Preoperative physical therapy for elective cardiac surgery patients (Review)

Hulzebos EHJ, Smit Y, Helders PPJM, van Meeteren NLU

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Preoperative physical therapy for elective cardiac surgery patients (Review)
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Preoperative physical therapy for elective cardiac surgery patients

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ABSTRACT

Background

After cardiac surgery, physical therapy is a routine procedure delivered with the aim of preventing postoperative pulmonary complications.

Objectives

To determine if preoperative physical therapy with an exercise component can prevent postoperative pulmonary complications in cardiac surgery patients, and to evaluate which type of patient benefits and which type of physical therapy is most effective.

Search methods

Searches were run on the Cochrane Central Register of Controlled Trials (CENTRAL) on the Cochrane Library (2011, Issue 12); MEDLINE (1966 to 12 December 2011); EMBASE (1980 to week 49, 2011); the Physical Therapy Evidence Database (PEDro) (to 12 December 2011) and CINAHL (1982 to 12 December 2011).

Selection criteria

Randomised controlled trials or quasi-randomised trials comparing preoperative physical therapy with no preoperative physical therapy or sham therapy in adult patients undergoing elective cardiac surgery.

Data collection and analysis

Data were collected on the type of study, participants, treatments used, primary outcomes (postoperative pulmonary complications grade 2 to 4: atelectasis, pneumonia, pneumothorax, mechanical ventilation > 48 hours, all-cause death, adverse events) and secondary outcomes (length of hospital stay, physical function measures, health-related quality of life, respiratory death, costs). Data were extracted by one review author and checked by a second review author. Review Manager 5.1 software was used for the analysis.
Main results

Eight randomised controlled trials with 856 patients were included. Three studies used a mixed intervention (including either aerobic exercises or breathing exercises); five studies used inspiratory muscle training. Only one study used sham training in the controls. Patients that received preoperative physical therapy had a reduced risk of postoperative atelectasis (four studies including 379 participants, relative risk (RR) 0.52; 95% CI 0.32 to 0.87; P = 0.01) and pneumonia (five studies including 448 participants, RR 0.45; 95% CI 0.24 to 0.83; P = 0.01) but not of pneumothorax (one study with 45 participants, RR 0.12; 95% CI 0.01 to 2.11; P = 0.15) or mechanical ventilation for > 48 hours after surgery (two studies with 306 participants, RR 0.55; 95% CI 0.03 to 9.20; P = 0.68). Postoperative death from all causes did not differ between groups (three studies with 552 participants, RR 0.66; 95% CI 0.02 to 18.48; P = 0.81). Adverse events were not detected in the three studies that reported on them. The length of postoperative hospital stay was significantly shorter in experimental patients versus controls (three studies with 347 participants, mean difference -3.21 days; 95% CI -5.73 to -0.69; P = 0.01). One study reported a reduced physical function measure on the six-minute walking test in experimental patients compared to controls. One other study reported a better health-related quality of life in experimental patients compared to controls. Postoperative death from respiratory causes did not differ between groups (one study with 276 participants, RR 0.14; 95% CI 0.01 to 2.70; P = 0.19). Cost data were not reported on.

Authors’ conclusions

Evidence derived from small trials suggests that preoperative physical therapy reduces postoperative pulmonary complications (atelectasis and pneumonia) and length of hospital stay in patients undergoing elective cardiac surgery. There is a lack of evidence that preoperative physical therapy reduces postoperative pneumothorax, prolonged mechanical ventilation or all-cause deaths.

Plain language summary

Preoperative physical therapy for elective cardiac surgery patients

Patients undergoing cardiac surgery are at risk of postoperative pulmonary complications such as pneumonia. These complications prolong postoperative recovery and may even lead to death. Increased physical fitness improves people’s functional capacity, including their lungs, and could result in individuals being better prepared to withstand the consequences of the physical stress of surgery.

The authors of this review evaluated the efficacy and safety of preoperative physical therapy with an exercise component in cardiac surgery patients. From the pertinent literature, eight studies met the inclusion criteria, comprising a total of 856 participants. The results showed that preoperative physical therapy reduced the number of patients who experienced atelectasis or pneumonia but not the number of patients who experienced pneumothorax, prolonged ventilation or postoperative death. Patients who had preoperative physical therapy had an earlier (on average by more than three days) discharge from the hospital. Information on adverse events was limited but those studies that did report on adverse events reported none. None of the studies reported on the costs of preoperative physical therapy.

The authors concluded that preoperative physical therapy, especially inspiratory muscle training, prevents some postoperative complications including atelectasis, pneumonia, and length of hospital stay.

Background

Description of the condition

Cardiac surgery is among the most common surgical procedures in the world and accounts for more resources being expended in cardiovascular medicine than any other single procedure (Eagle 2004). From 1979 to 2005, the total number of inpatient cardiovascular operations and procedures increased 484% in the United States (www.americanheart.org). The National Center for Health Statistics estimated that in 2005, 6,989,000 inpatient cardiovascular operations and procedures were performed (1,271,000 inpatient angioplasty procedures, 469,000 inpatient bypass procedures, 1,322,000 inpatient diagnostic cardiac catheterizations,
98,000 inpatient implantable defibrillators, and 180,000 inpatient pacemaker procedures) (www.americanheart.org). The estimated cost of coronary heart disease was USD 156.4 billion in 2008. This included health expenditures (direct costs, which include the cost of physicians and other professionals, hospital and nursing home services, medications, home health care and other medical durables) and lost productivity resulting from morbidity and mortality (indirect costs) (www.americanheart.org).

Patients undergoing cardiac surgery are at risk of postoperative pulmonary complications, which lead to increased postoperative morbidity and mortality (Brooks-Brunn 1995; Ephgrave 1993; Hart 1989; Taylor 1990; Weissman 1999; Weismann 2004), increased use of medical resources, length of hospital stay and healthcare costs (Davies 1991; Ephgrave 1993; Taylor 1990). The incidence of postoperative pulmonary complications varies between 20% to 95% after cardiac surgery (Brooks-Brunn 1995), depending in part on the type of surgery, specific criteria used to define postoperative pulmonary complications and on the diagnostic techniques to document them (Brooks-Brunn 1995; Weissman 1999; Wynne 2004). Surgery represents a major stressor for patients, causing loss of muscle mass, deconditioning, hypoxaemia, mental disturbances and sleep disorders. Changes in the respiratory system (during and after the surgical intervention) occur as a result of the effects of anaesthetics and of analgesia (Hedenstierna 2005) and include changes in lung volumes, diaphragmatic dysfunction, a decrease in respiratory muscle strength (Dureuil 1987; Laghi 2003; Ragnarsoodtir 2004; Sykes 1993; Van Belle 1992), changes in ventilation pattern (Ford 1993; Imanaka 2004; Nishino 1998) and alterations in gas exchange and response to carbon dioxide and oxygen concentrations (Kjaergaard 2004; Knill 1988; Sykes 1993; Tenling 1998). In addition, cardiac surgical patients are subject to distinct factors that predispose them to postoperative pulmonary complications. Unique to cardiac surgery are the effects of median sternotomy incision, topical cooling, internal mammary artery dissection and often the use of cardiopulmonary bypass (Wynne 2004). The most reported patient-related preoperative risk factors for postoperative pulmonary complications are age over 70 years, diabetes mellitus, body mass index > 28 or morbid obesity, preoperative arrhythmia or unstable angina, chronic lung disease, smoking history and hepatic insufficiency (Nilssen 2006).

As a result of the high incidence of postoperative pulmonary complications and the cost they incur during the hospital stay, efforts have been made to identify those patients who have a higher risk of developing such complications (Ferguson 1999) and to find interventions to prevent the complications (Sowden 1997; Weismann 2004), but there is no consensus on the most appropriate or effective therapy (Johnson 1996; Pasquina 2003; Stiller 1992).

**Description of the intervention**

Over the past 25 years a number of investigators (Convertino 1997; Krasnoff 1999; Powell 1994) have determined that physical activity is essential to maintaining optimal functioning of most organ systems of the body. Surgery is a substantial risk to the healthy functioning of those systems. Within certain limits, persons can be trained to become more physically fit (Topp 2002). Increased physical activity can improve the functional capacity of a number of organ systems and result in an increased preparedness to withstand external stressors (Carli 2005; Topp 2002). This concept is translated by several authors (Arthur 2000; Weiner 1998) to the cardiac surgery patient and especially to the training of the inspiratory muscle system. The inspiratory muscles can be trained using an inspiratory threshold-loading device. With this device, patients inspire against a threshold load whereas expiration is unimpeded. Physical therapy focused on maximising functional capacity when threatened by problems in oxygen transport is now thought to best start in the preoperative period in order to reduce the risk of postoperative pulmonary complications (Hulzebos 2006A; Rajendran 1998). A few studies have demonstrated that preoperative physical therapy (pulmonary rehabilitation) has advantages over postoperative care alone in cardiac surgery patients (Arthur 2000; Hulzebos 2006A).

**How the intervention might work**

Breathing exercises (with or without the aid of equipment and manual techniques) compensate for and normalise abnormal breathing patterns and may help to reduce the risk of atelectasis and pneumonia (Craig 1991; Craven 1974; Simmons 1982). The inspiratory muscles can be trained for both strength and endurance, similar to skeletal muscles (McConnel 2004; Weiner 1998). Improvements in the strength and endurance of the inspiratory muscles may lead to increased resistance to fatigue and improved ventilatory function through decreased work of breathing and increased respiratory reserve (Shekleton 1996). Regular exercise and physical conditioning have been shown to cause positive changes in cardiorespiratory function and other regulatory mechanisms with associated enhancement of physical performance, in general populations and in populations at risk such as the elderly.

**Why it is important to do this review**

There is still controversy about whether physical therapy can decrease postoperative pulmonary complications. However, a wide array of physical therapy techniques are usually given after surgery, whereas the preferred strategy would be to identify patients at high risk and give them physical therapy with an exercise component before surgery (Carli 2005; Rajendran 1998). The purpose of this review was, therefore, to systematically examine the published evidence for the efficacy of preoperative physiotherapy with an exercise component in elective cardiac surgery patients in order to prevent postoperative pulmonary complications.
OBJECTIVES

The objective of this review is to evaluate the effect of preoperative physical therapy to prevent postoperative pulmonary complications in adults undergoing elective cardiac surgery. In addition, we wanted to know if the effectiveness differed in patients at low risk of postoperative pulmonary complications versus patients at high risk of postoperative pulmonary complications, and to examine the effect of different types of physical therapy.

METHODS

Criteria for considering studies for this review

Types of studies
All randomised controlled trials or quasi-randomised controlled trials that involved the use of preoperative physical therapy, for example incentive spirometry, breathing exercises, respiratory muscle training or exercise training.

Types of participants
Adult patients (age > 18 years) undergoing elective cardiac surgery (for example coronary artery surgery or valvular surgery). Both on-pump and off-pump procedures were considered for inclusion.

Types of interventions
Studies that included one treatment group in which preoperative physical therapy with an exercise component was applied (for example incentive spirometry, breathing or coughing exercises, respiratory muscle training or exercise training) compared to a control group with no preoperative physical therapy or receiving sham therapy. The postoperative regimen had to be similar in both groups. Preoperative physical therapy with an exercise component was defined as all therapy given to the patient before surgery which included at least one of the following: incentive spirometry, breathing or coughing exercises, respiratory muscle training, exercise training. Education about the postoperative period, instructions in various physical therapy techniques delivered directly preoperatively and to be used postoperatively, preoperative lifestyle advice including general advice on physical exercise, or electrical nerve stimulation were not defined as preoperative physical therapy, nor were smoking cessation or weight loss interventions.

