



Review Article

Impact of yoga on pulmonary functions in clinical population: A systematic review and meta-analysis of randomized controlled trials (RCTs)

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ABSTRACT

This study aims to investigate the impact of yoga practice on pulmonary and respiratory functions in clinical populations. A thorough search was carried out in the Cochrane Library, PubMed, Science Direct databases, and Google Scholar, using the keywords “Yog*” and “pulmonary functions”, covering the period from January 2010 to December 2022. Studies that aligned with PRISMA recommendations were included. The Cochrane risk-assessment tool was employed to assess bias risk. We calculated weighted mean differences (WMDs) with 95 % confidence intervals (CIs) and used the I^2 test to assess heterogeneity. Initially, 529 studies were found through the search, with 10 randomized controlled trials (RCTs) involving 1007 patients meeting the inclusion criteria for quality assessment and meta-analysis. The results indicated that yoga intervention (YI) significantly improved FVC% (WMD: 3.03 L, 95 % CI: 1.71, 4.35, $P < 0.00001$), FEV1 (WMD: 0.47 L, 95 % CI: 0.43, 0.51, $P < 0.00001$), and FEV1% (WMD: 5.74 L, 95 % CI: 4.47, 7.01, $P < 0.00001$) when compared to control groups. However, no significant effect was observed on FVC (WMD: 0.23 L, CI: 0.16, 0.62, $P = 0.25$), PEFr (WMD: 0.49, CI: 0.70, 1.67, $P = 0.42$), MVV (WMD: 9.01, CI: 3.92, 21.94, $P = 0.17$), and FEV1/FVC (WMD: 3.17, CI: 1.15, 7.48, $P = 0.15$) as a result of YI. Based on the limited evidence and meta-analysis conducted, YI demonstrated a positive effect on pulmonary function in clinical populations and could be considered as an adjunct therapy for individuals with various respiratory diseases. Further rigorous research with larger sample sizes is necessary to confirm the long-term benefits of yoga.

1. Introduction

Chronic respiratory diseases pose significant global health challenges, contributing substantially to morbidity and mortality. In 2017, they ranked as the third leading cause of death worldwide, with a prevalence of 7.1 % [1]. These conditions often result in impaired lung function, adversely affecting the quality of life and placing a significant burden on healthcare systems. Pulmonary function tests (PFTs) serve as essential non-invasive tools for assessing and monitoring respiratory function, enabling the diagnosis and evaluation of various pulmonary disorders [2].

PFTs provide valuable insights into the pathophysiology of respiratory diseases by measuring key parameters like forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), and peak expiratory flow rate (PEFR). A restrictive pattern of ventilator failure, characterized by reduced FVC and total lung capacity (TLC) with a normal FEV1/FVC ratio, is often observed in these conditions [3]. The normal reference values for spirometry can be determined based on the patient's age, sex,

and height [4]. In patients with obstructive and restrictive lung disorders, spirometry offers a qualitative and quantitative assessment of pulmonary function [5]. By quantifying these parameters, PFTs play a crucial role in enhancing diagnostic accuracy, assessing disease severity, and evaluating treatment efficacy, thereby informing clinical decision-making.

There has been growing interest in the role of physical activity in maintaining respiratory health, with evidence supporting its beneficial effects on lung function and overall well-being in recent years. Regular physical exercise, including structured interventions such as yoga, has been shown to enhance respiratory muscle strength, improve lung compliance and modulate inflammatory responses, thereby reducing the risk of pulmonary complications [6]. Among different forms of exercise, yoga stands out as holistic intervention integrating physical postures (asanas), breathing mechanics (pranayama), meditation (dhyana), and relaxation practices, providing a unique mind-body approach to respiratory health [7]. Recent research has further highlighted the potential role of exerkines-molecules released during physical exercise that

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mediate beneficial effects on respiratory function and systematic health [8].

Emerging evidence suggests that yoga-based interventions may positively influence pulmonary function in both healthy individuals and clinical populations (patients with diagnosed respiratory or related conditions). Previous studies have reported improvements in parameters such as vital capacity (VC), FVC, FEV1, and PEFr following regular yoga practice in healthy [9,10] and clinical populations [11–13]. YI have shown promising results in chronic respiratory conditions of asthma [14], chronic obstructive pulmonary disease (COPD) [15,16], and distinct respiratory disorders, as well as in comorbidities such as coronary artery disease (CAD) [17], diabetes [18], and psychosomatic disorders [19,20].

Despite emerging evidence supporting the therapeutic benefits of yoga, previous systematic reviews and meta-analyses have primarily focused on healthy individuals [6]. Therefore, a systematic and comprehensive analysis is needed to evaluate the effects of yoga on pulmonary function in clinical populations, considering the diversity of study design, intervention protocols, and outcome measures. This study aims to address these gaps by conducting a systematic review and meta-analysis specifically targeting the clinical population. By critically analyzing the available evidence, we aim to provide a rigorous assessment of the impact of YI on pulmonary function in clinical population. This study also explores potential moderators such as the type, frequency and duration of yoga practice, which may influence pulmonary outcomes.

2. Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) standards [21] and Cochrane collaboration recommendations [22] were used to conduct the systematic review and meta-analysis.

2.1. Search strategy/literature searches

A comprehensive search was conducted across multiple databases, including the Cochrane Library, PubMed, Science Direct, and Google Scholar, from January 2010 to December 2022. The above-indicated databases were searched using the strategy 'Keywords in title, abstract, and keyword' methodology. In the title, abstract, or keywords, search terms about yoga practice and its effect on pulmonary functions were included in the chosen search strategy. The PubMed electronic search approach was developed "(Yog* [Title/Abstract]) AND (Pulmonary [Title/Abstract]), (Yog* [Title/Abstract]) AND (Pulmonary function [Title/Abstract]), (Yog* [Title/Abstract]) AND (FVC [Title/Abstract]), (Yog* [Title/Abstract]) AND (FEV1 [Title/Abstract]), (Yog* [Title/Abstract]) AND (MVV [Title/Abstract])". The Cochrane Library and Science Direct were searched similarly. The first 20 results were chosen based on their relevance for Google Scholar. Only randomized controlled trials involving human subjects and published in English were included in the search. The PRISMA guidelines were followed, and all potential studies meeting the inclusion criteria were considered for analysis.

2.2. Study selection

A two-step procedure was used to identify the studies: title/abstract screening, and full-text review. To identify possibly eligible searches, two independent reviewers (V.R. and S.S.) went through the titles/abstracts of the articles that were retrieved. Based on predetermined eligibility criteria, the entire texts of these potentially relevant studies were then evaluated for eventual inclusion. A third reviewer (N.Y.) was consulted to settle any disputes between the first two reviewers.

