Effects of yoga training in patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis

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Introduction: Currently, several studies have assessed the effect of yoga training on the management of chronic obstructive pulmonary disease (COPD), but these studies involved a wide variation of sample and convey inconclusive results. Hence, the present study was performed a systematic review and meta-analysis to investigate the efficacy of yoga training in COPD patients.

Methods: PubMed, EMBASE, the Cochrane Library, Google Scholar, and ClinicalTrials.gov databases were searched for relevant studies. The primary outcomes were forced expiratory volume in one second (FEV_1), FEV_1% predicted (% pred). Secondary outcomes included 6-min walking distance (6 MWD), arterial oxygen tension (PaO_2), and arterial carbon dioxide tension ($PaCO_2$). Weighted mean differences (WMDs) and 95% confidence intervals (CIs) were calculated, and heterogeneity was assessed with the I^2 test.

Results: Five randomized controlled trials (RCTs) involving 233 patients fulfilled the inclusion criteria. Yoga training significantly improved FEV_1 (WMD: 123.57 mL, 95% CI: 4.12-243, P=0.04), FEV_1% pred (WMD: 3.90%, 95% CI: 2.27-5.54, P<0.00001), and 6 MWD (WMD: 38.84 m, 95% CI: 15.52-62.16, P=0.001). However, yoga training had no significant effects on PaO_2 (WMD: 1.29 mmHg, 95% CI: –1.21-3.78, P=0.31) and $PaCO_2$ (WMD: –0.76 mmHg, 95% CI: –2.06-0.53, P=0.25).

Conclusions: The current limited evidence suggested that yoga training has a positive effect on improving lung function and exercise capacity and could be used as an adjunct pulmonary rehabilitation program in COPD patients. However, further studies are needed to substantiate our preliminary findings and to investigate the long-term effects of yoga training.

Keywords: Chronic obstructive pulmonary disease (COPD); yoga; pulmonary function; meta-analysis

Introduction

Chronic obstructive pulmonary disease (COPD) is an important cause of morbidity and mortality and poses a major public health problem. By 2020, COPD is predicted to rank as the third leading cause of death worldwide, whereas its social burden will rank fifth (1-3). COPD is characterized by irreversible airflow obstruction, a gradual decline in lung function, loss of lung tissue, reduced quality of life, and high rates of mortality. The Global Initiative for Chronic Obstructive Lung Disease (GOLD) management includes a reduction in symptoms, complications, and exacerbations, improved exercise tolerance, improved health status, and reduced mortality (2). Recent evidence-based clinical practice guidelines and statements have shown that pulmonary rehabilitation is widely accepted as the most effective non-pharmacotherapy in the management of COPD (4). Research have indicated that various exercises,

such as upper extremity exercise (5), Tai Chi (6), and yoga training (7), can relieve dyspnea, improve lung function, and improve the quality of life of COPD patients. Furthermore, a physical therapist-assisted intensive flexibility training that focuses on stretching and rib cage mobilization can significantly improve 6-min walking distance (6 MWD) (8).

Yoga originated in ancient India, and may denote the union between the individual self and the transcendental self. The body's organs and systems are cleansed through *asanas* (postures) and *pranayama* (controlling the breath). Along with meditation, yoga *asanas* and *pranayama* have become popular in the West, and the practice of yoga has become "westernized." Postures are taught as ends in themselves, that is, to heal an illness, reduce stress, or to look better (9). Yogic exercises have been shown to have positive effects on people with asthma (10,11), cardiac diseases (12), diabetes (13), tuberculosis (14), depressive disorders (15), osteoarthritis (16), and pleural effusion (17).

A number of clinical trials have suggested that yoga training may improve the pulmonary function of patients with COPD (18,19), but the quality of these studies have not been evaluated systematically. Therefore, we undertook a systematic review and meta-analysis of available randomized controlled trials (RCTs) to assess the efficacy of yoga training on pulmonary function and other clinical endpoints in patients with COPD.