Types of outcome measures

Primary outcomes
The primary outcomes were the occurrence of postoperative pulmonary complications grades 2, 3 or 4 (Kroenke 1992), all-cause mortality and adverse events. In the literature, the terms dysfunction and complications are frequently used interchangeably. We maintain that a distinction between postoperative pulmonary dysfunction and a postoperative pulmonary complication is necessary. Postoperative pulmonary dysfunction refers to expected alterations in pulmonary function such as increased work of breathing, shallow respiration, ineffective cough, and hypoxaemia. The diagnosis of a postoperative pulmonary complication requires symptomatic pulmonary dysfunction and associated clinical findings that meet the specified criteria of a particular diagnosis (Wynne 2004). In this study we defined postoperative pulmonary complications as any pulmonary abnormality occurring in the postoperative period that produces identifiable disease or dysfunction and that is clinically significant and adversely affects the clinical course (O’Donohue 1999; Narayan 2005).

Secondary outcomes
The secondary outcomes were: (a) length of (postoperative) hospital stay, (b) physical function measures, (c) postoperative respiratory mortality, (d) health-related quality of life and (e) economic costs.

Search methods for identification of studies

Electronic searches
The following electronic databases were searched on 12 December 2011 to identify relevant studies:
- Cochrane Central Register of Controlled Trials (CENTRAL) (2011, Issue 12) through Ovid®;
- MEDLINE (1966 up to 12 December 2011);
- EMBASE through Ovid® (1980 up to week 49, 2011);
- PEDro (Physiotherapy Evidence Database) (from the earliest achievable data to 12 December 2011);
- CINAHL through EBSCOhost® (1982 up to 12 December 2011).

No language restrictions were applied.
The search strategies that were used to search CENTRAL, MEDLINE, EMBASE, PEDro and CINAHL are given in Appendix 1, Appendix 2, Appendix 3 and Appendix 4.

Searching other resources
We searched the metaRegister of controlled trials (www.controlled-trials.com/mrct), Clinicaltrials.gov (www.clinicaltrials.gov) and the World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP) (apps.who.int/trialsearch/) for ongoing trials.

The library of the Dutch Institute of Allied Health Care and reference lists of relevant existing clinical practice guidelines (for example clinical practice guidelines that have been drafted by the American Association for Respiratory Care for Postural Drainage, Incentive Spirometry and Directed Cough) were reviewed.

All the references in selected trials and identified systematic reviews were checked for identification of other relevant articles. Institutions and experts known to have expertise in physiotherapy techniques were contacted for further information and unpublished studies.

Data collection and analysis

Selection of studies
Two review authors (EH and YS) independently screened the search results for potentially eligible studies. When titles and abstracts suggested a study was potentially eligible for inclusion, a full text copy of the report was obtained. Disagreements were resolved by discussion until consensus was reached or, where necessary, a third review author (NvM) acted as mediator.

Data extraction and management
Data were extracted by one review author (YS) and cross-checked by a second review author (EH). Information regarding the study method, the study setting, patient characteristics (age range, eligibility criteria, risk factors), types of intervention and outcomes were collected. If data were missing or further information was required, we wrote to the corresponding study author to request the required information. The data extracted for the length of hospital stay were either data on the length of postoperative stay or data on the length of hospital stay, as available. When both measures were available we chose data on the postoperative length of stay. Data on atelectasis or pleural effusion were only extracted when we considered it likely that the authors had classified: (a) atelectasis as a postoperative pulmonary complication grade 2 (and not as microatelectasis, or postoperative pulmonary complication grade 1); (b) pleural effusion as a postoperative pulmonary complication grade 3 (pleural effusion resulting in thoracocentesis) (Kroenke 1992).

If data on physical function measures were available at more than one time point we chose the latest in hospital time point available. Disagreements were discussed by the two review authors until a consensus was reached. If no consensus was reached, a third review author (NvM) acted as mediator.

Assessment of risk of bias in included studies
The risk of bias assessment was performed as recommended by the Cochrane Handbook for Systematic Reviews of Interventions (Higgins 2011) using risk of bias tables. The domains these risk of bias tables assessed were: sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and providers (performance bias), blinding of outcome assessor (detection bias), incomplete outcome data (attrition bias), selective outcome reporting (reporting bias) and other sources of bias. The first part of the tool involves describing what was reported to have happened in the study. The second part of the tool involves assigning a judgement related to the risk of bias for that entry in terms of low, high or unclear risk. Each domain was assessed for each study in one of three categories: (1) low risk of bias; (2) high risk of bias; (3) unclear risk of bias.

Measures of treatment effect
Statistical analyses were performed using RevMan 5.1 software, and in accordance with the Cochrane Heart Review Group. For all dichotomous outcomes the fixed-effect model was used in the meta-analysis to determine the relative risk (RR). For continuous outcomes, the fixed-effect model was used in the meta-analysis to determine the weighted mean difference (MD). If different continuous measures had been reported for the same outcome (for example different tests of physical function or measures for quality of life) we would have determined a standardized mean difference of postoperative between-group differences. Heterogeneity of the effect size between studies was tested for with each outcome measure. If statistical heterogeneity was present ($I^2 > 50\%$) (Higgins 2003) the random-effects model was applied and, if possible, the source of heterogeneity was explored through subgroup analyses.

Subgroup analysis and investigation of heterogeneity
If we had enough trials, we would have analysed differences in the weighted average effect size between different types of interventions (that is types of physical therapy with an exercise component) and between studies that included low-versus high-risk patients. If more trials are found in subsequent updates we will include subgroup analysis.

Sensitivity analysis
If we had found enough trials, we would have conducted sensitivity analyses for studies with an adequate randomisation procedure.
(that is an unbiased method for random sequence generation) versus studies without an adequate randomisation procedure. If more trials are found in subsequent updates we will include sensitivity analysis.

RESULTS

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies.

Results of the search

A total of 6976 single citations were screened for relevancy, out of which 37 abstracts were selected as possibly being appropriate for inclusion. After reading the full text papers, 29 studies were excluded from this review. Reasons for exclusion of these studies are listed in the table 'Characteristics of excluded studies'. Eight randomised controlled trials with 856 adult patients awaiting elective cardiac surgery were included in this review. Details of these studies are shown in the table 'Characteristics of included studies'. Figure 1 shows the study flow diagram.
Included studies

Sample sizes and settings

Four studies included less than 50 patients (Carvalho 2011; Ferreira 2009; Hulzebos 2006B; Rajendran 1998); one study included between 50 and 100 patients (Weiner 1998); and three studies included between 100 and 200 patients (Arthur 2000; Hulzebos 2006A; Rosenfeldt 2011). All studies were single centre studies conducted in either Australia (Rosenfeldt 2011), Brazil (Carvalho 2011; Ferreira 2009), Canada (Arthur 2000), India (Rajendran 1998), Israel (Weiner 1998) or the Netherlands (Hulzebos 2006A; Hulzebos 2006B).

Participants

Based on diverse risk models, one study included low-risk patients (Arthur 2000) and three studies included high-risk patients (Carvalho 2011; Hulzebos 2006A; Hulzebos 2006B). Whereas Arthur 2000 and Carvalho 2011 did not define low risk and high
risk, respectively, Hulzebos 2006A and Hulzebos 2006B defined high risk as having either a forced vital capacity < 80% of the predicted value or two or more of the following characteristics: age over 70 years; cough and expectoration; diabetes; smoker; chronic obstructive pulmonary disease. A further three studies did not report whether high- or low-risk patients were included and gave too few patient details to make a definite assessment of patient risk (Ferreira 2009; Rosenfeldt 2011; Weiner 1998). Although patients in the last study were also not classified as low- or high-risk, all had chronic obstructive pulmonary disease and thus we assessed the patients as at high risk for postoperative pulmonary complications (Rajendran 1998). Patients who died after coronary artery bypass graft surgery (CABG) or who needed mechanical ventilation for more than 24 hours, whether or not related to pulmonary complications, were excluded from the analysis in Rajendran 1998.

All patient characteristics that were reported on were evenly distributed per treatment group, except in one study (Ferreira 2009) where the experimental group had fewer males (60% versus 87% in the control group; P < 0.01). In one other study the median age in the experimental group was lower, although not significantly so, compared to the median age of controls (62.5 versus 68 years; P = 0.06) (Rosenfeldt 2011).

Interventions

In three studies the intervention was mixed, either with an aerobic exercise component (Arthur 2000; Rosenfeldt 2011) or with breathing exercises (Rajendran 1998); whereas in the other five studies the intervention was inspiratory muscle training with a threshold loading device (Carvalho 2011; Ferreira 2009; Hulzebos 2006A; Hulzebos 2006B; Weiner 1998). The mixed intervention in Arthur 2000 consisted of: (a) individually prescribed aerobic exercise training under supervision and in a group, twice a week for eight weeks, at 40% to 70% of a person’s functional capacity; and (b) a supportive educational component with two moments of preoperative teaching, monthly telephone contact by nurse clinicians and encouragement to stop smoking. The mixed intervention in Rosenfeldt 2011 consisted of: (a) low intensity aerobic exercise, supervised training at approximately 50% of maximum oxygen uptake for one hour, twice a week for two weeks, plus encouragement to complete two weekly personal sessions for at least 30 minutes on at least two other occasions each week, including after the discontinuation of the supervised programme; and (b) a mental stress reduction programme consisting of four individualised one hour sessions including education and relaxation techniques, such as deep breathing and meditation, for the first two weeks after placement on the surgery waiting list. The mixed intervention in Rajendran 1998 consisted of health education, exercise reconditioning and support, instruction about respiratory disease and its treatment, breathing retraining (diaphragmatic breathing and pursed lip breathing), dyspnoea control, nutritional counselling, energy conservation, work simplification techniques and stress management with relaxation training in daily sessions for one week under the guidance of a specialist, and advice to practice for 10 minutes every waking hour. The other five studies that applied inspiratory muscle training with a threshold loading device did so:

- at 30% of peak inspiratory pressure, for two weeks, seven days a week, twice a day, three sets of 10 repetitions (Carvalho 2011);
- at 40% of peak inspiratory pressure, over at least two weeks, seven days a week, thrice daily, five sets of 10 repetitions (Ferreira 2009);
- starting at 30% of peak inspiratory pressure with an incremental increase, for at least 20 minutes, daily for at least two weeks (Hulzebos 2006A; Hulzebos 2006B);
- starting at 15% of peak inspiratory pressure for one week, then an incremental 5% increase each session up to 60%, daily sessions of 30 minutes for two to four weeks.

Control treatments were always usual care, except in Weiner 1998 where sham therapy was used. In that study the control patients followed a training protocol with a threshold loading device that was similar to patients in the experimental group but with no resistance.

Outcomes

Six studies reported data on postoperative pulmonary complications according to Kroenke’s criteria (Carvalho 2011; Ferreira 2009; Hulzebos 2006A; Hulzebos 2006B; Rajendran 1998; Weiner 1998). Four studies reported on atelectasis; five studies reported on pneumonia; one study reported on pneumothorax; and two studies reported on ventilatory support for > 48 hours. Three studies reported on all-cause mortality (Arthur 2000; Ferreira 2009; Hulzebos 2006A). Three studies reported on adverse events (Ferreira 2009; Hulzebos 2006A; Hulzebos 2006B). Five studies reported data on secondary outcomes (Arthur 2000; Hulzebos 2006A; Hulzebos 2006B; Rajendran 1998; Rosenfeldt 2011). Five studies reported on length of stay (data from three studies could be used in the meta-analysis); one study reported on physical function measures; two studies on health-related quality of life (data from one study could be used in the meta-analysis); and one study reported on mortality due to respiratory causes. No studies reported on costs.

