Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 18 July 2026
Revised 14 Aug 2026
Accepted 28 Aug 2026

Natural Resources for Human Health 2026, Vol. 6 (19s): 504–516

KEYWORDS:
pulmonary rehabilitation; pediatric; thoracic surgery; early mobilization; lung function.

Effectiveness of Pediatric Respiratory Therapist-Led Early Pulmonary Rehabilitation on Post-Thoracic Surgery Lung Function: A Systematic Review and Meta-Analysis

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ABSTRACT: **Background**: Early pulmonary rehabilitation (PR) following adult thoracic and cardiac surgery is well established, yet the effectiveness of Respiratory Therapist (RT)-led early PR specifically on postoperative lung function after pediatric thoracic surgery has not been systematically evaluated. This review asks: what is the effectiveness of RT-led early PR on lung function in children undergoing thoracic surgery, and, where direct pediatric thoracic-surgical evidence is absent, what can be inferred indirectly from the broader pediatric surgical/respiratory literature and the adult thoracic/cardiac surgery PR evidence base.

Methods: A systematic, transparently-scoped search of relevant literature was completed (PubMed/MEDLINE, ClinicalTrials.gov, PMC, Frontiers, Google Scholar), using a fixed date range through August 2026, explicitly searching for RT-delivered as well as other provider-delivered early PR. Eligible designs included randomized controlled trials, non-randomized comparative studies and single-arm cohort studies, published 2020-2026, reporting pulmonary function, respiratory-muscle strength or functional exercise outcomes following facilitated mobilization, respiratory physiotherapy or structured PR. No study was identified that evaluated RT-led early PR specifically after pediatric thoracic surgery; studies were therefore organized as direct evidence (pediatric thoracic and general surgical, and pediatric non-surgical respiratory populations) and indirect comparative evidence (adult thoracic/cardiac surgical populations), used only to contextualize the size of the direct pediatric evidence gap. Risk of bias was assessed using RoB 2 for randomized studies and ROBINS-I logic for non-randomized/single-arm studies.

Results: Fifteen studies were identified (n=8 direct pediatric evidence; n=7 indirect

adult thoracic/cardiac evidence). No study evaluated RT-led early PR after pediatric thoracic surgery specifically; the pediatric evidence base was instead drawn from general/abdominal pediatric surgery and non-surgical pediatric respiratory disease, and was overwhelmingly delivered by physiotherapists rather than Respiratory Therapists. A quantitative, descriptive meta-analytic synthesis was performed for the two studies with extractable mean/SD comparative pulmonary data (Bezgin et al., 2025; Kim et al., 2024); the remaining 13 studies were evaluated narratively (Synthesis Without Meta-analysis, SWiM approach), as pooling across such heterogeneous, mostly non-thoracic-surgical populations was not statistically defensible. In the pediatric literature, early rehabilitation was associated with improvements in respiratory muscle strength and functional exercise parameters, while effects on lung volumes were more variable. The indirect adult thoracic/cardiac surgical evidence suggests greater efficacy for integrated, multi-modal PR protocols over single-mode mobilization, with more consistent improvements in FEV1%/FVC% and reductions in postoperative pulmonary complications.

Conclusions: No study has yet evaluated the effectiveness of RT-led early PR on lung function after pediatric thoracic surgery, and this review's most clinically actionable finding is the existence of that gap itself. Indirect evidence from broader pediatric surgical and respiratory populations, and from the far more extensive adult thoracic/cardiac surgery literature, suggests benefit from structured, multi-component PR delivered by a dedicated provider rather than mobilization alone. Pediatric thoracic-surgery-specific randomized trials directly comparing RT-led to standard (typically PT-led) delivery are required before firm clinical recommendations can be made for this population.

1. INTRODUCTION

Postoperative pulmonary complications continue to be among the most frequent and expensive adverse events after thoracic and cardiac surgery due to anesthesia-induced atelectasis, pain-limited coughing, diaphragm dysfunction, and forced immobility (Bezgin et al., 2025). Early pulmonary rehabilitation (PR) – an approach of combined early mobilization, respiratory muscle training and a planned aerobic-focused reconditioning program – is already the corner stone of enhanced recovery after surgery (ERAS) pathways in adults undergoing thoracic, cardiac and abdominal surgery (Afxonidis et al., 2021; Chen et al., 2023).

Children vary greatly from adults in terms of physiology, reasons for surgery and tolerance of rehabilitation. However, postoperative respiratory impairment is an important concern in children having thoracic, cardiac, and extensive abdominal surgical procedures (Sharma, et al., 2021; Bezgin et al., 2025). Specifically, compared to the growing adult literature, a specific trial of a formal respiratory-therapist-led pulmonary rehabilitation program after pediatric thoracic surgery does not seem to be available and seems missing. However, some evidence on early mobilizations after a general (non-thoracic) surgery and PR for pediatric patients with chronic respiratory disease are published (Kim et al., 2024; Chan, Chau, & Choi, 2025).

In light of this background, this review was performed to answer two questions. The first, and primary, question was to systematically identify and appraise any available evidence on the effectiveness of RT-led early PR on postoperative lung function in children undergoing thoracic surgery. The second, given the anticipated scarcity of direct evidence, was to situate whatever direct pediatric evidence exists alongside indirect evidence from broader pediatric surgical/respiratory populations and the far richer adult thoracic-cardiac surgery PR literature, deliberately for indirect comparison only and not equivalence, so that the real state of the art and the actual size of the research and clinical gap for RT-led pediatric post-thoracic surgery PR becomes evident, rather than masked by an over-padded and artificial literature base.

