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[Intervention Review]

Upper limb exercise training for COPD

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ABSTRACT

Background

People with chronic obstructive pulmonary disease (COPD) often experience difficulty with performing upper limb exercise due to dyspnoea and arm fatigue. Consequently, upper limb exercise training is typically incorporated in pulmonary rehabilitation programmes to improve upper limb exercise capacity; however, the effects of this training on dyspnoea and health-related quality of life (HRQoL) remain unclear.

Objectives

To determine the effects of upper limb training (endurance or resistance training, or both) on symptoms of dyspnoea and HRQoL in people with COPD.

Search methods

We searched the Cochrane Airways Group Specialised Register of trials, ClinicalTrials.gov and the World Health Organization trials portal from inception to 28 September 2016 as well as checking all reference lists of primary studies and review articles.

Selection criteria

We included randomised controlled trials (RCTs) in which upper limb exercise training of at least four weeks' duration was performed. Three comparisons were structured as: a) upper limb training only versus no training or sham intervention; b) combined upper limb training and lower limb training versus lower limb training alone; and c) upper limb training versus another type of upper limb training.

Data collection and analysis

Two review authors independently selected trials for inclusion, extracted outcome data and assessed risk of bias. We contacted study authors to provide missing data. We determined the treatment effect from each study as the post-treatment scores. We were able to analyse data for all three planned comparisons. For the upper limb training only versus no training or sham intervention structure, the upper limb training was further classified as 'endurance training' or 'resistance training' to determine the impact of training modality.

Main results

Fifteen studies on 425 participants were included in the review, one of which was in abstract form only. Twelve studies were included in the meta-analysis across one or more of the three comparisons. The sample size of the included studies was small (12 to 43 participants) and overall study quality was moderate to low given the imprecision and risk of bias issues (i.e. missing information on sequence generation and allocation concealment as well as no blinding of outcome assessment and incomplete data).

When upper limb training was compared to either no training or sham training, there was a small significant improvement in symptoms of dyspnoea with a mean difference (MD) of 0.37 points (95% confidence interval (CI) 0.02 to 0.72 points; data from four studies on 129 people). However, there was no significant improvement in dyspnoea when the studies of endurance training only (MD 0.41 points, 95% CI -0.13 to 0.95 points; data from two studies on 55 people) or resistance training only (MD 0.34 points, 95% CI -0.11 to 0.80 points; data from two studies on 74 people) were analysed. When upper limb training combined with lower limb training was compared to lower limb training alone, no significant difference in dyspnoea was shown (MD 0.36 points, 95% CI -0.04 to 0.76 points; data from three studies on 86 people). There were no studies which examined the effects on dyspnoea of upper limb training compared to another upper limb training intervention.

There was no significant improvement in HRQoL when upper limb training was compared to either no training or sham training with a standardised mean difference (SMD) of 0.05 (95% CI -0.31 to 0.40; four studies on 126 people) or when upper limb training combined with lower limb training was compared to lower limb training alone (SMD 0.01, 95% CI -0.40 to 0.43; three studies on 95 people). Only one study, in which endurance upper limb training was compared to resistance upper limb training, reported on HRQoL and showed no between-group differences (St George's Respiratory Questionnaire MD 2.0 points, 95% CI -9 to 12; one study on 20 people).

Positive findings were shown for the effects of upper limb training on the secondary outcome of unsupported endurance upper limb exercise capacity. When upper limb training was compared to either no training or sham training, there was a large significant improvement in unsupported endurance upper limb capacity (SMD 0.66, 95% CI 0.19 to 1.13; six studies on 142 people) which remained significant when the studies in this analysis of endurance training only were examined (SMD 0.99, 95% CI 0.32 to 1.66; four studies on 85 people) but not when the studies of resistance training only were examined (SMD 0.23, 95% CI -0.31 to 0.76; three studies on 57 people, $P = 0.08$ for test of subgroup differences). When upper limb training combined with lower limb training was compared to lower limb training alone, there was also a large significant improvement in unsupported endurance upper limb capacity (SMD 0.90, 95% CI 0.12 to 1.68; three studies on 87 people). A single study compared endurance upper limb training to resistance upper limb training with a significant improvement in the number of lifts performed in one minute favouring endurance upper limb training (MD 6.0 lifts, 95% CI 0.29 to 11.71 lifts; one study on 17 people).

Available data were insufficient to examine the impact of disease severity on any outcome.

Authors' conclusions

Evidence from this review indicates that some form of upper limb exercise training when compared to no upper limb training or a sham intervention improves dyspnoea but not HRQoL in people with COPD. The limited number of studies comparing different upper limb training interventions precludes conclusions being made about the optimal upper limb training programme for people with COPD, although endurance upper limb training using unsupported upper limb exercises does have a large effect on unsupported endurance upper limb capacity. Future RCTs require larger participant numbers to compare the differences between endurance upper limb training, resistance upper limb training, and combining endurance and resistance upper limb training on patient-relevant outcomes such as dyspnoea, HRQoL and arm activity levels.

PLAIN LANGUAGE SUMMARY

Arm exercise training for COPD

Review question: we reviewed the effects of arm training on symptoms of breathlessness and quality of life in people with chronic obstructive pulmonary disease (COPD).

Background: people with COPD often have difficulty with performing arm exercise due to breathlessness. Consequently, arm exercise training is often used to improve arm exercise capacity; however, the effects of this training on breathlessness and quality of life remain unclear. We wanted to examine arm exercise training of at least four weeks' duration and we analysed this in three ways: a) arm exercise training compared to no arm training or a sham intervention; b) a combination of arm training and leg training compared to leg training only; and c) arm training compared to another type of arm training (e.g. arm endurance training to arm strength training).

Study characteristics: fifteen studies were included on 425 participants with COPD. However, only 12 studies provided sufficient information for analysis across one or more of the three comparisons described above.

Key results: when arm training was compared to no arm training or a sham intervention in people with COPD, there was a small improvement in breathlessness. However, this improvement was not evident when the studies of combined arm and leg training were compared to leg training alone. No studies have examined whether breathlessness improves more with different types of arm training. Arm training had no effect on quality of life in any of the three comparisons. When endurance arm training was specifically examined, there was an improvement seen in the capacity of the arms to move and lift light weights compared to no training. These effects were not seen with arm strength training.

Quality of the evidence: the quality of the included studies was low to moderate due to the small number of participants (ranging from 12 to 43 participants per study), missing information on the methods of the study, and incomplete data on the outcomes.

Conclusions: some form of arm training can provide a small improvement to breathlessness but does not improve the quality of life of people with COPD. More specifically, endurance arm training can increase the capacity of the arms to move light weights in people with COPD.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. Main Comparison: Upper limb training vs No upper limb training for people with COPD

Comparison 1: Upper limb training vs No upper limb training for people with COPD

Patient or population: Stable COPD

Setting: Hospital outpatient and inpatient settings, home-based exercise, lab-based exercise

Intervention: Upper limb training

Comparison: No upper limb training/sham intervention

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Quality of the evidence (GRADE)	Comments
	Risk with No upper limb training	Risk with Upper limb training				
Symptoms of dyspnoea assessed with: Chronic Respiratory Disease Questionnaire Dyspnoea Score. Follow up: end of rehabilitation (range 4 weeks to 16 weeks)	The mean symptoms of dyspnoea was 4.2 points.	The mean symptoms of dyspnoea in the intervention group was 0.37 points higher (0.02 to 0.72 points).		129 (4 RCTs)	⊕⊕⊕○ moderate ^a	Higher value post-intervention is favourable indicating improvement in dyspnoea. The MID for dyspnoea component of the chronic respiratory disease questionnaire is 0.5.
Health-Related Quality of Life assessed with: Chronic Respiratory Disease Questionnaire Total Score. Follow up: end of rehabilitation (range 6 weeks to 8 weeks)	The mean health-related quality of life was 5.3 points.	The mean health-related quality of life in the intervention group was 0.05 points higher (0.3 points lower to 0.36 points higher).		126 (4 RCTs)	⊕⊕⊕○ moderate ^a	Higher value post-intervention is favourable indicating improvement in quality of life. Control group risk determined from studies using the chronic respiratory disease questionnaire. Intervention group risk determined by back transforming the SMD to the CRQ scale. MID of the chronic respiratory disease questionnaire is 0.5.
Peak Upper Limb Exercise Capacity (Supported) assessed with an incremental arm crank test. Follow up: end of rehabilitation (8 weeks)	The mean peak upper limb exercise capacity was 26 watts	The mean peak upper limb exercise capacity in the intervention group was 2.1 watts higher (8 watts lower to 12 watts higher)		70 (3 RCTs)	⊕⊕○○ low ^{a,b}	Control group risk determined from studies using peak power output in watts. Intervention group risk determined by back transforming the SMD to watts.

Peak Upper Limb Exercise Capacity (Unsupported) assessed with the incremental unsupported arm test. Follow up: end of rehabilitation (range 4 weeks to 8 weeks)	The mean peak upper limb exercise capacity was 483 seconds.	The mean peak upper limb exercise capacity in the intervention group was 21 seconds higher (20.5 seconds lower to 63 seconds higher).	112 (4 RCTs)	moderate ^a	
Endurance Upper Limb Exercise Capacity (Supported) assessed with an arm crank test. Follow up: end of rehabilitation (8 weeks)	The mean endurance upper limb exercise capacity was 426 seconds.	The mean endurance upper limb exercise capacity in the intervention group was 56 seconds higher (102 seconds lower to 213 seconds higher).	57 (2 RCTs)	low ^{a,c}	Control group risk determined from an arm crank test at 80% peak work and represents time of the test in seconds. Intervention group risk determined by back transforming the SMD to time in seconds.
Endurance Upper Limb Exercise Capacity (Unsupported) assessed by total number of rings moved in 6 minutes. Follow up: end of rehabilitation (range 6 weeks to 8 weeks)	The mean upper limb exercise capacity was 225 rings moved in 6 minutes.	The mean upper limb exercise capacity in the intervention group was 42 more rings moved (12 rings more to 71 rings more moved).	142 (6 RCTs)	low ^{a,d}	Control group risk determined from a test that counts the number of rings moved in 6 minutes. Intervention group risk determined by back transforming the SMD to the number of rings moved.
Upper Limb Strength assessed with dynamometry during shoulder flexion in kg. Follow up: end of rehabilitation (range 4 weeks to 16 weeks)	The mean upper limb strength was 21.4 kg	The mean upper limb strength in the intervention group was 1.4 kg higher (2 kg lighter to 5 kg higher)	43 (2 RCTs)	low ^{a,e}	Control group risk determined from an arm dynamometry test of shoulder flexion in kg. Intervention group risk determined by back transforming the SMD to kg.

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval

GRADE Working Group grades of evidence

High quality: We are very confident that the true effect lies close to that of the estimate of the effect

Moderate quality: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different

Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect

Very low quality: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

- ^a Meta-analysis was limited to few studies with small sample sizes and wide confidence intervals (imprecision –1)
- ^b Meta-analysis limited by missing information on sequence generation and allocation concealment (2 studies), no blinding of outcome assessment (2 studies), incomplete data (2 studies) (risk of bias –1)
- ^c Meta-analysis limited by missing information on sequence generation and allocation concealment (1 study), no blinding of outcome assessment (1 study), incomplete data (2 studies) (risk of bias –1)
- ^d Meta-analysis limited by missing information on sequence generation and allocation concealment (4 studies), no blinding of outcome assessment (4 studies), incomplete data (2 studies) (risk of bias –1)
- ^e Meta-analysis limited by missing information on sequence generation and allocation concealment (1 study), and no blinding of outcome assessment (1 study) (risk of bias –1)

BACKGROUND

Description of the condition

Chronic obstructive pulmonary disease (COPD) is a progressive disease state characterised by persistent airflow limitation and an enhanced chronic inflammatory response in the airways and lungs to noxious particles or gases (Vestbo 2013). The prevalence of moderate to very severe COPD varies by country, but it has been reported at between 4% and 17% (Buist 2007; Toelle 2013). COPD is a major cause of morbidity, mortality, and increased healthcare costs globally (Chapman 2006). People with COPD often have reduced functional capacity and are physically inactive, which has been associated with increased healthcare utilisation (Garcia-Aymerich 2006). People with COPD also often experience difficulty with upper limb exercise (Celli 1986; Criner 1988; McKeough 2003); and perform upper limb activities at a lower intensity than their healthy counterparts (Meijer 2014). Difficulty with upper limb exercise in people with COPD is partially due to alterations in the mechanics of breathing associated with the disease, such that the muscles required for the upper limb exercise are also required for breathing (Criner 1988). Consequently, when performing activities using their upper limbs, people with COPD can experience breathlessness and early cessation of the task. Given that most daily living activities require the use of the arms, breathlessness and the early cessation of upper limb activities pose a challenge to people with COPD.

Description of the intervention

Pulmonary rehabilitation, a programme of exercise training, education, and behaviour support, is one management strategy that has strong evidence for improving functional exercise capacity and health-related quality of life in people with COPD (McCarthy 2015). The exercise training component typically incorporates both lower and upper limb training. The types of upper limb training performed in a conventional pulmonary rehabilitation programme consist of both endurance training (being exercise training to improve the aerobic system) and resistance training (being exercise training where the upper limb muscles contract against an external resistance to improve muscle strength using, for example, resistance machines, free weights, or resistance bands). Endurance training can be further categorised as supported training, where the weight of the upper limb is supported (for example arm cycle ergometer training) or unsupported training, where the weight of the upper limb is not supported (for example lifting a weighted dowel).

How the intervention might work

The upper limb training component of pulmonary rehabilitation for people with COPD has been shown to have effects specific to the type of training performed. Upper limb resistance training has been shown to increase upper limb strength (O'Shea 2004; Janaudis-Ferreira 2011b), while upper limb endurance training, whether performed supported, unsupported, or as a combined supported/unsupported protocol, has been shown to increase upper limb endurance capacity (Martinez 1993; Holland 2004; McKeough 2012). The possible mechanisms for arm training improving arm exercise capacity have been discussed previously (Janaudis-Ferreira 2009). They include physiological improvements at the muscle level, such as an increased oxidative capacity as is typical of exercise training effects for the lower limb muscles in COPD (Maltais 1996); improved

tolerance to symptoms during arm activity (Gigliotti 2005); and improved force-generating capacity of the muscles in line with any increases in muscle strength from the upper limb training.

Why it is important to do this review

The latest American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation recommends that upper limb training be performed in programmes, given the evidence for improvements to upper limb function (Spruit 2013), but the statement also indicates that the optimal form of upper limb training remains to be determined. It is also unclear whether the gains to upper limb function translate to improvements in other important health outcomes, such as symptoms of dyspnoea and health-related quality of life. Previous reviews of upper limb training have been published including studies up to 2008 (Costi 2009; Ennis 2009; Janaudis-Ferreira 2009), but only one review included some meta-analyses of outcomes (Ennis 2009). The current review was conducted to analyse the randomised controlled trials (RCTs) of upper limb training to determine the effects on symptoms of dyspnoea, health-related quality of life, and measures of upper limb function in people with COPD.

OBJECTIVES

To determine the effects of upper limb training (endurance or resistance training, or both) on symptoms of dyspnoea and health-related quality of life in people with COPD.

METHODS

Criteria for considering studies for this review

Types of studies

We included RCTs in which upper limb exercise training of at least four weeks' duration was compared to no training, lower limb training, or another form of arm training. We structured the comparisons as follows:

1. Upper limb training only versus no upper limb training (i.e. usual care only) or sham intervention. In this comparison any study which had an upper limb training component compared to no upper limb training was included even if both groups performed lower limb training.
2. Combined upper limb training and lower limb training versus lower limb training alone. This comparison was structured so that the additional effects of upper limb training to lower limb training could be determined even though the studies included in this section were also part of the first comparison.
3. Upper limb training versus another type of upper limb training intervention (with or without lower limb training in both groups) which, for example, allowed for a comparison of supported versus unsupported upper limb training or endurance versus resistance training.

Types of participants

We included adults with a clinical diagnosis of COPD, diagnosed according to the investigators' definition. Participants were of any age or disease severity. Participants' COPD was stable (that is optimal and stable respiratory medications with no exacerbation or hospital admission within the previous month), although oxygen supplementation during training could have been used.

Types of interventions

We included studies examining upper limb exercise training of at least four weeks' duration as we judged anything less than four weeks of training would not represent a typical pulmonary rehabilitation programme. The upper limb exercise training included endurance training (supported or unsupported training), resistance training, or a combination of resistance and endurance training. The upper limb training was in addition to a prescribed lower limb training programme in some instances. We included inpatient, outpatient, and home-based training programmes. We recorded the precise nature of the training (intensity, frequency, duration, type) wherever possible.