2.3. Eligibility criteria

A set of predetermined eligibility criteria was developed to find pertinent studies to include in the systematic review and meta-analysis. The population, intervention, comparison, outcomes, and study design (PICOS) framework served as the basis for the formulation of these criteria. **Population:** The target population consisted of patients diagnosed with any chronic or acute medical conditions affecting pulmonary functions, asthma, COPD, cardiovascular diseases, Duchenne muscular dystrophy (DMD), and post-traumatic respiratory impairment. Healthy individuals or general populations were excluded. Studies that only measured subjective respiratory outcomes (quality of life & dyspnoea scores), and did not include objective PFTs, were excluded. **Intervention:** Yoga therapy, either as a stand-alone treatment or in combination with other therapies such as pharmacological interventions, lifestyle changes, or other complementary and alternative methods, was of interest. The study where yoga was combined with other exercise interventions (aerobic training & strength training) without isolating its effects on pulmonary functions was excluded from the intervention. **Comparison:** Any controlled intervention (no treatment, standard care, placebo interventions, and another active intervention) was accepted to evaluate the comparative effectiveness of yoga therapy. Studies without a well-defined control group were excluded. **Outcomes:** Standard pulmonary function measures such as FVC, FEV1, PEFr, MVV, and the FEV1/FVC ratio are included. Studies that reported only gaseous exchange parameters, such as the lung's diffusing capacity of carbon monoxide (DLCO), were excluded because DLCO is not commonly assessed in RCTs examining yoga-based interventions, and its measurement is methodologically heterogeneous. **Study Design:** Inclusion criteria were restricted to RCTs published as full-text articles. Observational studies, case reports, conference abstracts, and editorials were excluded. Non-English language publications were not considered.

2.4. Data extraction

The data extraction was performed independently using a predefined data extraction form. The extracted data included study characteristics (authors, year of publication, study design) with Jadad score, sample size, participant's characteristics (age, diagnosis), intervention details (type of yoga, frequency, and duration), comparator group details, and outcomes. Any disagreement in data extraction was settled through discussion or consultation with a third reviewer.

2.5. Quality assessment and risk-of-bias assessment

The Jadad scale assigns a score ranging from 0 to 5 based on randomization, blinding, and description of withdrawals & dropouts used for the methodological quality of the included studies [23]. Studies scoring ≤ 2 were considered to have low quality, while those scoring ≥ 3 were considered to have high quality [24]. The risk of bias in the included studies assessed using the guidelines provided in the "Cochrane Handbook for Systematic Reviews of Interventions". The researchers conducted a subjective assessment of each study and assigned a level of risks as "High", "Low", or "Unclear" for various bias domains, including selection bias (randomized sequence generation, allocation concealment), performance and detection bias (blinding of participants, staff, and outcomes), attrition bias (handling of incomplete outcome data), reporting bias (selective outcome reporting), and other potential sources of bias. The risk-of-bias assessment findings were summarized in Fig. 2 (a) and (b) respectively.

2.6. Data synthesis and analysis

A meta-analysis was conducted to assess the effect of yoga interventions on pulmonary outcomes. Data synthesis and analysis were carried out using "Review Manager Software (RevMan) version 5.3". For

the continuous outcomes, standardized mean differences (SMDs), with 95 % confidence intervals (CIs) were calculated. Random-effects models [25] were used when there was significant heterogeneity; otherwise, fixed-effects models were used. The I^2 statistics were used to assess study heterogeneity, which ranged from low (0–40 %) to moderate (30–60 %), substantial (50–90 %), and considerable (75–100 %) [26,27]. Due to the smaller number of studies included in each analysis (≤ 10), potential publication bias was not investigated. Statistical significance was defined as a p-value less than 0.05 when compared to the overall effect in the control group.

3. Results

3.1. Study selection

Fig. 1 shows the PRISMA flow diagram of the entire search procedure and the methodology used in the selection of the studies. After a preliminary database search, 529 studies were selected for screening. Ten studies met the inclusion criteria for the systematic review and quality evaluation. The meta-analysis included all ten studies, and Table 1 summarizes their main characteristics. The sample sizes ranged from 30 to 276. The included studies were published between January 2011 and December 2022, with intervention durations ranging from four weeks to one year.

3.2. Study characteristics

The studies included in this analysis demonstrated notable variations in sample range, age distribution, health conditions, intervention durations, and outcome measures. The sample range across the studies spanned from 30 participants [33] to a larger cohort of 276 participants [30], with a total of 1007 participants across the studies. The studies targeted diverse age groups, including older adults [28], children [35],

and specific age ranges such as 45–65 years [29] and 12–60 years [30]. The health conditions under investigation also varied, with studies focusing on frail older adults [28], patients with coronary artery disease [29], individuals diagnosed with asthma [30,32,34,37], and patients with COPD [31,33], on study focus on the patient with DMD [35] and isolated blunt chest trauma [36]. The duration and frequency of the YI varied across studies, with session lengths ranging from 20 min daily [29] to 60 min [31,33,34,36] and intervention durations ranged from four weeks [30,34,36] to longer-term study duration of one year [35], reflecting the diversity in the implementation of the intervention protocols. The outcome measures reported in the studies included FVC reported in five studies [29,31,32,34,35] three studies reported FVC% [30,36,37], five studies reported FEV1 [29,31–34] and three studies reported FEV1 % [30,36,37] PEFr was reported in three studies [29,32,35], and PEFr% was reported in two studies [30,37]. MVV and FEV1/FVC were reported in three [28,29,35] and two studies [32,34] respectively.

3.3. Quality assessment

Fig. 2a and (b) show the risk of bias assessment for each study. Among 10 RCTs, 4 studies had a high risk of bias [29,30,32,33] associated with random sequence generation, allotment concealment and other bias, and the remaining studies had some unclear bias [28,30,32,35,37] mostly related to blinding of the participants and assessment. All studies with incomplete outcome data and selective reporting had a low level of bias.

The quality assessment of clinical trials included in the study was performed using the Jadad score, as presented in Table 2. The Jadad score assesses various aspects of study quality, including randomization, blinding, presentation of withdrawals and dropouts, inclusion & exclusion criteria, assessment of adverse effects, and description of statistical analysis. Among the three included studies [29,34,36] the highest scores