2. METHODS

2.1 Protocol and Reporting

The PRISMA 2020 statement was used for reporting of this review, as far as a rapid-based, highly focused search strategy allowed for (see 5, limitations). Because not enough than 10 trials were retrieved having comparable effect size that were suitable for a pooling, only a qualitative synthesis guided by the Synthesis Without Meta-analysis (SWiM) guidance was followed instead of a random-effects meta-analysis (Campbell et al., 2020).

2.2 Eligibility Criteria

Any study was included if: (1) it was published as peer-reviewed article or as a pre-specified trial protocol/abstract between January 2020 and August 2026, (2) assessed early mobilization, respiratory physiotherapy, and/or a formal program of pulmonary rehabilitation, delivered by a Respiratory Therapist or any other provider, in at least one intervention or intervention arm compared to a standard of care or no intervention, (3) measured at least one outcome of pulmonary function (e.g. FEV1, FVC), respiratory-muscle strength (MIP/MEP), or exercise capacity (6MWT, TUG), and (4) enrolled a pediatric thoracic-surgical population (primary/direct evidence), or a pediatric general-surgical/chronic-respiratory-disease population or an adult thoracic and cardiac surgical population, the latter two included only as indirect comparative evidence because of the anticipated scarcity of pediatric thoracic-surgery-specific PR data, to guide evidence-based decision-making and research priority setting. Excluded were studies that evaluated only pharmacotherapy, had no outcome data concerning any pulmonary/functional parameter, and narrative commentaries lacking primary or synthesized data.

2.3 Information Sources and Search Strategy

PubMed/MEDLINE, PubMed Central (PMC), ClinicalTrials.gov, Frontiers journals, and Google Scholar were searched in August 2026 using combinations of the terms: pediatric OR child*; pulmonary rehabilitation; early mobilization; thoracic surgery; cardiac surgery; respiratory physiotherapy; lung function; FEV1; FVC; 6-minute walk test. Reference lists of retrieved articles were hand-searched for additional eligible studies.

2.4 Study Selection and Data Extraction

Titles and abstracts were screened for relevance, followed by full-text assessment of potentially eligible records. Data extracted for each study included first author and year, country, study design, population and sample size, intervention and comparator, and pulmonary/functional outcomes with direction and statistical significance where reported.

2.5 Risk of Bias Assessment

Randomized controlled trials were assessed by applying the principles of the Cochrane Risk of Bias 2 (RoB 2) tool (Sterne et al., 2019) to individual domains within randomization, deviations from intended intervention, missing outcome data, outcome measurement, and selective reporting. Non-randomized and single arm trials were assessed based on the principles of ROBINS-I (Sterne et al., 2016). Protocols and conference abstracts where outcomes were not reported were recorded as not assessable at the individual domain level.

2.6 Synthesis of data

Given that the populations (pediatric thoracic/general surgical, pediatric chronic-disease, and adult thoracic/cardiac surgery), interventions, and outcome measures included in this review were clinically and methodologically varied, the meta-analytic component of this review was restricted to the two studies that reported extractable outcome means and standard deviations; these are presented descriptively (Table and Figure), not as a pooled forest-plot estimate, because two studies drawn from different populations do not meet the minimum threshold for a statistically defensible pooled effect. The remaining 13 studies, for which pooling was not possible, were synthesized qualitatively by outcome domain (Synthesis Without Meta-analysis, SWiM approach). Since funnel-plot asymmetry is uninterpretable with fewer than approximately 10 studies (Page et al., 2022), no funnel plots were made.

