postoperative pulmonary complication[37] and targeted their intervention to patients determined *a priori* as high-risk. It is therefore possible that preoperative inspiratory muscle training is most effective in people at risk of developing postoperative pulmonary complications. Another study[28] attempted this risk stratification by targeting people diagnosed with chronic obstructive pulmonary disease (COPD) because, despite little evidence that people with COPD undergoing cardiac surgery are at higher risk of developing postoperative pulmonary complications, it could be expected that this would be observed, as in other populations such as people undergoing upper abdominal surgery.[38] However, COPD has not been consistently found to be a risk factor for postoperative pulmonary complications both within and across surgical populations.[39] Rather than *a priori* determination of high-risk groups, the use of a tool to predict postoperative pulmonary complications to improve the specificity of preoperative inspiratory muscle training should be considered. It is important to note that the diagnosis of postoperative pulmonary complications remains contentious; given the lack of consensus on a standard definition.[6] This lack of consensus increases the observed variability in the incidence of postoperative pulmonary complications. In this review, one study did not report on the methods used to diagnose postoperative pulmonary complications,[35] four studies used a combination of clinical signs and diagnostic imaging,[17,26,27,28] and one study identified the presence of postoperative pulmonary complications using diagnostic imaging alone.[18] Only two studies used standardised methods and operational definitions that had been previously described in the literature.[27,29] This discrepancy in measurement is representative of the broader literature[6] and makes comparison between studies difficult. Until a gold-standard operational definition for postoperative pulmonary complications is used consistently, the literature should be interpreted with caution, including the results of this review.

Studies investigating the effects of preoperative physical exercise programs could not be included in the meta-analyses because the data were insufficient. Hence, the results of the presented analyses can only be generalised to interventions that include breathing exercises and/or education. It is possible that physical training may have a greater effect on patient outcome than education, because education has been shown not to provide additional benefit over physical training in some populations[40] and the study by Arthur et al[21] demonstrated that preoperative physical training reduced length of stay. There were conflicting findings about the benefit of exercise training on length of stay in ICU and in hospital, so caution should be applied to these findings and to the finding that exercise training impacts on time to extubation, because only one study addressed this important issue.[16] Further high-quality randomised controlled trials should be conducted to establish the effectiveness of preoperative exercise training on these outcomes.

Only two studies measured objective postoperative physical outcomes[20,29] and it is a limitation of the included studies that objective, functional measures such as the six-minute walk test were not used. Not only is the six-minute walk test a valid and reliable measure of functional capacity in a cardiac rehabilitation population,[41] but it is a commonly used, inexpensive and safe test of cardiovascular endurance in cardiac surgery populations.[42,43] The most commonly used measure in this review was length of hospital stay, which is a measurement that is extremely important, as it reflects not only the participants' medical and physical health status but also the cost burden to the health service. However, only two included studies reported costs associated with preoperative intervention[23,24] and only one reported a reduction in costs in the intervention group.[23] Future research should also aim to include measures of cost effectiveness to allow clinicians, policy-makers and researchers to justify resource use in this population.

The majority of studies included in this review had good methodological quality and only a moderate risk of bias. The largest risk of bias came from the lack of blinding, which is difficult to achieve in the setting of non-pharmacological clinical research.[44] It is critical that study designs attempt to provide methods of blinding, including: sham education or rehabilitation; blinding participants to study hypotheses; and centralising assessment of outcome assessors to minimise the risk of bias associated with non-blinding.[44] The lack of concealed allocation also introduced bias into the included studies. There also may be clinical differences in people who undergo coronary artery bypass graft surgery alone versus combined coronary artery bypass graft and valvular surgery, though these populations were analysed together.

The inhomogeneity of the interventions was a limitation of this review. Also the long-term physical function outcomes of people undergoing cardiac surgery could not be attributed to their preoperative or hospital management in studies that included a follow-up period of weeks or months. During this time, it is possible that a proportion of people attended cardiac rehabilitation following cardiac surgery, which improves physical outcomes and mortality.[45] Subjective measures such as pain, quality of life and anxiety were not included in this review. Finally, it was not possible to include all relevant articles in the meta-analyses, as studies did not use homogenous variables.

In conclusion, preoperative interventions reduce the risk of postoperative pulmonary complications, reduce hospital length of stay in older populations and may shorten time to extubation in people undergoing cardiac surgery. Preoperative intervention did not significantly affect ICU length of stay. The clinical significance of these improvements was small, except in the case of inspiratory muscle training where hospital length of stay was reduced by a pooled mean difference of 2.1 days. No clear conclusions could be drawn regarding the effect of preoperative intervention on physical function or the cost-effectiveness of preoperative intervention. Further research would help in establishing the clinical significance and implications of these findings.

What is already known on this topic: People undergoing cardiac surgery recover in hospital for several days postoperatively. At this time, they risk developing pulmonary complications, which typically prolong length of stay in hospital.
What this study adds: Preoperative intervention intending to improve the patient's ability to cope with the surgery reduced postoperative pulmonary complications. A reduction in length of stay in hospital was only observed among trials with older participants. When evidence for specific preoperative interventions was considered, inspiratory muscle training reduced postoperative pulmonary complications and reduced length of stay in hospital, although the participants in these trials tended to be at high-risk of complications.

***eAddenda**:* Figures 6, 7, 8 and 11 and Appendix 1 can be found online at doi:10.1016/j.jphys.2014.04.002
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