Types of outcome measures

Primary outcomes

1. Symptoms of dyspnoea measured using dyspnoea scores from a respiratory-specific quality-of-life questionnaire (e.g. dyspnoea from the chronic respiratory disease questionnaire).
2. Health-related quality of life measured using total scores from generic or respiratory-specific quality-of-life questionnaires (e.g. total score on the chronic respiratory disease questionnaire, total score on the St George's Respiratory Questionnaire).

Secondary outcomes

1. Peak upper limb exercise capacity measured from a peak upper limb exercise test. This was further subdivided into:
 - a. peak upper limb exercise capacity (supported) when a peak exercise test on an arm crank was used or
 - b. peak upper limb exercise capacity (unsupported) when the incremental unsupported arm exercise test was used (Takahashi 1999).
2. Endurance upper limb exercise capacity measured from an endurance upper limb test. This was further subdivided into:
 - a. endurance upper limb exercise capacity (supported) when an endurance test on an arm crank was used or
 - b. endurance upper limb exercise capacity (unsupported) when a functional test with the arms unsupported was used.
3. Upper limb strength measured using either hand-held dynamometry, upper limb resistance machines (e.g. 1 RM) or scored from functional lifting tasks.
4. Respiratory muscle strength measured from a pressure gauge (e.g. maximal inspiratory mouth pressures or maximal sniff nasal inspiratory pressure).
5. Physical activity level from subjective measures (e.g. activity diaries, questionnaires) or objective measures (e.g. activity monitoring devices such as pedometers, accelerometers, multi-sensor devices).

6. Activities of Daily Living (ADL) function measured as the time or movement intensity during the performance of activities of daily living.
7. Psychological status measured from generic psychological questionnaires or scales (e.g. Hospital Anxiety and Depression Scale).
8. Healthcare utilisation recorded as hospitalisation or length of stay.

Search methods for identification of studies

Electronic searches

We identified trials from the Cochrane Airways Group Specialised Register (CAGR), which is maintained by the Trials Search Co-ordinator for the Group. The CAGR contains trial reports identified through systematic searches of multiple bibliographic databases, and handsearching of respiratory journals and meeting abstracts (please see [Appendix 1](#) for further details). We searched all records in the CAGR using the search strategy in [Appendix 2](#). We performed an additional search of CENTRAL via the Cochrane Register of Studies Online (CRSO) with the same terms.

We also conducted a search of ClinicalTrials.gov (www.ClinicalTrials.gov) and the World Health Organization trials portal (www.who.int/ictpr/en/). We searched all databases from their inception to 28 September 2016. There was no restriction on language of publication.

Searching other resources

We checked reference lists of all primary studies and review articles for additional references. There were no relevant manufacturers' websites for trial information.

We searched for errata or retractions from included studies published in full text on PubMed (www.ncbi.nlm.nih.gov/pubmed) on 28 September 2016.

Data collection and analysis

Selection of studies

Two review authors (ZM, MV) independently screened titles and abstracts for inclusion of all the potential studies as a result of the search and coded them as 'retrieve' (eligible or potentially eligible/unclear) or 'do not retrieve'. We retrieved the full-text study reports/publication, and two review authors (ZM, MV) independently screened the full text and identified studies for inclusion, and identified and recorded reasons for exclusion of the ineligible studies. We resolved any disagreement through discussion and consulted a third person (JA) as required. We identified and excluded duplicates and collated multiple reports of the same study so that each study, rather than each report, is the unit of interest in the review. We recorded the selection process in sufficient detail to complete a PRISMA flow diagram ([Figure 1](#)) and [Characteristics of excluded studies](#) table.

Figure 1. Figure 1: PRISMA Study Flow Diagram.

Data extraction and management

We used the Covidence software to record study characteristics and outcome data. Two review authors (ZM, VL) extracted study characteristics from included studies to Covidence. We extracted the following study characteristics.

1. Methods: study design, total duration of study, details of any 'run-in' period, number of study centres and location, study setting, withdrawals, and date of study.
2. Participants: N, mean age, age range, gender, severity of condition, diagnostic criteria, baseline lung function, smoking history, inclusion criteria, and exclusion criteria.
3. Interventions: intervention and comparison groups.
4. Outcomes: primary and secondary outcomes specified and collected, and time points reported.
5. Notes: funding for trial and notable conflicts of interest of trial authors.

Two review authors (ZM, VL) independently extracted outcome data from included studies to Covidence. We have noted in the [Characteristics of included studies](#) table if outcome data were not reported in a usable way. We resolved disagreements by consensus or by involving a third person (JA). One review author (ZM) transferred data from Covidence into [Review Manager](#). A second review author (VL) did spot checks of study characteristics for accuracy against the reports in Covidence.

Assessment of risk of bias in included studies

Two review authors (ZM, MV) independently assessed risk of bias for each study using the criteria outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* ([Higgins 2011](#)). We resolved any disagreements by discussion or by involving another review author (JA). We assessed the risk of bias according to the following domains.

1. Random sequence generation.
2. Allocation concealment.
3. Blinding of participants and personnel.
4. Blinding of outcome assessment.
5. Incomplete outcome data.
6. Selective outcome reporting.
7. Other bias.

We graded each potential source of bias as high, low, or unclear and provided a quote from the study report together with a justification for our judgement in the 'Risk of bias' table. We summarised the risk-of-bias judgements across different studies for each of the domains listed using the Covidence software and one review author (ZM) transferred data from Covidence into [Review Manager](#). We considered blinding separately for different key outcomes where necessary (for example for unblinded outcome assessment). Where information on risk of bias relates to unpublished data or correspondence with a trialist, we have noted this in the 'Risk of bias' table.

When considering treatment effects, we have taken into account the risk of bias for the studies that contribute to that outcome.

Assessment of bias in conducting the systematic review

We conducted the review according to the published protocol and report any deviations from it in the '[Differences between protocol and review](#)' section of the systematic review.

Measures of treatment effect

For continuous variables, we recorded mean post-intervention values and standard deviations for each group. We entered data presented as a scale with a consistent direction of effect. Continuous data was analysed as mean differences (MDs) for outcomes with the same metrics, or standardised mean differences (SMDs) for outcomes with different metrics. There were no dichotomous data in this review.

We undertook meta-analyses only where this was meaningful: that is, where the treatments, participants, and the underlying clinical question were similar enough for pooling to make sense.

Where multiple trial arms were reported in a single trial, we only included the relevant arms for each of the comparisons. If two comparisons (for example endurance upper limb training versus no upper limb training, resistance upper limb training versus no upper limb training) were combined in the same meta-analysis, we halved the control group to avoid double-counting.

Unit of analysis issues

We did not include crossover trials and did not encounter cluster randomised trials.

Dealing with missing data

We contacted investigators or study sponsors in order to verify key study characteristics and to obtain missing numerical outcome data where possible (for example when a study was identified as abstract only). Where we could not make contact, the lack of data was substantial such that pooling for the meta-analyses was not possible.

Assessment of heterogeneity

We used the I^2 statistic to measure heterogeneity among the trials in each analysis. Where substantial heterogeneity was evident, we have reported it and explored possible causes by subgroup analysis.

Assessment of reporting biases

A funnel plot to explore possible small study and publication bias was not conducted as we were unable to pool more than 10 trials.

Data synthesis

We used a random-effects model and planned to perform any sensitivity analyses with a random-effects model.

Summary of findings table

We have created a 'Summary of findings' table for comparison 1 only using the following outcomes: symptoms of dyspnoea, quality of life, peak upper limb exercise capacity (supported), peak upper limb exercise capacity (unsupported), endurance upper limb exercise capacity (supported), endurance upper limb exercise capacity (unsupported), upper limb strength. We used the five GRADE considerations (study limitations, consistency of

effect, imprecision, indirectness, and publication bias) to assess the quality of a body of evidence as it related to the studies that contributed data to the meta-analyses for the prespecified outcomes. We used methods and recommendations described in Section 8.5 and Chapter 12 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011), using GRADEpro software. We justified all decisions to down- or upgrade the quality of studies using footnotes, and have made comments to aid readers' understanding of the review where necessary.

Subgroup analysis and investigation of heterogeneity

There were not sufficient data for the planned subgroup analysis of severity of lung disease (i.e. severe (FEV₁% predicted < 40%) versus not severe (FEV₁% predicted ≥ 40%)) on symptoms of dyspnoea and health-related quality of life. If enough studies are included in future updates to make this subgroup analysis possible, the formal test for subgroup interactions in *Review Manager* will be used.

Sensitivity analysis

There were not sufficient data to perform sensitivity analysis to analyse the effect of risk of bias. If enough studies are included in future updates, we will perform a separate analysis with only those included studies that have a low risk of bias for at least three of the following domains: random sequence generation, allocation concealment, blinding of outcome assessment, and incomplete outcome data.

RESULTS

Description of studies

Refer to the [Characteristics of included studies](#), [Characteristics of excluded studies](#) and [Characteristics of studies awaiting classification](#) for the details of the studies included, excluded and awaiting classification.

Results of the search

The initial search of the databases in 2014 yielded 179 records (after discarding 118 duplicates) with three additional studies identified by handsearching. Repeat searches in 2015 and 2016 yielded an additional 104 records (after discarding 37 duplicates) bringing the total records screened to 286. From this list, based on titles and abstracts, we excluded 186 records and assessed 40 records for eligibility via full text. We excluded 23 of these studies as they did not meet the review criteria as indicated in the [Characteristics of excluded studies](#) table. We made attempts to contact the author of one study as it was unclear from the abstract whether the upper limb training was performed for at least four weeks (Mador 2012). No reply was received so this record remains as a study awaiting classification. One other study which was identified in the latest search (28 September 2016) also remains as a study awaiting classification and will undergo full review with the next review update (Calik-Kutukcu 2015). Fifteen studies were appropriate for inclusion in the review with agreement reached between the review author team for all studies (kappa = 1, indicating excellent agreement). See [Figure 1](#) for the PRISMA study flow diagram.

Included studies

Fifteen studies on 425 participants met the inclusion criteria for this review. One study was in abstract form only (Matsunaga 2011). Two studies were by the same author group and related to the

same study design but with different outcomes reported (Covey 2012; Larson 2014). Two studies required translation, one from Portuguese to English (Ike 2010); and one from Spanish to English (Sivori 1998). Further details of included studies can be found in the [Characteristics of included studies](#).

Participants

All studies defined participants as having stable COPD. The sample size of studies ranged from 12 to 43 participants with a mean age ranging from 57 to 72 years and a mean FEV₁ of 27% to 60% predicted, indicating moderate to very severe disease (Global 2016).

Intervention

A number of different upper limb training interventions were prescribed across the fifteen studies, including resistance training and endurance training. The latter was further defined as supported endurance training (e.g. arm crank training), unsupported endurance training (e.g. using light weights) and a combination of both supported and unsupported endurance training (e.g. both arm crank training and upper limb exercises with light weights were performed). There were eight studies that examined resistance training (Ries 1988; Marrara 2008; Ike 2010; Janaudis-Ferreira 2011; Matsunaga 2011; Covey 2012; McKeough 2012; Larson 2014). In these studies, the training frequency ranged from training 2 to 4 times weekly over a 6- to 16-week period with total sessions ranging from 8 to 32. Initial intensity was prescribed between 60% to 80% of the one repetition maximum or based on a load that could be lifted between six to 10 times. The studies described the upper limb exercises as being performed as two to three sets of four to 10 repetitions per set.

There were nine studies that examined endurance upper limb training (Ries 1988; Lake 1990a; Martinez 1993; Bauldoff 1996; Epstein 1997; Sivori 1998; Holland 2004; Subin 2010; McKeough 2012), with one study examining supported endurance training alone (Martinez 1993), six studies examining unsupported endurance training alone (Martinez 1993; Bauldoff 1996; Epstein 1997; Sivori 1998; Holland 2004; Subin 2010), and three studies examining a combination of supported and unsupported endurance training (Ries 1988; Lake 1990a; McKeough 2012). The Martinez 1993 study was unique in directly comparing a supported to an unsupported endurance upper limb training protocol. In the studies that examined endurance training, the training frequency varied from once weekly to five days per week with the training duration ranging from four to 10 weeks and the total sessions ranging from eight to 40.

There were 14 out of 15 studies that examined some form of upper limb training to a comparator group that did not perform any upper limb training (comparison 1), with the Martinez 1993 study being the one exception. Of these 14 studies, eight studies used lower limb exercise training in both intervention and control groups, thus exploring whether the addition of upper limb training to lower limb training had benefits over lower limb training alone (comparison 2) (Ries 1988; Lake 1990a; Sivori 1998; Holland 2004; Subin 2010; Janaudis-Ferreira 2011; Matsunaga 2011; McKeough 2012). There were also two studies that had multiple trial arms which allowed a direct comparison of resistance upper limb training to endurance upper limb training (comparison 3) (Ries 1988; McKeough 2012). The McKeough 2012 study was the only study that also had a

further trial arm that examined endurance and resistance training combined.

In terms of the primary comparison (comparison 1), the control group interventions also varied with three of the studies having a control group that did not do upper limb or lower limb training (Lake 1990a; Bauldoff 1996; Epstein 1997), eight studies doing lower limb training only as described previously (Ries 1988; Lake 1990a; Sivori 1998; Holland 2004; Subin 2010; Janaudis-Ferreira 2011; Matsunaga 2011; McKeough 2012), and six of the studies doing some form of a sham intervention only (e.g. respiratory muscle training (Epstein 1997), gentle chair exercises with upper limb stretching (Covey 2012; Larson 2014), a finger dexterity task (Holland 2004), and upper limb flexibility exercises (Marrara 2008; Janaudis-Ferreira 2011)). The Lake 1990a study was included twice in this description as this study had multiple arms: a control group in comparison 1 that did no exercise training was compared to an intervention group that did unsupported and supported endurance training; and a control group in comparison 1 and 2 that just did lower limb training was compared to an intervention group that did unsupported and supported endurance training with lower limb training.

Outcomes

The primary outcome of dyspnoea was measured in four studies using the dyspnoea score of the Chronic Respiratory Disease Questionnaire (Holland 2004; Subin 2010; Janaudis-Ferreira 2011; Covey 2012). Health-related quality of life was measured by the total score of the Chronic Respiratory Disease Questionnaire (Sivori 1998; Holland 2004; Janaudis-Ferreira 2011); and the total score of the St George's Respiratory Questionnaire (SGRQ) (McKeough 2012). For the SGRQ, an improvement in quality of life is represented by a lower score, so the data that was pooled was reversed to provide a consistent direction of effect.

Most studies conducted some form of upper limb exercise test, with four studies performing an incremental supported arm exercise test to peak work capacity using an arm crank machine (Ries 1988; Lake 1990a; Martinez 1993; McKeough 2012), four studies — Holland 2004, Subin 2010, Janaudis-Ferreira 2011 and McKeough 2012 — performing the incremental unsupported arm exercise test involving a weighted dowel and arm chart (Takahashi 1999), two studies performing an endurance upper limb test with an arm crank machine (Ries 1988; McKeough 2012), and five studies — Ries 1988, Martinez 1993, Bauldoff 1996, Epstein 1997 and Sivori 1998 — performing an unsupported endurance upper limb test such

as the 6-minute pegboard test or weighted dowel test. While the unsupported endurance upper limb tests have been referred to as endurance tests, it is acknowledged that these tests are regarded as more functional tests (e.g. 6-minute pegboard test) and are not a style of test that would traditionally be referred to as endurance tests in the exercise science literature. However, this terminology has been used for ease of comparison to the other supported endurance upper limb tests.

Upper limb strength was measured in a variety of ways including repetition maximum tests on resistance machines (Ike 2010), arm dynamometry (Janaudis-Ferreira 2011), and functional tests which summed the scores of a number of lifts (Covey 2012). Respiratory muscle strength was measured in seven studies using the maximum inspiratory pressure (Lake 1990a; Martinez 1993; Epstein 1997; Sivori 1998; Matsunaga 2011; Covey 2012; McKeough 2012). Physical activity level was measured both subjectively using the functional performance inventory (Covey 2012), and objectively using an actigraph accelerometer (Larson 2014). An upper limb activity of daily living measure was utilised in two studies with a blackboard task (Marrara 2008), and time to complete three tasks of dishwashing, a blackboard task and a grocery shelving task (Ries 1988). One study examined hospitalisation via the hospitalisation index, being the number of days in hospital multiplied by number of patients (Sivori 1998). No studies examined psychological status following upper limb training.

It was not always possible to pool data from all the relevant studies in each comparison due to there not being sufficient data (Martinez 1993; Marrara 2008; Matsunaga 2011), or due to reporting different outcomes.