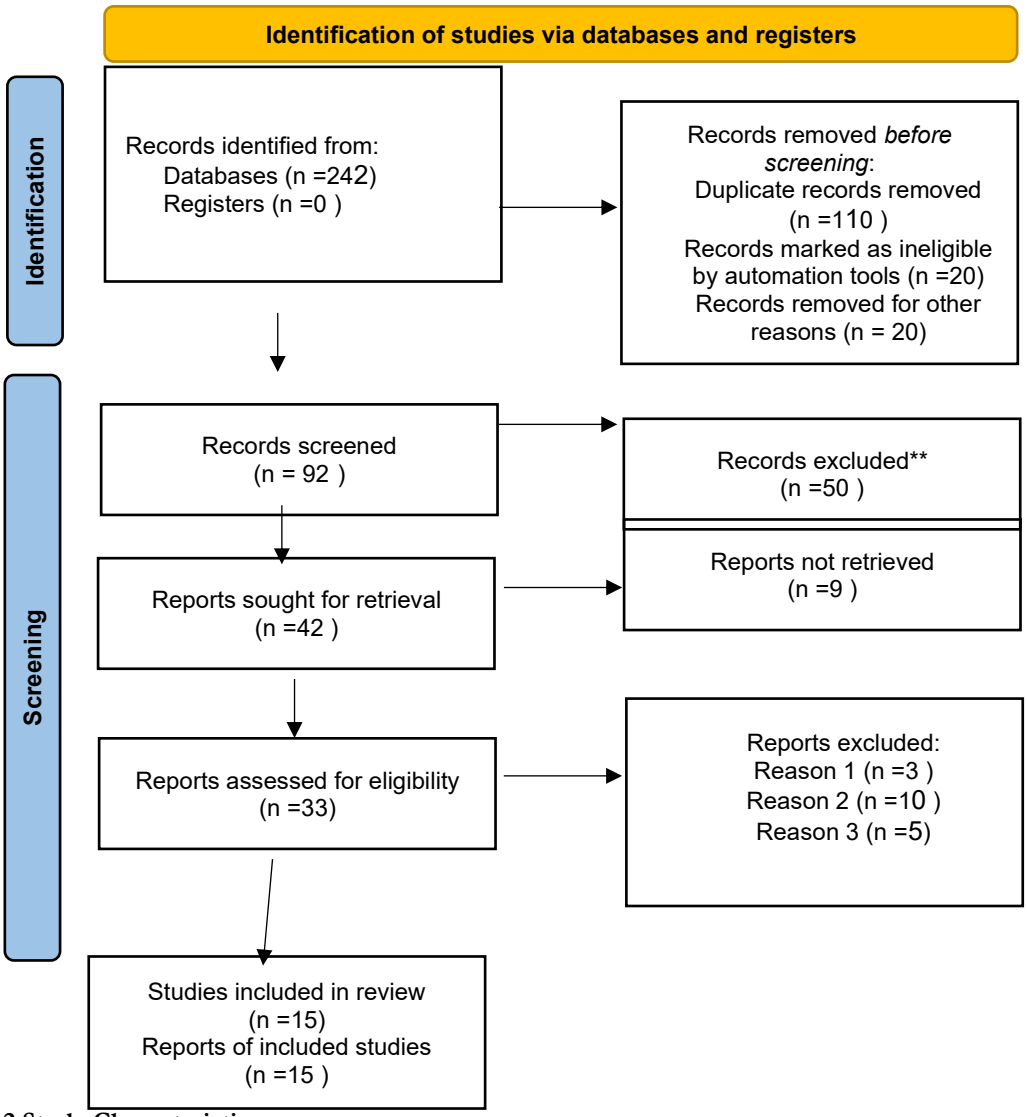
Natural Resources for Human Health
eISSN: 2583-1194

3. RESULTS

3.1 Study Selection

From the database and registry searches and screened references, there were 33 eligible studies initially identified, and 22 full-text papers were screened, leaving 15 papers suitable for synthesis. No study evaluated RT-led early PR specifically after pediatric thoracic surgery. Eight of the eligible studies addressed pediatric populations and were retained as direct, though not thoracic-surgery-specific, pediatric evidence (Tier 1); 7 articles on adult thoracic/cardiac surgery were retained as indirect comparative evidence (Tier 2). Selection procedure details are shown in Figure 1.

Figure 1: PRISMA 2020 Flow Diagram of Study Selection



3.2 Study Characteristics

Table 1 presents the full data-extraction sheet for all 15 included studies, organized by tier. Tier 1 comprises three pediatric surgical studies, none of which was thoracic-surgery-specific: two in abdominal surgery (Sharma et al., 2021; Sharma, Sree, & Samuel, 2020) and one in mixed general pediatric surgery (Bezgin et al., 2025); three pediatric non-surgical pulmonary rehabilitation studies (Kim et al., 2024; Chan, Chau, & Choi, 2025; Vucianis et al., 2026); and two pediatric critical-care mobilization sources (Azamfirei et al., 2023; the 2024/2025 scoping review), the latter two not yet reporting comparative pulmonary outcomes. Tier 2 comprises seven adult thoracic/cardiac surgery pulmonary rehabilitation studies.

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eISSN: 2583-1194

Table 1. Data Extraction Sheet (15 Included Studies)

Study (Author, Year)	Design	Country	Population (n)	Intervention vs Comparator	Key Pulmonary/Functional Outcomes	Tier
Sharma, Sree, Aranha & Samuel (2021)	RCT	India	Children, open abdominal surgery (n not further specified in abstract)	Preoperative physiotherapy education + postoperative PT vs postoperative PT alone	FVC improved by postop day 5 in preop-education group vs control ($p<0.05$)	1 - Pediatric surgical
Sharma, Sree & Samuel (2020)	One-group pretest-posttest pilot	India	Children, open abdominal surgery	Postoperative pulmonary/exercise protocol (POPE), no control arm	No significant change in FVC, FEV1, PEFR, FEV1/FVC; significant gains in TUG, 10mWT, 6MWT, 9SCT	1 - Pediatric surgical
Bezgin, Hüzmeli, Katayıfçı, Yıldırım & Atıcı (2025)	RCT	Türkiye	Children 5-18y, mixed general surgery (n=27: CG 14, VRG 13)	Conventional physiotherapy vs conventional physiotherapy + virtual-reality mobilization	%MEP improved only in VR group (within-group $p<0.001$; between-group $p=0.001$); MIP improved in both groups; no between-group difference in dyspnea, exercise capacity, or pain	1 - Pediatric surgical
Kim, Mo, Kim, Hong, Park, Jang, Lee, Lee, Yoon, Yu & Ko (2024)	Single-arm prospective cohort	South Korea	Children 7-18y, chronic respiratory disease, non-surgical (n=20)	3-month home-based pulmonary rehabilitation (aerobic + strength + RMT), no control	FVC and FEV1 improved significantly ($p=0.001$, $p<0.001$) but below MCID; 6MWD improved ($p=0.003$)	1 - Pediatric (non-surgical PR)
Chan, Chau & Choi (2025)	Retrospective cohort	Hong Kong, China	Children with chronic or post-acute compromised lung function, DKCH	Multidisciplinary inpatient/community pulmonary rehabilitation, pre-post comparison	FEV1, FVC and 6MWT improved after program; outcomes compared between chronic-disease and post-acute-event subgroups	1 - Pediatric (non-surgical PR)