Methods

Data sources and search strategy

The following electronic databases were searched: PubMed, Embase databases, Cochrane Central Register of Controlled Trials, Google Scholar, and ClinicalTrials. gov (until Jan 2014). The employed keywords were "yoga" and "COPD," or "yoga" and "COPD". The searches were limited to English publications in humans as well as RCTs. Bibliographies of all potentially relevant studies, articles (including unpublished data and meta-analyses), and international guidelines were manually searched. Furthermore, we also attempted to contact the authors of potentially relevant studies to obtain additional information.

Study selection

The following inclusive selection criteria inPICOS order involved the following: (I) population: patients with COPD; (II) intervention: yoga training with or without other

treatments; (III) comparison intervention: any type of control; (IV) outcome measures: the primary outcomes were forced expiratory volume in one second (FEV_1) and FEV_1% predicted (% pred), whereas secondary outcomes included 6 MWD, arterial oxygen tension (PaO_2), and arterial carbon dioxide tension ($PaCO_2$); and (V) study design: RCT reported in a full paper article.

Data extraction

For each candidate article, Xun-Chao Liu and Lei Pan recorded the characteristics of the patients being studied, i.e., first author, year of publication, COPD stage, sample size of the study population (intervention/control), grade, staging, age, study design, Jadad scale, interventions (i.e., style of intervention, training frequency, exercise time, and duration), outcome parameters, and their results. Liang Dong checked all of the data. Disagreements were resolved by discussion.

Quality assessment and risk-of-bias assessment

The methodological quality of each research was evaluated using the Jadad scale (20). A score ≤2 indicates low quality, whereas a score ≥3 indicates high quality (21). The risk of bias was assessed using the *Cochrane Handbook for Systematic Reviews of Interventions* (http://ims.cochrane.org/revman). Two authors (Xun-Chao Liu and Lei Pan) subjectively reviewed all studies and assigned a value of 'high,' 'low,' or 'unclear' to the following: (I) selection bias (was there adequate generation of the randomization sequence? was allocation concealment satisfactory?); (II) blinding (i.e., performance bias and detection bias) (was there blinding of participants, personnel, and outcome assessment?); (III) attrition bias (were incomplete outcome data sufficiently assessed and dealt with?); (IV) reporting bias (was there evidence of selective outcome reporting?); and (V) other biases (was the study apparently free of other problems that could place it at a high risk of bias?).

Statistical analysis

This systematic review and meta-analysis is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (22). We used Revman version 5.1 software for all data and statistical analyses. For continuous outcomes, the pooled mean difference was calculated by using the weighted
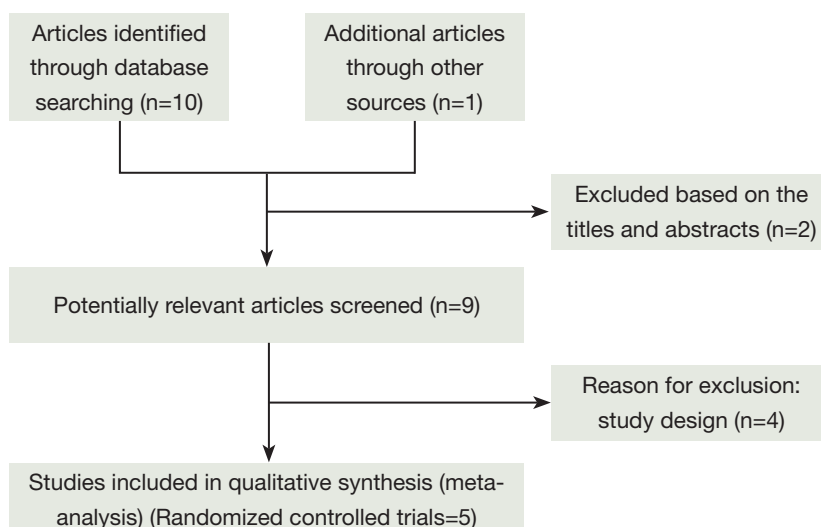
Figure 1 Search strategy and flow chart of screened, excluded, and eventually analyzed articles.

mean difference (WMD). Heterogeneity was assessed with the I^2 statistic and defined as low ($I^2 \le 25\%$), moderate ($25\% < I^2 \le 50\%$), or high ($I^2 > 50\%$) (23,24). A random-effects model was undertaken whether heterogeneity was high or not. Potential publication bias was not assessed because of the limited number of studies (<10) included in each analysis. A P value of <0.05 was considered statistically significant. The overall treatment effect was compared with its minimal clinically important difference (MCID).