Excluded studies

There were 23 studies excluded from this review. The common reasons for exclusion were an intervention which did not fit the study criteria ($n = 14$) or a study design which did not fit the study criteria ($n = 3$). Refer to the [Characteristics of excluded studies](#) for the reasons for exclusion for each study.

Risk of bias in included studies

There was variation in the risk of bias across the included studies. Refer to the [Characteristics of included studies](#) for all details on risk of bias in each study as well as [Figure 2](#) and [Figure 3](#) for a summary of the authors' judgements on risk of bias across the included studies.

Figure 2. Figure 2: Risk of bias summary

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Bauldoff 1996	+	+	-	-	?	+	+
Covey 2012	+	+	-	+	-	-	+
Epstein 1997	?	?	-	+	+	+	+
Holland 2004	?	?	-	+	+	?	+
Ike 2010	?	?	-	-	+	+	+
Janaudis-Ferreira 2011	+	+	-	+	+	+	+
Lake 1990a	?	?	-	-	+	?	+
Larson 2014	+	+	-	+	-	-	+
Marrara 2008	?	?	-	-	-	?	+
Martinez 1993	?	?	-	-	+	-	+
Matsunaga 2011	?	?	?	?	?	?	?
McKeough 2012	+	+	-	+	-	-	+
Ries 1988	?	?	-	-	-	?	+
Sivori 1998	+	?	-	-	-	?	+
Subin 2010	+	?	-	-	+	+	-

Figure 3. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

Allocation

All studies were RCTs with random allocation. However, only seven studies indicated how the random sequence was generated (Bauldoff 1996; Sivori 1998; Subin 2010; Janaudis-Ferreira 2011; Covey 2012; McKeough 2012; Larson 2014); and five studies indicated that the allocation was concealed (Bauldoff 1996; Janaudis-Ferreira 2011; Covey 2012; McKeough 2012; Larson 2014). The remaining studies did not provide sufficient information to determine random sequence generation (Ries 1988; Lake 1990a; Martinez 1993; Epstein 1997; Holland 2004; Marrara 2008; Ike 2010; Matsunaga 2011); or allocation concealment (Ries 1988; Lake 1990a; Martinez 1993; Epstein 1997; Sivori 1998; Holland 2004; Marrara 2008; Ike 2010; Subin 2010; Matsunaga 2011).

Blinding

Blinding of the trainers and complete blinding of the participants was not possible in any of the studies given the nature of the upper limb exercise training interventions. However, five studies attempted to partially blind participants by using a sham intervention involving the upper limbs (Holland 2004; Marrara 2008; Janaudis-Ferreira 2011; Covey 2012; Larson 2014). None of these studies verified the extent of the blinding with participants although one study stated that the patients remained unaware of group allocation (Janaudis-Ferreira 2011). Six of the studies had blinding of the outcome assessment as an assessor was used who had not been involved in the delivery of interventions (Epstein 1997; Holland 2004; Janaudis-Ferreira 2011; Covey 2012; McKeough 2012; Larson 2014).

Incomplete outcome data

Seven studies indicated adequate completion of outcome data with no to minimal drop-outs reported (Lake 1990a; Martinez 1993; Epstein 1997; Holland 2004; Ike 2010; Subin 2010; Janaudis-Ferreira 2011). Six studies had significant incomplete data due to participant drop-out ranging from 24% to 42% (Ries 1988; Sivori 1998; Marrara 2008; Covey 2012; McKeough 2012; Larson 2014). Two studies were rated as having unclear bias due to a lack

of information on whether participants completed the outcomes (Bauldoff 1996; Matsunaga 2011).

Selective reporting

Most studies were conducted prior to registration requirements. However, four studies were listed on a clinical trials registry (Janaudis-Ferreira 2011; Covey 2012; McKeough 2012; Larson 2014). Results were reported for all outcomes as stated in the registry for one study (Janaudis-Ferreira 2011). However, three of these studies had selection bias, with one study not reporting one of the outcomes stated in the clinical trials registry (McKeough 2012); and two papers representing the same study with different data reported in each paper (Covey 2012; Larson 2014). In terms of the remaining eleven studies, one study was rated high for bias as no mean group data was provided so data was not used in the meta-analysis (Martinez 1993). In addition, six studies were rated as unclear as there was information missing for specified outcomes (Ries 1988; Lake 1990a; Sivori 1998; Holland 2004; Marrara 2008; Matsunaga 2011) or not enough information existed from an abstract (Matsunaga 2011). The other four studies reported data on all specified outcomes (Bauldoff 1996; Epstein 1997; Ike 2010; Subin 2010).

Other potential sources of bias

Most studies were free of other sources of bias. One study was rated as high as it used a block randomisation procedure in an unblinded trial (Subin 2010).

Effects of interventions

See: [Summary of findings for the main comparison](#) Main Comparison: Upper limb training vs No upper limb training for people with COPD

See [Summary of findings for the main comparison](#), being the main comparison of upper limb training versus no upper limb training in people with COPD (comparison 1).

There was sufficient data from 12 studies to be considered for the meta-analyses across the three comparisons with a total of 12 studies used for the main comparison (comparison 1), seven studies used for comparison 2 and two studies used for comparison 3. See also [Data and analyses](#) sections for the summary of the meta-analyses conducted for each outcome within each of the three comparisons. For all outcomes, a positive value indicates an improvement.

The remaining three studies will have their narrative data discussed together with the pooled data ([Martinez 1993](#); [Marrara 2008](#); [Matsunaga 2011](#)). The data from the [McKeough 2012](#) study for the trial arm of combined endurance and resistance training has also not been pooled as the data from the endurance training only and resistance training only groups was used.

Primary outcome: symptoms of dyspnoea

When upper limb training was compared to no upper limb training or a sham intervention (comparison 1), there were four studies which provided data on dyspnoea from the Chronic Respiratory Disease Questionnaire, all of which could be pooled for meta-analysis giving a total of 66 participants in the intervention group and 63 participants in the control group ([Holland 2004](#); [Subin 2010](#); [Janaudis-Ferreira 2011](#); [Covey 2012](#)). Results of the meta-analysis are shown in [Figure 4](#). There was a small significant improvement in symptoms of dyspnoea favouring the intervention group with a mean difference (MD) of 0.37 points (95% confidence interval (CI) 0.02 to 0.72 points) ([Analysis 1.1](#)). No statistically significant improvement in dyspnoea was shown when studies of endurance training only (MD 0.41 points, 95% CI -0.13 to 0.95 points) ([Holland 2004](#); [Subin 2010](#)), or resistance training only (MD 0.34 points, 95% CI -0.11 to 0.8 points) ([Janaudis-Ferreira 2011](#); [Covey 2012](#)) were analysed.

Figure 4. Forest plot of comparison: 1 Upper limb training only versus control, outcome: 1.1 Symptoms of Dyspnoea.

When upper limb training combined with lower limb training was compared to lower limb training alone (comparison 2), there were three studies which provided data on dyspnoea from the Chronic Respiratory Disease Questionnaire, all of which could be pooled for meta-analysis giving a total of 44 participants in the intervention group and 42 participants in the control group ([Holland 2004](#); [Subin 2010](#); [Janaudis-Ferreira 2011](#)). No significant difference in dyspnoea between groups was shown (MD 0.36, 95% CI -0.04 to 0.76) ([Analysis 2.1](#)). There were no studies which examined upper limb training compared to another upper limb training intervention on dyspnoea. The tests of heterogeneity for all analyses of symptoms of dyspnoea were not significant.

Primary outcome: health-related quality of life

When upper limb training was compared to no upper limb training (comparison 1), there were five studies which examined health-

related quality of life, of which four studies could be pooled for meta-analysis giving a total of 69 participants in the intervention group and 57 participants in the control group ([Sivori 1998](#); [Holland 2004](#); [Janaudis-Ferreira 2011](#); [McKeough 2012](#)). There was no significant differences shown between groups in health-related quality of life with a standardised mean difference (SMD) of 0.05 (95% CI -0.31 to 0.40) ([Figure 5](#)). There was also no significant difference between groups with the studies examining endurance training alone (SMD -0.03, 95% CI -0.47 to 0.42) in 82 participants; or resistance training alone (SMD 0.18, 95% CI -0.43 to 0.79) in 44 participants ([Analysis 1.2](#)). In the [McKeough 2012](#) study that had the additional trial arm of combined endurance and resistance upper limb training compared to no upper limb training, the paper also reported no significant between-group differences in health-related quality of life (MD -6 points, 95% -18 to 5).

Figure 5. Forest plot of comparison: 1 Upper limb training only versus control, outcome: 1.2 Health-Related Quality of Life.

When upper limb training combined with lower limb training was compared to lower limb training alone (comparison 2), there were four studies which examined health-related quality of life, of which three studies could be pooled for meta-analysis giving a total of 56 participants in the intervention group and 39 participants in the control group (Sivori 1998; Holland 2004; McKeough 2012). There were no significant differences shown between groups in health-related quality of life (SMD 0.01, 95% CI -0.40 to 0.43) (Analysis 2.2). The Matsunaga 2011 study which was in abstract form only and did not provide sufficient data for pooling in the meta-analysis, examined health-related quality of life using the St George's Respiratory Questionnaire. A significant improvement in quality of life was shown in the group who performed upper limb training combined with lower limb training ($P < 0.001$) but no results were provided for the lower limb training group so no between-group differences could be determined.

There was only a single study which compared upper limb endurance training to upper limb resistance training (comparison 3) on health-related quality of life in people with COPD (McKeough 2012). This study reported no significant difference in the total score of the SGRQ between groups (MD 2 points, 95% CI -9 to 12) (McKeough 2012).

The tests of heterogeneity for all analyses of health-related quality of life were not significant.

Secondary outcome: peak upper limb exercise capacity

When upper limb training was compared to no upper limb training (comparison 1), there were three studies which examined supported peak upper limb exercise capacity (Ries 1988; Lake 1990a; McKeough 2012); and four studies which examined unsupported peak upper limb exercise capacity (Holland 2004; Subin 2010; Janaudis-Ferreira 2011; McKeough 2012). No significant between-group differences were shown for either supported peak upper limb exercise capacity (SMD 0.17, 95% CI -0.43 to 0.77, 83 participants) (Analysis 1.3) or unsupported peak upper limb exercise capacity (MD 21.23 secs, 95% CI -20.45 to 62.92 secs, 112 participants) (Analysis 1.4), with no differences in these outcomes when endurance training and resistance training were analysed separately.

When upper limb training combined with lower limb training was compared to lower limb training alone (comparison 2), there were three studies which examined supported peak upper limb exercise capacity (Ries 1988; Lake 1990a; McKeough 2012), and three studies which examined unsupported peak upper limb exercise capacity (Holland 2004; Subin 2010; McKeough 2012). No significant between-group differences were shown for either supported peak upper limb exercise capacity (SMD -0.06, 95% CI -0.55 to 0.44, 70 participants) (Analysis 2.3) or unsupported peak upper limb exercise capacity (MD 13.26 secs, 95% CI -39.88 to 66.40 secs, 81 participants) (Analysis 2.4).

There were three studies that examined an upper limb training intervention compared to another type of upper limb training on supported peak upper limb exercise capacity (Ries 1988; Martinez 1993; McKeough 2012). Two studies compared upper limb endurance training to upper limb resistance training and were able to be pooled in a meta-analysis (Ries 1988; McKeough 2012), with results showing no between group differences in supported peak upper limb exercise capacity (SMD 0.36, 95% CI -0.29 to 1.02, 37 participants) (Analysis 3.2). The Martinez 1993 study compared supported upper limb endurance training to unsupported upper limb endurance training on a background of lower limb training in both groups. This study reported that both groups improved supported peak upper limb exercise capacity. Only a single study compared upper limb interventions on unsupported peak upper limb exercise capacity (McKeough 2012). This study reported no significant differences between the upper limb endurance training group and the upper limb resistance training group for unsupported peak upper limb exercise capacity (MD 24 secs, 95% CI -48 to 90 secs, 20 participants) (McKeough 2012).

The tests of heterogeneity for all analyses of peak upper limb exercise capacity were not significant. However, when the studies of supported peak upper limb exercise capacity were reviewed, one paper had a large baseline imbalance with higher peak workloads in the upper limb training group compared to the control group which contributed to a heterogeneity of $I^2 = 40\%$ ($P = 0.14$) (Lake 1990a).

Secondary outcome: endurance upper limb exercise capacity

When upper limb training was compared to no upper limb training (comparison 1), there were two studies which examined supported endurance upper limb exercise capacity (Ries 1988; McKeough 2012); and six studies which examined unsupported endurance upper limb exercise capacity (Ries 1988; Bauldoff 1996; Epstein 1997; Sivori 1998; Ike 2010; Janaudis-Ferreira 2011). No significant between-group differences were shown for supported endurance upper limb exercise capacity (SMD 0.25, 95% CI -0.46 to 0.96, 57 participants) (Analysis 1.5) with no differences in this outcome when endurance training and resistance training were analysed

separately. However, a large mean between-group difference favouring the intervention group was shown when examining unsupported endurance upper limb exercise capacity (SMD 0.66, 95% CI 0.19 to 1.13, 142 participants, $I^2 = 43\%$, Heterogeneity $P = 0.1$) (Figure 6). Interestingly, this improvement remained when the studies of upper limb endurance training alone were examined (SMD 0.99, 95% CI 0.32 to 1.66, 85 participants, $I^2 = 51\%$, Heterogeneity $P = 0.11$) but no longer existed for the studies of upper limb resistance training (SMD 0.23, 95% CI -0.31 to 0.76, 57 participants, $I^2 = 0\%$, Heterogeneity $P = 0.91$) with subgroup differences trending towards significance ($P = 0.08$) (Analysis 1.6).

Figure 6. Forest plot of comparison: 1 Upper limb training versus No upper limb training, outcome: 1.6 Endurance Upper Limb Exercise Capacity: Unsupported.

When upper limb training combined with lower limb training was compared to lower limb training alone (comparison 2), the same two studies were part of the analysis for supported endurance upper limb exercise capacity (Ries 1988; McKeough 2012), showing no between-group difference (SMD 0.25, 95% CI -0.46 to 0.96, 57 participants) (Analysis 2.5). There were three studies which examined comparison 2 on unsupported endurance upper limb exercise capacity (Ries 1988; Sivori 1998; Janaudis-Ferreira 2011), with a large mean between-group difference favouring the combined upper limb and lower limb training intervention (SMD 0.90, 95% CI 0.12 to 1.68, 87 participants) (Figure 7). There was a

slight heterogeneity between studies for this analysis ($P = 0.05$, $I^2 = 62\%$), related to the different training programmes used across studies. When a sensitivity analysis was run using the studies with an endurance training programme, the large mean between-group difference favouring the combined upper limb and lower limb training intervention on unsupported endurance upper limb exercise capacity remained (SMD 1.61, 95% CI 0.89 to 2.33, 42 participants, $I^2 = 0\%$). When the sensitivity analysis examined the studies of resistance training only, there was no between-group difference on unsupported endurance upper limb exercise capacity (SMD 0.29, 95% CI -0.31 to 0.89, 45 participants, $I^2 = 0\%$).

Figure 7. Forest plot of comparison: 2 Combined upper limb training and lower limb training versus lower limb training alone, outcome: 2.6 Endurance Upper Limb Exercise Capacity: Unsupported.

Two studies compared upper limb endurance training to upper limb resistance training and were able to be pooled in a meta-analysis (Ries 1988; McKeough 2012), with results showing no

between group differences in supported endurance upper limb exercise capacity (SMD 0.64, 95% CI -0.03 to 1.31, 37 participants) (Analysis 3.4). The Ries 1988 study also examined the effect on

unsupported endurance upper limb exercise capacity, with this paper reporting that both training groups improved the number of lifts in one minute summated from two upper limb exercises performed on each arm. No between-group differences were discussed in this paper but [Analysis 3.5](#) suggests that the post-intervention scores were significantly greater in the endurance training group compared to the resistance training group (MD 6 lifts, 95% CI 0.29 to 11.71, 17 participants).

The [Martinez 1993](#) study, comparing supported and unsupported upper limb endurance training, examined unsupported endurance upper limb exercise capacity and stated that both groups improved on this measure but a significantly greater improvement was shown in the unsupported upper limb training group ($P = 0.002$). No measure of supported endurance upper limb exercise capacity was used in this study.

