

doi: 10.4081/monaldi.2026.3735

SUPPLEMENTARY MATERIAL

**Efficacy of positive expiratory pressure in the prevention and treatment of postoperative pulmonary complications following thoracic and abdominal surgery.
A systematic review and meta-analysis**

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Key words: positive expiratory pressure, postoperative pulmonary complications, thoracic surgery, abdominal surgery.

Supplementary Table 1. Search strings.

Search string	Search engine
("Coronary Artery Bypass, Off-Pump" OR "Coronary Artery Bypass" OR "Thoracic Surgery" OR "Thoracic Surgery, Video-Assisted" OR "Surgical Procedures, Operative" OR "heart surgery" OR "lung surgery" OR "pleuro-pulmonary surgery" OR "cardiac surgery" OR "pulmonary surgery" OR "chest surgery" OR "abdominal surgery" OR "thoracic surgery" OR "thoracoabdominal resection") AND ("Postoperative Care" OR "Breathing Exercises" OR "positive expiratory pressure" OR "PEP" OR "bottle" OR "chest physiotherapy" OR "blow bottle" OR "bubble PEP" OR "Positive-Pressure Respiration" OR "water bottle PEP" OR "blow bottle-device" OR "mask physiotherapy") AND ("Postoperative Complications" OR "postoperative pulmonary complications" OR "post-operative pulmonary complications" OR "PPCs" OR "PPC" OR "lung recovery" OR "pulmonary function" OR "pulmonary complication" OR "pulmonary complications")	Original string
("Coronary Artery Bypass, Off-Pump"[Mesh] OR "Coronary Artery Bypass"[Mesh] OR "Thoracic Surgery"[Mesh] OR "Thoracic Surgery, Video-Assisted"[Mesh] OR "Surgical Procedures, Operative"[Mesh] OR "heart surgery"[Title/Abstract] OR "lung surgery"[Title/Abstract] OR "pleuro-pulmonary surgery"[Title/Abstract] OR "cardiac surgery"[Title/Abstract] OR "pulmonary surgery"[Title/Abstract] OR "chest surgery"[Title/Abstract] OR "abdominal surgery"[Title/Abstract] OR "thoracic surgery"[Title/Abstract] OR "thoracoabdominal resection"[Title/Abstract]) AND ("Postoperative Care"[Mesh] OR "Breathing Exercises"[Mesh] OR "positive expiratory pressure"[Title/Abstract] OR "PEP"[Title/Abstract] OR "bottle"[Title/Abstract] OR "chest physiotherapy"[Title/Abstract] OR "blow bottle"[Title/Abstract] OR "bubble PEP"[Title/Abstract] OR "Positive-Pressure Respiration"[Mesh] OR "water bottle PEP"[Title/Abstract] OR "blow bottle-device"[Title/Abstract] OR "mask physiotherapy"[Title/Abstract]) AND ("Postoperative Complications"[Mesh] OR "postoperative pulmonary complications"[Title/Abstract] OR "post-operative pulmonary complications"[Title/Abstract] OR "PPCs"[Title/Abstract] OR "PPC"[Title/Abstract] OR "lung recovery"[Title/Abstract] OR "pulmonary function"[Title/Abstract] OR "pulmonary complication"[Title/Abstract] OR "pulmonary complications"[Title/Abstract])	PubMed
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Supplementary Table 2. Overview of studies included in the systematic review.

Author (Year) and Country	Total participants (experimental/control) + mean age and gender	Type of surgical intervention	PEP device used	Comparator	Duration, frequency, and treatment modality	Follow-up	Primary outcome (a) + secondary outcome (b) + (evaluation method)
Rotolo et al., (2021) Italy	50 (26 E - 24 C) Mean age: - 67 ± 9 (E) - 68 ± 8 (C) 17 M - 9 F (E) 14 M - 10 F (C)	Pulmonary lobectomy for cancer	PEP bottle	EFA device (Expiratory Flow Accelerator)	20 min, 3 times per day for 7 days, expiration against resistance in a water bottle	7 days	- Prevalence of PPC (a) (Melbourne Group Scale) - Length of hospital stay (a) (hospital record)
Westerdahl et al., (2005) Sweden	90 (48 E - 42 C) Mean age: - 66 ± 9 (E) - 65 ± 9 (C) 36 M - 12 F (E) 31 M - 11 F (C)	Coronary artery bypass surgery	PEP blow bottle	No breathing exercises	30 deep and slow breaths performed with a PEP blow-bottle device at 10 cm H ₂ O, hourly during the day for 4 days	4 days	- Atelectasis (a) (assessed via spiral CT) - Pulmonary function (a) (spirometry)
Westerdahl et al., 2001 Sweden	98 (36 E - 30 C1 - 32 C2) Mean age: - 66 ± 9 (E) - 66 ± 9 (C1) - 64 ± 9 (C2) 22 M - 14 F (E) 20 M - 10 F (C1) 21 M - 11 F (C2)	Coronary artery bypass surgery	PEP blow bottle	IR-PEP (C1) and Deep breathing (without device) (C2)	30 deep and slow breaths performed with a PEP blow-bottle device at 10 cm H ₂ O, hourly during the day for 4 days	4 days	- Reduction of lung capacity (a) (VC, FEV1, TLC) - Atelectasis (a) (chest X-ray) - Pleural effusion (a) (chest X-ray)
Frølund et al., (1986) Denmark	75 (35 E - 40 C) Mean age: - 56 (E) - 62 (C) 27 M - 8 F (E) 32 M - 8 F (C)	Thoracotomy	Self-administered PEP mask	Face-mask without resistance	10 minutes every hour during the day for 3 postoperative days	3 days	- Atelectasis (a) (chest X-ray) - PaO ₂ (a) (arterial blood gas analysis)
Christensen et al., (1991) Denmark	51 (17 E - 17 C1 - 17 C2) Mean age: - 64 (S) - 62 (C1) - 64 (C2)	Upper abdominal surgery	PEP mask	Conventional respiratory physiotherapy (C1) and inspiratory resistance (C2)	2 minutes with expiratory resistance of 5-15 cm H ₂ O, diaphragmatic breathing exercises twice a day for 3 days	3 days	- Prevalence of PPC (a) (chest X-ray), - FVC, FEV1, PaO ₂ , Sao ₂ (a) (spirometry and arterial blood gas analysis)