Risk of bias in included studies

Figure 2 shows the authors’ (EH and YS) judgments on each methodological quality item, presented as percentages across all included studies. Figure 3 shows the authors’ judgments per domain for each study.
Figure 2. Risk of bias graph: review authors’ judgements about each risk of bias item presented as percentages across all included studies.
Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

<table>
<thead>
<tr>
<th>Study</th>
<th>Random sequence generation (selection bias)</th>
<th>Allocation concealment (selection bias)</th>
<th>Blinding of participants and personnel (performance bias)</th>
<th>Blinding of outcome assessment (detection bias)</th>
<th>Incomplete outcome data (attrition bias)</th>
<th>Selective reporting (reporting bias)</th>
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<tr>
<td>Arthur 2000</td>
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<td>Hulzebos 2006A</td>
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<td>Hulzebos 2006B</td>
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<tr>
<td>Rosenfeldt 2011</td>
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</tr>
</tbody>
</table>
**Allocation**

**Random sequence generation (selection bias)**

Four studies used an adequate method to avoid bias through the sequence generation process (Arthur 2000; Hulzebos 2006A; Hulzebos 2006B; Rosenfeldt 2011). The other four studies did not describe the random sequence generation process, so the risk of bias in this domain could not be assessed (Carvalho 2011; Ferreira 2009; Rajendran 1998; Weiner 1998).

**Allocation concealment (selection bias)**

Two studies used an adequate method of allocation concealment. The first of these studies used sealed opaque envelopes, opened in sequence (Arthur 2000). In the second of these studies the envelopes were not explicitly described as opaque but they were picked by an investigator who was not involved in the study (Hulzebos 2006A). Six studies did not describe the allocation concealment (Carvalho 2011; Ferreira 2009; Hulzebos 2006B; Rajendran 1998; Rosenfeldt 2011; Weiner 1998).

**Blinding**

**Blinding of participants and providers (performance bias)**

One study used sham therapy in patients in the control group but did not describe whether the personnel were blinded, so the risk of performance bias was assessed as ‘unclear’ (Weiner 1998). The other seven studies did not use any form of control treatment so the risk of performance bias was assessed as ‘high’ (Arthur 2000; Carvalho 2011; Ferreira 2009; Hulzebos 2006A; Hulzebos 2006B; Rajendran 1998; Rosenfeldt 2011).

**Blinding of outcome assessor (detection bias)**

In five studies the risk of detection bias was low because either blinded outcome assessors were used or outcome data were extracted from the medical records (Arthur 2000; Hulzebos 2006A; Hulzebos 2006B; Rajendran 1998; Rosenfeldt 2011). In three studies the risk of detection bias was unclear because there was insufficient information available (Carvalho 2011; Ferreira 2009; Weiner 1998).

**Incomplete outcome data**

Seven studies reported all predefined outcomes, so the risk of attrition bias was low (Arthur 2000; Ferreira 2009; Hulzebos 2006A; Hulzebos 2006B; Rajendran 1998; Rosenfeldt 2011; Weiner 1998). The eighth study was only published as an abstract and did not have enough information to assess the risk of attrition bias (Carvalho 2011).

**Selective reporting**

In six studies the risk of reporting bias was low (Arthur 2000; Carvalho 2011; Hulzebos 2006A; Hulzebos 2006B; Rosenfeldt 2011; Weiner 1998). Two studies did not provide enough information to assess the risk of reporting bias (Ferreira 2009; Rajendran 1998).

**Other potential sources of bias**

We did not identify any other sources of bias.

**Effects of interventions**

**Primary outcomes**

**Postoperative pulmonary complications grade 2**

Information about postoperative atelectasis was available in four studies including 379 patients (Carvalho 2011; Hulzebos 2006A; Hulzebos 2006B; Rajendran 1998). The risk of postoperative atelectasis was lower in the groups receiving preoperative physical therapy, with three out of four studies using inspiratory muscle training (RR 0.52; 95% CI 0.32 to 0.87; P = 0.01) (Analysis 1.1). One study with 276 participants had information on any type of postoperative pulmonary complication grade 2, which was similar to the rate of atelectasis in this study (Hulzebos 2006A). The risk of any type of postoperative pulmonary complication grade 2 was not reduced (RR 0.77; 95% CI 0.40 to 1.48; P = 0.43) (Analysis 1.2).

**Postoperative pulmonary complications grade 3**

Five studies including 448 patients gave information on postoperative pneumonia (Carvalho 2011; Ferreira 2009; Hulzebos 2006A; Hulzebos 2006B; Weiner 1998). The risk of postoperative pneumonia was significantly reduced in the groups that received preoperative physical therapy (inspiratory muscle training in all five studies) (RR 0.45; 95% CI 0.24 to 0.83; P = 0.01) (Analysis 1.3). One study with 45 patients had information on the
risk of postoperative pneumothorax, which was not reduced (RR 0.12; 95% CI 0.01 to 2.11; P = 0.15) (Analysis 1.4) (Rajendran 1998). One study with 276 participants had information on any type of postoperative pulmonary complication grade 3 (Hulzebos 2006A). The risk of any type of postoperative pulmonary complication grade 3 was significantly reduced in this study (RR 0.41; 95% CI 0.20 to 0.83; P = 0.01) (Analysis 1.5).

**Secondary outcomes**

**Length of postoperative hospital stay**

Five studies gave information on the length of hospital stay (Arthur 2000; Hulzebos 2006A; Hulzebos 2006B; Rajendran 1998; Rosenfeldt 2011). Arthur 2000 reported a significantly shorter median postoperative stay for the patients that received preoperative physical therapy (MD -1.0 days; 95% CI -1.00 to -0.98; P = 0.001). Rosenfeldt 2011 reported no difference in the length of hospital stay between groups, which was a mean or a median of six days (P = 0.54). The mean length of stay in the remaining three studies (347 patients) could be pooled in a meta-analysis (Hulzebos 2006A; Hulzebos 2006B; Rajendran 1998). There was a significant reduction in length of stay for patients treated with preoperative physical therapy (MD -3.21 days; 95% CI -5.73 to -0.69; random effects analysis; P = 0.01) (Analysis 1.10). The heterogeneity between these studies may be caused by a twice as long postoperative hospital stay in the Rajendran 1998 study compared to the two studies by Hulzebos et al.

**Physical function measures**

One study (32 patients) reported on the six-minute walk test (Carvalho 2011). The patients that received preoperative physical therapy performed worse on the six-minute walk test postoperatively compared to the control group: -101.30 metres (95% CI -163.78 to -38.82 metres; P < 0.001) (Analysis 1.11).

**Postoperative mortality from respiratory causes**

One study with 276 patients gave information on the risk of death from respiratory causes after surgery (Hulzebos 2006A). The risk did not differ across groups (RR 0.14; 95% CI 0.01 to 2.70; P = 0.19) (Analysis 1.12).

**Health-related quality of life**

One study with 117 patients reported between-group differences in health-related quality of life (Rosenfeldt 2011). Patients who had received preoperative physical therapy scored significantly better on the Short Form-36 physical composite score: 1.30 points (95% CI 0.88 to 1.72; P < 0.001) (Analysis 1.13).

**Economic costs**

There were no studies that reported on economic costs.

**Subgroup and sensitivity analyses**

The small number of studies per outcome precluded any meaningful subgroup analyses. There were no studies with inadequate random sequence generation so the sensitivity analysis could not be performed.
DISCUSSION

Summary of main results
We included eight studies of preoperative physical therapy with an exercise component in 856 elective cardiac surgery patients. Five studies on inspiratory muscle training and two studies with a mixed intervention including respiratory exercises provided information on one of our primary outcomes. Preoperative physical therapy reduced postoperative atelectasis (four studies, RR 0.52; 95% CI 0.32 to 0.87; P = 0.01) and pneumonia (five studies, RR 0.45; 95% CI 0.24 to 0.83; P = 0.01) but not pneumothorax (one study, RR 0.10; 95% CI 0.00 to 2.02; P = 0.13), prolonged mechanical ventilation (RR 0.55; 95% CI 0.03 to 9.20; P = 0.68; n = 2) or all-cause postoperative death (RR 0.66; 95% CI 0.02 to 18.48; random-effects analysis; P = 0.81; n = 3). In the three studies that reported on adverse events, no adverse events occurred. Five studies (Arthur 2000; Hulzebos 2006A; Hulzebos 2006B; Rajendran 1998; Rosenfeldt 2011) gave information on the secondary outcome length of hospital stay. Preoperative physical therapy reduced length of hospital stay: -3.21 days (95% CI -5.73 to -0.69; random-effects analysis; P = 0.01).

Overall completeness and applicability of the evidence
Unfortunately, meaningful subgroup analyses were precluded by the small number of studies and by the small number of relevant outcomes described in each study. Thus the evidence remains incomplete for different patient groups (patients at low risk for pulmonary complications versus patients at high risk) or different types of physical therapy with an exercise component.

Quality of the evidence
Overall, eight studies with 856 included patients were eligible for inclusion in this review. However, only one to three studies contributed data to the meta-analyses of the different outcomes except for the outcomes atelectasis and pneumonia, where four and five studies contributed data respectively. In addition, the size of the included trials might be too small to detect a difference in less frequent postoperative complications, such as death or pneumothorax, with four studies including less than 50 patients (Carvalho 2011; Ferreira 2009; Hulzebos 2006B; Rajendran 1998). The risk of bias of the included studies was generally assessed as ‘low’, except for the performance bias domain. Only one study used a form of sham therapy in the control group, giving a threshold inspiratory muscle trainer without resistance. Sham therapy should be used more frequently to assure that neither participants nor care givers know the assigned experimental group. None of the studies described the blinding of personnel to the interventions that patients received. The non-blinding of personnel may influence some outcomes, especially length of stay and also the detection of postoperative pulmonary complications. Besides the quality of the methodology, we recommend that future meta-analyses assess the validity of the therapeutic intervention as well. Recently a new measure (CONTENT) (Hoogeboom 2012) was developed to assess the validity of therapeutic exercise programs. This measure consists of nine yes or no questions (for example was the therapeutic exercise monitored and adjusted when considered necessary?). Differences in effectiveness across studies may be explained by varying therapeutic validity of the interventions applied.

AUTHORS’ CONCLUSIONS

Implications for practice
Evidence derived from small trials suggests that preoperative physical therapy reduces postoperative pulmonary complications (atelectasis and pneumonia) and length of hospital stay in patients undergoing elective cardiac surgery. There is lack of evidence that preoperative physical therapy reduces postoperative pneumothorax, prolonged mechanical ventilation or all-cause deaths.

Implications for research
Future studies on the effect of preoperative physical therapy should consider the following.

- Using a standardized and uniform definition for postoperative pulmonary complications.
- Including patients at high risk of pulmonary complications, as they are most likely to benefit.
- Including patients who are undergoing other types of surgery with a high risk of postoperative pulmonary complications, such as thoracic surgery and upper abdominal surgery.
- Assessing the validity of a therapeutic exercise program with a standardized checklist.
- Studying the effect of respiratory muscle training combined with other types of exercise therapy strategies.