Results

Bibliographic search

Figure 1 shows the study search process according to PRISMA guidelines (22). Of the 11 studies retrieved from the initial search, six met our inclusion criteria (7,18,19,25-27), but one study was excluded upon secondary analysis (27). The reasons for exclusion are presented in *Figure 1*. Finally, five RCTs, which had a combined cohort size of 233 participants, were selected for this meta-analysis, and their main characteristics are presented in *Table 1*. The sample size per RCT ranged from 30 to 100. These studies were published between 1978 and 2012, and their duration ranged from 12 weeks to 9 months. Four RCTs reported FEV_1 (18,19) or $FEV_1\%$ (7,25), and two RCTs reported 6 MWD (7,25). Meanwhile, two RCTs reported PaO_2 and $PaCO_2$ (18,19). The mean Jadad score of the studies included was 2.4 (SD=0.89). The risk of bias analysis is presented in *Table 2*.

Primary outcomes

Two RCTs reported primary outcomes as FEV_1 (18,19), and another two RCTs reported $FEV_1\%$ pred (7,25). The aggregate results of these studies suggested that yoga training was associated with a significant improvement in FEV_1 [WMD: 123.57 mL, 95% confidence interval (CI): 4.12-243, P=0.04] (*Figure 2*) and $FEV_1\%$ (WMD: 3.90, 95% CI: 2.27-5.54, P<0.00001) (*Figure 3*). The test for heterogeneity was not significant (FEV_1: P for heterogeneity=0.68, I^2=0%; $FEV_1\%$: P for heterogeneity=0.39, I^2=0%). We subsequently performed sensitivity analyses to explore potential sources of heterogeneity. The mean changes of FEV_1 were greater than the MCID (>100 mL) (28).

Secondary outcomes

Meanwhile, two RCTs reported results in terms of 6 MWD (7,25). The aggregate results of these studies suggested that yoga training was associated with a statistically significant improvement in 6 MWD (WMD: 38.84 m, 95% CI: 15.52-62.16, P=0.001). The results for the heterogeneity test was not significant (P for heterogeneity=0.08, I^2=67%) (*Figure 4*). Subsequently, the mean changes of 6 MWD were greater than the MCID (>26 m) (29). Two RCTs reported PaO_2 and $PaCO_2$ (18,19), and these studies suggested that yoga training was not associated with a significant difference on PaO_2 (WMD: 1.29 mmHg, 95% CI: –1.21-3.78, P=0.31) or $PaCO_2$ (WMD: –0.76 mmHg, 95% CI: –2.06-0.53,

Table 1 Characteristics of randomized controlled trials included in the meta-analysis

First author	Patients No. (I/C), Grade, Staging	Age (years), (Mean, I/C)	Form or style		Protocol	Duration	Study design/ Jadad score
			Yoga group	Control group			
Donesky-Cuenco et al./2009	29 (14/15), Stable, NR	69.9±9.5	Pranayama, asana	Usual-care control	60 min/per time 2 times/w	12 w	RCT/2
Soni et al./2012	60 (30/30), Stable, Mild or Moderate	30-60	Pranayama, asana	Conventional treatment	45 min/d	2 mon	RCT/2
Kulpati et al./1982	75 (25/50), NR, NR	50.6/48.65	Pranayama	Conventional treatment and breathing exercises	30 min/per time 2 times/d	12 w	RCT/2
Tandon et al./1978	24 (12/12), Stable, NR	<65	Yogic breathing exercises and postures	Physiotherapy breathing exercises	60 min/per time 1-4 w: 3 times/w; 5-8 w: 2 times/w; 9 w-9 mo: 2 times/w	9 mon	RCT/2
Katiyar et al./2006	45 (23/22), Stable, severe	53.3/51.1	Pranayama	Usual-care control	30 min/per time 6 times/w	3 mon	RCT/4

I/C, intervention/control; RCT, randomized controlled trial; NR, not reported.