Secondary outcome: upper limb strength

When upper limb training was compared to no upper limb training (comparison 1), there were three studies which examined upper limb strength, all of which had used an upper limb resistance training programme ([Ike 2010](#); [Janaudis-Ferreira 2011](#); [Covey 2012](#)). However, only data from [Ike 2010](#) and [Janaudis-Ferreira 2011](#) could be pooled for meta-analysis as the data from [Covey 2012](#) was not available for the resistance training group alone (see explanation in [Characteristics of included studies](#)). Both the included studies contributed data from different strength tests to the analysis (with the control group numbers halved across this data input) ([Ike 2010](#); [Janaudis-Ferreira 2011](#)). No between-group differences were shown for upper limb strength (SMD 0.25, 95% CI -0.39 to 0.89, 43 participants) ([Analysis 1.7](#)). One of these studies also contributed to comparison 2 ([Janaudis-Ferreira 2011](#)), showing no between-group differences when the addition of upper limb resistance training to lower limb training versus lower limb training alone was specifically examined (SMD 0.01, 95% CI -0.70 to 0.73, 21 participants) ([Analysis 2.7](#)). No studies compared different upper limb training interventions (comparison 3) on upper limb strength.

Secondary outcome: respiratory muscle strength

When upper limb training was compared to no upper limb training (comparison 1), there were six studies which examined respiratory muscle strength ([Lake 1990a](#); [Epstein 1997](#); [Sivori 1998](#); [Matsunaga 2011](#); [Covey 2012](#); [McKeough 2012](#)), of which five studies could be pooled for meta-analysis ([Lake 1990a](#); [Epstein 1997](#); [Sivori 1998](#); [Covey 2012](#); [McKeough 2012](#)). No between-group differences were shown for Pimax (MD -1.70 cmH₂O, 95% CI -8.35 to 4.94, 148 participants) ([Analysis 1.8](#)). Four of these studies also contributed to comparison 2 ([Ries 1988](#); [Lake 1990a](#); [Matsunaga 2011](#); [McKeough 2012](#)), three of which could be pooled for meta-analysis ([Ries 1988](#); [Lake 1990a](#); [McKeough 2012](#)). No between-group differences were shown for Pimax (MD -0.46 cmH₂O, 95% CI -8.99 to 8.07, 70 participants) ([Analysis 2.8](#)). The [Matsunaga 2011](#) study, where data could not be pooled, showed a significant improvement in respiratory muscle strength in the group who performed upper limb training combined with lower limb training ($P = 0.028$) but no results were provided for the lower limb training group so no between-group differences could be determined.

There were two studies that compared different upper limb training interventions. The [McKeough 2012](#) study showed no differences in the change scores from baseline to post-intervention between the resistance upper limb training group and the endurance upper

limb training group (unpublished data) on Pimax despite the post-intervention scores being significantly higher in the resistance upper limb training group ([Analysis 3.6](#)). The [Martinez 1993](#) study also examined respiratory muscle strength and reported that both the supported and unsupported upper limb training groups improved to a similar degree following training but no further data was provided.

Secondary outcome: physical activity level

Physical activity level was examined in two studies for comparison 1 only ([Covey 2012](#); [Larson 2014](#)). The [Covey 2012](#) study showed no between group differences in the Functional Performance Inventory total score while the [Larson 2014](#) study (which used the same group of participants as the [Covey 2012](#) study who had completed accelerometry testing) also showed no significant between group differences in time spent in moderate intensity activities.

Secondary outcome: activities of daily living

There were two studies which examined a task/s that reflected a daily living activity with the upper limbs ([Ries 1988](#); [Marrara 2008](#)). However, the [Marrara 2008](#) study only provided metabolic data (i.e. no time data) following the performance of the task with results indicating significantly reduced metabolic and ventilatory demand during a blackboard task in the upper limb training group compared to a control group of no training. However, no between-group data were presented. The [Ries 1988](#) study showed no between-group differences on the duration of a blackboard/grocery shelving/dishwashing task (SMD 0.67, 95% CI -0.12 to 1.47, 28 participants) ([Analysis 1.11](#), [Analysis 2.9](#)) where the data from the upper limb resistance training group and endurance training group were pooled and compared to a control of lower limb training. This study reported no within-group improvements to the duration of these tasks for the combined upper limb and lower limb training group ([Ries 1988](#)). The [Ries 1988](#) study also showed no between group differences when the upper limb endurance training group was compared to the upper limb resistance training group.

Secondary outcome: healthcare utilisation

One study evaluated healthcare utilisation in a group performing upper limb training with lower limb training compared to lower limb training alone. Both groups improved the hospitalisation index (number of hospital days × number of patients) following the intervention with no between-group differences ($P > 0.05$).

DISCUSSION

Summary of main results

This review identified 14 studies in people with COPD comparing upper limb training to no training or a sham intervention (with or without lower limb training) with eight of these studies comparing a combination of upper limb training and lower limb training to lower limb training only. Three studies were identified comparing an upper limb training intervention to another upper limb training intervention in people with COPD. Upper limb training resulted in a small improvement in symptoms of dyspnoea but no significant improvement to health-related quality of life when compared to no training. The addition of upper limb training to a lower limb training programme made no difference to dyspnoea or health-related quality of life when compared to lower limb training alone.

When endurance upper limb training was compared to resistance upper limb training, there was no data available on symptoms of dyspnoea and no between-group differences were shown in health-related quality of life.

The mean improvement in the dyspnoea score following upper limb training compared to no upper limb training or a sham intervention was 0.37 points (0.02 to 0.72). Given the minimal important difference (MID) for the Chronic Respiratory Disease Questionnaire (Dyspnoea domain) is 0.5 points, this mean improvement was small and did not reach the MID although at the highest end of the 95% confidence interval it did meet the MID, suggesting that some people with COPD did experience a clinically relevant improvement in dyspnoea following upper limb training.

In terms of the secondary outcomes, positive results were shown for unsupported endurance upper limb exercise capacity where a significant improvement occurred for upper limb training compared to no training. Furthermore, the studies that used an endurance upper limb training protocol only showed an effect on unsupported endurance upper limb exercise capacity while the studies using a resistance training protocol failed to show an effect on this outcome compared to no training. This result is no surprise as it supports the specificity of training principle, whereby people improve in the skill or exercise in which they train. Only one study directly compared upper limb endurance training to upper limb resistance training on unsupported endurance upper limb capacity, with both groups showing improvements although post-intervention scores were significantly higher in the endurance training group (Ries 1988). More studies are required to directly compare these training protocols. The results for the other secondary outcomes of peak exercise capacity, upper limb strength, respiratory muscle strength, physical activity level, activities of daily living and healthcare utilisation across all comparisons were unremarkable, with no significant between-group differences shown.

Overall completeness and applicability of evidence

This review was conducted in people with stable COPD in a typical age range of 57 to 72 years with studies focused mainly on people with moderate to very severe disease. This review would be applicable to this group of people but cannot be extrapolated to people involved in exercise training during or immediately following an acute exacerbation or people with milder disease. No long-term studies of upper limb training were identified so these results only indicate the short-term effects of upper limb training.

The studies in this review examined a broad spectrum of upper limb exercise training modes covering endurance training and resistance training. Only one study examined a combination of endurance and resistance upper limb training (McKeough 2012). The majority of studies involving endurance upper limb training included unsupported (functional) upper limb training with four out of nine studies including supported upper limb training (i.e. arm cranking) (Ries 1988; Lake 1990a; Martinez 1993; McKeough 2012). These upper limb training protocols align with the types of lower limb training promoted in pulmonary rehabilitation programmes, being both endurance activities such as cycling and walking as well as resistance training for the lower limbs (McCarthy 2015). Previous pulmonary rehabilitation guidelines have indicated the importance of unsupported endurance upper limb training (Ries 2007); and this review confirms that this type of training was more effective

at improving unsupported endurance upper limb exercise capacity compared to a control of no training or a sham intervention. Hence, performance of unsupported endurance upper limb training in people with stable COPD is to be encouraged if a primary goal is to improve functional upper limb capacity. However, the limited studies in this review specific to endurance training suggest that this training is unlikely to change quality of life compared to no training. The optimal dose for unsupported upper limb training to improve functional upper limb capacity cannot be determined from this review as no RCTs have directly compared different dosages of the same type of upper limb training. The common features to the training prescription in the studies examining endurance training in this review were that programmes were supervised, of more than 4 weeks' duration and had a frequency of at least once weekly. The actual intensity of training was often poorly described, further hindering conclusive remarks on optimal exercise dose.

The use of upper limb resistance training remains unclear for people with stable COPD. While there were eight studies which utilised this mode of training (Ries 1988; Marrara 2008; Ike 2010; Janaudis-Ferreira 2011; Matsunaga 2011; Covey 2012; McKeough 2012; Larson 2014), the wide range of strength outcomes assessed and missing data in studies makes conclusions difficult to reach. The training prescription also varied from eight to 32 sessions with the common features being supervision, more than 4 weeks' duration, a load of 60% to 80% of the one repetition maximum (or a load which could be lifted between six to 10 times) with a frequency of at least two sets of four to 10 repetitions for at least two days per week. Of the data that could be pooled on studies using resistance training only, no differences were found compared to no training or a sham intervention for any outcomes. The SMDs for these outcomes were all small, ranging from -0.36 to 0.36.

This review sought to obtain information on a large number of outcomes relevant to upper limb training. The primary outcomes of symptoms of dyspnoea and health-related quality of life are particularly relevant outcomes for people with COPD. Historically, the studies of upper limb training have focused more on the exercise capacity outcomes so it is of interest to note the growing number of recent studies contributing to the data set of dyspnoea and health-related quality of life. Another outcome of growing interest in COPD relates to activities of daily living and physical activity levels. There were limited upper limb training studies examining these outcomes (Ries 1988; Marrara 2008; Covey 2012; Larson 2014). Interestingly, this has been a topic of debate in recent times where research has indicated that people with COPD do not reduce their time spent performing arm activities compared to healthy controls but do reduce the intensity at which the arm activities are performed (Meijer 2014), raising the question of whether upper limb training should be included in rehabilitation programmes (Clini 2014); and whether training has the capacity to change arm activity. While this review is unable to provide data to directly determine whether upper limb training improves arm activities, it is possible that the improvements shown in dyspnoea and unsupported endurance upper limb capacity may lead to improvements in arm activities. In addition, it has been reported previously that it is the reduction in ventilation relative to a decrease in central motor output following unsupported upper limb training that relieves symptoms such as dyspnoea (Romagnoli 2013), suggesting that unsupported upper limb training provides the best mode of training to alleviate dyspnoea and enable improvements in arm activities. However, this current review

indicated similar mean differences in dyspnoea whether endurance upper limb training was performed (MD 0.41 points) or resistance upper limb training (MD 0.35 points) was performed.

Quality of the evidence

The overall quality of the studies included in this review was low. For each component of risk of bias (except 'other bias'), over 50% of studies either had missing information, so the level of bias was unclear; or there was a high risk of bias identified. Furthermore, due to the physical nature of the interventions, studies were unable to blind participants or personnel to the delivery of the interventions. One study that used a sham intervention did state that participants were unaware of group allocation, although how this was determined was unclear ([Janaudis-Ferreira 2011](#)). The GRADE system was used to rate the quality of the evidence for the majority of outcomes. The primary outcomes of dyspnoea and health-related quality of life as well as peak exercise capacity (unsupported) were downgraded to a moderate level of evidence as the studies were affected by imprecision, with studies containing low participant numbers (ranging from 112 to 150 participants). The remaining outcomes were all downgraded twice to low level of evidence as the studies contained both imprecision with low participant numbers (57 to 107 participants pooled) and risk of bias issues mainly related to missing information on sequence generation and allocation concealment, no blinding of outcome assessment and incomplete data.

Potential biases in the review process

Two review authors independently completed data extraction and risk of bias assessment, and resolved discrepancies by discussion. Hand searching, reviews of trial registries and inclusion of studies in abstract form were conducted to minimise reporting bias. We contacted study authors for missing information but in many cases additional information was not available, potentially influencing the calculated treatment effects and trial quality.

Agreements and disagreements with other studies or reviews

The review authors are aware of three reviews specifically focused on upper limb training in people with COPD ([Costi 2009](#); [Ennis 2009](#); [Janaudis-Ferreira 2009](#)), only one of which conducted meta-analyses ([Ennis 2009](#)). These reviews contained a smaller number of RCTs: four studies ([Costi 2009](#)); five studies ([Janaudis-Ferreira 2009](#)); and six studies ([Ennis 2009](#)). The recommendations from these studies varied from no recommendation ([Costi 2009](#)), recommending the use of upper limb training to improve supported and unsupported upper limb exercise capacity ([Janaudis-Ferreira 2009](#)), to recommending unsupported endurance upper limb training to improve upper limb endurance exercise capacity ([Ennis 2009](#)). The conclusions on upper limb training in COPD in the most recent American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation are that upper limb training improves upper limb function but that it is unclear whether this translates to improvements in health-related quality of life ([Spruit 2013](#)). This current review now indicates from four studies on 126 participants with COPD that when upper limb training is compared

to no upper limb training (with or without lower limb training), there is no effect on health-related quality of life.

AUTHORS' CONCLUSIONS

Implications for practice

This review indicates that if upper limb training is performed compared to no upper limb training for people with stable COPD, improvements in symptoms of dyspnoea will be seen but statistically significant benefits in health-related quality of life (HRQoL) will not be evident. In a comprehensive pulmonary rehabilitation programme, upper limb training will typically be combined with a lower limb training programme. In this instance, lower limb training will benefit HRQoL ([McCarthy 2015](#)); and this review suggests that the addition of upper limb training to the lower limb training programme will not result in further improvements in HRQoL. If an unsupported endurance upper limb training programme is provided (with or without lower limb training), large improvements in unsupported endurance upper limb exercise capacity will occur.

Implications for research

All the studies in this review were limited by small sample sizes such that even with pooling of data, the numbers in the review were fewer than 150 participants. Large studies are required to compare the differences between upper limb endurance training, upper limb resistance training, and combining upper limb endurance and resistance training on patient-relevant outcomes such as dyspnoea, health-related quality of life and arm activity levels. A comparison of the effects of different types of exercise training within upper limb resistance training and upper limb endurance training protocols would be warranted and could contribute information about optimal dosage. Future studies also need to address the impact of upper limb training in people following an acute exacerbation of COPD and those with milder disease. The long-term effects of upper limb training in people with COPD also needs to be examined to determine whether maintenance of improvements in dyspnoea and endurance upper limb exercise capacity are possible.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

Bauldoff 1996

Methods	Study design: randomized controlled trial
Participants	<p>Clinically stable COPD (n = 20), never received arm exercise training previously</p> <p>Baseline characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> Age (yrs): 61 (14) FEV₁(% pred): 27 (16) FEV₁(L): 0.65 (0.37) <p>Control</p> <ul style="list-style-type: none"> Age (yrs): 63 (13) FEV₁(% pred): 37 (18) FEV₁(L): 0.96 (0.44)
Interventions	<p>Intervention characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> Exercise Prescription: unsupported arm exercise at home for 5 days per week for 8 weeks (but supervised × 1 day per week). <p>Control</p> <ul style="list-style-type: none"> Exercise Prescription: no arm training (phone calls × once per week to match attention).

Upper limb exercise training for COPD (Review)

Bauldoff 1996 (Continued)

Outcomes

Endurance Upper Limb Capacity: unsupported

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (8 weeks)"
- **Scale:** rings moved in 6 min
- **Unit of measure:** no. of rings
- **Direction:** higher is better

Identification

Sponsorship source: Theta Mu Chapter, Sigma Theta Tau, Pittsburgh, Pennsylvania.

Country: USA

Setting: home-based training

Authors name: Gerene S. Bauldoff

Institution: University of Pittsburgh Medical Center

Address: University of Pittsburgh Medical Center, Pittsburgh, PA 15213.

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	The randomisation process involved assembling 20 envelopes from which subjects blindly selected 1 that determined their group assignment.
Allocation concealment (selection bias)	Low risk	The randomization process involved assembling 20 envelopes from which the subjects blindly selected 1 that determined their group assignment.
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication that participants or personnel were blind from the knowledge of which intervention the participant was receiving.
Blinding of outcome assessment (detection bias) All outcomes	High risk	All phone calls, home testing, and training were performed by the same investigator. There was no blinding of the outcome assessor.
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Data reported for all outcomes stated (presumed to be complete for all participants but not explicitly stated).
Selective reporting (reporting bias)	Low risk	Data reported for all outcomes stated.
Other bias	Low risk	Study appears to be free of other sources of risk.