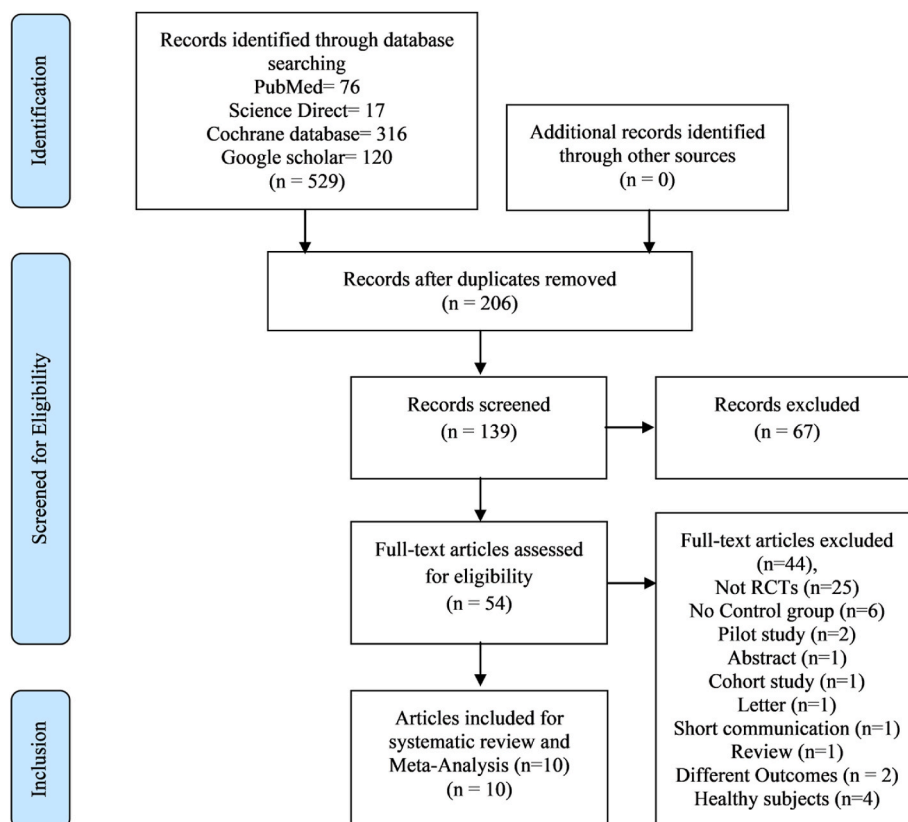


Fig. 1. showing the PRISMA chart for extraction of data.

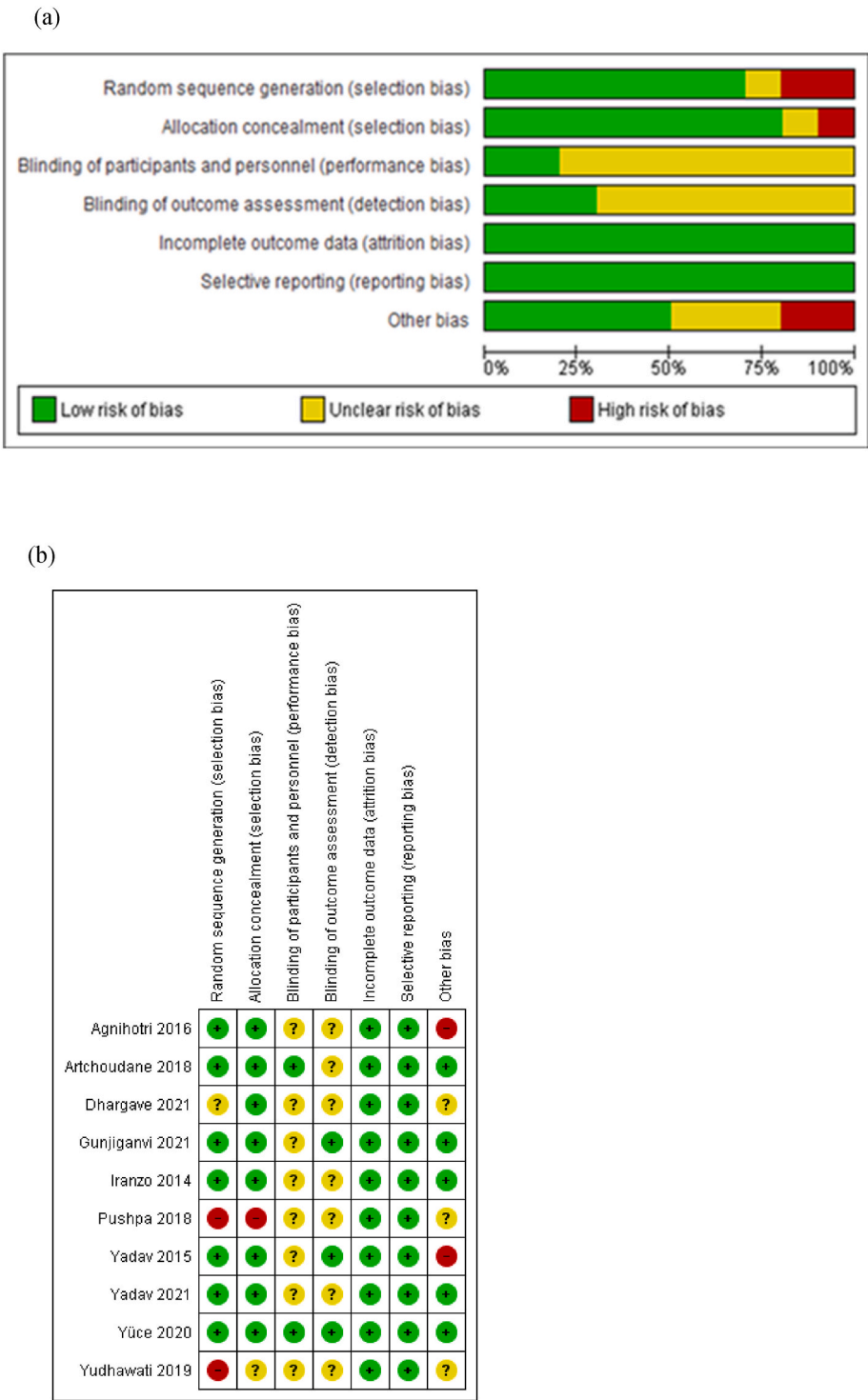


Fig. 2. (a) Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies (b) Risk of bias summary: review author's judgements about each risk of bias item for each included study.

were obtained, indicating the overall quality of these studies with scores of 5.5, 6.5, and 6 respectively. On the other hand, two studies [32,33] had a lower score of two, indicating some limitations in these studies. The remaining five studies [28,30,31,35,37] scored between 4 and 5, indicating moderate to good quality in terms of the assessed criteria.

3.4. Meta-analysis

In the present meta-analysis, a comprehensive examination of the

impact of YI on various pulmonary and respiratory functions was conducted based on the findings of multiple studies. Out of the 10 articles included in the analysis, five reported outcomes for FVC [29,31,32,34, 35]. The combined results from these articles indicated a non-significant improvement in FVC ($Z = 1.14$) with a WMD of 0.23 L, 95 % confidence interval (CI) $[-0.16, 0.62]$, at a p-value of 0.25. However, considerable heterogeneity was observed ($I^2 = 95\%$) with a significant p-value of less than 0.00001 (Fig. 3a).

Three articles provided data on forced vital capacity percentage (FVC

Table 1

Characteristics of studies included in systematic review and meta-analysis.