Table 2 Assessing risk of bias

Study/year	Sequence generation	Allocation concealment	Blinding	Incomplete outcome data addressed	Selective outcome reporting	Free of other bias
Donesky-Cuenco et al./2009	Unclear	No	No	Yes	Yes	Unclear
Soni et al./2012	Unclear	No	No	Yes	Yes	Unclear
Kulpati et al./1982	Unclear	No	No	Yes	Yes	Unclear
Tandon et al./1978	Unclear	No	No	Yes	Yes	Unclear
Katiyar et al./2006	Yes	No	Yes	Yes	Yes	Unclear

P=0.25). The test for heterogeneity was not significant (PaO$_2$: P for heterogeneity=0.47, I^2=0%; PaCO$_2$: P for heterogeneity=0.23, I^2=31%) (*Figures 5,6*).

Discussion

This study is the first meta-analysis to evaluate the effects of yoga training on COPD patients. Our results suggested that yoga training has a positive improvement effect on lung function and exercise capacity and could be used as an adjunct pulmonary rehabilitation program for COPD patients.

Currently, no drugs could hinder the progress of COPD, but lung training and pulmonary rehabilitation have been shown to reduce disability in many chronic respiratory diseases and have become valuable means

of COPD treatment (30-33). Studies have indicated an increase in tidal volume and FVC, reduction in respiratory rate, increase in FEV$_1$, FEV$_1$%, maximum voluntary ventilation, and breath holding capacity after short-term yoga practice (34,35). Furthermore, studies suggested that yoga training may improve exercise capacity, prevent lung function decline, improve quality of life, and reduce dyspnea in patients with COPD (36,37). However, these studies did not provide adequate data or sufficient clinical evidence to support the beneficial effects of yoga training on these relevant findings.

Our results suggested that yoga training improved FEV$_1$ or FEV$_1$% pred in four studies (7,18,19,25). However, the results required comparison with the MCID, which is defined as the smallest change in the measurement used to evaluate the clinical significance of intervention effects. The
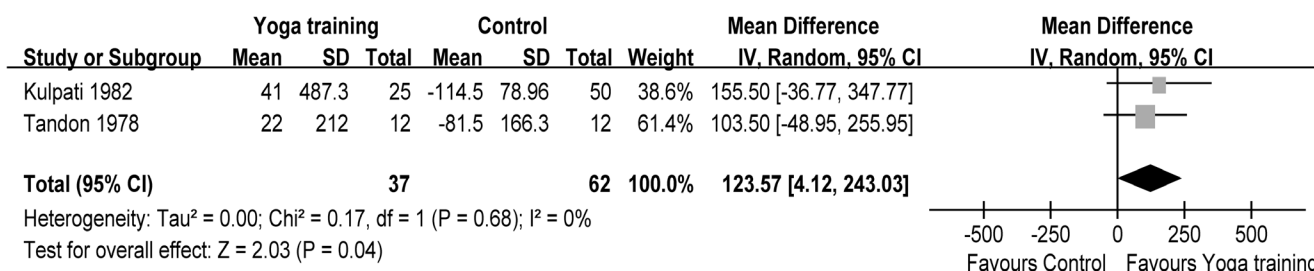
Study or Subgroup	Yoga training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Kulpati 1982	41	487.3	25	-114.5	78.96	50	38.6%	155.50 [-36.77, 347.77]
Tandon 1978	22	212	12	-81.5	166.3	12	61.4%	103.50 [-48.95, 255.95]
Total (95% CI)			37			62	100.0%	123.57 [4.12, 243.03]

Heterogeneity: Tau² = 0.00; Chi² = 0.17, df = 1 (P = 0.68); I² = 0%
Test for overall effect: Z = 2.03 (P = 0.04)

Figure 2 Meta-analysis of randomized controlled trials evaluating effects of yoga training on FEV_1 by the random-effects model. FEV_1, forced expiratory volume in one second.