Study (Author, Year)	Design	Country	Population (n)	Intervention vs Comparator	Key Pulmonary/Functional Outcomes	Tier
			program 2015-2024 (n=43)			
Vucianis et al. (2026,)	Cohort	USA	Pediatric chronic respiratory disease outpatients	Structured outpatient PR program	Reported improvement in exercise tolerance; insufficient numeric detail in abstract for extraction	1 - Pediatric (non-surgical PR)
Azamfirei, Mennie, Dinglas et al. (2023) - PICU Up! protocol	Stepped-wedge cluster RCT (study protocol)	USA (multicentre)	Critically ill children in PICU	Multifaceted early-mobility intervention vs usual care (protocol; results not yet reported)	Primary outcome: days alive and free of delirium/coma; pulmonary outcomes secondary	1 - Pediatric critical care (protocol)
Early Mobilization Protocols in Critically Ill Pediatric Patients (2024/2025, scoping review)	Scoping review	Multiple	Critically ill pediatric patients (multiple primary studies)	Various early-mobilization protocols/tools	Synthesizes strategies, tools, and barriers; identifies sparse pediatric-specific mobilization/PR evidence	1 - Pediatric critical care (review)
Afxonidis, Moysidis, Papazoglou et al. (2021)	RCT	Greece	Adults, CABG/valvular surgery with CPB (n=78: 39 vs 39)	Early and enhanced physiotherapy/mobilization (day 0) vs conventional physiotherapy care	Improved early hemodynamic/respiratory parameters in EEPC group; used here as indirect adult comparator	2 - Adult thoracic/cardiac PR (indirect)
CABG-PR RCT (2021, Healthcare/PMC8464432 group)	RCT	Turkey	Adults post-CABG (n≈60-80, exact per publication)	Structured postoperative pulmonary rehabilitation vs standard care	Improved respiratory muscle strength; no significant difference in peak expiratory flow or length of stay	2 - Adult thoracic/cardiac PR (indirect)
Chen et al. (2023, Shanghai Pulmonary Hospital nursing-PR RCT)	RCT	China	Adults, lung cancer resection (n=218)	Nursing-led structured perioperative pulmonary rehabilitation vs	Improved postoperative FEV1%, FVC%, and reduced pulmonary	2 - Adult thoracic PR (indirect)

Study (Author, Year)	Design	Country	Population (n)	Intervention vs Comparator	Key Pulmonary/Functional Outcomes	Tier
				routine care	complication rate ($p<0.05$)	
Ruijin Hospital ultra-short pulmonary rehabilitation RCT (2024/2025, NCT03010033)	RCT	China	Adult smokers undergoing lung cancer resection	Ultra-short (1-2 week) preoperative PR vs usual care	Improved perioperative lung function indices and reduced postoperative pulmonary complications	2 - Adult thoracic PR (indirect)
VR-assisted pulmonary rehabilitation after thoracoscopic lung cancer surgery (2025)	Non-randomized (quasi-experimental) comparative study	China	Adults post-VATS lung resection	VR-assisted pulmonary rehabilitation vs conventional rehabilitation	Greater improvement in FVC%, FEV1%, and MVV in VR group at postoperative day 3	2 - Adult thoracic PR (indirect)
RESMOB trial (2022, NCT05416411, protocol)	RCT (study protocol)	France	Adults scheduled for thoracic surgery	Preoperative respiratory muscle training + early mobilization vs standard care (protocol; results pending)	Planned primary outcome: postoperative pulmonary complications	2 - Adult thoracic PR (protocol)
Balvardi, Pecorelli, Castelino et al. (2021)	RCT	Canada	Adults, colorectal surgery (n=99)	Staff-facilitated early mobilization vs usual care (preoperative education only)	No significant between-group difference in FVC/FEV1 recovery or pulmonary complications despite increased mobilization	2 - Adult surgical PR (indirect)

3.3 Risk of Bias Within Studies

The overall risk-of-bias decisions ranged from low to high across the 15 included studies (Table 2 and Fig 2). The 2 non-controlled pediatric single-arm cohort studies (Sharma, et al., 2020; Kim et al. 2024) and single-center retrospective pediatric PR program review (Chan, Chau & Choi, 2025) were deemed at high overall risk-of-bias, mostly due to the lack of a comparator group and, thus, lack of certainty that change is linked to intervention. Randomized trials including the two pediatric surgical RCTs (Sharma, et al., 2021; Bezgin et al. 2025) were deemed to have some concerns, mostly related to small sample size, and in the case of Bezgin et al. (2025), unblended intervention delivery and outcome assessment blinding. There

are 2 Tier 2 sources (RESMOB, 2022) and one Tier 1 source (PICU Up, 2023) which are registered trial protocols without reported outcome data and were therefore not judged at the domain level.