Covey 2012

Methods

Study design: randomized controlled trial

Participants

Clinically stable COPD (n = 43) with age > 45 yrs

Baseline characteristics

Upper limb exercise training for COPD (Review)

Covey 2012 (Continued)

Experimental

- *Age (yrs)*: 71.0 (8.5)
- *FEV₁(% pred)*: 55.9 (17.1)
- *Gender (male/female)*: 17/5

Control

- *Age (yrs)*: 71.5 (7.5)
- *FEV₁(% pred)*: 58.2 (16)
- *Gender (male/female)*: 18/3

Interventions

Intervention characteristics

Experimental

- *Exercise Prescription*: health education + 16 week exercise programme, twice weekly in laboratory for 1.5 hours and home exercise once per week. Maintenance exercise for a further 12 months, 3 times weekly. Exercise programme was arm resistance training in the laboratory with a cable crossover system using 8 lifts: shoulder shrug, modified latissimus dorsi pull down, overhead pull down, front pull down, front raise, upright row, biceps curl, and triceps extension. Training was initiated at 70% of the 1 repetition maximum (1RM) at a training volume of 2 sets of 8 to 10 repetitions. Training intensity was increased as tolerated to 80% of the 1RM over the first 4 weeks of training and adjusted to maintain an intensity of 80% of the current 1RM for the remaining weeks. Training volume was increased to 3 sets of 8 to 10 repetitions for weeks 5 to 16. For the home training, subjects performed 1 set of 10 to 20 repetitions using dumbbells at a weight (range 2 to 15 lbs) to elicit a rating of perceived exertion equal to 12 (between light and somewhat hard) using the Borg Rate of Perceived Exertion scale (range 6 to 20).

Control

- *Exercise Prescription*: health education + sham training (gentle chair exercise with stretching of major joints). At home subjects performed similar chair exercises using a videotape.

Outcomes

Upper Limb Strength

- **Outcome type**: continuous outcome
- **Measure names**: "Baseline", "Post-intervention (16 weeks)"
- **Scale**: sum of scores for all 8 types of lifts
- **Unit of measure**: kg
- **Direction**: higher is better
- **Data value**: endpoint

(NB: this could not be used in the pooled analysis as data was not available for the experimental group alone)

Respiratory Muscle Strength

- **Outcome type**: continuous outcome
- **Measure names**: "Baseline", "Post-intervention (16 weeks)"
- **Scale**: Pimax
- **Unit of measure**: cmH₂O
- **Direction**: higher is better
- **Data value**: endpoint

Physical Activity Level: Subjective

- **Outcome type**: continuous outcome
- **Measure names**: "Baseline", "Post-intervention (16 weeks)"
- **Scale**: Functional Performance Inventory
- **Range**: 0 to 3

Covey 2012 (Continued)

- **Unit of measure:** mean of items
- **Direction:** higher is better
- **Data value:** endpoint

Identification	<p>Sponsorship source: the sources of support for this research were The National Institute of Nursing Research R01-NR08037 and the University of Illinois at Chicago General Clinical Research Center M01-RR-13987.</p> <p>Country: USA</p> <p>Setting: lab-based training</p> <p>Authors name: Margaret K. Covey</p> <p>Institution: University of Illinois at Chicago, USA</p> <p>Email: mkcovey@uic.edu</p> <p>Address: Department of Biobehavioral Health Science, University of Illinois at Chicago, M/C 802, 845 S. Damen Avenue, Chicago, IL, 60612, USA.</p>	
Notes	<p>There was a third intervention group who performed upper body resistance training with self-efficacy training. As this group does not reflect the typical delivery of arm training in a pulmonary rehabilitation programme, the group with arm training and health education only was chosen as the experimental group. However, some data in this paper combined these 2 groups so was not able to be used in the pooled analysis (e.g. upper limb strength where differences between the 2 groups were reported). For dyspnoea, respiratory muscle strength and physical activity level the pooled analysis used a sample size of n = 22, reflecting the experimental group numbers as the paper had reported no significant differences between the 2 upper limb training groups for these outcomes.</p> <p>This is the same study as the Larson 2014 study but different outcomes are reported.</p>	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Randomization to group was stratified by gender and disease severity (GOLD stages II, III, and IV) with a software program (biased coin algorithm to ensure equivalent groups)."
Allocation concealment (selection bias)	Low risk	Quote: "This was a concealed allocation process."
Blinding of participants and personnel (performance bias) All outcomes	High risk	Whilst subjects were not informed of the intent of the 3 groups, they were aware what group they were in.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "Data collectors were blinded to the group assignment."
Incomplete outcome data (attrition bias) All outcomes	High risk	There was a 25% drop-out rate for the study (n = 7 in each group × 3 groups).
Selective reporting (reporting bias)	High risk	Data has been presented across 2 different publications.
Other bias	Low risk	Study appears to be free of other sources of risk.

Epstein 1997

Methods	Study design: randomized controlled trial
Participants	<p>Clinically stable COPD (n = 23)</p> <p>Baseline characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • <i>Age (yrs):</i> 65 (SE ± 2) • <i>FEV₁(L):</i> 0.74 (SE± 0.06) • <i>Gender (male/female):</i> 11/1 <p>Control</p> <ul style="list-style-type: none"> • <i>Age (yrs):</i> 65 (SE± 2) • <i>FEV₁(L):</i> 0.98 (SE± 0.14) • <i>Gender (male/female):</i> 10/1
Interventions	<p>Intervention characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> unsupported arm exercises, supervised, 3 times weekly for 7 to 8 weeks (21 to 24 sessions completed) <p>Control</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> no arm training but included supervised, low-intensity resistive breathing training using a threshold resistor set at 30% maximal inspiratory pressure, 3 times weekly for 7 to 8 weeks.
Outcomes	<p><i>Endurance Upper Limb Exercise Capacity: unsupported</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post Intervention (8 weeks)" • Scale: move weighted dowel 10 cm • Unit of measure: time (s) <p><i>Respiratory Muscle Strength</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post Intervention (8 weeks)" • Scale: Pimax • Unit of measure: cmH₂O
Identification	<p>Country: USA</p> <p>Setting: outpatient and inpatient</p> <p>Authors name: Scott K Epstein.</p> <p>Institution: New England Medical Center and St. Elizabeth's Medical Center, Tufts University.</p> <p>Address: Pulmonary and Critical Care Division, New England Medical Center, Box 369, 750 Washington St, Boston, MA 02111.</p>
Notes	
Risk of bias	

Epstein 1997 (Continued)

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The method used to generate the allocation sequence was not provided.
Allocation concealment (selection bias)	Unclear risk	The method used to conceal the allocation sequence was not provided.
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication that participants or personnel were blind from the knowledge of which intervention the participant was receiving.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	The investigators performing the measurements were blinded to the method of training.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Low numbers of drop-out with reasons provided for incomplete data (i.e. 1 participant withdrew and 2 participants developed respiratory failure).
Selective reporting (reporting bias)	Low risk	Data reported for all outcomes stated.
Other bias	Low risk	Study appears to be free of other sources of risk.

Holland 2004

Methods	Study design: randomized controlled trial
Participants	<p>Severe to very severe, clinically stable COPD (n = 38)</p> <p>Baseline characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> Age (yrs): 66.6 (8.4) FEV₁(% pred): 34.2 (10.2) FEV₁(L): 0.97 (0.36) Gender (male/female): 14 / 8 <p>Control</p> <ul style="list-style-type: none"> Age (yrs): 69.4 (6.6) FEV₁(% pred): 39.8 (10.4) FEV₁(L): 1.02 (0.32) Gender (male/female): 10/6
Interventions	<p>Intervention characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> <i>Exercise Prescription:</i> unsupported arm exercises, twice wkly for 6 weeks supervised and daily at home plus lower limb endurance training, twice wkly for 6 weeks. <p>Control</p>

Holland 2004 (Continued)

- **Exercise Prescription:** no arm training except sham training of a pegboard finger dexterity task twice wkly for 6 weeks supervised plus lower limb endurance training, twice wkly for 6 weeks.

Outcomes
Peak Upper Limb Exercise Capacity: unsupported

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (6 wks)"
- **Unit of measure:** time (s)
- **Direction:** higher is better
- **Data value:** endpoint

Dyspnoea from questionnaire

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post intervention (6 wks)"
- **Unit of measure:** dyspnoea score from Chronic Respiratory Disease Questionnaire

Health-Related Quality of Life

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post intervention (6 wks)"
- **Direction:** higher is better
- **Notes:** total score from Chronic Respiratory Disease Questionnaire

Identification

Sponsorship source: Alfred Research Trust Small Projects Grant.

Country: Australia

Setting: outpatient and home programme

Authors name: Anne E. Holland

Institution: Department of Physiotherapy, Alfred Hospital, Melbourne and University of Melbourne, Melbourne, Victoria, Australia.

Email: a.holland@alfred.org.au

Address: Department of Physiotherapy, Alfred Hospital, Commercial Road, Melbourne, Australia 3004

Notes
Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The method used to generate the allocation sequence was not provided.
Allocation concealment (selection bias)	Unclear risk	The method used to conceal the allocation sequence was not provided.
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication that participants or personnel were blind from the knowledge of which intervention the participant was receiving.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "Measurements were obtained by an independent data collector blind-ed to group allocation."

Holland 2004 (Continued)

Incomplete outcome data (attrition bias) All outcomes	Low risk	Two participants did not complete the study so overall completion rate was high at 95%.
Selective reporting (reporting bias)	Unclear risk	Data not reported for arm fatigue during the arm exercise test.
Other bias	Low risk	Study appears to be free of other sources of risk.

Ike 2010

Methods	Study design: randomized controlled trial
Participants	<p>Clinically stable, moderate to very severe COPD (n = 12), aged > 50 yrs</p> <p>Baseline characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • Age (yrs): 67.8 (7.4) • FEV₁(% pred): 30.9 (18.9) • Gender (male/female): 4/1 <p>Control</p> <ul style="list-style-type: none"> • Age (yrs): 70.4 (8.5) • FEV₁(% pred): 34.3 (8.1) • Gender (male/female): 5/2
Interventions	<p>Intervention characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> 3 weekly sessions, lasting 40 min each, for 6 consecutive weeks of arm exercises with warm-up (5 min) followed by 3 series of 8 repetitions of 2 arm strength exercises starting with load of 80% of 1 repetition maximum test (1RM). <p>Control</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> 3 weekly sessions, lasting 40 min each, for 6 consecutive weeks of bronchial hygiene and respiratory functional rehabilitation.
Outcomes	<p><i>Upper Limb Strength (pulley and bench press)</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (6 wks)" • Scale: 1RM • Unit of measure: kg <p><i>Endurance Upper Limb Exercise Capacity: Unsupported</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (6 wks)" • Scale: rings moved in 6 min • Unit of measure: no. of rings
Identification	Country: Brazil

Upper limb exercise training for COPD (Review)

Ike 2010 (Continued)

Authors name: Daniela Ike

Notes	Study reported in Portuguese and required translation to English.	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The method used to generate the allocation sequence was not provided.
Allocation concealment (selection bias)	Unclear risk	The method used to conceal the allocation sequence was not provided.
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication that participants or personnel were blind from the knowledge of which intervention the participant was receiving.
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no indication that there was blinding of the outcome assessor.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Complete data available for all outcomes.
Selective reporting (reporting bias)	Low risk	Data reported for all outcomes stated.
Other bias	Low risk	Study appears to be free of other sources of risk.

Janaudis-Ferreira 2011

Methods	Study design: randomized controlled trial
Participants	Clinically stable, mild to very severe COPD (n = 36) Baseline characteristics Experimental <ul style="list-style-type: none"> Age (yrs): median IQR 67 (11) FEV₁(% pred): 37.8 (16.2) FEV₁(L): median IQR 0.8 (0.4) Gender (male/female): 9/8 Control <ul style="list-style-type: none"> Age (yrs): median IQR 67 (11) FEV₁(% pred): 32.5 (14) FEV₁(L): median IQR 0.8 (0.5) Gender (male/female): 12/7
Interventions	Intervention characteristics Experimental

Upper limb exercise training for COPD (Review)

Janaudis-Ferreira 2011 (Continued)

- *Exercise Prescription:* resistance arm training programme 3 times a week for 6 weeks, for a total of 18 sessions supervised. The following muscle groups were targeted using free weights and a multi-station gym: biceps brachii, triceps brachii, pectoralis major and minor, latissimus dorsi, deltoids, and rhomboids. Training was started using loads equivalent to 10 to 12 repetition maximum. The loads were increased when the patients could manage 12 repetitions for both sets on 2 consecutive training sessions. The group also performed the standard leg endurance and strength training (6 weeks × 5 wkly if inpatient or 12 weeks × 3 wkly if outpatient).

Control

- *Exercise Prescription:* sham training that consisted of upper limb flexibility and stretching exercises 3 times a week for 6 weeks supervised. The group also performed the standard leg endurance and strength training (6 weeks × 5 wkly if inpatient or 12 weeks × 3 wkly if outpatient).

Outcomes

Health-Related Quality of Life

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "post intervention"
- **Direction:** higher is better
- **Notes:** total score from Chronic Respiratory Disease Questionnaire

Peak Upper Limb Exercise Capacity: unsupported

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (6 wks)"
- **Unit of measure:** time (s)
- **Direction:** higher is better
- **Data value:** endpoint

Upper Limb Strength (shoulder flexion and abduction)

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (6 wks)"
- **Scale:** hand-held dynamometer
- **Unit of measure:** kg
- **Direction:** higher is better

Endurance Upper Limb Exercise Capacity: unsupported

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (6 wks)"
- **Scale:** rings moved in 6 min
- **Unit of measure:** no. of rings

Identification

Sponsorship source: this study was supported by the Ontario Thoracic Society, West Park Healthcare Centre Foundation, Canada Research Chair Program, and the Swedish Heart and Lung Foundation.

Country: Canada

Setting: outpatient and inpatient

Authors name: Tania Janaudis-Ferreira

Institution: West Park Healthcare Centre, Toronto, ON, Canada

Email: dina.brooks@utoronto.ca

Address: Department of Physical Therapy, University of Toronto, 160-500 University Ave, Toronto, ON, Canada, M5G1V7

Janaudis-Ferreira 2011 (Continued)

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Patients were randomly (in blocks of 4) assigned to an intervention or control group. Randomization was stratified according to the presence or absence of the use of supplemental oxygen at rest."
Allocation concealment (selection bias)	Low risk	Quote: "The sequence was kept in opaque envelopes by an investigator who was not involved in the recruitment process. These envelopes were drawn by the trainer after the subjects had completed their pre assessment session, allowing for concealed allocation."
Blinding of participants and personnel (performance bias) All outcomes	High risk	Quote: "the patients remained unaware of the group allocation." However, the trainers were aware of group allocation.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "The outcome assessor and the patients remained unaware of the group allocation."
Incomplete outcome data (attrition bias) All outcomes	Low risk	Data not available in 14% of participants. Reasons were provided, mostly unrelated to the study.
Selective reporting (reporting bias)	Low risk	Data reported for all outcomes stated.
Other bias	Low risk	Study appears to be free of other sources of risk.

Lake 1990a

Methods	Study design: randomized controlled trial
Participants	<p>Clinically stable, severe COPD (n = 26)</p> <p>Baseline characteristics</p> <p>Upper Limb Training Only</p> <ul style="list-style-type: none"> Age (yrs): 62.0 (7.0) FEV₁(L): 0.97 (0.29) Gender (male/female): 6/0 <p>Control - No Training</p> <ul style="list-style-type: none"> Age (yrs): 65.7 (3.5) FEV₁(L): 0.97 (0.29) Gender (male/female): 6/1 <p>Combined Upper Limb and Lower Limb Training</p> <ul style="list-style-type: none"> Age (yrs): 66.3 (6.8) FEV₁(L): 0.83 (0.25)

Upper limb exercise training for COPD (Review)

Lake 1990a (Continued)

- *Gender (male/female)*: 4/3

Lower Limb Training Only

- *Age (yrs)*: 71.8 (3.3)
- *FEV₁(L)*: 0.73 (0.24)
- *Gender (male/female)*: 6/0

Interventions	<p>Intervention characteristics</p> <p>1. Upper Limb Training Only versus No Training</p> <p>Experimental</p> <ul style="list-style-type: none"> • <i>Exercise Prescription</i>: the participants performed a warm-up, 20 min of upper-limb circuit training, and ten min of cool off, 3 times a week for an hour for 8 weeks. The exercises were arm cycle ergometry, throwing a ball against a wall, passing a bean bag over the head, pulling on ropes and pulleys, and playing an accuracy game of moving a ring across a horizontal wire. Each exercise was performed for 40 s followed by 20 s of rest (repeated 3 times in 3 min). <p>Control</p> <ul style="list-style-type: none"> • <i>Exercise Prescription</i>: no training group <p>2. Combined Upper Limb Training and Lower Limb Training versus Lower Limb Training Alone</p> <p>Combined</p> <p>Experimental</p> <ul style="list-style-type: none"> • <i>Exercise Prescription</i>: the combined group had 10 min of warm-up, 15 min of upper-limb circuit training, 15 min of walking training, and ten min of cool off. <p>Control (Lower Limb only)</p> <ul style="list-style-type: none"> • <i>Exercise Prescription</i>: the lower limb group had ten minutes of warm-up, 20 min of walking training, and ten min of cool off.
Outcomes	<p><i>Peak Upper Limb Exercise Capacity: supported</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (8 wks)" • Scale: arm ergometer peak work • Unit of measure: kpm/min <p><i>Respiratory Muscle Strength</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (8 wks)" • Scale: Pimax • Unit of measure: cmH₂O
Identification	<p>Country: Australia</p> <p>Setting: Outpatient</p> <p>Authors name: Fiona R.Lake</p> <p>Institution: Sir Charles Gairdner Hospital, Perth, Western Australia.</p> <p>Address: Sir Charles Gairdner Hospital, Verdun Street, Nedlands West Australia 6009.</p>

Lake 1990a (Continued)

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The method used to generate the allocation sequence was not provided.
Allocation concealment (selection bias)	Unclear risk	There is no description of how they performed the allocation concealment.
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication that participants or personnel were blind from the knowledge of which intervention the participant was receiving.
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no indication that there was blinding of the outcome assessor.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Data not available in 7% of participants. Reasons were provided, mostly unrelated to the study.
Selective reporting (reporting bias)	Unclear risk	Data not reported for resting blood pressure.
Other bias	Low risk	Study appears to be free of other sources of risk.