Study or Subgroup	Yoga training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Donesky-Cuencoet 2009	0	11.56	14	1.5	21.49	15	1.7%	-1.50 [-13.95, 10.95]
Katiyar 2006	4	2.48	23	0	3.12	22	98.3%	4.00 [2.35, 5.65]
Total (95% CI)			37			37	100.0%	3.90 [2.27, 5.54]

Heterogeneity: Tau² = 0.00; Chi² = 0.74, df = 1 (P = 0.39); I² = 0%
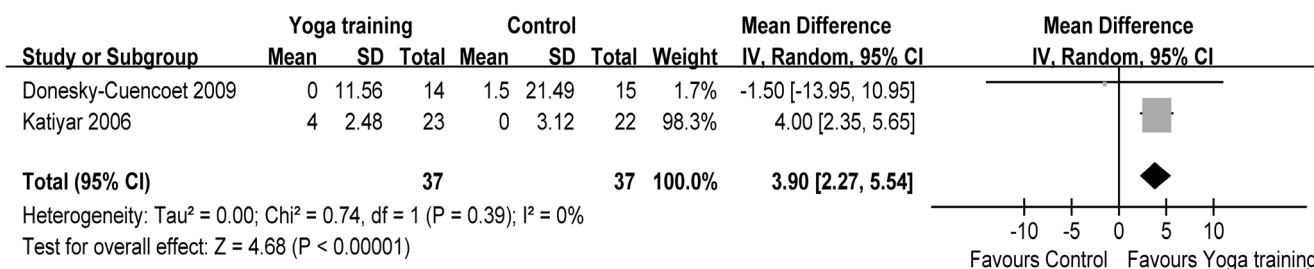Test for overall effect: Z = 4.68 (P < 0.00001)

Figure 3 Meta-analysis of randomized controlled trials evaluating effects of yoga training on $FEV_1\%$ by the random-effects model. FEV_1, forced expiratory volume in one second.

Study or Subgroup	Yoga training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Donesky-Cuencoet 2009	21.67	6.64	14	-8.41	11.03	15	64.8%	30.08 [23.50, 36.66]
Katiyar 2006	50	47.16	23	-5	46.624	22	35.2%	55.00 [27.60, 82.40]
Total (95% CI)			37			37	100.0%	38.84 [15.52, 62.16]

Heterogeneity: Tau² = 207.12; Chi² = 3.00, df = 1 (P = 0.08); I² = 67%
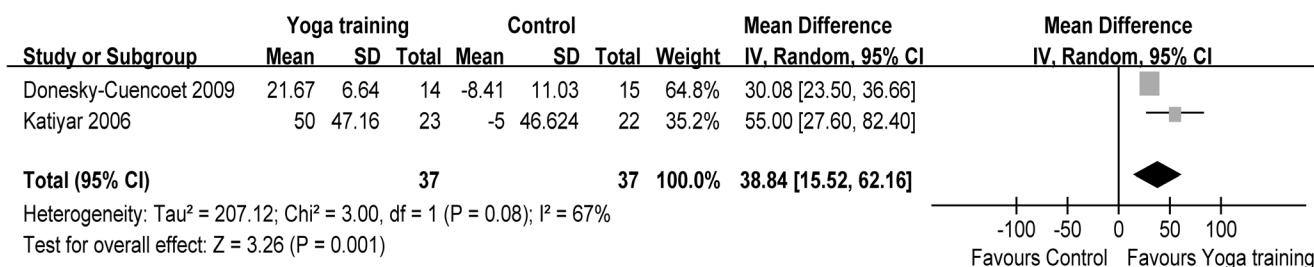Test for overall effect: Z = 3.26 (P = 0.001)