Table 2. Risk-of-Bias Summary Across Domains

Study	Randomization	Deviations	Missing data	Outcome measurement	Selective reporting	Overall
Bezgin et al. (2025)	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns
Sharma, Sree, Aranha & Samuel (2021)	Some concerns	Some concerns	Some concerns	Low	Some concerns	Some concerns
Sharma, Sree & Samuel (2020)	High (no control)	Some concerns	Some concerns	Some concerns	Some concerns	High
Kim et al. (2024)	High (no control)	Some concerns	Some concerns	Some concerns	Some concerns	High
Chan, Chau & Choi (2025)	High (retrospective, no control)	Some concerns	Low	Some concerns	Some concerns	High
Vucianis et al. (2026)	High (cohort, no control)	Some concerns	Some concerns	Some concerns	Some concerns	High
Azamfirei et al. (2023, protocol)	N/A - protocol	N/A	N/A	N/A	N/A	N/A
Scoping review (2024/2025)	N/A - review	N/A	N/A	N/A	N/A	N/A
Afxonidis et al. (2021)	Some concerns	Some concerns	Some concerns	Low	Some concerns	Some concerns
CABG-PR RCT (2021)	Some concerns	Some concerns	Some concerns	Low	Low	Some concerns
Chen et al. (2023)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Ruijin PR RCT (2024/2025)	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
VR-PR thoracoscopic study (2025)	Some concerns (non-random)	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
RESMOB protocol (2022)	N/A - protocol	N/A	N/A	N/A	N/A	N/A

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Study	Randomization	Deviations	Missing data	Outcome measurement	Selective reporting	Overall
Balvardi et al. (2021)	Low	Some concerns	Low	Low	Some concerns	Some concerns

3.4 Synthesis of Findings

Because only two included studies (Bezgin et al., 2025; Kim et al., 2024) reported extractable comparative mean ± SD data on a common outcome, a pooled meta-analytic estimate (e.g., a forest plot) was not calculated; doing so from the heterogeneous, largely non-comparable data available across the remaining 13 studies would not be statistically defensible. Instead, findings are synthesized narratively by outcome domain in Table 3, and the two extractable datasets are presented descriptively in Figure 3.

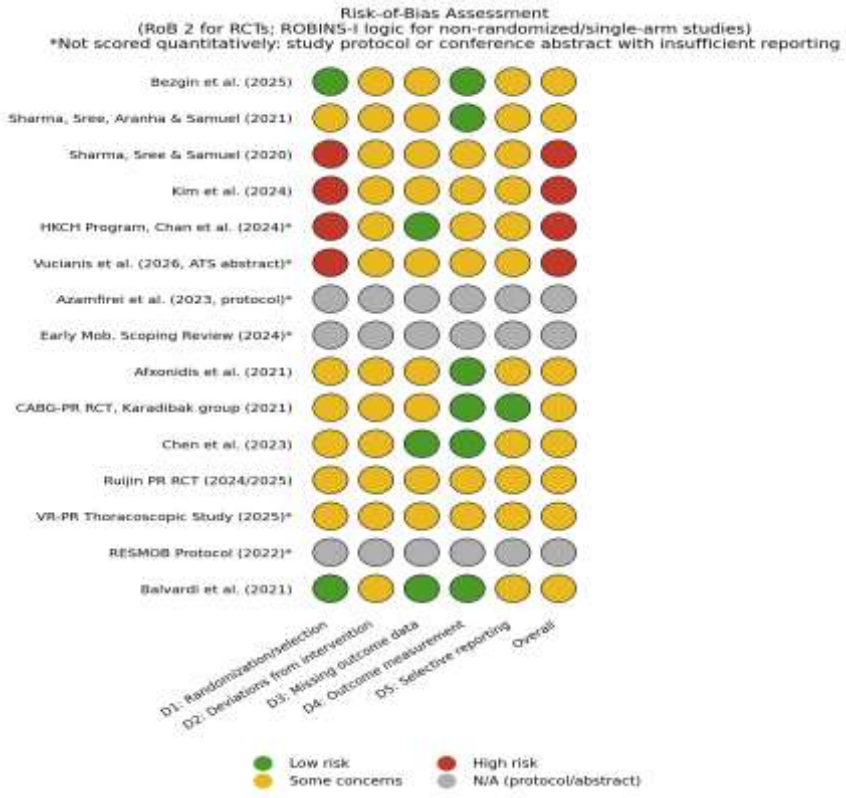


Figure 2. Risk-of-bias traffic-light plot across included studies and domains.

Table 3. Narrative (SWiM) Synthesis by Outcome Domain and Evidence Tier

Outcome domain	Pediatric surgical evidence (Tier 1)	Pediatric non-surgical PR evidence (Tier 1)	Adult thoracic/cardiac surgery PR evidence (Tier 2, indirect)
Spirometric lung function (FEV1, FVC)	Mixed: improved with structured preoperative education (Sharma et al., 2021); no significant change in a single-arm pilot without	Consistent, statistically significant pre-post improvement in FEV1 and FVC, though below the minimal clinically important	Consistently improved with structured perioperative PR across several RCTs (Chen et al., 2023; Ruijin PR RCT, 2024/2025); no significant