Author, year	Study design/ Jadad score	N	Age	Health condition	Program length, frequency, and duration		Outcomes	Salient findings
					Treatment	Control		
Iranzo et al., 2014 [28]	Open-label randomized controlled trial/5	81	Older than 65 years	Frail older adults	(1) ITT group performed inspiratory muscle training (2) YRT group performed yoga breathing exercises 5 days/week for 6 weeks	Not performed any training	Maximum respiratory pressures (MIP, MEP, MVV)	YRT group had a greater increase of RM strength (MIP and MEP) and endurance (MVV) than control and/or ITT groups
Yadav et al., 2015 [29]	Prospective randomized parallel group controlled study/5.5	80	45–65 years	CAD patients	Yoga regimen (yogic postures, pranayama breathing, exercises, dietary modification, and holistic teaching) daily for 60 min (6 days/week) for 3 months	Conventional medicine	HR, SBP, DBP, MBP and SVC, FVC, FEV1, PEFR, MVV, DLCO	Significant improvement in SLC, FVC, PEFR, MVV, DLCO, HR, SBP and DBP in Group-I
Agnihotri et al., 2016 [30]	RCT/5	276	12–60 years.	Asthmatic patients	Yogic intervention (asanas, pranayama, and meditation) for 30 min per day, 5 days in a week for a period of 6 months	Standard medical treatment	FVC, FEV1, FEV1/FVC, and PEFR	Significantly better improvement in all spirometric variables in yoga group.
Artchoudane et al., 2018 [31]	RCT (prospective two-arm, single-blinded)/4.5	72	53.04 ± 9.71 years	COPD patients	Yoga therapy (loosening exercises, postures, breathing techniques and relaxation), 60 min for 4 weeks.	Standard medical management	FVC, FEV1, FEV1/FVC and quality of life	Significant improvement in FVC, FEV1 and QoL scores in YG; significant correlation was found between pulmonary function and QoL in yoga group.
Pushpa and Sharma., 2018 [32]	RCT/2	60	18–50 years	Bronchial asthma	Pranayamas (kapalabhati, bhastrika, ujjayi and sukhapurvaka pranayama), meditation, and shavasana, 45 min twice daily, regularly for remaining 6 weeks	Pharmacological treatment	FEV1, FVC, PEFR, FEV1/FVC%, FEF25-75, RAW kPa, sGAW	Yoga group showed progressive improvement in FEV1, FVC, FEV1/FVC, PEFR, FEF25-75, and sGAW; significant reduction in RAW after 4th and 8th weeks of yoga training
Yudhawati and RasjidHs., 2019 [33]	RCT (pre and post-test control group design)/2	30	Above 40 years	COPD group B	Yoga practice for 1 h, 2 times a week for 12 weeks	Lung rehabilitation brochure	FEV1, 6-MWD and quality of life	Significant increase in FEV1, 6-MWD and quality of life in YG as well as treatment group as compared to control group
Yüce and Tasci, 2020 [34]	Single-blind, randomized, controlled trial/6.5	55	Above 18 years	Asthma patient	Pranayama (Kapalabhati, ujjayi and anuloma viloma), 20 min once daily for a month.	(1) Progressive relaxation, 20 min once daily for 1 month (2) standard medical treatment	Asthma control test (ACT), asthma quality of life Questionnaire (AQLQ), pulmonary functions (FEV1, FVC, FEV1/FVC%, PEF)	Significant increase in ACT score and overall AQLQ score in pranayama group; no significant difference between the groups in terms of PFT parameters
Dhargav et al., 2021 [35]	RCT/5	124	5–10 years	Duchenne muscular dystrophy	Yoga session in morning and Physiotherapy session in evening each 45 min for an year	Home based physiotherapy exercises for 45 min, two sessions a day for an year	FVC, PEFR, Tidal volume, MVV, MVt	Significant increase in FVC, PEFR, MVV and MVt in group I; significant increase in FVC, MVt from baseline up to one year and MVV increase from baseline up to nine months in group II
Gunjiganvi et al., 2021 [36]	Prospective open-label randomized controlled study/6	89	18–65 years	Isolated blunt chest trauma	Yoga therapy for max. 1 h daily for 4 week	Conventional chest physiotherapy	VT, FVC, FEV1, PEF, FVC/FEV1 %, quality of life, respiratory muscle endurance, respiratory muscle strength, chest wall mobility and Cytokine levels	Significant increase in FVC, FEV in the yoga therapy group; significant improvement in physical component of QoL, respiratory muscle endurance and axillary cytometry
Yadav et al., 2021 [37]	RCT/4	140	10–16 year	Bronchial asthma	Yogic intervention (asanas, pranayama, and meditation) for 45 min per day, 6 days in a week for a period of 12 weeks	Pharmacological treatment	FVC, FEV1, FEV1/FVC and PEFR, quality of life	Significant improvement in FVC, FEV1, FEV1/FVC, PEFR and mean-PAQLQ score in yoga group as compared to control

ITT= Inspiratory threshold training; YRT= Yoga respiratory training; MIP = Maximum inspiratory pressure; MEP = Maximum expiratory pressure; MVV = Maximum voluntary ventilation; CAD= Coronary artery disease; HR= Heart rate; SBP= Systolic blood pressure; DBP = Diastolic blood pressure; MBP = Mean blood pressure; SVC= Slow vital capacity; FVC = Forced vital capacity; FEV1 = Forced expiratory volume in 1st sec; PEFR = Peak expiratory flow rate; RAW kPa = Airway resistance measured in Kilo Pascal; sGAW = Specific airway conductance; FEF25-75 = Forced expiratory flow at 25 % and 75 %; DLCO = Diffusion factor of the lung for carbon monoxide; RCT = Randomized control design; COPD= Chronic obstructive pulmonary disease; 6-MWD = 6-min walk distance; PEF= Peak expiratory flow; PFT= Pulmonary function test; MVt = Maximum voluntary ventilation; VT= Tidal Volume; PAQLQ= Pediatric Asthma Quality of Life Questionnaire.

Table 2
Clinical trials quality assessment according to Jadad score.

Author, Year	Was the research described as randomized?	Was the Approach of randomization appropriate?	Was the research described as blinding?	Was the approach of blinding appropriate?	Was there a presentation of withdrawal and dropouts?	Was there a presentation of the inclusion/ exclusion criteria?	Was the approach used to assess adverse effects described?	Was the approach of statistical analysis described?	Total
Iranzo et al., 2014 [28]	1	1	0	0	1	1	0	1	5
Yadav et al., 2015 [29]	1	1	0.5	1	0	1	0	1	5.5
Agnihotri et al., 2016 [30]	1	1	0	0	1	1	0	1	5
Artchoudane et al., 2018 [31]	1	1	0.5	−1	1	1	0	1	4.5
Yudhawati and RasjidHs., 2019 [32]	1	−1	0	0	0	1	0	1	2
Pushpa and Sharma., 2018 [33]	1	−1	0	0	0	1	0	1	2
Yüce and Tasci., 2020 [34]	1	1	0.5	1	1	1	0	1	6.5
Dhargave et al., 2021 [35]	1	1	0	0	1	1	0	1	5
Gunjiganvi et al., 2021 [36]	1	1	0	0	1	1	1	1	6
Yadav et al., 2021 [37]	1	1	0	0	0	1	0	1	2