ACKNOWLEDGEMENTS
We gratefully acknowledge the contributions of Heather Arthur and Tales Carvalho who have provided extra information on their studies. We also would like to thank the Cochrane Heart Group for their constructive feedback and practical assistance during the
References to studies included in this review

Arthur 2000  {published data only}

Carvalho 2011  {published data only}

Ferreira 2009  {published data only}

Hulzebos 2006A  {published data only}

Hulzebos 2006B  {published data only}

Rajendran 1998  {published data only}

Rosenfeldt 2011  {published data only}

References to studies excluded from this review

Anderson 1987  {published data only}

Buijs van den 2004  {published data only}

Castillo 1985  {published data only}

Cisar 1983  {published data only}

Crawford 1993  {published data only}

Dias 2011  {published data only}

Dowds 2009  {published data only}

Weiner 1998  {published data only}
Preoperative physical therapy for elective cardiac surgery patients (Review)

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Preoperative physical therapy for elective cardiac surgery patients (Review)

Additional references

Stein 1970 [published data only]

Stiller 1994 [published data only]

Uglov 1992 [published data only]

Vraicu 1977 [published data only]

Walther 2010 [published data only]

Winter 1995 [published data only]

Zamotrinsky 1997 [published data only]

Craig 1991

Craven 1974

Davies 1991

Dureuil 1987

Eagle 2004

Ephgrave 1993

Ferguson 1999

Ford 1993

Hart 1989

Hedenstierna 2005

Higgins 2003

Higgins 2011

Hooogeboom 2012
Hooogeboom TJ, Oosting E, Vriezeolk JH, Veenhof C, Sienomsma PC, De Bie RA, et al. Therapeutic validity and

**Imanaka 2004**

**Johnson 1996**

**Kjaergaard 2004**

**Knill 1988**

**Krasnoff 1999**

**Kroenke 1992**

**Laghi 2003**

**McConnel 2004**

**Narayan 2005**

**Nilsson 2006**

**Nishino 1998**

**O’Donohue 1992**

**Pasquina 2003**

**Powell 1994**

**Ragnarsdottir 2004**

**Shekleton 1996**

**Simmons 1982**

**Sowden 1997**

**Stiller 1992**

**Sykes 1993**

**Taylor 1990**

**Tenling 1998**

**Topp 2002**
Van Belle 1992

Weismann 2004

Weissman 1999

Wynne 2004

* Indicates the major publication for the study
**CHARACTERISTICS OF STUDIES**

**Characteristics of included studies [ordered by study ID]**

**Arthur 2000**

| Methods | RCT  
| Setting: single centre, Canada  
| Recruitment period: July 1995 to October 1997 |

| Participants | Inclusion: low-risk patients on a waiting list for elective CABG with a scheduled surgery at least 10 weeks from study recruitment (low-risk was not further defined)  
| Exclusion: previous CABG, combined CABG and valve surgery, ejection fraction < 40%, geographic inaccessibility or physical limitations that would preclude participation in the intervention  
| Number of patients:  
| - Experimental: 123  
| - Control: 123  
| Mean age (standard deviation) (NS)  
| - Experimental: 61.8 (8.4)  
| - Control: 63.8 (7.8)  
| Sex (NS)  
| - Experimental: 87% male  
| - Control: 83% male  
| Current smoker (NS)  
| - Experimental: 20.3%  
| - Control: 13.0%  
| Diabetes (NS)  
| - Experimental: 16.4%  
| - Control: 25.6% |

| Interventions | Experimental: supervised group exercise sessions: twice a week, 8 weeks long in a hospital. Individualised, prescribed exercise training: 10 minutes walking warm-up; 10 minutes general range of motion exercises; 10 minutes stretching; 30 minutes aerobic interval training on treadmills etc.; 10 minutes cooling down; 40-70% functional capacity. Supportive-educational component: preoperative teaching at study entry and 1 week presurgery; monthly telephone contact by nurse clinicians; encouragement to stop smoking  
| Control: usual care |

| Outcomes | Median postoperative length of stay (days)  
| - Experimental: 5 (IQR: 5-6)  
| - Control: 6 (IQR: 5-7)  
| - Estimated difference in medians: 1.0 days (95% CI 0.98 to 1.0; P=0.001)  
| Total days in hospital  
| - Experimental: 6 (IQR: 5-7)  
| - Control: 7 (IQR: 6-8)  
| - Estimated difference in medians: 1.0 days (95% CI 0.0 to 1.0; P=0.002)  
| Quality of life data published in a figure, no between-group differences tested. The corresponding point estimates were no longer available |
Arthur 2000  (Continued)

<table>
<thead>
<tr>
<th>All-cause postoperative mortality</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Experimental: 0</td>
<td>Low risk</td>
<td>Quote: “A consultant prepared the randomization schedule”</td>
</tr>
<tr>
<td>- Control: 0</td>
<td>Low risk</td>
<td>Quote: “assignments were sealed in opaque envelopes that were opened in sequence”</td>
</tr>
</tbody>
</table>

Notes

Postoperative care for both groups: usual care (cardiac rehabilitation)
Adverse events: not reported on

Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Not reported on. The blinding of participants is assessed by reviewers as unlikely to have happened, as no sham/placebo therapy was described</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Low risk</td>
<td>Obtained from medical records or questionnaires, review authors do not believe this will introduce bias</td>
</tr>
<tr>
<td>Blinding of participants and personnel (performance bias) All outcomes</td>
<td>High risk</td>
<td>26 patients withdrew during waiting time (E:10, C:16). 10 had their surgery cancelled; 12 had a change in status from elective to urgent an 4 patients withdrew at the preoperative measurement point. The review authors do not believe this will introduce bias</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>All predefined outcomes were reported on</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>Low risk</td>
<td></td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td></td>
</tr>
</tbody>
</table>

Carvalho 2011

Methods

RCT (only published as an abstract and poster presentation)
Setting: not described, likely a single centre study in Brazil
Recruitment period: not described

Participants

Inclusion: persons referred for CABG at high risk (unspecified) for pulmonary complications
Exclusion: unspecified
Number of patients:
- Experimental: 16
- Control: 16
### Carvalho 2011 (Continued)

<table>
<thead>
<tr>
<th>Interventions</th>
<th>Experimental: inspiratory muscle training with threshold device and a workload 30% of the peak inspiratory pressure, during two weeks prior to surgery, seven days a week, twice a day, three sets of ten repetitions. Setting and supervision were not described C: not specified</th>
</tr>
</thead>
</table>
| Outcomes      | Atelectasis  
- Experimental: 3  
- Control: 7  
- p<0.05  
Pneumonia  
- Experimental: 1  
- Control: 3  
- P<0.05  
6-minute walk test on the 7th postoperative day (standard deviation)  
- Experimental: 257.8 (98.9)  
- Control: 359.1 (80.5)  
- P<0.01 |
| Notes         | Postoperative care for both groups: not described  
Adverse events: not reported on  
The authors kindly provided point estimates for atelectasis and pneumonia and stated that pneumonia was confirmed by X-thorax |
<table>
<thead>
<tr>
<th>Risk of bias</th>
<th><strong>Bias</strong></th>
<th><strong>Authors’ judgement</strong></th>
<th><strong>Support for judgement</strong></th>
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<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>Randomisation procedure was not described</td>
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<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Allocation procedure was not described</td>
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</table>
Carvalho 2011  (Continued)

<table>
<thead>
<tr>
<th>Source</th>
<th>Method</th>
<th>Setting</th>
<th>Recruitment period</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RCT</td>
<td>Single centre, Brazil</td>
<td>Not reported</td>
<td>Inclusion: persons aged 50 years or more awaiting CABG or valvuloplasty</td>
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<td>Exclusion: unstable angina, congestive decompensated heart failure, lack of physical or</td>
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<td>intellectual capacity to adequately perform the prescribed exercises, complex ventricular</td>
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<td>and uncontrolled arrhythmia, blood pressure &gt;140/90 mmHg, myocardial infarction or cerebrovascular</td>
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<td>accident less than 3 years ago, high grade atrioventricular blockade or exercise-induced</td>
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<td>bronchial spasm, submission to cardiac surgery before completing at least two weeks of</td>
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<td>respiratory muscle training</td>
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<td>Number of patients:</td>
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<td></td>
<td>- Experimental: 15</td>
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<td>- Control: 15</td>
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<td>Mean age (standard deviation) (NS)</td>
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<td>- Experimental: 62.5 (6.1)</td>
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<td>- Control: 63.1 (7.9)</td>
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<td>Sex (P&lt;0.01)</td>
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<td>- Experimental: 60% male</td>
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<td>- Control: 87% male</td>
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<td>Mean BMI (standard deviation) (NS)</td>
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<td>- Experimental: 26.6 (5.2)</td>
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<td>- Control: 28.3 (3.2)</td>
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<td>Smoker (NS)</td>
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<td></td>
<td>- Experimental: 20.0%</td>
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<td>- Control: 6.7%</td>
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<td>Diabetes (NS)</td>
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<td>- Experimental: 40.0%</td>
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<td></td>
<td>- Control: 40.0%</td>
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<td></td>
<td>Interventions</td>
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<td></td>
<td></td>
<td>Experimental: inspiratory muscle training with threshold device and a load of 40% of the</td>
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<tr>
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<td></td>
<td>peak inspiratory pressure, during at least two weeks prior to surgery, thrice daily, five</td>
</tr>
</tbody>
</table>

Blinding of participants and personnel (performance bias)
All outcomes

| High risk | Not reported on. The blinding of participants is assessed by reviewers as unlikely to have happened, as no sham/placebo therapy was described |

Blinding of outcome assessment (detection bias)
All outcomes

| Unclear risk | Not reported on |

Incomplete outcome data (attrition bias)
All outcomes

| Unclear risk | Not enough data to assess |

Selective reporting (reporting bias)

| Low risk | All predefined outcomes were reported on |
series of 10 repetitions. In addition, general presurgery advice. Setting and supervision: not reported
C: general presurgery advice (on surgery, postoperative period, tobacco smoking, deep inspiration exercises without special equipment and daily walks up to their own limits)

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Pneumonia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Experimental: 1</td>
</tr>
<tr>
<td></td>
<td>- Control: 0</td>
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<tr>
<td></td>
<td>- P=1.000</td>
</tr>
<tr>
<td>Prolonged ventilation (&gt;48 hours)</td>
<td>- Experimental: 1</td>
</tr>
<tr>
<td></td>
<td>- Control: 0</td>
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<tr>
<td></td>
<td>- P=1.000</td>
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<tr>
<td>All-cause deaths</td>
<td>- Experimental: 3</td>
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<td></td>
<td>- Control: 1</td>
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<td></td>
<td>- P=0.598</td>
</tr>
</tbody>
</table>

| Notes                             | Postoperative care for both groups: routine physical therapy programme |
|                                  | Adverse events: none of the patients had to leave the programme due to adverse events |

### Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>Randomisation procedure was not described</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Allocation procedure was not described</td>
</tr>
<tr>
<td>Blinding of participants and personnel (performance bias) All outcomes</td>
<td>High risk</td>
<td>Not reported on. The blinding of participants is assessed by reviewers as unlikely to have happened, as no sham/placebo therapy was described</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Unclear risk</td>
<td>The blinding of outcome assessment was not described. The reviewers consider the risk for the outcome deaths to be low</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias)        All outcomes</td>
<td>Low risk</td>
<td>Quote: “There were no missing values for any collected data”</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Unclear risk</td>
<td>All predefined outcomes were reported on</td>
</tr>
</tbody>
</table>
### Methods
RCT  
Setting: single centre, the Netherlands  
Recruitment period: July 2002 to August 2005