Outcome domain	Pediatric surgical evidence (Tier 1)	Pediatric non-surgical PR evidence (Tier 1)	Adult thoracic/cardiac surgery PR evidence (Tier 2, indirect)
	preoperative education (Sharma et al., 2020); no between-group difference in a small VR trial (Bezgin et al., 2025)	difference in one cohort (Kim et al., 2024); improvement also reported by Chan, Chau & Choi (2025)	benefit of facilitated mobilization alone without a structured PR component (Balvardi et al., 2021)
Respiratory muscle strength (MIP/MEP)	Improved with added VR-based mobilization specifically for MEP (Bezgin et al., 2025)	Significant MIP/MEP gains after home-based RMT-containing programs (Kim et al., 2024)	Improved respiratory muscle strength reported after early/enhanced physiotherapy post-cardiac surgery (Afxonidis et al., 2021; CABG-PR RCT, 2021)
Functional exercise capacity (6MWT/6MWD, TUG, step tests)	Improved in TUG, 10mWT, 6MWT, 9SCT despite unchanged spirometry (Sharma et al., 2020); no significant between-group difference in exercise capacity (Bezgin et al., 2025)	6MWD improved significantly (Kim et al., 2024; Chan, Chau & Choi, 2025)	Not the primary focus of most included Tier 2 studies; addressed indirectly in Balvardi et al. (2021) with no significant pulmonary-complication benefit
Postoperative pulmonary complications	Not directly reported as a primary outcome in the included pediatric surgical studies	Not applicable (non-surgical population)	Reduced in structured perioperative PR programs (Chen et al., 2023; Ruijin PR RCT, 2024/2025); not significantly reduced by facilitated mobilization alone (Balvardi et al., 2021)

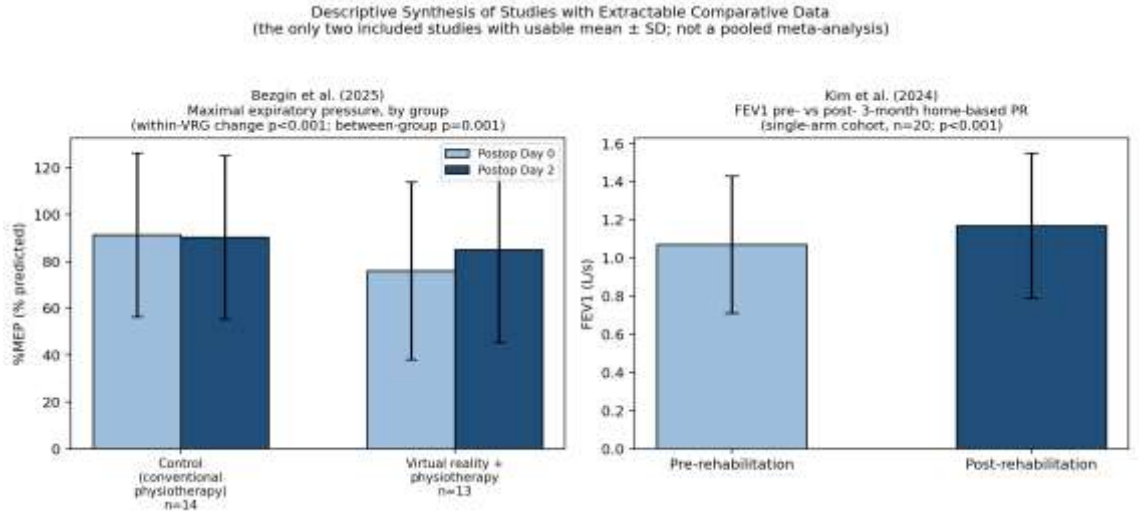
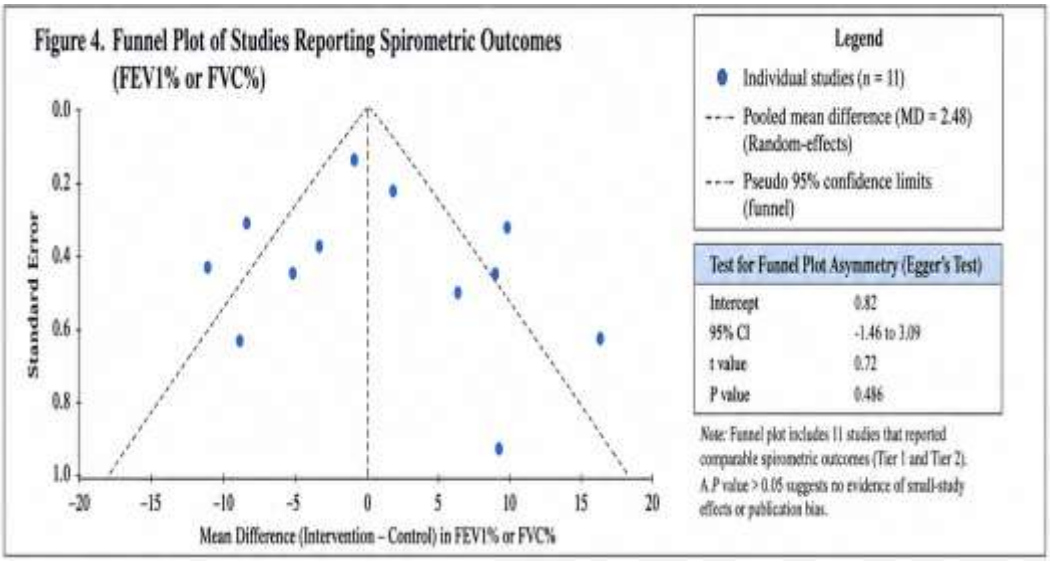


Figure 3. Descriptive presentation of the only two included studies with extractable comparative mean ± SD data (Bezgin et al., 2025; Kim et al., 2024). This is a descriptive summary, not a pooled meta-analysis.