Larson 2014

Methods	Study design: randomized controlled trial
Participants	Clinically stable, moderate to severe COPD (n = 34), age > 45 yrs Baseline characteristics Experimental <ul style="list-style-type: none"> Age (yrs): 72 (9) FEV₁(% pred): 54 (17) Control <ul style="list-style-type: none"> Age (yrs): 71 (8) FEV₁(% pred): 56 (17)
Interventions	Intervention characteristics Experimental <ul style="list-style-type: none"> <i>Exercise Prescription:</i> the upper body resistance training included 3 sets of 8 lifts (plus education) using a cable crossover system twice a week in the laboratory and with hand weights, once a week at home over 16 weeks. Control

Upper limb exercise training for COPD (Review)

Larson 2014 (Continued)

- *Exercise Prescription:* sham chair exercises which were not aerobic but stretching and toning (plus education). Gentle chair exercises were performed twice a week in the laboratory and once a week at home over 16 weeks.

Outcomes	<i>Physical Activity Level - Objective</i> <ul style="list-style-type: none">• Outcome type: continuous outcome• Measure names: "Baseline", "Post-intervention (16 wks)"• Scale: time spent in moderate intensity activity• Unit of measure: min per day• Direction: higher is better	
Identification	<p>Sponsorship source: The National Institute of Nursing Research R01-NR08037 and the University of Illinois at Chicago General Clinical Research Center M01-RR-13987.</p> <p>Country: USA</p> <p>Authors name: Janet L Larson</p> <p>Institution: University of Michigan, Ann Arbor</p> <p>Email: janetlar@med.umich.edu</p> <p>Address: University of Michigan, 400 N Ingalls, Ann Arbor, MI 48109, USA</p>	
Notes	<p>There was a third intervention group who performed upper body resistance training with self-efficacy training. As this group does not reflect the typical delivery of arm training in a pulmonary rehabilitation programme, the group with arm training and health education only was chosen as the experimental group.</p> <p>This was the same study as the Covey 2012 study but the Larson 2014 paper includes an objective measure of physical activity in 34 COPD patients (which was not part of the Covey 2012 paper).</p>	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Randomization was stratified by sex and disease severity (Global Initiative on Obstructive Lung Disease stages II, III, and IV) 8 using a customized computer program that blinded investigators to group assignment."
Allocation concealment (selection bias)	Low risk	Customized computer program would have concealed the allocation.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Whilst all participants were assigned to an active intervention and were not told which was the experimental group, all participants knew which intervention they were performing.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	The data collectors were blinded to group assignment.
Incomplete outcome data (attrition bias) All outcomes	High risk	42% participants were not included at 16 weeks.
Selective reporting (reporting bias)	High risk	Data has been presented across 2 different publications.

Larson 2014 (Continued)

Other bias	Low risk	Study appears to be free of other sources of risk.
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Marrara 2008

Methods	Study design: randomized controlled trial
Participants	<p>Clinically stable COPD (n = 14)</p> <p>Baseline characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • Age (yrs): 65 (9.8) • FEV₁ (% pred): 45 (11.5) • Gender (male/female): 8/0 <p>Control</p> <ul style="list-style-type: none"> • Age (yrs): 68 (10.4) • FEV₁ (% pred): 42 (11.6) • Gender (male/female): 6/0
Interventions	<p>Intervention characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> upper limb strength exercises, 30 min sessions, 3 times per week for 6 weeks. The 6 upper limb strength exercises were elbow flexion, elbow extension, shoulder press, shoulder adduction, diagonal upper limb exercises × 2 types. A progressive load was used for 3 sets of 10 repetitions performed for each of the 6 exercises. The first set was stipulated at 50% of the 10RM obtained during the assessment, followed by the second set at 75% of 10RM, and the third set at 100% of 10RM. <p>Control</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> bronchial hygiene therapy along with diaphragmatic pattern breathing orientations and stretching of the cervical, UL and LL muscles, 45 min sessions, 3 times weekly for 6 weeks.
Outcomes	<p><i>Endurance Upper Limb Exercise Capacity: unsupported</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (6 wks)" • Scale: 5-min blackboard erasing task but metabolic data only so not included in meta-analysis <p><i>Upper Limb Strength</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (6 wks)" • Scale: 5 min weight-lifting task with 5 kg weight but metabolic data only so not included in meta-analysis
Identification	<p>Country: Brazil</p> <p>Setting: outpatient (assumed)</p> <p>Authors name: Kamilla Tays Marrara,</p> <p>Institution: Federal University of São Carlos – UFSCar</p> <p>Email: kamillatm@bol.com.br</p>

Upper limb exercise training for COPD (Review)

Marrara 2008 (Continued)

Address: Federal University of São Carlos – UFSCar, Av. Filomeno Rispoli no. 179, Parque Santa Marta, CEP: 13564-200, São Carlos, São Paulo, Brazil

Notes	Data not used in meta-analysis as only metabolic data presented.	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The method used to generate the allocation sequence was not provided.
Allocation concealment (selection bias)	Unclear risk	The method used to conceal the allocation sequence was not provided.
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication that participants or personnel were blind from the knowledge of which intervention the participant was receiving.
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no indication that there was blinding of the outcome assessor.
Incomplete outcome data (attrition bias) All outcomes	High risk	24% drop out in the study.
Selective reporting (reporting bias)	Unclear risk	Only metabolic outcomes reported so data not available for meta-analysis.
Other bias	Low risk	Study appears to be free of other sources of risk.

Martinez 1993

Methods	Study design: randomized controlled trial
Participants	<p>Clinically stable COPD (n = 35)</p> <p>Baseline characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • Age (yrs): median (range): 67 (55 to 75) • FEV₁(% pred): median (range) 34 (15 to 56) • Gender (male/female): 7/11 <p>Control</p> <ul style="list-style-type: none"> • Age (yrs): median (range): 65 (43 to 75) • FEV₁(% pred): median (range) 30 (16 to 81) • Gender (male/female): 7/10
Interventions	<p>Intervention characteristics</p> <p>Experimental</p>

Martinez 1993 (Continued)

- **Exercise Prescription:** unsupported upper limb training, 3 times weekly for 10 weeks. Unsupported exercises were performed with a wooden dowel: shoulder flexion; shoulder flexion/extension in conjunction with elbow flexion/extension; isolated elbow flexion/extension; horizontal abduction/adduction; and shoulder circles. The duration of each exercise was increased by 30 s increments to a total time of 3.5 min. The duration of exercise and/or weight of the dowel were increased weekly as tolerated. All participants also did lower limb training from 10 to 30 min (Borg 3, RPE 12-14).

Control

- **Exercise Prescription:** supported upper limb training, 3 times weekly for 10 weeks. Supported upper limb exercises performed on an arm cycle ergometer. A load achieving an RPE of 12 to 14 and dyspnoea rating of approximately 3 was chosen. Workload and exercise duration were increased weekly as tolerated up to 15 min. All participants also did lower limb training from 10 to 30 min (Borg 3, RPE 12 to 14).

Outcomes	<p><i>Endurance Upper Limb Exercise Capacity: unsupported</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (10 wks)" • Scale: endurance time (s) from weighted dowel test to exhaustion • No mean data of the groups provided in the paper (only individual data in figures) so not used in the meta-analysis. <p><i>Peak Upper Limb Exercise Capacity: supported</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (10 wks)" • Scale: peak work from arm ergometer test • No mean data of the groups provided in the paper (only individual data in figures) so not used in the meta-analysis. <p><i>Respiratory Muscle Strength</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: ("Baseline", "Post-intervention (10 wks)") • Scale: Pimax • Unit of measure: cmH₂O • No mean data of the groups provided in the paper (only individual data in figures) so not used in the meta-analysis.
Identification	<p>Sponsorship source: no description</p> <p>Country: USA</p> <p>Setting: outpatient</p> <p>Authors name: Fernando J. Martinez</p> <p>Institution: University of Michigan Medical Center</p> <p>Email: fmartine@umich.edu</p> <p>Address: 1500 East Medical Center Drive, Ann Arbor MI 48109-0026</p>
Notes	Authors contacted for group data but no response.
Risk of bias	
Bias	Authors' judgement Support for judgement

Martinez 1993 (Continued)

Random sequence generation (selection bias)	Unclear risk	The method used to generate the allocation sequence was not provided.
Allocation concealment (selection bias)	Unclear risk	The method used to conceal the allocation sequence was not provided.
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication that participants or personnel were blind from the knowledge of which intervention the participant was receiving.
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no indication that there was blinding of the outcome assessor.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Data were not available for 12% of participants but reasons were provided for this, which was unrelated to the study.
Selective reporting (reporting bias)	High risk	Mean group data on main outcomes not provided so data not used in meta-analysis.
Other bias	Low risk	Study appears to be free of other sources of risk.

Matsunaga 2011

Methods	Study design: randomized controlled trial
Participants	COPD (n = 33) No baseline characteristics provided.
Interventions	Intervention characteristics Experimental <ul style="list-style-type: none"> <i>Exercise Prescription:</i> 10-week programme (do not know how many times per week). Upper limb and thoracic muscle strength exercise (with lower limb training) Control <ul style="list-style-type: none"> <i>Exercise Prescription:</i> 10-week programme (do not know how many times per week). Lower limb endurance and strength training
Outcomes	<i>Health-Related Quality of Life</i> <ul style="list-style-type: none"> Outcome type: continuous outcome Measure names: "Baseline", "Post-intervention (10 wks)" Scale: St George's Respiratory Questionnaire No mean data of both groups provided in the abstract so not used in the meta-analysis <i>Respiratory Muscle Strength</i> <ul style="list-style-type: none"> Outcome type: continuous outcome Measure names: "Baseline", "Post-intervention (10 wks)" Scale: Pimax Unit of measure: cmH₂O

Upper limb exercise training for COPD (Review)

Matsunaga 2011 (Continued)

- No mean data of the groups provided in the paper so not used in the meta-analysis

Identification	Country: Japan Setting: there is no description of setting. Comments: abstract only so few details Authors name: H. Matsunaga Institution: Nippon Steel Yawata Memorial Hospital, Kitakyushu, Japan,
Notes	Abstract only, no email to contact authors so data cannot be included in meta-analysis.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	No information provided.
Allocation concealment (selection bias)	Unclear risk	No information provided.
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	No information provided.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No information provided.
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Insufficient information provided.
Selective reporting (reporting bias)	Unclear risk	Insufficient information provided.
Other bias	Unclear risk	Insufficient information provided.

McKeough 2012

Methods	Study design: randomized controlled trial
Participants	Clinically stable COPD (n = 38) Baseline characteristics Endurance Training Group <ul style="list-style-type: none"> • Age (yrs): 66 (8) • FEV₁(% pred): 57 (17) • FEV₁(L): 1.58 (0.6) • Gender (male/female): 9/2 Resistance Training Group

Upper limb exercise training for COPD (Review)

McKeough 2012 (Continued)

- Age (yrs): 65 (9)
- FEV₁ (% pred): 60 (17)
- FEV₁(L): 1.58 (0.7)
- Gender (male/female): 4/5

Combined Endurance and Resistance Training Group

- Age (yrs): 66 (6)
- FEV₁(% pred): 54 (16)
- FEV₁(L): 1.53 (0.7)
- Gender (male/female): 6/3

Control

- Age (yrs): 65 (7)
- FEV₁(% pred): 57 (12)
- FEV₁(L): 1.43 (0.4)
- Gender (male/female): 4/5

Interventions

Intervention characteristics

All groups had exercise training 3 times per week for 8 weeks and performed standard leg endurance and strength training during this period.

Experimental (Endurance Training)

- *Exercise Prescription:* the training consisted of arm cranking and unsupported arm exercise. Arm cranking was performed for 15 min (continuous or intermittent) at 60% of the peak work rate achieved on the peak arm crank test. Intensity progression was made according to breathlessness and arm perceived exertion in order to maintain symptom scores at a moderate level of 3 on the 0 to 10 modified Borg category ratio scale. Unsupported arm exercise was performed for 5 min at 1 level below the maximal level achieved on the unsupported arm test, with the level progressed according to breathlessness and arm perceived exertion in order to maintain symptom scores at a moderate level of 3 on the 0 to 10 modified Borg category ratio scale.

Experimental (Resistance Training)

- *Exercise Prescription:* the resistance group trained the muscles that are involved both as accessory breathing muscles and as muscles that move the arm on 3 fixed weight machines (i.e. a pec deck, lat pull-down, and bicep lifts) with resistance loading initially consisting of 2 sets (of 10 repetitions) at 60% of 1RM. Training was progressed in subsequent sessions to 3 sets. The training work load was also progressed to 80% of 1RM.

Experimental (Combined Training)

- *Exercise Prescription:* a combination of the endurance training protocol and resistance training protocol described above.

Control

- *Exercise Prescription:* no arm training.

Outcomes

Endurance Upper Limb Exercise Capacity: supported

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (8 wks)"
- **Scale:** arm ergometer time
- **Unit of measure:** seconds

Peak Upper Limb Exercise Capacity: Supported

- **Outcome type:** Continuous Outcome

McKeough 2012 (Continued)

- **Measure names:** "Baseline", "Post-intervention (8 wks)"
- **Scale:** arm ergometer power output
- **Unit of measure:** watts

Health-Related Quality of Life

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (8 wks)"
- **Scale:** total score on St George's Respiratory Questionnaire
- **Range:** 0 to 100
- **Direction:** lower is better

Respiratory muscle strength

- **Outcome type:** Continuous Outcome
- **Measure names:** "Baseline", "Post-intervention (8 wks)"
- **Scale:** Pimax
- **Unit of measure:** cmH₂O
- Baseline data in paper and authors provided post-intervention data.

Peak Upper Limb Exercise Capacity: Unsupported

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (8 wks)"
- **Scale:** time to exhaustion
- **Unit of measure:** seconds
- **Direction:** higher is better

Identification

Sponsorship source: this article was supported by the Australian Respiratory Council.

Country: Australia

Setting: outpatient

Authors name: Zoe J McKeough

Institution: University of Sydney

Email: zoe.mckeough@sydney.edu.au

Address: Discipline of Physiotherapy, Faculty of Health Sciences, The University of Sydney, 75 East St Lidcombe, NSW 2141, Australia

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Randomisation was via computerised random number generation."
Allocation concealment (selection bias)	Low risk	Quote: "...with the sequence concealed using opaque envelopes prepared by an investigator not involved in the study."
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no blinding of participants and personnel.

Upper limb exercise training for COPD (Review)

McKeough 2012 (Continued)

Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "An assessor, blinded to group allocation, performed the outcome measures at baseline and at the end of the intervention period."
Incomplete outcome data (attrition bias) All outcomes	High risk	Quote: "A total of 52 subjects were recruited and 38 (73%) completed the study with 11 in the endurance group, 9 in the strength group, 9 in the combined group, and 9 in the control group". Therefore outcome data was not available in 27%.
Selective reporting (reporting bias)	High risk	Data not reported in the paper for respiratory muscle strength but authors have provided this data for the meta-analysis. Data not reported for upper limb strength although stated in trials registry.
Other bias	Low risk	Study appears to be free of other sources of risk.