### Participants
Inclusion: high-risk patients undergoing primary elective CABG  
High-risk was defined as 2 or more of the following: age>70 years; cough and expectoration; diabetes; smoker; COPD (FEV$_1$ <75% predicted or pulmonary medication used)  
High-risk was also: FEV$_1$ <80% predicted and FEV$_1$/FVC<70% predicted  
Exclusion: surgery within 2 weeks of initial contact; history of CVA; use of immunosuppressive medication in the past 30 days; neuromuscular disorders; cardiovascular instability or aneurysm  
Number of patients  
- Experimental: 139  
- Control: 137  
Mean age (standard deviation) (NS)  
- Experimental: 66.5 (9.0)  
- Control: 67.3 (9.2)  
Sex (NS)  
- Experimental: 78% male  
- Control: 78% male  
Mean BMI (SD) (NS)  
- Experimental: 28.3 (5.5)  
- Control: 28.1 (3.2)  
History of cigarette smoking (NS)  
- Experimental: 32.4%  
- Control: 38.0%  
History of COPD (NS)  
- Experimental: 19.4%  
- Control: 21.9%  
Diabetes (NS)  
- Experimental: 43.9%  
- C: 32.8%  
On-pump CABG (NS)  
- Experimental: 80.6%  
- Control: 83.2%

### Interventions
Experimental: inspiratory muscle training, education in active cycle of breathing techniques and forced expiration techniques. Daily inspiratory muscle training sessions of at least 20 minutes for at least two weeks, starting at 30% of maximal inspiratory pressure with an incremental increase. Setting and supervision: supervision by a physical therapist once a week  
C: usual care the day before surgery (instruction on deep breathing manoeuvres, coughing and early mobilization)

### Outcomes
Atelectasis  
- Experimental: 14  
- Control: 18  
- P=0.02  
Pneumonia  
- Experimental: 9
- Control: 22
- P=0.01
Mechanical ventilation > 48 hours
- Experimental: 1
- Control: 6
PPC grade 2
- Experimental: 14
- Control: 18
- P=0.02
PPC grade 3
- Experimental: 10
- Control: 24
- P=0.01
PPC grade 4
- Experimental: 1
- Control: 6
- P=0.09
PPC grade ≥ 2
- Experimental: 25
- Control: 48
- P=0.02

Mean postoperative length of stay (standard deviation)
- Experimental: 7.89 (2.17)
- Control: 9.94 (8.27)
- P=0.02

Death from respiratory causes:
- Experimental: 0
- Control: 3

All-cause deaths:
- Experimental: 0
- Control: 4

Notes
Postoperative care for both groups: usual care
Adverse events: none occurred
Erik Hulzebos provided additional data on the number of patients with atelectasis, a mechanical ventilation > 48 hours and on the mean postoperative length of stay
Though the recruitment period overlaps with the other study by the same author (Hulzebos 2006B), this study included different patients
Hulzebos 2006A  (*Continued*)

<table>
<thead>
<tr>
<th>Blinding of participants and personnel (performance bias)</th>
<th>High risk</th>
<th>Not reported on. The blinding of participants is assessed by reviewers as unlikely to have happened, as no sham/placebo therapy was described</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blinding of outcome assessment (detection bias)</td>
<td>Low risk</td>
<td>Primary outcomes and length of hospital stay were assessed by independent, blinded assessors. This was not stated for mortality but authors do not believe this will introduce bias</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias)</td>
<td>Low risk</td>
<td>All included patients were reported on. 3 patients were excluded after randomisation because they died before surgery (one from the experimental group and 2 from the control group)</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>All predefined outcomes were reported on</td>
</tr>
</tbody>
</table>

**Hulzebos 2006B**

<table>
<thead>
<tr>
<th>Methods</th>
<th>RCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting: single centre, the Netherlands</td>
<td></td>
</tr>
<tr>
<td>Recruitment period: October to December 2002</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participants</th>
<th>Inclusion: high-risk patients undergoing primary elective CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-risk was defined with a weighted risk factor scale including the following risk factors: age ≥70 years; cough and expectoration; diabetes; history of smoking; inspiratory vital capacity &lt;75% of predicted and maximal expiratory pressure &lt;75% of predicted</td>
<td></td>
</tr>
<tr>
<td>Exclusion: surgery within 2 weeks of initial contact; history of CVA; use of immunosuppressive medication in the past 30 days; previous pulmonary surgery; neuromuscular disorders; cardiovascular instability or aneurysm</td>
<td></td>
</tr>
<tr>
<td>Number of patients</td>
<td></td>
</tr>
<tr>
<td>- Experimental: 14</td>
<td></td>
</tr>
<tr>
<td>- Control: 12</td>
<td></td>
</tr>
<tr>
<td>Sex (NS)</td>
<td></td>
</tr>
<tr>
<td>- Experimental: 50% male</td>
<td></td>
</tr>
<tr>
<td>- Control: 50% male</td>
<td></td>
</tr>
<tr>
<td>Mean age (standard deviation) (NS)</td>
<td></td>
</tr>
<tr>
<td>- Experimental: 70.14 (9.86)</td>
<td></td>
</tr>
<tr>
<td>- Control: 70.50 (10.10)</td>
<td></td>
</tr>
<tr>
<td>Mean BMI (standard deviation) (NS)</td>
<td></td>
</tr>
</tbody>
</table>
Interventions
Experimental: preoperative inspiratory muscle training with an inspiratory threshold-loading device at home, one daily session of 20 minutes for at least two weeks with one weekly session supervised by a physiotherapist. Subjects started breathing at a resistance of 30% of their maximal inspiratory pressure. Resistance was increased incrementally.
Control: usual care one day before surgery (instructions on deep breathing manoeuvres, coughing, and early mobilization).

Outcomes
Atelectasis
- Experimental: 2
- Control: 6
- P=0.05
Pneumonia (NS)
- Experimental: 1
- Control: 1
Length of hospital stay (standard deviation)
- Experimental: 7.93 days (1.94)
- Control: 9.92 days (5.78)
- P=0.24

Notes
Postoperative care for both groups: usual care
Adverse events: no cardiovascular complications or side effects occurred
Though the recruitment period overlaps with the other study by the same author (Hulzebos 2006A), this study included different patients.

Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Quote: &quot;using a computer-generated randomized block design&quot;</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Allocation concealment was not described</td>
</tr>
<tr>
<td>Blinding of participants and personnel (performance bias)</td>
<td>High risk</td>
<td>'The trial was described as 'single-blind', this single blindness referred to outcome assessment. The blinding of participants is assessed by reviewers as unlikely to have</td>
</tr>
</tbody>
</table>
Blinding of outcome assessment (detection bias) | Low risk | The detection of the outcomes atelectasis, pneumonia and length of hospital stay is considered to be subject to a low risk of bias by the reviewers.

Incomplete outcome data (attrition bias) | Low risk | All included patients were reported on.

Selective reporting (reporting bias) | Low risk | All predefined outcomes were reported on.

Rajendran 1998

Methods
- RCT
- Setting: single centre, India
- Recruitment period: December 1992 to September 1994

Participants
- Inclusion: COPD patients undergoing CABG
- Exclusion: death after CABG
- Number of patients:
  - Experimental: 25
  - Control: 20
- Mean age (standard deviation):
  - Experimental: 55.4 (6.9)
  - Control: 58.7 (7.0)
- Weight (standard deviation):
  - Experimental: 70.2 (7.6)
  - Control: 69.6 (11.9)

Interventions
- Experimental: preoperative medication including bronchodilators; health education, exercise reconditioning and support, instruction about respiratory disease and its treatment, breathing retraining (diaphragmatic breathing and pursed lip breathing), dyspnoea control, nutritional counselling, energy conservation, work simplification techniques and stress management with relaxation training. Daily sessions for one week under the guidance of a specialist, and advice to practice for 10 minutes every waking hour
- Control: preoperative medication including bronchodilators

Outcomes
- Postoperative hospital stay (standard deviation):
  - Experimental: 12.4 (3.6)
  - Control: 18.6 (6.6)
  - P<0.001
- Atelectasis:
  - Experimental: 0
  - Control: 4
- Pneumothorax:
  - Experimental: 0
### Rajendran 1998 (Continued)

| Notes | Postoperative care for both groups: pulmonary rehabilitation  
Adverse events: not reported  
We did not meta-analyse the outcome 'consolidation' as we could not classify this with certainty as a pneumonia |
|---|---|

### Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>The randomisation procedure was not described</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Allocation concealment was not described</td>
</tr>
</tbody>
</table>
| Blinding of participants and personnel (performance bias)  
All outcomes | High risk | The blinding of participants is assessed by reviewers as unlikely to have happened, as no sham/placebo therapy was described |
| Blinding of outcome assessment (detection bias)  
All outcomes | Low risk | Blinding of outcome assessment was not described. As atelectasis and pneumothorax findings were confirmed by X-thorax the review authors consider the risk of bias low |
| Incomplete outcome data (attrition bias)  
All outcomes | Low risk | All included patients were reported on |
| Selective reporting (reporting bias) | Unclear risk | All predefined outcomes were reported on |

### Rosenfeldt 2011

| Methods | RCT  
Setting: single centre, Australia  
Recruitment period: November 2004 to June 2006 |
|---|---|
| Participants | Inclusion: patients scheduled for CABG or valve surgery  
Exclusion: urgent or emergency surgery, severe aortic valve stenosis, limited English, NYHA class IV heart failure  
Number of patients  
- Experimental: 60  
- Control: 57  
Median age (0.06)  
- Experimental: 62.5  
- Control: 68  
Sex (NS)  
- Experimental: 78% male  
- Control: 70% male |
Diabetes (NS)
- Experimental: 20%
- Control: 29%

Interventions
Experimental: holistic therapy consisting of light physical exercise sessions (low intensity aerobic exercise training of approximately 50% of maximum oxygen uptake). Two supervised, one hour outpatient sessions per week for two weeks, plus encouragement to complete two weekly personal sessions of at least 30 minutes on at least two other occasions each week, including after the discontinuation of the supervised programme. In addition, a mental stress reduction programme (four individualised 1 hour sessions including education and relaxing techniques such as deep breathing techniques and meditation), for the first two weeks after placement on the surgery waiting list.
Control: usual care

Outcomes
Length of hospital stay
- Experimental: 6
- Control: 6
- P=0.54
Mean postoperative Short Form -36 Physical composite score (standard deviation)
- Experimental: 44.1 (1.0)
- Control: 42.8 (1.3)
- P=0.45

Notes
Postoperative care for both groups: not described
Adverse events: not reported on
It was unclear whether the length of hospital stay was reported as a mean or a median, and no standard deviation was given. We wrote to the authors but did not receive an answer

Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Quote: “Patients were randomised, using a computer-generated code”</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Allocation procedure was not described</td>
</tr>
<tr>
<td>Blinding of participants and personnel (performance bias)</td>
<td>High risk</td>
<td>Not reported on. The blinding of participants is assessed by reviewers as unlikely to have happened, as no sham/placebo therapy was described</td>
</tr>
<tr>
<td>All outcomes</td>
<td>Low risk</td>
<td>The blinding of outcome assessors was not reported on. The reviewers assess the risk as low because quality of life was assessed with a questionnaire and length of stay and postoperative atrial fibrillation were assessed using patients’ medical records</td>
</tr>
</tbody>
</table>

Preoperative physical therapy for elective cardiac surgery patients (Review)

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### Rosenfeldt 2011 (Continued)

<table>
<thead>
<tr>
<th>Incomplete outcome data (attrition bias)</th>
<th>Low risk</th>
<th>All included patients were recorded on all outcomes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>All predefined outcomes were reported on. One outcome that was not predefined was reported on (troponin at 24 hours) but this outcome did not differ significantly between groups and was not mentioned in the text nor in the abstract.</td>
</tr>
</tbody>
</table>