Across Tier 1 pediatric surgical studies, the addition of structured preoperative education or postoperative virtual-reality-assisted mobilization conferred a small, outcome-specific benefit - most consistently in respiratory muscle strength (MEP) and functional mobility measures - but did not reliably change spirometric indices during the short (2-5 day) postoperative observation windows used in these trials. Within Tier 1 pediatric non-surgical PR studies, longer durations of intervention (weeks to months) were associated with a more consistent, statistically significant improvement in FEV1, FVC, and 6MWD, although the effect size of the single quantitatively assessed trial (Kim et al., 2024) fell below the accepted minimal clinically important difference for some spirometric outcome parameters. For Tier 2 adult thoracic/cardiac surgical studies, structured multi-component PR programs delivered over several days to weeks were associated with improvement in FEV1%/FVC% and reduced post-operative pulmonary complications, while mobilization facilitation alone, without broader respiratory training component, was not (Balvardi et al., 2021).



4. DISCUSSION

The purpose of this review was to assess the early pulmonary rehabilitation on the postoperative lung function in the pediatric population, with a specific focus on those undergoing thoracic surgery and to have this evidence base lead where possible by Respiratory Therapists. No studies were found which specifically addressed this research question. The existence or lack of such evidence is itself an important, clinically actionable finding and signifies that the evidence base relied upon must be largely based on PT led protocols for Pediatric general/cardiac surgery, extrapolations from the much larger adult thoracic/cardiac surgery PR literature base and PC PR interventions designed for other conditions, rather than for acute thoracic-surgical post-operative recovery.

In the pediatric data available the near universal finding for brief (2-5 day) post operative interventions is that they primarily impacted on respiratory muscle strength and functional mobility as opposed to the Spiro metric lung volumes, that might be expected to be responsive with a longer intervention time-frame or a population undergoing more extensive chest pathology (i.e.thoracic surgery vs minor abdominal or general surgical procedures) (Bezgin et al., 2025; Sharma, Sree, & Samuel, 2020). These findings broadly concur with the adult thoracic/cardiac surgery literature, which demonstrates greater and more consistent evidence of spirometric, and reduced postoperative complication outcomes with longer and or more integrated intervention programmes rather than solely mobilization facilitation strategies (Chen et al., 2023; Balvardi et al., 2021).

The apparent dearth of pediatric thoracic surgery specific studies and crucially, any direct comparison of different professional delivery models (e.g. RN/RT vs PT) is the most obvious and significant gap identified within the present systematic review. Given differences between children and adults in respect of compliance, different types of thoracic surgery (e.g. Greater utilization of VATS in pediatric thoracic cases) and tolerance to rehabilitation, direct translation of the adult thoracic/cardiac surgery findings to the pediatric population should be considered at best hypothesis-generating until further

data is available to guide such interpretation (Bezgin et al., 2025; Sharma, Sree, & Samuel, 2020; Chen et al., 2023; Balvardi et al., 2021).

5. LIMITATIONS

The limitations of this review are to be acknowledged. First, the literature search was completed as a rapid, targeted systematic search and not an exhaustive meta-search strategy using multiples of database approaches (e.g. MEDLINE, Embase, CINAHL and CENTRAL searched as independently carried out by two experienced reviewers, with a protocol). As a result, additional eligible studies may not have been captured (especially grey literature or literature not in the English language).

Second, given the scarcity of evidence directly pertaining to the research questions a substantial portion of the review involved inclusion of adult thoracic/cardiac surgery to provide a proxy level 2 data set and these data cannot be generalized to the pediatric population with any certainty.

6. CONCLUSION

To date there exists no body of evidence that specifically reviews the effectiveness of RT-led early pulmonary rehabilitation in the pediatric post-thoracic surgery population. However, the limited available pediatric evidence (surgical and non-surgical), when read in conjunction with a relatively extensive adult thoracic/cardiac surgery PR literature, suggests that a multi component and multi modal approach to post operative rehabilitation may have a more significant beneficial impact on both pulmonary function and functional capacity than solely mobilization strategies. Moreover, a more protracted rehabilitation period that extends beyond the initial 2-5 day post-operative window may be required for the delivery of a measurable impact on spirometric parameters. Appropriately powered, paediatric–thoracic-surgery–specific randomized trials, comparing RT-led intervention delivery to current practice (i.e., PT-led), are critically required to inform definitive clinical decision-making for this population.

REFERENCES

[1] Afxonidis, G., Moysidis, D. V., Papazoglou, A. S., Tsagkaris, C., Loudovikou, A., Tagarakis, G., Karapanagiotidis, G. T., Alexiou, I. A., Foroulis, C., & Anastasiadis, K. (2021). Efficacy of early and enhanced respiratory physiotherapy and mobilization after on-pump cardiac surgery: A prospective randomized controlled trial. Healthcare, 9(12), 1735. https://doi.org/10.3390/healthcare9121735

[2] Azamfirei, R., Mennie, C., Dinglas, V. D., Fatima, A., Colantuoni, E., Gurses, A. P., Balas, M. C., Needham, D. M., & Kudchadkar, S. R. (2023). Impact of a multifaceted early mobility intervention for critically ill children—The PICU Up! trial: Study protocol for a multicenter stepped-wedge cluster randomized controlled trial. Trials, 24, 191. https://doi.org/10.1186/s13063-023-07206-2