Figure 4 Meta-analysis of randomized controlled trials evaluating effects of yoga training on 6WMD by the random-effects model. WMD, weighted mean difference.
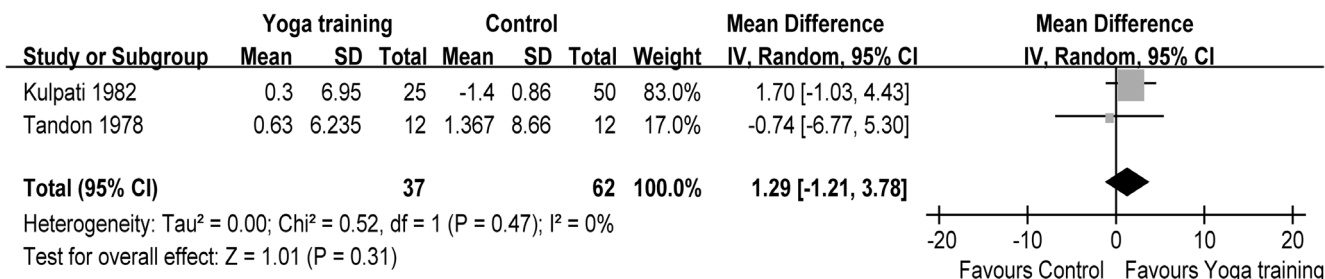
Study or Subgroup	Yoga training Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Kulpati 1982	0.3	6.95	25	-1.4	0.86	50	83.0%	1.70 [-1.03, 4.43]
Tandon 1978	0.63	6.235	12	1.367	8.66	12	17.0%	-0.74 [-6.77, 5.30]
Total (95% CI)			37			62	100.0%	1.29 [-1.21, 3.78]

Heterogeneity: Tau² = 0.00; Chi² = 0.52, df = 1 (P = 0.47); I² = 0%
Test for overall effect: Z = 1.01 (P = 0.31)

Figure 5 Meta-analysis of randomized controlled trials evaluating effects of yoga training on PaO_2 by the random-effects model. PaO_2, arterial oxygen tension.
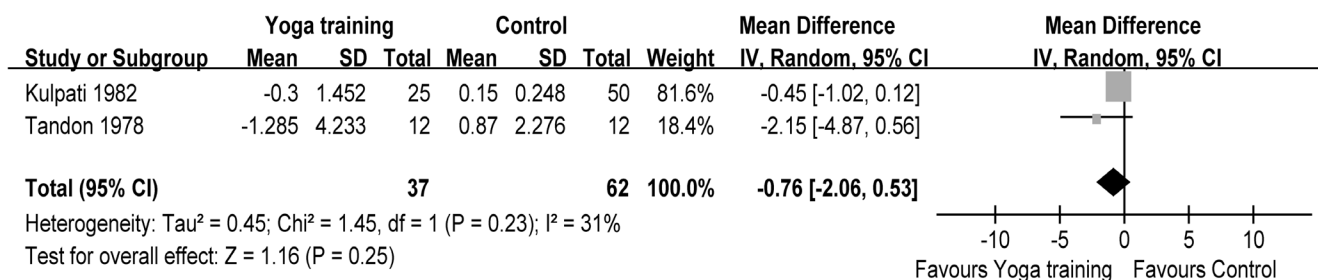
Study or Subgroup	Yoga training			Control			Weight	Mean Difference IV, Random, 95% CI	Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total			
Kulpati 1982	-0.3	1.452	25	0.15	0.248	50	81.6%	-0.45 [-1.02, 0.12]	
Tandon 1978	-1.285	4.233	12	0.87	2.276	12	18.4%	-2.15 [-4.87, 0.56]	
Total (95% CI)			**37**			**62**	**100.0%**	**-0.76 [-2.06, 0.53]**	

Heterogeneity: Tau² = 0.45; Chi² = 1.45, df = 1 (P = 0.23); I² = 31%
Test for overall effect: Z = 1.16 (P = 0.25)

-10 -5 0 5 10
Favours Yoga training   Favours Control

Figure 6 Meta-analysis of randomized controlled trials evaluating effects of yoga training on $PaCO_2$ by the random-effects model. $PaCO_2$, arterial carbon dioxide tension.