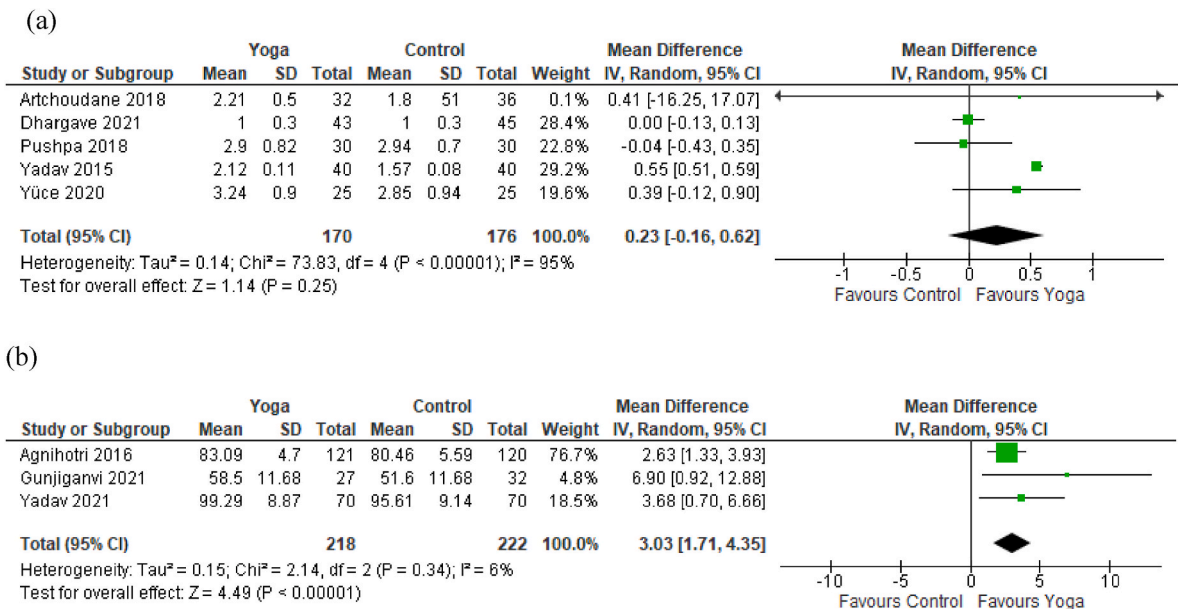


Fig. 3. (a) Forest plot evaluating yoga’s effect on FVC (L) using a random-effects model across five RCTs. (b) Forest plot of comparison for evaluating effects of yogic intervention on FVC by random-effect model, Forced Vital Capacity (FVC%).

%) [30,36,37]. The pooled findings from these articles demonstrated a significant improvement in FVC % (Z = 4.49) with a WMD of 3.03 L, 95 % CI [1.71, 4.35], at a p-value of less than 0.00001. The heterogeneity

observed was not significant at p = 0.34, I² = 6 % (Fig. 3b).
Forced expiratory volume in 1st second (FEV1) outcomes was reported in five studies [29,31–34]. The combined results showed a

significant increase in FEV1 ($Z = 26.02$) with a WMD of 0.47 L, 95 % CI [0.43, 0.51], at a p-value of less than 0.00001. There was no significant heterogeneity at $p = 0.63$, $I^2 = 0\%$ (Fig. 4a).

Similarly, three studies reported changes in FEV1 % [30,36,37], and the pooled findings demonstrated a significant increase in FEV1 % ($Z = 8.84$) with a WMD of 5.74 L, 95 % CI [4.47, 7.01], at a p-value of less than 0.00001. The heterogeneity observed was not significant at $p = 0.50$, $I^2 = 0\%$ (Fig. 4b).

Regarding PEFR, three articles reported outcomes [29,32,35]. The cumulative analysis showed that YI did not have a significant effect on PEFR ($Z = 0.80$) with a WMD of 0.49 L, 95 % CI [-0.70, 1.67], at a p-value of 0.42. Considerable heterogeneity was observed at $p < 0.00001$, $I^2 = 98\%$ (Fig. 5a).

Two articles reported changes in PEFR % [30,37], and the analysis indicated no significant improvement in PEFR % ($Z = 0.03$) with a WMD of 0.08 L, 95 % CI [-5.66, 5.82], at a p-value of 0.98. Substantial heterogeneity was observed at $p = 0.04$, $I^2 = 77\%$ (Fig. 5b).

Three studies reported outcomes for MVV [28,29,35]. The overall findings suggested a non-significant difference in MVV ($Z = 1.37$) with a WMD of 9.01, 95 % CI [-3.92, 21.94], at a p-value of 0.17. Considerable heterogeneity was observed at $p < 0.00001$, $I^2 = 96\%$ (Fig. 6).

Finally, two articles reported changes in FEV1/FVC [32,34]. The combined results indicated no significant difference in FEV1/FVC ($Z = 1.44$) with a WMD of 3.17 L, 95 % CI [-1.15, 7.48], at a p-value of 0.15. Considerable heterogeneity was observed at $p < 0.00001$, $I^2 = 91\%$ (Fig. 7).

These findings suggest that YI has a variable impact on different pulmonary and respiratory functions in the clinical population.

4. Discussion

The study is the first meta-analysis evaluating the effectiveness of yoga intervention on pulmonary functions in the clinical population. We did not find any published articles related to the variables included in this meta-analysis. Qualitative findings show that yoga as an intervention strategy significantly improves pulmonary function and can be used as an adjunct therapy for patients with a range of respiratory conditions. There are only two systematic reviews and one meta-analysis available on this topic, which included only a healthy population and found evidence for the positive effect of yoga practice on pulmonary functions [6,

38].

The duration and style of the yoga practice protocol had an impact on the outcomes of YI. The yoga protocols used in these studies are presented in Table 1. A minimum of four weeks of yoga therapy lasting 60 min has been found to significantly improve pulmonary function. Yoga training time experiments have shown that a 12-week regimen performed at least twice a week for an hour is likely to result in noticeable improvements in pulmonary function.