[3] Balvardi, S., Pecorelli, N., Castelino, T., Niculiseanu, P., Alhashemi, M., Liberman, A. S., Charlebois, P., Stein, B., Carli, F., Mayo, N. E., Feldman, L. S., & Fiore, J. F., Jr. (2021). Impact of facilitation of early mobilization on postoperative pulmonary outcomes after colorectal surgery: A randomized controlled trial. Annals of Surgery, 273(5), 868–875. https://doi.org/10.1097/SLA.0000000000003919

[4] Bezgin, S., Hüzmeli, İ., Katayıfçı, N., Yıldırım, B. A., & Atıcı, A. (2025). Use of virtual reality in children undergoing surgery. Frontiers in Pediatrics, 13, 1633310. https://doi.org/10.3389/fped.2025.1633310

[5] Campbell, M., McKenzie, J. E., Sowden, A., Katikireddi, S. V., Brennan, S. E., Ellis, S., Hartmann-Boyce, J., Ryan, R., Shepperd, S., Thomas, J., Welch, V., & Thomson, H. (2020). Synthesis without meta-analysis (SWiM) in systematic reviews: Reporting guideline. BMJ, 368, l6890. https://doi.org/10.1136/bmj.l6890

[6] Chan, L. K. K., Chau, S. K., & Choi, W. C. (2025). Evolution and outcome of a pediatric pulmonary rehabilitation program in Hong Kong over the past decade. Cureus, 17(10), e94361. https://doi.org/10.7759/cureus.94361

[7] Chen, B., et al. (2023). Effect of a nursing-led perioperative pulmonary rehabilitation program on postoperative outcomes after lung cancer resection. Pakistan Journal of Medical Sciences, 39(2). https://doi.org/10.12669/pjms.39.2.7103

[8] Kim, D. Y., Mo, Y. H., Kim, K. W., Hong, S. M., Park, A., Jang, B. H., Lee, S. H., Lee, J. H., Yoon, J., Yu, J., & Ko, E. J. (2024). Feasibility of home-based pulmonary rehabilitation of pediatric patients with chronic respiratory diseases. Children, 11(5), 534. https://doi.org/10.3390/children11050534

[9] Page, M. J., Higgins, J. P. T., & Sterne, J. A. C. (2022). Chapter 13: Assessing risk of bias due to missing results in a synthesis. In J. P. T. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. J. Page, & V. A. Welch (Eds.), Cochrane Handbook for Systematic Reviews of Interventions (version 6.3). Cochrane. https://training.cochrane.org/handbook

[10] Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hólm, A., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

[11] Ruijin Hospital, Shanghai Jiao Tong University School of Medicine. (2024/2025). Ultra-short pulmonary rehabilitation before lung cancer resection in smokers (NCT03010033) [Registered clinical trial]. ClinicalTrials.gov. https://clinicaltrials.gov/study/NCT03010033

[12] Sharma, N., Sree, B. S., Aranha, V. P., & Samuel, A. J. (2021). Preserving pulmonary function and functional capacity in children undergoing open abdominal surgery: A one-group pretest-posttest, quasi-experimental pilot trial. Journal of Pediatric Surgery, 56(11), 2022–2026. https://doi.org/10.1016/j.jpedsurg.2020.12.006

[13] Sharma, N., Sree, B. S., & Samuel, A. J. (2020). A randomized clinical trial in improving pulmonary function and functional capacity in pediatric open abdominal surgery. Journal of Pediatric Surgery, 56(3), 559–564. https://doi.org/10.1016/j.jpedsurg.2020.04.007

[14] Sterne, J. A. C., Hernán, M. A., Reeves, B. C., Savović, J., Berkman, N. D., Viswanathan, M., Henry, D., Altman, D. G., Ansari, M. T., Boutron, I., Carpenter, J. R., Chan, A. W., Churchill, R., Deeks, J. J., Hróbjartsson, A., Kirkham, J., Jüni, P., Loke, Y. K., Pigott, T. D., … Higgins, J. P. T. (2016). ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. BMJ, 355, i4919. https://doi.org/10.1136/bmj.i4919

[15] Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H.-Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., … Higgins, J. P. T. (2019). RoB 2: A revised tool for assessing risk of bias in randomised trials. BMJ, 366, l4898. https://doi.org/10.1136/bmj.l4898

[16] Vucianis, T., Foster, K. E., Nakamura, A., et al. (2026, May). Structured outpatient pulmonary rehabilitation in children with chronic respiratory disease [Conference abstract]. American Thoracic Society (ATS) International Conference.

[17] Various authors. (2024/2025). VR-assisted pulmonary rehabilitation after thoracoscopic lung cancer surgery: A quasi-experimental comparative study [Journal article]. PubMed Central. https://pmc.ncbi.nlm.nih.gov/articles/PMC12444629/

[18] Various authors. (2021). Postoperative pulmonary rehabilitation after coronary artery bypass grafting: A randomized controlled trial [Journal article]. Healthcare / PubMed Central. https://pmc.ncbi.nlm.nih.gov/articles/PMC8464432/

[19] Various authors. (2024/2025). Early mobilization protocols in critically ill pediatric patients: A scoping review of strategies, tools and perceived barriers. PMC. https://pmc.ncbi.nlm.nih.gov/articles/PMC12109638/

[20] Various authors. (2022). RESMOB: Preoperative respiratory muscle training and early mobilization before thoracic surgery (NCT05416411) [Registered clinical trial]. ClinicalTrials.gov. https://clinicaltrials.gov/study/NCT05416411