MCID is claimed to be a 100-mL change in FEV_1 from baseline (28), and the 123.57 mL increment in FEV_1 in our study is greater than the MCID. This result indicates that yoga training can have a clinical effect on COPD patients. Unfortunately, we failed to compare further the $FEV_1\%$ pred with the MCID because of insufficient available data. Our meta-analysis also found that yoga training statistically improved 6 MWD in patients with COPD. The 38.84 m change for 6 MWD was greater than the MCID (≥26 m) (29). However, our meta-analysis showed that yoga training did not affect arterial blood gas analyses, which included PaO_2 and $PaCO_2$. PaO_2 and $PaCO_2$ are affected by various factors, such as temperature factors (38), breathing frequency (39), varying levels of light intensities (40), sampling location, blood volume, and inspection time (41). We believed that PaO_2 and $PaCO_2$ are not suitable evaluation parameters of yoga training in COPD patients because of their instability. However, further study is needed to investigate this noteworthy topic.

The mechanisms of yoga training responsible for its beneficial effects that differ from other forms of exercise have yet to be elucidated. Several factors may be responsible for the beneficial effects seen in the patients undergoing yoga training aside from exercises (42-45). Yoga training aids in toning up general body systems (42), increasing respiratory stamina, relaxing chest muscles, expanding the lungs, raising energy levels, and calming the body (43). Additionally, yoga training improves blood circulation and increases the strength of respiratory muscles (44). Finally, yoga training also helps patients to breathe more deeply by utilizing the shoulder, thoracic, and abdominal muscles efficiently (45).

Yoga training can provide a complementary strategy for patients with COPD. Apart from relaxing tense muscles, yoga can also alleviate mental pressure (15). However further studies are needed to examine the effectiveness of

yoga training compared with other breathing exercises. Our study showed follow-up durations that ranged from 12 weeks to 9 months, and the long-term effects of yoga training optimal exercise duration currently remain unknown. Future research should focus on optimizing training intensity, duration, and frequency. Moreover, it should be emphasized that the severity may greatly influence the effect of yoga. However, not all studies have noted the severity of COPD patients. Further research should focus on the relationship between the severity and efficacy in COPD patients, which can help to determine the best yoga exercise prescription and the best suitable patients. Finally, most studies lacked other physiological outcome measures, such as inflammatory biomarkers, continuous monitoring, sensitive measures of change, and peripheral muscle strength. Further studies that focus on these will enrich clinical evidence regarding yoga.

Several limitations are identified in our study. First, included trials significantly varied in terms of interventions protocol, duration, patient populations, severity, and study quality, which limit the conclusive extent for the overall effectiveness of yoga training on FEV_1, $FEV_1\%$ pred, 6 MWD, and blood gas analysis in COPD patients. Secondly, our analysis is based on only five RCTs, and only a maximum of two studies were available for the main outcomes. In addition, studies ranged from 1978 to 2012 hence it encompasses a wide time frame which may affect the results as over the years better drugs are available such anticholinergics to ameliorate symptoms of COPD and more standardized and accurate methods are available to measure some clinical endpoints such as lung function and arterial blood gas analysis. Moreover, these studies have a wide variation in patient populations. The smaller sample size of trials may have significantly overestimated the treatment effect. Finally, several missing and unpublished data may lead to bias.

Conclusions

Our meta-analysis suggested that yoga training that lasts from 12 weeks to 9 months may improve lung function and functional exercise capacity in patients with COPD compared with conventional therapy. Moreover, we suggest that yoga could be a useful adjunct pulmonary rehabilitation program for COPD patients. To help clarify the issue, further rigorously designed, larger-scale trials should be conducted to evaluate the long-term effects of yoga training in COPD patients.

Acknowledgements

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