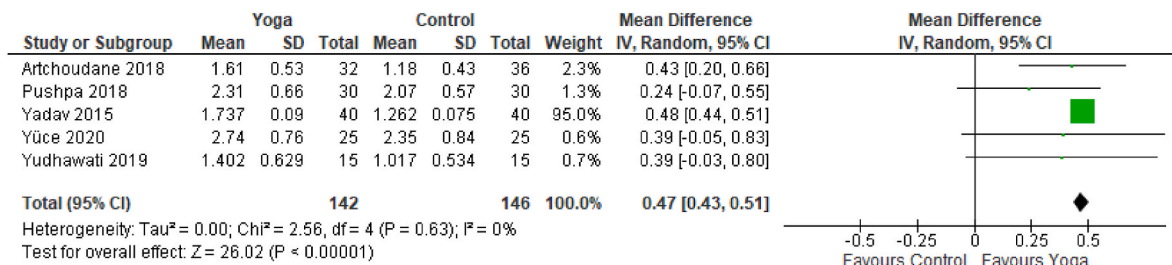
4.1. Effect of the yoga protocol on pulmonary function

According to the findings of this study, participants who engaged in yoga demonstrated an improvement in FVC compared to the control group. FVC is a measure of the elasticity of the respiratory system. The analysis encompassed 5 studies involving 346 patients for FVC assessment and 3 articles involving 440 patients for FVC%. The results revealed a non-significant WMD of 0.23 L for FVC ($p = 0.25$) and a significant WMD of 3.03 L of FVC% ($p < 0.00001$). These significant improvements in FVC can be attributed to the practice of yoga asanas and pranayama, which enhance the strength of respiratory muscles, thereby improving lung compliance and elasticity [5].

The evaluation of FEV1 and FEV1 % included 5 studies with 288 patients and 3 studies with 440 patients, respectively. The analysis showed a significant WMD of 0.47 L for FEV1 ($p < 0.00001$) and a significant WMD of 5.74 L for FEV1 % ($p < 0.00001$). PEFR assessment involving 288 patients resulted in a non-significant WMD of 0.49 ($p = 0.42$), while PEFR% analysis with 381 patients revealed a non-significant WMD of 0.08 ($p = 0.98$). MVV was assessed to 216 patients and exhibited a non-significant WMD of 9.01 ($p = 0.17$). Similarly, the analysis of FEV1/FVC involved 550 patients across five studies, showing a non-significant WMD of 3.17 ($p = 0.15$). Meta-analysis indicated improvements in pulmonary functions, such as FVC%, FEV1, and FEV1 %, with non-significant differences observed in FVC, PEFR, PEFR%, MVV, and FEV1/FVC.

Several factors likely contribute to these findings. Primarily, the isometric contraction of muscles during yoga poses is known to increase skeletal muscle strength [39]. Yoga poses involving lumbar and thoracic extension assist in expanding the chest wall, as demonstrated in various studies highlighting the positive affect of increased spinal mobility on pulmonary function in patients with spinal cord injuries [40,41].

(a)



(b)

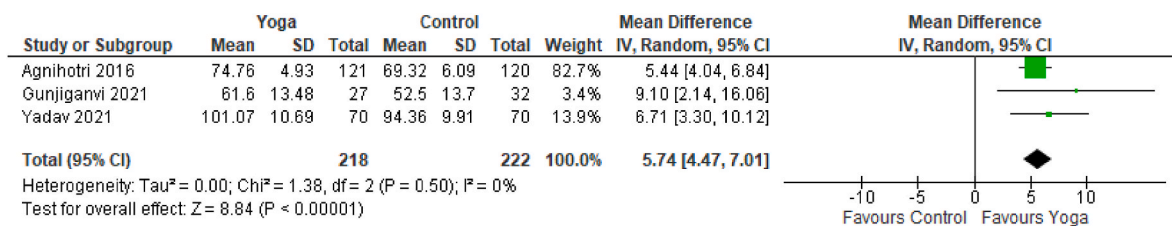


Fig. 4. (a) Forest plot of comparison for evaluating effects of yogic intervention on FEV1 by random-effect model, Forced expiratory volume in 1 s (FEV1) (b) Forest plot of comparison for evaluating effects of yogic intervention on FEV1 by random-effect model, Forced expiratory volume in 1 s (FEV1 %).

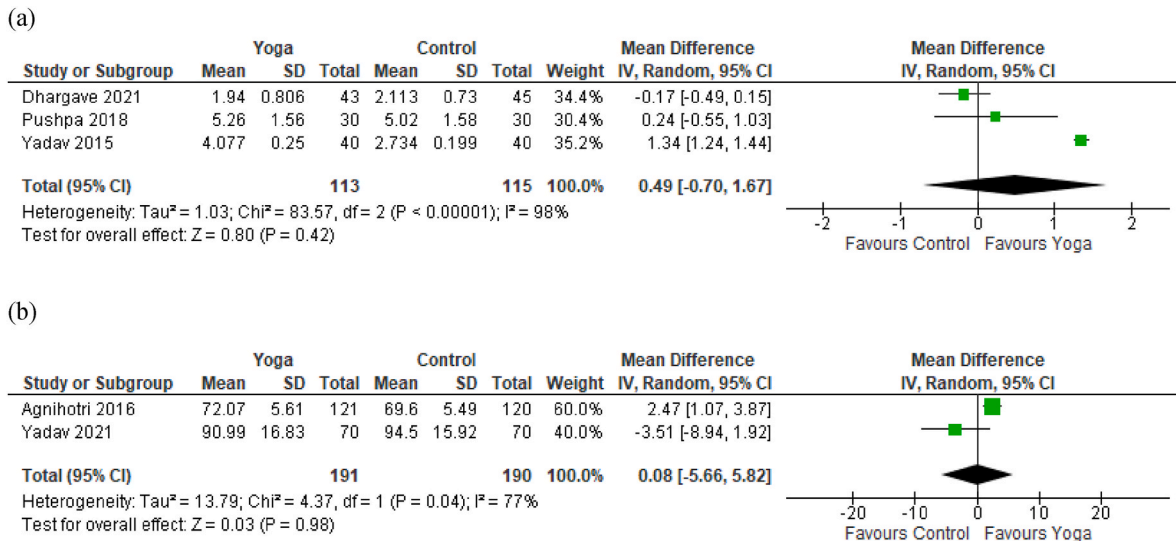


Fig. 5. (a) Forest plot of comparison for evaluating effects of yogic intervention on PEFR by random-effect model, peak expiratory flow rate (PEFR) (b) Forest plot of comparison for evaluating effects of yogic intervention on PEFR by random-effect model, peak expiratory flow rate (PEFR %).