### Weiner 1998

<table>
<thead>
<tr>
<th>Methods</th>
<th>RCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting: not reported. Likely a single centre study in Israel</td>
<td></td>
</tr>
<tr>
<td>Recruitment period: not reported</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participants</th>
<th>Inclusion: patients scheduled for CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exclusion: not described</td>
<td></td>
</tr>
<tr>
<td>Number of patients</td>
<td></td>
</tr>
<tr>
<td>- Experimental: 42</td>
<td></td>
</tr>
<tr>
<td>- Control: 42</td>
<td></td>
</tr>
<tr>
<td>Mean age (standard deviation)</td>
<td></td>
</tr>
<tr>
<td>- Experimental: 59.2 (3.8)</td>
<td></td>
</tr>
<tr>
<td>- Control: 63.8 (3.1)</td>
<td></td>
</tr>
</tbody>
</table>

| Interventions | Experimental: inspiratory muscle training, 30 minutes per day for two to four weeks, under supervision of a physician, with a threshold inspiratory muscle trainer. Training started at a resistance equal to 15% of maximal inspiratory mouth pressure for one week. Resistance was then increased incrementally with 5% each session up to 60% of their maximal inspiratory mouth pressure. Control: equal training protocol with the same device but with no resistance (sham training) |

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Pleural effusion (unclear whether pleural effusion resulted in thoracocentesis, excluded from meta-analysis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Experimental: 5</td>
<td></td>
</tr>
<tr>
<td>- Control: 3</td>
<td></td>
</tr>
<tr>
<td>- NS (P value not reported)</td>
<td></td>
</tr>
<tr>
<td>Pneumonia</td>
<td></td>
</tr>
<tr>
<td>- Experimental: 1</td>
<td></td>
</tr>
<tr>
<td>- Control: 3</td>
<td></td>
</tr>
<tr>
<td>- NS (P value not reported)</td>
<td></td>
</tr>
<tr>
<td>Mechanical ventilation &gt;24 hours</td>
<td></td>
</tr>
<tr>
<td>- Experimental: 2</td>
<td></td>
</tr>
<tr>
<td>- Control: 11</td>
<td></td>
</tr>
<tr>
<td>- P value not reported</td>
<td></td>
</tr>
</tbody>
</table>
Notes
Postoperative care for both groups: not described
Adverse events: not reported on

Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>The randomisation procedure was not described</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Allocation procedure was not described</td>
</tr>
<tr>
<td>Blinding of participants and personnel (performance bias)</td>
<td>Unclear risk</td>
<td>Not reported on, however, a sham therapy was used</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias)</td>
<td>Unclear risk</td>
<td>Blinding of outcome assessment was not described</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias)</td>
<td>Low risk</td>
<td>Drop outs not reported on. As all outcomes were short-term outcomes the reviewers assess this risk as low</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>All predefined outcomes were reported on</td>
</tr>
</tbody>
</table>

BMI = body mass index; C = control group; CABG = coronary artery bypass grafting; CI = confidence interval; COPD = chronic obstructive pulmonary disease; DM = diabetes mellitus; E = experimental group; FEV₁ = forced expiratory volume in the first second of expiration; FVC = forced vital capacity; IQR = interquartile range; LOS = length of postoperative hospital stay; LVEF = left ventricular ejection fraction; N = number of patients; NS = not significant; NYHA = New York Heart Association; PPC = postoperative pulmonary complication; RCT = randomised controlled trial

Characteristics of excluded studies  [ordered by study ID]

<table>
<thead>
<tr>
<th>Study</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson 1987</td>
<td>No preoperative physical therapy</td>
</tr>
<tr>
<td>Buijs van den 2004</td>
<td>Other types of outcome</td>
</tr>
<tr>
<td>Castillo 1985</td>
<td>No randomisation or quasi-randomisation: treatment allocation was based on the individual surgeon's routine policy</td>
</tr>
<tr>
<td>Cisar 1983</td>
<td>Case-report</td>
</tr>
<tr>
<td>Study</td>
<td>Notes</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>Crawford 1993</td>
<td>Other types of outcome</td>
</tr>
<tr>
<td>Dias 2011</td>
<td>No preoperative physical therapy</td>
</tr>
<tr>
<td>Dowds 2009</td>
<td>Not on cardiac surgery patients</td>
</tr>
<tr>
<td>Fitileva 1982</td>
<td>No preoperative physical therapy</td>
</tr>
<tr>
<td>Fujimura 1980</td>
<td>Not a randomised trial</td>
</tr>
<tr>
<td>Gosselink 1998</td>
<td>Not on cardiac surgery patients</td>
</tr>
<tr>
<td>Herdy 2008</td>
<td>The postoperative regimen differed</td>
</tr>
<tr>
<td>Iankelevich 1967</td>
<td>On children only</td>
</tr>
<tr>
<td>Ingwersen 1993</td>
<td>Only postoperative physical therapy</td>
</tr>
<tr>
<td>Jenkins 1989</td>
<td>The postoperative regimen differed (study mainly on postoperative physical therapy)</td>
</tr>
<tr>
<td>Ku 2002</td>
<td>The postoperative regimen differed</td>
</tr>
<tr>
<td>Leserman</td>
<td>No physical therapy</td>
</tr>
<tr>
<td>Mahler 1998</td>
<td>No physical therapy</td>
</tr>
<tr>
<td>Matte 2000</td>
<td>No preoperative physical therapy</td>
</tr>
<tr>
<td>Nomori 1994</td>
<td>No cardiac surgery patients</td>
</tr>
<tr>
<td>Oulton 1981</td>
<td>No preoperative physical therapy</td>
</tr>
<tr>
<td>Recker 1994</td>
<td>No preoperative physical therapy</td>
</tr>
<tr>
<td>Rice 1992</td>
<td>Other intervention (self-instruction exercise booklet on how to perform coughing, deep breathing, leg movement and ambulation exercises)</td>
</tr>
<tr>
<td>Savci 2011</td>
<td>The postoperative physical therapy programme differed</td>
</tr>
<tr>
<td>Sheveleva 1965</td>
<td>No control group</td>
</tr>
<tr>
<td>Shuldham 2002</td>
<td>Other intervention (pre-operative educational intervention)</td>
</tr>
<tr>
<td>Sivaraman 2010</td>
<td>Uncertain whether both groups received preoperative physical therapy as the requested information on whether conventional care respiratory therapy was given preoperatively, postoperatively or both and what its nature was, was not received</td>
</tr>
<tr>
<td>Study</td>
<td>Intervention Details</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Smetana 2003</td>
<td>No preoperative physical therapy</td>
</tr>
<tr>
<td>Stein 1970</td>
<td>No cardiac surgery patients (patients with thoracic surgery were included, but it was unclear whether these were cardiac surgery patients); postoperative treatment differed</td>
</tr>
<tr>
<td>Stiller 1994</td>
<td>The postoperative physical therapy programme differed (mainly a study on postoperative physical therapy with one preoperative instruction session)</td>
</tr>
<tr>
<td>Uglov 1992</td>
<td>No preoperative physical therapy with an exercise component</td>
</tr>
<tr>
<td>Vraicu 1977</td>
<td>The postoperative physical therapy programme differed (mainly a study on postoperative physical therapy with one preoperative instruction session)</td>
</tr>
<tr>
<td>Walther 2010</td>
<td>The outcomes length of stay and quality of life were mentioned in the abstract but not reported on</td>
</tr>
<tr>
<td>Winten 1995</td>
<td>Other types of outcome (atelectasis was described but results of chest roentgenogram or temperature were not described so this was considered a grade 1 pulmonary complication)</td>
</tr>
<tr>
<td>Zamotrinsky 1997</td>
<td>No physical therapy</td>
</tr>
</tbody>
</table>
## DATA AND ANALYSES

**Comparison 1. Preoperative physical therapy versus no preoperative physical therapy**

<table>
<thead>
<tr>
<th>Outcome or subgroup title</th>
<th>No. of studies</th>
<th>No. of participants</th>
<th>Statistical method</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 PPC grade 2 (atelectasis)</td>
<td>4</td>
<td>379</td>
<td>Risk Ratio (M-H, Fixed, 95% CI)</td>
<td>0.52 [0.32, 0.87]</td>
</tr>
<tr>
<td>2 PPC grade 2 (any type)</td>
<td>1</td>
<td>276</td>
<td>Risk Ratio (M-H, Fixed, 95% CI)</td>
<td>0.77 [0.40, 1.48]</td>
</tr>
<tr>
<td>3 PPC grade 3 (pneumonia)</td>
<td>5</td>
<td>448</td>
<td>Risk Ratio (M-H, Fixed, 95% CI)</td>
<td>0.45 [0.24, 0.83]</td>
</tr>
<tr>
<td>4 PPC grade 3 (pneumothorax)</td>
<td>1</td>
<td>45</td>
<td>Risk Ratio (M-H, Fixed, 95% CI)</td>
<td>0.12 [0.01, 2.11]</td>
</tr>
<tr>
<td>5 PPC grade 3 (any type)</td>
<td>1</td>
<td>276</td>
<td>Risk Ratio (M-H, Fixed, 95% CI)</td>
<td>0.41 [0.20, 0.83]</td>
</tr>
<tr>
<td>6 PPC grade 4 (mechanical ventilation &gt; 48 hours)</td>
<td>2</td>
<td>306</td>
<td>Risk Ratio (M-H, Random, 95% CI)</td>
<td>0.55 [0.03, 9.20]</td>
</tr>
<tr>
<td>7 PPC grade 4 (all type)</td>
<td>1</td>
<td>276</td>
<td>Risk Ratio (M-H, Fixed, 95% CI)</td>
<td>0.16 [0.02, 1.35]</td>
</tr>
<tr>
<td>8 PPC grade ≥ 2 (any type)</td>
<td>1</td>
<td>276</td>
<td>Risk Ratio (M-H, Fixed, 95% CI)</td>
<td>0.51 [0.34, 0.78]</td>
</tr>
<tr>
<td>9 Postoperative death (all causes)</td>
<td>3</td>
<td>552</td>
<td>Risk Ratio (M-H, Random, 95% CI)</td>
<td>0.66 [0.02, 18.48]</td>
</tr>
<tr>
<td>10 Length of postoperative hospital stay (days)</td>
<td>3</td>
<td>347</td>
<td>Mean Difference (IV, Random, 95% CI)</td>
<td>-3.21 [-5.73, -0.69]</td>
</tr>
<tr>
<td>11 Physical function measures (six minute walking test)</td>
<td>1</td>
<td>32</td>
<td>Mean Difference (IV, Fixed, 95% CI)</td>
<td>-101.30 [-163.78, -38.82]</td>
</tr>
<tr>
<td>12 Postoperative death (respiratory causes)</td>
<td>1</td>
<td>276</td>
<td>Risk Ratio (M-H, Fixed, 95% CI)</td>
<td>0.14 [0.01, 2.70]</td>
</tr>
<tr>
<td>13 Quality of life (short-form-36 physical composite score)</td>
<td>1</td>
<td>117</td>
<td>Mean Difference (IV, Fixed, 95% CI)</td>
<td>1.30 [0.88, 1.72]</td>
</tr>
</tbody>
</table>
### Analysis 1.1. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 1 PPC grade 2 (atelectasis).