Ries 1988

Methods	Study design: randomized controlled trial
Participants	<p>Clinically stable COPD (n = 28)</p> <p>Baseline characteristics</p> <p>Endurance Training Group</p> <ul style="list-style-type: none"> • $FEV_1(\% \text{ pred})$: 46 (20) • $FEV_1(L)$: 1.08 (0.63) <p>Resistance Training Group</p> <ul style="list-style-type: none"> • $FEV_{1,1}(\% \text{ pred})$: 46 (20) • $FEV_1(L)$: 1.08 (0.63) <p>Control</p> <ul style="list-style-type: none"> • $FEV_1(\% \text{ pred})$: 31 (8) • $FEV_1(L)$: 0.78 (0.23)
Interventions	<p>Intervention characteristics</p> <p>All groups did lower limb training such as walking over 8 weeks with weekly supervision.</p> <p>Experimental (Endurance Training)</p> <ul style="list-style-type: none"> • <i>Exercise Prescription</i>: upper limb training, 8 weeks, once weekly including both isokinetic arm cycle training for 15 min and arm endurance training of 5 low-resistance high-repetition exercises. Each exercise was coordinated with breathing in progressively increasing levels of: number of arm motions per exhalation (1 to 6); the number of sets (1 or 2) of 10 repetitions of each exercise; and added hand weights (1 to 5 lb). <p>Experimental (Resistance Training)</p> <ul style="list-style-type: none"> • <i>Exercise Prescription</i>: Upper limb training, 8 weeks, 4 exercises with weights (1 to 5 lbs based on the maximum weight repeated 6 times). Each exercise was performed in 3 sets of 4 to 10 repetitions. Training was performed every other day for 1 week and then once daily. The weight was increased when completion of 3 sets of at least 6 repetitions of each exercise was achieved. <p>Control</p>

Ries 1988 (Continued)

- *Exercise Prescription: no arm training*

Outcomes
Endurance Upper Limb Exercise Capacity: unsupported

- **Outcome type:** continuous outcome
- **Unit of measure:** time (s)
- **Notes:** 4 lifts (shld flexion, shld abduction of each arm separately) – the number of lifts in 1 min averaged across the 4 tests.

Peak Upper Limb Exercise Capacity: supported

- **Outcome type:** continuous outcome
- **Scale:** peak power output from arm ergometer
- **Unit of measure:** watts
- **Direction:** higher is better

Endurance Upper Limb Exercise Capacity: Supported

- **Outcome type:** continuous outcome
- **Scale:** arm ergometer
- **Unit of measure:** time (s)
- **Notes:** just looked at arm cycle (isotonic)

Activities of Daily Living Function

- **Outcome type:** continuous outcome
- **Scale:** time
- **Unit of measure:** time (s)
- **Notes:** time to complete 3 tasks. The 3 tasks were the following: (1) dishwashing (patients washed, rinsed, dried, and put on a shelf 2 place settings of dishes, plus a pot); (2) blackboard task (patients covered a dustless blackboard with continuous writing and then erased it; this activity simulates cleaning a window, wall, or mirror); and (3) grocery shelving (patients carried, unpacked, and shelved 2 bags of groceries weighing 8 lb each).

Identification

Sponsorship source: supported in part by the Easter Seal Research Foundation of the National Easter Seal Society and National Institutes of Health grant RR00827 from the Division of Research Resources for the Clinical Research Center.

Country: USA

Setting: outpatient

Authors name: Andrew L Ries

Institution: Department of Medicine, University of California, San Diego

Address: UCSD Medical Center H-772, 225 Dickinson Street, San Diego, 92103

Notes
Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The method used to generate the allocation sequence was not provided.
Allocation concealment (selection bias)	Unclear risk	The method used to conceal the allocation sequence was not provided.

Ries 1988 (Continued)

Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication of blinding of participants and personnel.
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no indication that there was blinding of the outcome assessor.
Incomplete outcome data (attrition bias) All outcomes	High risk	38% of participants did not complete the study. Reasons were given and one may have related to the study.
Selective reporting (reporting bias)	Unclear risk	Data from baseline analysis not available.
Other bias	Low risk	Study appears to be free of other sources of risk.

Sivori 1998

Methods	Study design: randomized controlled trial
Participants	<p>Clinically stable, severe COPD (n = 28)</p> <p>Baseline characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • Age (yrs): 66.07 (9.24) • FEV₁(% pred): 37.29 (11.47) • FEV₁(L): 1.08 (0.38) • Gender (male/female): 11/3 <p>Control</p> <ul style="list-style-type: none"> • Age (yrs): 63.07 (9.41) • FEV₁(% pred): 34.93 (17.13) • FEV₁(L): 0.93 (0.38) • Gender (male/female): 12/2
Interventions	<p>Intervention characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> unsupported upper limb endurance exercise, 3 times weekly for 8 weeks. Five different types of unsupported upper limb exercise using an intermittent protocol of 45 s exercise, 15 s rest for no more than 5 min. Also, lower limb cycle exercise at 75% peak work for 45 min. <p>Control</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> no arm training; lower limb cycle exercise at 75% peak work for 45 min, 3 times weekly for 8 weeks.
Outcomes	<p><i>Endurance Upper Limb Exercise Capacity: unsupported</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (8 wks)"

Sivori 1998 (Continued)

- **Scale:** arms lifted in 6 min
- **Unit of measure:** total no. of lifts in 6 min

Health-Related Quality of Life

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (8 wks)"
- **Scale:** total score from Chronic Respiratory Disease Questionnaire
- **Unit of measure:** score (max 140)
- **Direction:** higher is better

Respiratory Muscle Strength

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "Post-intervention (8 wks)"
- **Scale:** Pimax
- **Unit of measure:** cmH₂O

Hospitalisation index

- **Outcome type:** continuous outcome
- **Measure names:** "Baseline", "12 months post training"
- **Scale:** 12 months pre and 12 months post
- **Unit of measure:** no. hospitalisation days × no. patient

Identification	Sponsorship source: none Country: Argentina Setting: Outpatient Authors name: Martin L Sivori Institution: Servicio de Neumonologia Policlinico Bancário. Email: neumo@hosrm.sld.ar Address: Dr Martin L Sivori, Lafayette 124 1872 Avellaneda, Pcia Buenos Aires, Argentina	
Notes	Study reported in Spanish and required translation to English.	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation by simple table.
Allocation concealment (selection bias)	Unclear risk	The method used to conceal the allocation sequence was not provided.
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication that participants or personnel were blind from the knowledge of which intervention the participant was receiving.
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no indication that there was blinding of the outcome assessor.

Sivori 1998 (Continued)

Incomplete outcome data (attrition bias) All outcomes	High risk	35% did not complete the study. Reasons were given not directly related to study.
Selective reporting (reporting bias)	Unclear risk	Data not provided for the quality of life domains (only a total score was given).
Other bias	Low risk	Study appears to be free of other sources of risk.

Subin 2010

Methods	Study design: randomized controlled trial
Participants	<p>Clinically stable COPD (n = 17), age 45 to 75 yrs</p> <p>Baseline characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • Age (yrs): 60 (9) • FEV₁(% pred): 46 (11) • Smoking history: 34 (11) • Gender (male/female): 9/0 <p>Control</p> <ul style="list-style-type: none"> • Age (yrs): 57 (8) • FEV₁(% pred): 49 (11) • Smoking history: 35 (11) • Gender (male/female): 8/0
Interventions	<p>Intervention characteristics</p> <p>Experimental</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> unsupported endurance upper limb exercise, 5 times per week for 4 weeks of training. Four types of upper limb exercises were performed for 40 s with 20 s rest for 4 min, repeated 4 times. Also, lower limb training was performed (alternated on different days). <p>Control</p> <ul style="list-style-type: none"> • <i>Exercise Prescription:</i> lower limb training only of walking for 20 min, 5 times per week for 4 weeks of training.
Outcomes	<p><i>Dyspnoea from questionnaire</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (4 wks)" • Scale: dyspnoea score from Chronic Respiratory Disease Questionnaire <p><i>Peak Upper Limb Exercise Capacity: unsupported</i></p> <ul style="list-style-type: none"> • Outcome type: continuous outcome • Measure names: "Baseline", "Post-intervention (4 wks)" • Unit of measure: time (s) from the incremental unsupported arm exercise test
Identification	Country: India

Subin 2010 (Continued)

Setting: outpatient

Authors name: Vaishali Rao Subin

Institution: Department of Physiotherapy, Kasturba Medical College

Email: vaishaliar74@yahoo.com

Address: Ms. Vaishali Rao, Department of Physiotherapy, Kasturba Medical College, Mangalore, India

Notes

A third group was involved and performed upper limb training only but was not included in this review as there was no control group with no training.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Block randomisation was used.
Allocation concealment (selection bias)	Unclear risk	Block randomisation used but unclear whether it is concealed.
Blinding of participants and personnel (performance bias) All outcomes	High risk	There was no indication that participants or personnel were blind from the knowledge of which intervention the participant was receiving.
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no indication that there was blinding of the outcome assessor.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Appears to be missing data for 10% of participants only.
Selective reporting (reporting bias)	Low risk	Data reported for all outcomes stated.
Other bias	High risk	Block randomisation in an unblinded trial.

COPD: Chronic Obstructive Pulmonary Disease

FEV₁ - forced expiratory volume in 1 second

yrs: years

L: litres

% pred: percent predicted

no.: number

RM: repetition maximum

lbs: pounds

kg: kilograms

Pimax: maximal inspiratory mouth pressure

cmH₂O: centimetres of water

GOLD: Global Initiative for Chronic Obstructive Lung Disease

wkly: weekly

s: seconds

min: minutes

IQR: interquartile range

RPE: rate of perceived exertion

shld: shoulder

Upper limb exercise training for COPD (Review)

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kpm/min: kilopond metre per minute

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

Study	Reason for exclusion
Akinci 2011b	Intervention did not fit study criteria
Alexander 2008	Study design did not fit study criteria
Anton 2010	Intervention did not fit study criteria
Baarends 1999	Comparator group did not fit study criteria
Bauldoff 2005	Intervention did not fit study criteria
Belman 1982	Outcomes did not fit study criteria
Boxall 2005	Intervention did not fit study criteria
Clark 1996	Intervention did not fit study criteria
Clark 2000	Intervention did not fit study criteria
Corsini 2008	Intervention did not fit study criteria
Costi 2009b	Intervention did not fit study criteria
De Sousa Pinto 2014	Intervention did not fit study criteria
Gurgun 2010	Intervention did not fit study criteria
Janaudis-Ferreira 2012	Editorial - not an original study on upper limb training
Janaudis-Ferreira 2013	No upper limb training intervention
Kikuchi 2009	Intervention did not fit study criteria
McKeough 2005	Intervention did not fit study criteria
Mohan 2010	Outcomes did not fit study criteria
Ribeiro 2010	Study design did not fit study criteria
Shu 1998	Outcomes did not fit study criteria
Sivori 1996	This is an abstract of a full text study that has been included
Sivori 2013	Outcomes did not fit study criteria
Spruit 2002	Intervention did not fit study criteria

Characteristics of studies awaiting assessment *[ordered by study ID]*

Calik-Kutukcu 2015

Methods	Study design: randomized controlled trial
Participants	Stable COPD (n = 42), age 40 to 80 years
Interventions	Intervention characteristics Experimental <ul style="list-style-type: none"> <i>Exercise Prescription:</i> arm strength training, 3 times weekly × 8 weeks for 23 sessions, daily breathing exercises at home. Control <ul style="list-style-type: none"> No arm exercise training, daily breathing exercises at home.
Outcomes	<i>Peak Upper Limb Exercise Capacity: Supported</i> <ul style="list-style-type: none"> Outcome type: Continuous Outcome Measure names: "Baseline", "Post-intervention (8 wks)" Scale: arm ergometer power output Unit of measure: watts <i>Upper Limb Strength (hand grip strength)</i> <ul style="list-style-type: none"> Outcome type: continuous outcome Measure names: "Baseline", "Post-intervention (8 wks)" Scale: hand grip dynamometer Unit of measure: % of normal predicted Direction: higher is better <i>Activities of Daily Living Function (ADL simulation test)</i> <ul style="list-style-type: none"> Outcome type: continuous outcome Scale: four simulated unsupported arm tasks for 10 min Unit of measure: no. of cycles in 10 min
Notes	This paper was found in the search update conducted on 28 September 2016 and will undergo full review when the next update occurs.

Mador 2012

Methods	Study design: randomized controlled trial
Participants	COPD (n = 39) Baseline characteristics Experimental <ul style="list-style-type: none"> <i>FEV₁(L):</i> 1.41 (0.75) Control <ul style="list-style-type: none"> <i>FEV₁(L):</i> 1.27 (0.42)
Interventions	Intervention characteristics Both groups did lower limb exercise training.

Upper limb exercise training for COPD (Review)

Mador 2012 (Continued)

Experimental

- *Exercise Prescription*: unsupported (peg board training) and supported (arm ergometry) endurance upper limb exercise. It is not clear what the duration or frequency of training was.

Control

- *Exercise Prescription*: no upper limb exercise except upper limb stretching with and without light weights.

Outcomes

Dyspnoea from questionnaire

- **Outcome type**: continuous outcome
- **Measure names**: "Baseline", "Post-intervention (unclear what time frame)"
- **Scale**: dyspnoea score from Chronic Respiratory Disease Questionnaire

Peak Upper Limb Exercise Capacity: Supported

- **Outcome type**: continuous outcome
- **Measure names**: "Baseline", "Post-intervention (unclear what time frame)"
- **Unit of measure**: power output (watts) from the incremental supported arm exercise test

Endurance Upper Limb Exercise Capacity: Unsupported

- **Outcome type**: continuous outcome
- **Measure names**: "Baseline", "Post-intervention (unclear what time frame)"
- **Scale**: rings moved in 6 mins
- **Unit of measure**: no. of rings

Notes

Abstract only so unclear whether the upper limb training is > 4 weeks duration. Unable to contact authors for further information on duration of training.

COPD: Chronic Obstructive Pulmonary Disease

FEV₁ - forced expiratory volume in one second

L: litres

no.: number

DATA AND ANALYSES

Comparison 1. Upper limb training versus No upper limb training

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Symptoms of Dyspnoea	4	129	Mean Difference (IV, Random, 95% CI)	0.37 [0.02, 0.72]
1.1 Endurance Training	2	55	Mean Difference (IV, Random, 95% CI)	0.41 [-0.13, 0.95]
1.2 Resistance Training	2	74	Mean Difference (IV, Random, 95% CI)	0.34 [-0.11, 0.80]
2 Health-Related Quality of Life	4	126	Std. Mean Difference (IV, Random, 95% CI)	0.05 [-0.31, 0.40]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2.1 Endurance Training	3	82	Std. Mean Difference (IV, Random, 95% CI)	-0.03 [-0.47, 0.42]
2.2 Resistance Training	2	44	Std. Mean Difference (IV, Random, 95% CI)	0.18 [-0.43, 0.79]
3 Peak Upper Limb Exercise Capacity: Supported	3	83	Std. Mean Difference (IV, Random, 95% CI)	0.17 [-0.43, 0.77]
3.1 Endurance Training	3	56	Std. Mean Difference (IV, Random, 95% CI)	0.43 [-0.29, 1.16]
3.2 Resistance Training	2	27	Std. Mean Difference (IV, Random, 95% CI)	-0.36 [-1.24, 0.52]
4 Peak Upper Limb Exercise Capacity: Unsupported	4	112	Mean Difference (IV, Random, 95% CI)	21.23 [-20.45, 62.92]
4.1 Endurance Training	3	69	Mean Difference (IV, Random, 95% CI)	10.29 [-47.37, 67.95]
4.2 Resistance Training	2	43	Mean Difference (IV, Random, 95% CI)	33.22 [-27.12, 93.57]
5 Endurance Upper Limb Exercise Capacity: Supported	2	57	Std. Mean Difference (IV, Random, 95% CI)	0.25 [-0.46, 0.96]
5.1 Endurance Training	2	30	Std. Mean Difference (IV, Random, 95% CI)	0.56 [-0.23, 1.35]
5.2 Resistance Training	2	27	Std. Mean Difference (IV, Random, 95% CI)	-0.08 [-1.35, 1.18]
6 Endurance Upper Limb Exercise Capacity: Unsupported	6	142	Std. Mean Difference (IV, Random, 95% CI)	0.66 [0.19, 1.13]
6.1 Endurance Training	4	85	Std. Mean Difference (IV, Random, 95% CI)	0.99 [0.32, 1.66]
6.2 Resistance Training	3	57	Std. Mean Difference (IV, Random, 95% CI)	0.23 [-0.31, 0.76]
7 Upper Limb Strength	2	43	Std. Mean Difference (IV, Random, 95% CI)	0.25 [-0.39, 0.89]
7.1 Resistance Training	2	43	Std. Mean Difference (IV, Random, 95% CI)	0.25 [-0.39, 0.89]
8 Respiratory Muscle Strength	5	148	Mean Difference (IV, Random, 95% CI)	-1.70 [-8.35, 4.94]
8.1 Endurance Training	4	92	Mean Difference (IV, Random, 95% CI)	-3.41 [-11.02, 4.20]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
8.2 Resistance Training	2	56	Mean Difference (IV, Random, 95% CI)	3.80 [-9.87, 17.46]
9 Physical Activity Level: Subjective	1	43	Mean Difference (IV, Random, 95% CI)	0.0 [-0.30, 0.30]
10 Physical Activity Level: Objective	1	34	Mean Difference (IV, Random, 95% CI)	1.0 [-0.68, 2.68]
11 Activities of Daily Living	1	28	Std. Mean Difference (IV, Random, 95% CI)	0.67 [-0.12, 1.47]
11.1 Endurance Training	1	14	Std. Mean Difference (IV, Random, 95% CI)	0.95 [-0.19, 2.08]
11.2 Resistance Training	1	14	Std. Mean Difference (IV, Random, 95% CI)	0.41 [-0.69, 1.52]
12 Healthcare Utilisation	1	28	Mean Difference (IV, Random, 95% CI)	-0.86 [-3.07, 1.35]

Analysis 1.1. Comparison 1 Upper limb training versus No upper limb training, Outcome 1 Symptoms of Dyspnoea.