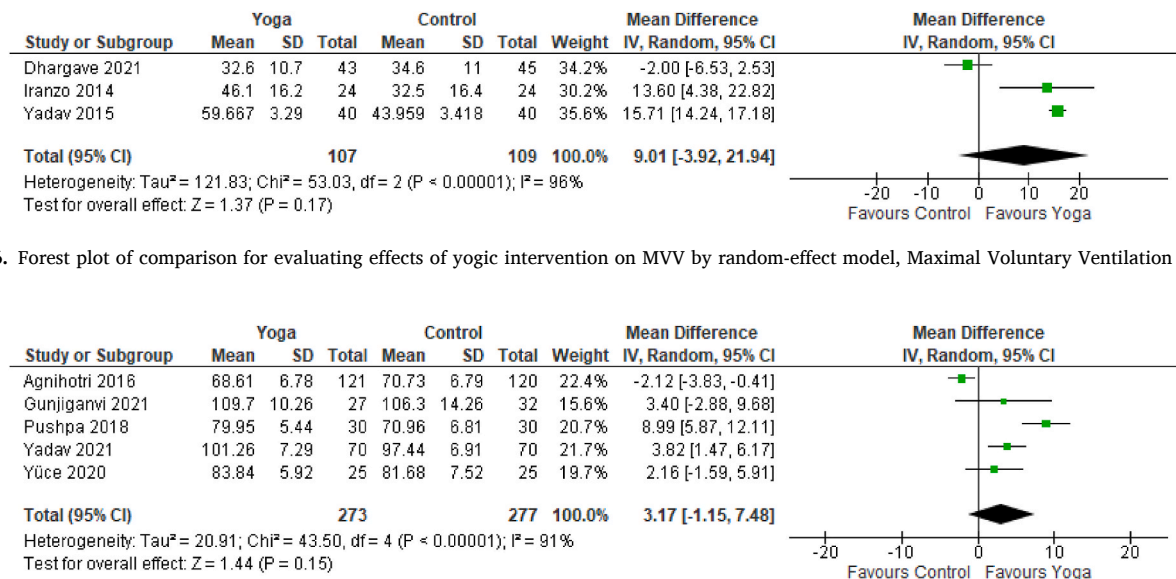


Fig. 6. Forest plot of comparison for evaluating effects of yogic intervention on MVV by random-effect model, Maximal Voluntary Ventilation (MVV).

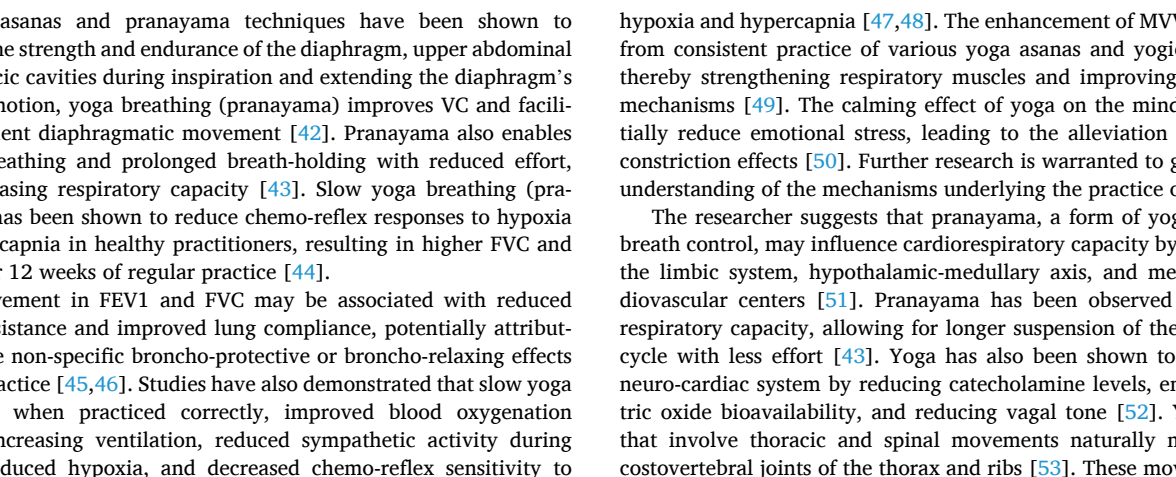


Fig. 7. Forest plot of comparison for evaluating effects of yogic intervention on FEV1/FVC by random-effect model, Forced Vital Capacity/Forced expiratory volume in 1 s FEV1/FVC.

Different asanas and pranayama techniques have been shown to enhance the strength and endurance of the diaphragm, upper abdominal and thoracic cavities during inspiration and extending the diaphragm's range of motion, yoga breathing (pranayama) improves VC and facilitates efficient diaphragmatic movement [42]. Pranayama also enables deeper breathing and prolonged breath-holding with reduced effort, thus increasing respiratory capacity [43]. Slow yoga breathing (pranayama) has been shown to reduce chemo-reflex responses to hypoxia and hypercapnia in healthy practitioners, resulting in higher FVC and PEFR after 12 weeks of regular practice [44].

Improvement in FEV1 and FVC may be associated with reduced airway resistance and improved lung compliance, potentially attributable to the non-specific broncho-protective or broncho-relaxing effects of yoga practice [45,46]. Studies have also demonstrated that slow yoga breathing, when practiced correctly, improved blood oxygenation without increasing ventilation, reduced sympathetic activity during altitude-induced hypoxia, and decreased chemo-reflex sensitivity to

hypoxia and hypercapnia [47,48]. The enhancement of MVV may result from consistent practice of various yoga asanas and yogic breathing, thereby strengthening respiratory muscles and improving respiratory mechanisms [49]. The calming effect of yoga on the mind can potentially reduce emotional stress, leading to the alleviation of broncho-constriction effects [50]. Further research is warranted to gain a better understanding of the mechanisms underlying the practice of yoga.

The researcher suggests that pranayama, a form of yoga involving breath control, may influence cardiorespiratory capacity by influencing the limbic system, hypothalamic-medullary axis, and medullary cardiovascular centers [51]. Pranayama has been observed to increase respiratory capacity, allowing for longer suspension of the respiratory cycle with less effort [43]. Yoga has also been shown to benefit the neuro-cardiac system by reducing catecholamine levels, enhancing nitric oxide bioavailability, and reducing vagal tone [52]. Yoga asanas that involve thoracic and spinal movements naturally mobilize the costovertebral joints of the thorax and ribs [53]. These movement help

maintain mobility in the thoracic cage, which is essential for preventing a decline in chest compliance over time.

The vertical nature of yoga breathing provides additional benefits. Vertical breathing ensures a uniform opening of alveoli in both lungs. When all alveoli expand uniformly, a significant portion of the alveolar membrane becomes available for gas exchange. Optimal gas exchange occurs when a vast surface area is accessible [54]. Normally, only a small portion of lung capacity is utilized, leading to inadequate oxygen supply and compromised waste disposal processes. Controlled breathing activities, such as pranayama, deepen respiration, expand the lungs beyond their usual limits, and re-engage previously collapsed alveoli. Lung muscle endurance improves with regular yoga practice [55].

Yoga-based intervention, including yoga asanas and pranayama, has been found to have a positive impact on pulmonary function. The improvements observed in FVC%, FEV1, and FEV1 % can be attributed to enhanced respiratory muscle strength, improved lung compliance, reduced airway resistance, and broncho-protective effects. The practice of yoga also contributes to increased respiratory capacity, thoracic mobility, and alveolar ventilation. Further research is needed to gain deeper insights into the underlying mechanisms and optimize the therapeutic application of yoga for respiratory health.