**Review:** Preoperative physical therapy for elective cardiac surgery patients  
**Comparison:** 1 Preoperative physical therapy versus no preoperative physical therapy  
**Outcome:** 1 PPC grade 2 (atelectasis)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>M-H,Fixed,95% CI</td>
<td></td>
<td>M-H,Fixed,95% CI</td>
</tr>
<tr>
<td>Carvalho 2011</td>
<td>3/16</td>
<td>7/16</td>
<td>19.1 % 0.43 [ 0.13, 1.37 ]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hulzebos 2006A</td>
<td>14/139</td>
<td>18/137</td>
<td>49.6 % 0.77 [ 0.40, 1.48 ]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hulzebos 2006B</td>
<td>2/14</td>
<td>6/12</td>
<td>17.7 % 0.29 [ 0.07, 1.16 ]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rajendran 1998</td>
<td>0/25</td>
<td>4/20</td>
<td>13.6 % 0.09 [ 0.01, 1.57 ]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>194</strong></td>
<td><strong>185</strong></td>
<td></td>
<td>100.0 % 0.52 [ 0.32, 0.87 ]</td>
<td></td>
</tr>
</tbody>
</table>

Total events: 19 (Experimental), 35 (Control)  
Heterogeneity: Chi² = 3.58, df = 3 (P = 0.31); I² = 16%  
Test for overall effect: Z = 2.50 (P = 0.012)  
Test for subgroup differences: Not applicable

### Analysis 1.2. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 2 PPC grade 2 (any type).

**Review:** Preoperative physical therapy for elective cardiac surgery patients  
**Comparison:** 1 Preoperative physical therapy versus no preoperative physical therapy  
**Outcome:** 2 PPC grade 2 (any type)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>M-H,Fixed,95% CI</td>
<td></td>
<td>M-H,Fixed,95% CI</td>
</tr>
<tr>
<td>Hulzebos 2006A</td>
<td>14/139</td>
<td>18/137</td>
<td>100.0 % 0.77 [ 0.40, 1.48 ]</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>139</strong></td>
<td><strong>137</strong></td>
<td></td>
<td>100.0 % 0.77 [ 0.40, 1.48 ]</td>
<td></td>
</tr>
</tbody>
</table>

Total events: 14 (Experimental), 18 (Control)  
Heterogeneity: not applicable  
Test for overall effect: Z = 0.79 (P = 0.43)  
Test for subgroup differences: Not applicable
### Analysis 1.3. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 3 PPC grade 3 (pneumonia).

#### Review:
Preoperative physical therapy for elective cardiac surgery patients

#### Comparison:
1 Preoperative physical therapy versus no preoperative physical therapy

#### Outcome:
3 PPC grade 3 (pneumonia)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>M-H,Fixed</td>
<td>95% CI</td>
<td>M-H,Fixed</td>
</tr>
<tr>
<td>Carvalho 2011</td>
<td>1/16</td>
<td>3/16</td>
<td>10.1 %</td>
<td>0.33 [ 0.04, 2.87 ]</td>
<td></td>
</tr>
<tr>
<td>Ferreira 2009</td>
<td>1/15</td>
<td>0/15</td>
<td>1.7 %</td>
<td>3.00 [ 0.13, 68.26 ]</td>
<td></td>
</tr>
<tr>
<td>Hulzebos 2006A</td>
<td>9/139</td>
<td>22/137</td>
<td>74.5 %</td>
<td>0.40 [ 0.19, 0.84 ]</td>
<td></td>
</tr>
<tr>
<td>Hulzebos 2006B</td>
<td>1/14</td>
<td>1/12</td>
<td>3.6 %</td>
<td>0.86 [ 0.06, 12.28 ]</td>
<td></td>
</tr>
<tr>
<td>Weiner 1998</td>
<td>1/42</td>
<td>3/42</td>
<td>10.1 %</td>
<td>0.33 [ 0.04, 3.08 ]</td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>226</strong></td>
<td><strong>222</strong></td>
<td><strong>100.0 %</strong></td>
<td><strong>0.45 [ 0.24, 0.83 ]</strong></td>
<td></td>
</tr>
</tbody>
</table>

Total events: 13 (Experimental), 29 (Control)
Heterogeneity: $\chi^2 = 1.87, df = 4 (P = 0.76)$; $I^2 =0.0%$
Test for overall effect: $Z = 2.54 (P = 0.011)$
Test for subgroup differences: Not applicable
### Analysis 1.4. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 4 PPC grade 3 (pneumothorax).

**Review:** Preoperative physical therapy for elective cardiac surgery patients

**Comparison:** 1 Preoperative physical therapy versus no preoperative physical therapy

**Outcome:** 4 PPC grade 3 (pneumothorax)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental n/N</th>
<th>Control n/N</th>
<th>Risk Ratio M-H,Fixed 95% CI</th>
<th>Weight</th>
<th>Risk Ratio M-H,Fixed 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rajendran 1998</td>
<td>0/25</td>
<td>3/20</td>
<td></td>
<td>100.0%</td>
<td>0.12 [ 0.01, 2.11 ]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>25</td>
<td>20</td>
<td></td>
<td>100.0%</td>
<td>0.12 [ 0.01, 2.11 ]</td>
</tr>
</tbody>
</table>

Total events: 0 (Experimental), 3 (Control)

Heterogeneity: not applicable

Test for overall effect: $Z = 1.46$ ($P = 0.15$)

Test for subgroup differences: Not applicable

---

### Analysis 1.5. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 5 PPC grade 3 (any type).

**Review:** Preoperative physical therapy for elective cardiac surgery patients

**Comparison:** 1 Preoperative physical therapy versus no preoperative physical therapy

**Outcome:** 5 PPC grade 3 (any type)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental n/N</th>
<th>Control n/N</th>
<th>Risk Ratio M-H,Fixed 95% CI</th>
<th>Weight</th>
<th>Risk Ratio M-H,Fixed 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hulzebos 2006A</td>
<td>10/139</td>
<td>24/137</td>
<td></td>
<td>100.0%</td>
<td>0.41 [ 0.20, 0.83 ]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>139</td>
<td>137</td>
<td></td>
<td>100.0%</td>
<td>0.41 [ 0.20, 0.83 ]</td>
</tr>
</tbody>
</table>

Total events: 10 (Experimental), 24 (Control)

Heterogeneity: not applicable

Test for overall effect: $Z = 2.50$ ($P = 0.013$)

Test for subgroup differences: Not applicable

---

Preoperative physical therapy for elective cardiac surgery patients (Review) 38

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### Analysis 1.6. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 6 PPC grade 4 (mechanical ventilation > 48 hours).

**Review:** Preoperative physical therapy for elective cardiac surgery patients

**Comparison:** 1 Preoperative physical therapy versus no preoperative physical therapy

**Outcome:** 6 PPC grade 4 (mechanical ventilation > 48 hours)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Favours experimental</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n/N</strong></td>
<td><strong>n/N</strong></td>
<td><strong>M-H,Random,95% CI</strong></td>
<td><strong>Weight</strong></td>
<td></td>
</tr>
<tr>
<td>Ferreira 2009</td>
<td>1/15</td>
<td>0/15</td>
<td>41.8 %</td>
<td>41.8 %</td>
</tr>
<tr>
<td>Hulzebos 2006A</td>
<td>1/139</td>
<td>6/137</td>
<td>58.2 %</td>
<td>58.2 %</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>154</strong></td>
<td><strong>152</strong></td>
<td><strong>100.0 %</strong></td>
<td><strong>0.55 [ 0.03, 9.20 ]</strong></td>
</tr>
</tbody>
</table>

Total events: 2 (Favours experimental), 6 (Control)

Heterogeneity: Tau² = 2.38; Chi² = 2.29; df = 1 (P = 0.13); I² = 56%

Test for overall effect: Z = 0.41 (P = 0.68)

Test for subgroup differences: Not applicable

### Analysis 1.7. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 7 PPC grade 4 (all type).

**Review:** Preoperative physical therapy for elective cardiac surgery patients

**Comparison:** 1 Preoperative physical therapy versus no preoperative physical therapy

**Outcome:** 7 PPC grade 4 (all type)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n/N</strong></td>
<td><strong>n/N</strong></td>
<td><strong>M-H,Fixed,95% CI</strong></td>
<td><strong>Weight</strong></td>
<td></td>
</tr>
<tr>
<td>Hulzebos 2006A</td>
<td>1/139</td>
<td>6/137</td>
<td>100.0 %</td>
<td>0.16 [ 0.02, 1.35 ]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>139</strong></td>
<td><strong>137</strong></td>
<td><strong>100.0 %</strong></td>
<td><strong>0.16 [ 0.02, 1.35 ]</strong></td>
</tr>
</tbody>
</table>

Total events: 1 (Experimental), 6 (Control)

Heterogeneity: not applicable

Test for overall effect: Z = 1.68 (P = 0.092)

Test for subgroup differences: Not applicable
Analysis 1.8. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy,
Outcome 8 PPC grade ≥ 2 (any type).

Review: Preoperative physical therapy for elective cardiac surgery patients
Comparison: 1 Preoperative physical therapy versus no preoperative physical therapy
Outcome: 8 PPC grade ≥ 2 (any type)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>M-H,Fixed,95% CI</td>
<td>M-H,Fixed,95% CI</td>
<td></td>
</tr>
<tr>
<td>Hulzebos 2006A</td>
<td>25/139</td>
<td>48/137</td>
<td>0.51 [ 0.34, 0.78 ]</td>
<td>100.0 %</td>
<td>0.51 [ 0.34, 0.78 ]</td>
</tr>
</tbody>
</table>

Total (95% CI) 139 137 100.0 % 0.51 [ 0.34, 0.78 ]

Total events: 25 (Experimental), 48 (Control)
Heterogeneity: not applicable
Test for overall effect: Z = 3.10 (P = 0.0020)
Test for subgroup differences: Not applicable
Analysis 1.9. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 9 Postoperative death (all causes).

Review: Preoperative physical therapy for elective cardiac surgery patients
Comparison: 1 Preoperative physical therapy versus no preoperative physical therapy
Outcome: 9 Postoperative death (all causes)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>H Random, 95% CI</td>
<td>H Random, 95% CI</td>
</tr>
<tr>
<td>Arthur 2000</td>
<td>0/123</td>
<td>0/123</td>
<td>0.0 [ 0.0, 0.0 ]</td>
<td></td>
</tr>
<tr>
<td>Ferreira 2009</td>
<td>3/15</td>
<td>1/15</td>
<td>3.00 [ 0.35, 25.68 ]</td>
<td></td>
</tr>
<tr>
<td>Hulzebos 2006A</td>
<td>0/139</td>
<td>4/137</td>
<td>0.11 [ 0.01, 2.02 ]</td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>277</strong></td>
<td><strong>275</strong></td>
<td><strong>0.66 [ 0.02, 18.48 ]</strong></td>
<td></td>
</tr>
</tbody>
</table>

Total events: 3 (Experimental), 5 (Control)
Heterogeneity: \( \tau^2 = 4.11 \); \( \chi^2 = 3.41 \), df = 1 (\( P = 0.06 \)); \( I^2 = 71\%
Test for overall effect: \( Z = 0.24 \) (\( P = 0.81 \))
Test for subgroup differences: Not applicable
### Analysis 1.10. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 10 Length of postoperative hospital stay (days).