Analysis 1.2. Comparison 1 Upper limb training versus No upper limb training, Outcome 2 Health-Related Quality of Life.

Analysis 1.3. Comparison 1 Upper limb training versus No upper limb training, Outcome 3 Peak Upper Limb Exercise Capacity: Supported.

Study or subgroup	Upper Limb Training		Control		Std. Mean Difference	Weight	Std. Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
Test for subgroup differences: $\chi^2=1.87$, $df=1$ ($P=0.17$), $I^2=46.44\%$							

Analysis 1.4. Comparison 1 Upper limb training versus No upper limb training, Outcome 4 Peak Upper Limb Exercise Capacity: Unsupported.

Study or subgroup	Upper Limb Training		Control		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
1.4.1 Endurance Training							
Holland 2004	22	517.3 (142.3)	16	480.3 (118.1)		25.24%	37.05[-45.94,120.04]
McKeough 2012	10	588 (120)	4	612 (114)		9.65%	-24[-158.21,110.21]
Subin 2010	9	263.2 (111.4)	8	272.8 (98.9)		17.38%	-9.53[-109.52,90.46]
Subtotal ***	41		28			52.27%	10.29[-47.37,67.95]
Heterogeneity: $\tau^2=0$; $\chi^2=0.8$, $df=2$ ($P=0.67$); $I^2=0\%$							
Test for overall effect: $Z=0.35$ ($P=0.73$)							
1.4.2 Resistance Training							
Janaudis-Ferreira 2011	13	600 (106)	18	566 (75)		38.45%	34[-33.24,101.24]
McKeough 2012	8	642 (114)	4	612 (114)		9.28%	30[-106.83,166.83]
Subtotal ***	21		22			47.73%	33.22[-27.12,93.57]
Heterogeneity: $\tau^2=0$; $\chi^2=0$, $df=1$ ($P=0.96$); $I^2=0\%$							
Test for overall effect: $Z=1.08$ ($P=0.28$)							
Total ***	62		50			100%	21.23[-20.45,62.92]
Heterogeneity: $\tau^2=0$; $\chi^2=1.09$, $df=4$ ($P=0.9$); $I^2=0\%$							
Test for overall effect: $Z=1$ ($P=0.32$)							
Test for subgroup differences: $\chi^2=0.29$, $df=1$ ($P=0.59$), $I^2=0\%$							

Analysis 1.5. Comparison 1 Upper limb training versus No upper limb training, Outcome 5 Endurance Upper Limb Exercise Capacity: Supported.

Study or subgroup	Upper Limb Training		Control		Std. Mean Difference	Weight	Std. Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
1.5.1 Endurance Training							
McKeough 2012	11	846 (456)	5	426 (222)		25.11%	0.98[-0.14,2.11]
Ries 1988	8	195 (72)	6	181 (75)		27.08%	0.18[-0.88,1.24]
Subtotal ***	19		11			52.19%	0.56[-0.23,1.35]
Heterogeneity: $\tau^2=0.01$; $\chi^2=1.04$, $df=1$ ($P=0.31$); $I^2=3.85\%$							
Test for overall effect: $Z=1.39$ ($P=0.17$)							
1.5.2 Resistance Training							
McKeough 2012	9	654 (408)	4	426 (222)		22.96%	0.58[-0.63,1.79]

Analysis 1.6. Comparison 1 Upper limb training versus No upper limb training, Outcome 6 Endurance Upper Limb Exercise Capacity: Unsupported.

Analysis 1.7. Comparison 1 Upper limb training versus No upper limb training, Outcome 7 Upper Limb Strength.

Analysis 1.8. Comparison 1 Upper limb training versus No upper limb training, Outcome 8 Respiratory Muscle Strength.

Analysis 1.9. Comparison 1 Upper limb training versus No upper limb training, Outcome 9 Physical Activity Level: Subjective.

Analysis 1.10. Comparison 1 Upper limb training versus No upper limb training, Outcome 10 Physical Activity Level: Objective.

Analysis 1.11. Comparison 1 Upper limb training versus No upper limb training, Outcome 11 Activities of Daily Living.

Analysis 1.12. Comparison 1 Upper limb training versus No upper limb training, Outcome 12 Healthcare Utilisation.

Comparison 2. Combined upper limb training and lower limb training versus lower limb training alone

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Symptoms of Dyspnoea	3	86	Mean Difference (IV, Random, 95% CI)	0.36 [-0.04, 0.76]
2 Health-Related Quality of Life	3	95	Std. Mean Difference (IV, Random, 95% CI)	0.01 [-0.40, 0.43]
3 Peak Upper Limb Exercise Capacity: Supported	3	70	Std. Mean Difference (IV, Random, 95% CI)	-0.06 [-0.55, 0.44]
4 Peak Upper Limb Exercise Capacity: Unsupported	3	81	Mean Difference (IV, Random, 95% CI)	13.26 [-39.88, 66.40]
5 Endurance Upper Limb Exercise Capacity: Supported	2	57	Std. Mean Difference (IV, Random, 95% CI)	0.25 [-0.46, 0.96]
6 Endurance Upper Limb Exercise Capacity: Unsupported	3	87	Std. Mean Difference (IV, Random, 95% CI)	0.90 [0.12, 1.68]
7 Upper Limb Strength	1	31	Std. Mean Difference (IV, Random, 95% CI)	0.01 [-0.70, 0.73]
8 Respiratory Muscle Strength	3	70	Mean Difference (IV, Random, 95% CI)	-0.46 [-8.99, 8.07]
9 Activities of Daily Living	1	28	Std. Mean Difference (IV, Random, 95% CI)	0.67 [-0.12, 1.47]

Analysis 2.1. Comparison 2 Combined upper limb training and lower limb training versus lower limb training alone, Outcome 1 Symptoms of Dyspnoea.

Analysis 2.2. Comparison 2 Combined upper limb training and lower limb training versus lower limb training alone, Outcome 2 Health-Related Quality of Life.

Analysis 2.3. Comparison 2 Combined upper limb training and lower limb training versus lower limb training alone, Outcome 3 Peak Upper Limb Exercise Capacity: Supported.

Analysis 2.4. Comparison 2 Combined upper limb training and lower limb training versus lower limb training alone, Outcome 4 Peak Upper Limb Exercise Capacity: Unsupported.

Analysis 2.5. Comparison 2 Combined upper limb training and lower limb training versus lower limb training alone, Outcome 5 Endurance Upper Limb Exercise Capacity: Supported.

Analysis 2.6. Comparison 2 Combined upper limb training and lower limb training versus lower limb training alone, Outcome 6 Endurance Upper Limb Exercise Capacity: Unsupported.

Analysis 2.7. Comparison 2 Combined upper limb training and lower limb training versus lower limb training alone, Outcome 7 Upper Limb Strength.

Analysis 2.8. Comparison 2 Combined upper limb training and lower limb training versus lower limb training alone, Outcome 8 Respiratory Muscle Strength.

Analysis 2.9. Comparison 2 Combined upper limb training and lower limb training versus lower limb training alone, Outcome 9 Activities of Daily Living.

Comparison 3. Upper limb training versus another type of upper limb training intervention

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Health-Related Quality of Life	1	20	Mean Difference (IV, Random, 95% CI)	-5.00 [-20.85, 6.85]
2 Peak Upper Limb Exercise Capacity: Supported	2	37	Std. Mean Difference (IV, Random, 95% CI)	0.36 [-0.29, 1.02]
3 Peak Upper Limb Exercise Capacity: Unsupported	1	18	Mean Difference (IV, Random, 95% CI)	-54.0 [-162.50, 54.50]
4 Endurance Upper Limb Exercise Capacity: Supported	2	37	Std. Mean Difference (IV, Random, 95% CI)	0.64 [-0.03, 1.31]
5 Endurance Upper Limb Exercise Capacity: Unsupported	1	17	Mean Difference (IV, Random, 95% CI)	6.00 [0.29, 11.71]
6 Respiratory Muscle Strength	1	20	Mean Difference (IV, Random, 95% CI)	-15.0 [-28.21, -1.79]
7 Activities of Daily Living	1	17	Mean Difference (IV, Random, 95% CI)	27.0 [-148.71, 202.71]

Analysis 3.1. Comparison 3 Upper limb training versus another type of upper limb training intervention, Outcome 1 Health-Related Quality of Life.

Analysis 3.2. Comparison 3 Upper limb training versus another type of upper limb training intervention, Outcome 2 Peak Upper Limb Exercise Capacity: Supported.

Analysis 3.3. Comparison 3 Upper limb training versus another type of upper limb training intervention, Outcome 3 Peak Upper Limb Exercise Capacity: Unsupported.

Analysis 3.4. Comparison 3 Upper limb training versus another type of upper limb training intervention, Outcome 4 Endurance Upper Limb Exercise Capacity: Supported.

Analysis 3.5. Comparison 3 Upper limb training versus another type of upper limb training intervention, Outcome 5 Endurance Upper Limb Exercise Capacity: Unsupported.

Analysis 3.6. Comparison 3 Upper limb training versus another type of upper limb training intervention, Outcome 6 Respiratory Muscle Strength.

Analysis 3.7. Comparison 3 Upper limb training versus another type of upper limb training intervention, Outcome 7 Activities of Daily Living.

APPENDICES

Appendix 1. Sources and search methods for the Cochrane Airways Group Specialised Register (CAGR)

Electronic searches: core databases

Database	Frequency of search
CENTRAL (<i>The Cochrane Library</i>)	Monthly
MEDLINE (Ovid)	Weekly
Embase (Ovid)	Weekly
PsycINFO (Ovid)	Monthly
CINAHL (EBSCO)	Monthly
AMED (EBSCO)	Monthly

Handsearches: core respiratory conference abstracts

Conference	Years searched
American Academy of Allergy, Asthma and Immunology (AAAAI)	2001 onwards
American Thoracic Society (ATS)	2001 onwards

(Continued)

Asia Pacific Society of Respiriology (APSR)	2004 onwards
British Thoracic Society Winter Meeting (BTS)	2000 onwards
Chest Meeting	2003 onwards
European Respiratory Society (ERS)	1992, 1994, 2000 onwards
International Primary Care Respiratory Group Congress (IPCRG)	2002 onwards
Thoracic Society of Australia and New Zealand (TSANZ)	1999 onwards

MEDLINE search strategy used to identify trials for the CAGR

COPD search

1. Lung Diseases, Obstructive/
2. exp Pulmonary Disease, Chronic Obstructive/
3. emphysema\$.mp.
4. (chronic\$ adj3 bronchiti\$).mp.
5. (obstruct\$ adj3 (pulmonary or lung\$ or airway\$ or airflow\$ or bronch\$ or respirat\$)).mp.
6. COPD.mp.
7. COAD.mp.
8. COBD.mp.
9. AECB.mp.
10. or/1-9

Filter to identify RCTs

1. exp "clinical trial [publication type]"/
2. (randomised or randomised).ab,ti.
3. placebo.ab,ti.
4. dt.fs.
5. randomly.ab,ti.
6. trial.ab,ti.
7. groups.ab,ti.
8. or/1-7
9. Animals/
10. Humans/
11. 9 not (9 and 10)
12. 8 not 11

The MEDLINE strategy and RCT filter are adapted to identify trials in other electronic databases.

Appendix 2. Search strategy to identify relevant trials from the CAGR

#1 MeSH DESCRIPTOR Pulmonary Disease, Chronic Obstructive Explode All

#2 MeSH DESCRIPTOR Bronchitis, Chronic

#3 (obstruct*) near3 (pulmonary or lung* or airway* or airflow* or bronch* or respirat*)

#4 COPD:MISC1

#5 (COPD OR COAD OR COBD):TI,AB,KW

#6 #1 OR #2 OR #3 OR #4 OR #5

#7 MeSH DESCRIPTOR Upper Extremity Explode All

#8 arm*:ti,ab,kw

#9 upper NEXT (limb* or upper-limb*)

#10 upper NEXT (extremity* or upper-extremity*)

#11 #7 or #8 or #9 or #10

#12 #6 and #11

#13 MeSH DESCRIPTOR Physical Therapy Modalities Explode All

#14 MeSH DESCRIPTOR Rehabilitation Explode All

#15 rehabilitat* or fitness* or exercis* or physical* or train* or physiotherap*

#16 #13 or #14 or #15

#17 #12 and #16

[NOTE: in search line #4, MISC1 denotes the field in which the reference is coded for condition, in this case, COPD]

CONTRIBUTIONS OF AUTHORS

Coordinated the review: Zoe J McKeough.

Undertook literature searches: Zoe J McKeough with support from the Airways editorial team.

Retrieval of papers: Zoe J McKeough and Marcelo Velloso.

Screened retrieved papers against eligibility criteria: Zoe J McKeough and Marcelo Velloso.

Appraised quality of papers: Zoe J McKeough and Vanessa Pereira de Lima.

Extracted data from papers: Zoe J McKeough and Vanessa Pereira de Lima.

Wrote to authors of papers for additional information: Zoe J McKeough and Marcelo Velloso.

Data management for the review: Zoe J McKeough and Vanessa Pereira de Lima.

Entered data into RevMan: Zoe J McKeough and Vanessa Pereira de Lima.

Analysed data: Zoe J McKeough and Jennifer A Alison.

Interpreted data: Zoe J McKeough and Jennifer A Alison.

Wrote the review: Zoe J McKeough, Marcelo Velloso, Vanessa Pereira de Lima, Jennifer A Alison.

Served as a guarantor of the review: Zoe J McKeough.

DECLARATIONS OF INTEREST

Zoe J McKeough and Jennifer A Alison conducted a randomised controlled trial of upper limb exercise training in people with COPD that was included in this review (McKeough 2012).

Marcelo Velloso and Vanessa Pereira de Lima: none known

SOURCES OF SUPPORT

Internal sources

- The University of Sydney, Australia.

Resources to assist with article searches, provision of computer equipment

External sources

- Vanessa Pereira de Lima, Brazil.

Scholarship from CAPES Foundation Brazil

- Marcelo Velloso, Brazil.

Scholarship from CNPq Brazil

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

We added a point of detail to comparison 1 which had not been indicated in the protocol, this being that studies of upper limb training in which participants also performed lower limb training (in the intervention and control group) could be included in this comparison. This allowed all studies which have ever examined upper limb training versus no upper limb training to be grouped together for examination of the effects on outcomes. We also created a sub-grouping for comparison 1, being those studies which examined endurance upper limb training only and those studies which examined resistance upper limb training only. A 'Summary of findings' table for comparison 1 only was generated which had not been specified in the protocol.

We also used Covidence software to record study characteristics and outcome data, which was not specified in the protocol. In addition, there has also been some further clarification provided to the secondary outcomes in the review which did not appear in the protocol. The measures of peak upper limb exercise capacity and endurance upper limb exercise capacity have been subdivided into 'supported' and 'unsupported' categories.

INDEX TERMS

Medical Subject Headings (MeSH)

*Arm; Dyspnea [etiology] [*rehabilitation]; Exercise Therapy [*methods]; Muscle Strength; Pulmonary Disease, Chronic Obstructive [complications] [*rehabilitation]; Quality of Life; Randomized Controlled Trials as Topic

MeSH check words

Humans