4.2. Relevance of the duration of specific YI

This review looked into the effect of yoga on pulmonary functions and discovered that it only improved three parameters. The reason for yoga being non-responsive on dependent variables can be assessed as the use of diverse demographics, low sample sizes, and lack of true randomization to produce a challenging substantial effect of yoga practice in the research. According to a study, regular yoga practice for 10 weeks can improve pulmonary function [38], and another study confirmed that at least 8 weeks of yoga training can improve pulmonary function [6]. Researchers claimed in their study that a minimum of 4 weeks of yoga training is optimum to enhance pulmonary functions [31, 36]. Another study had taken a one-year time duration for YI and found a significant increase in pulmonary function [35]. A study employed a month of YI and found no significant improvement in PFT parameters [34]. Two studies implemented 6 weeks of yoga intervention and enhanced respiratory muscle strength and pulmonary function [28,33]. A randomized controlled trial after performing 12 weeks of YI reported an improvement in pulmonary and cardiovascular parameters [29] such as slow vital capacity (SVC), FVC, FEV1, PEFR, MVV, DLCO, Heart Rate (HR), Systolic Blood Pressure (SBR), Diastolic Blood Pressure (DBP), and Mean Blood Pressure (MBR). This indicates that the yoga protocol duration had varied impacts on various clinical populations. As this systematic review revealed YI is likely to improve pulmonary function and should last at least 4 weeks daily, every day for a minimum of 60 minutes. To observe a noticeable improvement in pulmonary function parameters, yoga training for at least 45 minutes twice a day must be practiced for 6 weeks. The current study revealed that yoga protocol durations ranged from 4 weeks to a year. It is likely that longer and more frequent training sessions each week and regular yoga practice results in greater therapeutic benefits. The ideal practice timeframe for a YI's long-term effects needs to be investigated extensively.

While pharmacological treatments such as bronchodilators, corticosteroids, and pulmonary rehabilitation programs remain essential for managing chronic respiratory diseases like asthma and COPD, yoga-based interventions provide additional benefits. Studies suggest that yoga, particularly pranayama, can enhance respiratory muscle endurance, improve airway resistance, and promote autonomic regulation effects that are not directly targeted by traditional medicines [45,46].

Yoga has been linked to higher oxygenation saturation, lower inflammation, and increased vagal tone, which contributes to long-term respiratory benefits [56]. Pranayama, as opposed to traditional pulmonary rehabilitation, may offer a non-pharmacological approach to improving lung function and exercise tolerance [47,48]. More rigorous

comparative studies are required to directly compare yoga intervention and its effectiveness to standard medical treatments.

4.3. The requirement for a homogeneous study

The studies included in this meta-analysis reported improvement in pulmonary function; however, only three parameters (FVC%, FEV1 & FEV1 %) demonstrated statistically significant improvement. One of the major contributors to these mixed findings was the substantial heterogeneity observed across the included studies.

The study population was diverse in terms of age, gender, and ethnicity, and the duration and frequency of the interventions varied significantly, ranging from 4 weeks to a year and twice a week to daily sessions. Variations in the type of yoga intervention were also notable, with some studies focusing solely on pranayama and other incorporating asana, meditation, or a combination of these techniques. Inconsistency in methodology in pulmonary functions testing, differences in spirometry models, calibration methods and test administration procedures across studies could have contributed to measurement inconsistencies.

Although we identified these potential sources of heterogeneity, we did not conduct a formal moderator analysis due to the small number of studies available for each subgroup. Future meta-analyses should aim to quantify the impact of yoga type, duration, and frequency on pulmonary function outcomes. Adopting a homogeneous study design can help to eliminate inconsistent findings. It is necessary to standardize yoga interventions for different study populations and age categories.

4.4. Strengths and limitations of the study

A comprehensive search strategy was employed, ensuring the inclusion of all relevant studies, while a rigorous screening and quality assessment process minimized bias and strengthened the validity of these results. The use of meta-analysis improved the accuracy of effect estimates and provided a clear understanding of yoga's impact on pulmonary functions. This study also focuses on the duration of the yoga interventions, offering valuable insights for practitioners and healthcare professionals in designing effective programs. Unlike previous reviews that primarily examined healthy populations, this study emphasizes yoga's role in the clinical population.

The study has several limitations. The heterogeneity in yoga protocols, including differences in intervention duration, frequency, and type of practice, limits the ability to determine an optimal yoga regimen for pulmonary function improvement. Variations in sample sizes and patient characteristics across studies affect the generalizability of the findings. We did not conduct an assessment of potential publication bias, as the number of meta-analysis studies for each parameter was relatively small (<10). Different devices were used across studies to measure the same pulmonary function, which introduces potential measurement variability and the presence of unpublished or missing data may have introduced bias into our analysis.

5. Conclusion

This meta-analysis demonstrated that yoga interventions can significantly improve pulmonary function in clinical populations and may serve as an effective adjunct therapy for managing respiratory conditions. The findings suggest that yoga, particularly pranayama (breathing exercises) and asanas (physical postures), contributes to improvements in key pulmonary functions. However, variations in study designs, intervention protocols and population characteristics introduce heterogeneity, highlighting the need for standardized methodologies in future research. To establish the long-term effect of yoga on pulmonary health, larger, well-designed RCTs are required, particularly those directly comparing yoga with conventional medical treatment.

5.1. Implication on practice

In clinical practice, yoga can be integrated as a complementary therapy adjunct to standard medical treatments for respiratory conditions like asthma or COPD. Healthcare professionals should consider incorporating structured yoga interventions into treatment plans to enhance pulmonary function. Unlike pharmacological treatments that primarily target inflammation and bronchoconstriction, yoga focuses on respiratory muscle strengthening, autonomic regulation, and breath control, offering an additional therapeutic dimension that could improve overall lung function and exercise tolerance.

5.2. Implication on policy

The findings have policy implications for the integration of yoga into mainstream healthcare. Policymakers should consider including yoga-based interventions in standard respiratory care protocols, particularly for patients with chronic pulmonary conditions. Healthcare systems and insurance providers may explore coverage or subsidization of yoga programs as part of pulmonary rehabilitation efforts, recognizing its potential to reduce hospital admissions and improve quality of life.

5.3. Future implications

Future research should focus on optimizing the therapeutic application of yoga by standardized intervention protocols, investing in long-term effectiveness and comparing its efficacy with conventional pulmonary rehabilitation programs. Studies exploring population-specific effects, including different age groups, severity levels of respiratory disease, and comorbid conditions, will be critical in refining clinical recommendations. By integrating yoga with conventional respiratory therapies, future research and policy initiatives can maximize its potential in improving pulmonary health outcomes and enhancing patient well-being.

Author contributions

VR: Conceptualization, Writing - Original draft, Data curation, Formal analysis, Methodology, Software, Investigation; **SS:** Conceptualization, Supervision, Resources, Writing - Review and editing, Validation; **NY:** Visualization, Project administration, Writing - Review and editing, Validation.

Declaration of generative AI in scientific writing

The author(s) did not use any kind of Artificial Intelligence (AI) tools during the preparation of this manuscript. The author(s) reviewed and edited the content as and when suggested and takes full responsibility for the content of the publication.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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