	8 M - 9 F (S) 5 M - 12 F (C1) 3 M - 14 F (C2)						
Pieczkoski et al., (2021) Brasil	48 (16 E - 16 C1 - 16 C2) Mean age: - 61 ± 9 (E) - 65 ± 8 (C1) - 62 ± 10 (C2) 11 M - 5 F (E) 11 M - 5 F (C1) 16 M - 0 F (C2)	Cardiac surgery (CABG or valve replacement)	PEP blow-bottle device + conventional physiotherapy	EPAP + conventional physiotherapy (C1) and conventional physiotherapy (C2)	Three sets of 10 repetitions for each technique, twice a day for the first 3 days	3 days	- Pulmonary function (a) (spirometry) - Respiratory muscle strength (b) (manovacuometry) - Pulmonary complications (b) (X-rays) - Duration of stay in intensive care and hospital (b)
Ricksten et al., (1986) Sweden	43 (15 E - 13 C1 - 15 C2) Mean age: - 57 (E) - 53 (C1) - 52 (C2) 8 M - 7 F (E) 7 M - 6 F (C1) 6 M - 9 F (C2)	Upper abdominal surgery	PEP mask	CPAP (C1) and Deep breathing (with 'Tiiflo' device) (C2)	30 breaths performed with a PEP mask device at 10/15 cm H ₂ O, every hour during the day for 3 days	3 days	- Atelectasis (a) (chest X- ray) - Alveolar-arterial oxygen gradient (a) (blood gas analysis) - PaO ₂ , FVC, PEF (a) (spirometry and arterial blood gas analysis)
Fagevik Olsä n et al., (2002) Sweden	70 (36 E - 34 C) Mean age: - 64 (E) - 62 (C) 31 M - 5 F (E) 29 M - 5 F (C)	Thoraco- abdominal resection for cancer	IR-PEP (Inspiratory Resistance-PEP)	CPAP	30 breaths against expiratory resistance (10 cm H ₂ O) and inspiratory resistance (5 cm H ₂ O) every 2 hours during the day for 3 days	3 days	- Need for reintubation (a) - FVC and PEF (a) (spirometry) - PaO ₂ (a) (blood gas analysis) - SpO ₂ (a) (pulse oximetry)
Fagevik Olsä n et al., (1997) Sweden	353 (174 E - 179 C) Mean age: - 53 (E) - 52 (C) 72 M - 102 F (E) 86 M - 108 F (C)	Major abdominal surgery	PEP mask	No treatment until the onset of pulmonary complications	30 deep breaths performed with a PEP mask device (10 cm H ₂ O expiratory and 5 cm H ₂ O inspiratory resistance) every hour during the day for 6 days	6 days	- FVC and PEFR (a) (spirometry) - Pulmonary complications (a) (chest X-ray)
Richter Larsen et al., (1995) Denmark	66 (28 E - 24 C1 - 14 C2) Mean age: N.I. All participants were male.	Coronary artery bypass surgery	PEP mask	IR-PEP and no treatment (control group)	PEP device treatment (10/15 cm H ₂ O) for 5 minutes per hour during waking hours	6 days	- PaO ₂ (a) (blood gas analysis) - FVC and PEFR (a)

							(spirometry) - Atelectasis (a) (chest X-ray)
Westerdahl et al., (2003) Sweden	61 (20 E - 20 C1 - 21 C2) Mean age: - 64 ± 8 (E) - 64 ± 10 (C1) - 66 ± 9 (C2) 16 M - 4 F (E) 15 M - 5 F (C1) 18 M - 3 F (C2)	Coronary artery bypass surgery	Blow bottle PEP	IR-PEP (C1) and Deep breathing without device (C2)	Three sets of 10 deep breaths performed with a Blow Bottle PEP device (10 cm H ₂ O), with a 30–60 second pause between sets	2 days	- Reduction in atelectasis area (a) (CT scan) - Increase in aerated lung area - PaO ₂ (a) (blood gas analysis)
Ingwersen et al., (1993) Denmark	160 participants (N.I. PEP, CPAP, IR-PEP) N.I. (Mean age and sex)	Cardiac and thoracic surgery	PEP mask	IR-PEP and CPAP	5 minutes of PEP mask device use (10/15 cm H ₂ O) every hour during waking hours	9 days	- FVC (a) (spirometry) - PaO ₂ (a) (blood gas analysis) - Atelectasis (a) (chest X-ray)

CABG, coronary artery bypass grafting; CPAP, continuous positive airway pressure; CT, computed tomography; EFA, expiratory flow accelerator; EPAP, expiratory positive airway pressure; FEV₁, forced expiratory volume in 1 second; FRC, functional residual capacity; FVC, forced vital capacity; IR-PEP, inspiratory resistance–positive expiratory pressure; PaO₂, arterial partial pressure of oxygen; PEF_R, peak expiratory flow rate; PEP, positive expiratory pressure; PPC, postoperative pulmonary complications; SaO₂, arterial oxygen saturation; SpO₂, peripheral oxygen saturation (pulse oximetry); TLC, total lung capacity; C1/C2, study-specific comparator group labels as reported by the original authors.