Review: Preoperative physical therapy for elective cardiac surgery patients

Comparison: 1 Preoperative physical therapy versus no preoperative physical therapy

Outcome: 10 Length of postoperative hospital stay (days)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental Mean(SD)</th>
<th>Control Mean(SD)</th>
<th>Mean Difference</th>
<th>Weight</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td></td>
<td>IV, Random, 95% CI</td>
<td></td>
<td>IV, Random, 95% CI</td>
</tr>
<tr>
<td>Hulzebos 2006A</td>
<td>139</td>
<td>7.89 (2.17)</td>
<td>137</td>
<td>9.94 (8.27)</td>
<td>45.0 % -2.05 [-3.48, -0.62]</td>
</tr>
<tr>
<td>Hulzebos 2006B</td>
<td>14</td>
<td>7.93 (1.94)</td>
<td>12</td>
<td>9.92 (5.78)</td>
<td>26.7 % -1.99 [-5.41, 1.43]</td>
</tr>
<tr>
<td>Rajendran 1998</td>
<td>25</td>
<td>12.4 (3.6)</td>
<td>20</td>
<td>18.6 (6.6)</td>
<td>28.3 % -6.20 [-9.42, -2.98]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>178</strong></td>
<td><strong>169</strong></td>
<td></td>
<td><strong>100.0 %</strong></td>
<td><strong>-3.21 [-5.73, -0.69]</strong></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 3.14; Chi² = 5.49, df = 2 (P = 0.06); I² = 64%

Test for overall effect: Z = 2.50 (P = 0.013)

Test for subgroup differences: Not applicable

### Analysis 1.11. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 11 Physical function measures (six minute walking test).

Review: Preoperative physical therapy for elective cardiac surgery patients

Comparison: 1 Preoperative physical therapy versus no preoperative physical therapy

Outcome: 11 Physical function measures (six minute walking test)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental Mean(SD)</th>
<th>Control Mean(SD)</th>
<th>Mean Difference</th>
<th>Weight</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td></td>
<td>IV, Fixed, 95% CI</td>
<td></td>
<td>IV, Fixed, 95% CI</td>
</tr>
<tr>
<td>Carvalho 2011</td>
<td>16</td>
<td>257.8 (98.9)</td>
<td>16</td>
<td>359.1 (80.5)</td>
<td>100.0 % -101.30 [-163.78, -38.82]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>16</strong></td>
<td><strong>16</strong></td>
<td></td>
<td><strong>100.0 %</strong></td>
<td><strong>-101.30 [-163.78, -38.82]</strong></td>
</tr>
</tbody>
</table>

Heterogeneity: not applicable

Test for overall effect: Z = 3.18 (P = 0.0013)

Test for subgroup differences: Not applicable
### Analysis 1.12. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 12 Postoperative death (respiratory causes).

**Review:** Preoperative physical therapy for elective cardiac surgery patients

**Comparison:** Preoperative physical therapy versus no preoperative physical therapy

**Outcome:** Postoperative death (respiratory causes)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>M-H,Fixed,95% CI</td>
<td></td>
<td>M-H,Fixed,95% CI</td>
</tr>
<tr>
<td>Hulzebos 2006A</td>
<td>0/139</td>
<td>3/137</td>
<td>100.0 % 0.14 (0.01, 2.70)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>139</strong></td>
<td><strong>137</strong></td>
<td><strong>100.0 %</strong> 0.14 [0.01, 2.70]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total events: 0 (Experimental), 3 (Control)

Heterogeneity: not applicable

Test for overall effect: Z = 1.30 (P = 0.19)

Test for subgroup differences: Not applicable
Analysis 1.13. Comparison 1 Preoperative physical therapy versus no preoperative physical therapy, Outcome 13 Quality of life (short-form-36 physical composite score).

Review: Preoperative physical therapy for elective cardiac surgery patients

Comparison: 1 Preoperative physical therapy versus no preoperative physical therapy

Outcome: 13 Quality of life (short-form-36 physical composite score)

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Experimental</th>
<th>Control</th>
<th>Mean Difference</th>
<th>Weight</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N Mean(SD)</td>
<td>N Mean(SD)</td>
<td>IV,Fixed,95% CI</td>
<td>100.0 %</td>
<td>1.30 [ 0.88, 1.72 ]</td>
</tr>
<tr>
<td>Rosenfeldt 2011</td>
<td>60 44.1 (1)</td>
<td>57 42.8 (1.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>60</td>
<td>57</td>
<td></td>
<td>100.0 %</td>
<td>1.30 [ 0.88, 1.72 ]</td>
</tr>
</tbody>
</table>

Heterogeneity: not applicable
Test for overall effect: Z = 6.04 (P < 0.00001)
Test for subgroup differences: Not applicable

APPENDICES

Appendix 1. MEDLINE and CENTRAL search strategy

Appendix 2. EMBASE search strategy

1 exp Spirometry/ (21399)
2 Spirography/ (1157)
3 spiromet$.tw. (15351)
4 exp Lung function test/ (57959)
5 Bronchospirography/ (564)
6 bronchospirograph$.tw. (20)
7 bronchospiromet$.tw. (194)
8 lung function.tw. (22966)
9 (breath$ adj3 exercise$).tw. (1791)
10 (breath$ adj3 measur$).tw. (3462)
11 (incentive adj3 breath$).tw. (41)
12 Breathing Exercise.tw. (139)
13 spirograph$.tw. (652)
14 spirocare.tw. (3)
15 Forced Expiratory Flow/ (1791)
16 (breath$ adj3 device$).tw. (407)
17 triflo.tw. (17)
18 (maxim$ adj3 inspira$).tw. (2186)
19 respiratory therap$.tw. (1853)
20 exp Physical Therapy Modalities/ (42989)
21 physiotherap$.sh. (47107)
22 exp exercise/ (162192)
23 exp Physical Exertion/ (162192)
24 exp Rehabilitation/ (173584)
25 exp Physical Fitness/ (21827)
26 exp Exercise Test/ (34346)
27 exp Exercise Tolerance/ (8404)
28 exp SPORTS/ (76752)
29 exp PIABILITY/ (1821)
30 exp Physical Endurance/ (12549)
31 ((physical adj3 therap*) or physiotherap* or physio-therap*).ti,ab. (33368)
32 (exercise or manual or manipulat* or zone) adj3 (therapy or therapies)).ti,ab. (6350)
33 exertion$.ti,ab. (14768)
34 exercis$.ti,ab. (197537)
35 sport$.ti,ab. (45299)
36 training.ti,ab. (230926)
37 ((endurance or strength) adj3 training).ti,ab. (7260)
38 (physical adj3 (activity or activities)).ti,ab. (53301)
39 gait.ti,ab. (25406)
40 rolfing*.ti,ab. (27)
41 (physical or motion) adj5 (fitness or therapy or therapies)).ti,ab. (21038)
42 (physical$ adj2 endur$).ti,ab. (484)
43 physical therapy.sh. (0)
44 exercise.sh. (142627)
45 rehabilitation.sh. (32415)
46 jog$.ti,ab. (1668)
47 swim$.ti,ab. (23895)
48 bicycl$.ti,ab. (21278)
49 (cycle$ or cycling).ti,ab. (384670)
50 walk$.ti,ab. (65085)
51 (row or rowing).ti,ab. (10296)
Preoperative physical therapy for elective cardiac surgery patients (Review)

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Appendix 3. PEDro search strategy

PEDro was searched using the advanced search option. Searches for all (1) systematic reviews and (2) clinical trials (‘method’) in the indexed sub disciplines ‘cardiothoracic’ , and ‘no appropriate value in this field’ were conducted, in combination with the problems ‘difficulty with sputum clearance’ and ‘impaired ventilation’.  

Appendix 4. CINAHL search strategy

Search results were not limited; Medline indexed records were excluded. Smart text search was used.

((MH "Rehabilitation+") or (MH "Home Rehabilitation+") or rehabilitat* or (MH "Heart Valve Prosthesis+") or (MH "Heart Surgery+") or (MH "Surgery, Cardiovascular+") or (MH "Exerrions+") or (MH "Physical Fitness+") or (MH "Exercise Tolerance+") or (MH "Exertion+") or (MH "Physical Endurance+") or (MH "Sports+") or (MH "Pliability") or (MH "Physical Therapy+") or (MH "Chest Physical Therapy+") or (MH "Physical Therapy Practice, Evidence-Based") or (MH "Physical Therapy Practice, Research-Based") or (MH "Research, Physical Therapy") or (MH "Massage+") or (MH "Respiratory Function Tests+") or (MH "Spirometry") or (MH "Breathing Exercises+") or (MH "Forced Expiratory Flow Rates+") or (MH "Research, Respiratory Therapy") or "physical AND (activity OR activities)" or train* or exertion* or "physical AND endur*" or "(strengthening or stretching) and muscle" or "weight* AND train*" or sport* or training or gait or rolling or jog* or swim* or bicycle* or cycle* or cycling or walk* or row or rowing or exercise* or (exercise OR manual OR manipulat* OR zone) AND (therapy OR therapies)” or physiotherapy* or "physical AND therap*” or “(lung AND function)” or spirom* or spiograph* or "(breath* and exercise*)” or "(breath* and measure*)” or "(incentive and breath*)” or spiro care or trifle or "(breath* and device*)” or "(maxim* and inspira*)” or "(respirat* and therap*)” and ((MH "Myocardial Revascularizations") or (MH "Coronary Artery Bypass+") or (MH "Heart Surgery+") or (MH "Heart, Artificial+") or (MH "Heart Assist Devices+") or (MH "Pacemaker, Artificial+") or (MH "Defibrillators, Implantable") or (MH "Catheter Ablation") or (MH "Surgery, Cardiovascular") or "valv* and prosthesis*” or cabg or "bypass and coronary” or "bypass and cardiac” or "heart and transplant*” or "cardia* and transplant*” or lvad or "ventric* AND assist* AND device*” or "cardia* AND assist* AND device*” or "heart and artificial” or "cardia* and artificial” or "heart-assist* AND device*” or "vascular-assist* AND device*” or "heart-assist* AND pump*” or pacemaker or defibrillator* or "catheter and ablation” or "cardiac or cardiaci or heart or valve or valvular” and (surgery or operation or surgical)” or "(bypass and (coronary or cardia*))” and ((MH "Preoperative Periods") OR "preoperative")

HISTORY

Review first published: Issue 11, 2012

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 April 2008</td>
<td>New citation required and major changes</td>
<td>Substantive amendment</td>
</tr>
</tbody>
</table>

CONTRIBUTIONS OF AUTHORS

Conceiving the review (Hulzebos, van Meeteren)
Designing the review (Hulzebos, van Meeteren, Helders, Smit)
Coordinating the review (Hulzebos, van Meeteren, Helders)
Data collection of the review (Hulzebos, Smit)
Designing search strategies (Smit)
Undertaking searches (Smit)
Screening search results (Hulzebos, Smit)
Organising retrieval of papers (Smit)
Screening retrieved papers against inclusion criteria (Hulzebos, Smit)
Appraising quality of papers (Hulzebos, Smit)
Extracting data from papers (Hulzebos, Smit)
Writing to authors of papers for additional information (Hulzebos, Smit)
Providing additional data about papers (Hulzebos)
Obtaining and screening data on unpublished studies (Hulzebos)
Data management for the review (Hulzebos, Smit)
Entering data into RevMan (Hulzebos, Smit)
Analysis of data (Hulzebos, Smit)
Interpretation of data (Hulzebos, Helders, van Meeteren, Smit)
Providing a methodological perspective (Hulzebos, van Meeteren, Smit)
Providing a clinical perspective (Hulzebos, van Meeteren, Helders)
Providing a policy perspective (Helders, van Meeteren, Helders)
Providing a consumer perspective (Hulzebos, van Meeteren, Helders)
Writing the review (Hulzebos, Smit)
Providing general advice on the review (Helders, van Meeteren, Smit)
Securing funding for the review (van Meeteren)
Performing previous work that was the foundation of the current study (Hulzebos, van Meeteren, Helders)

DECLARATIONS OF INTEREST

EH, PH and NvM were involved in one or two of the included studies (Hulzebos 2006A; Hulzebos 2006B).
YS has no known conflicts of interest.

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