Effect of Active and Passive Stretching on Symptoms in Stable COPD: A Systematic Review and Meta-Analysis

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Abstract

Background:
Chronic obstructive pulmonary disease (COPD) is a chronic lung disease with high mortality and disability rate. It caused the progressive airflow obstruction along with the change of relevant soft tissue. Stretching could lengthen the shorten respiratory muscle and increase its flexibility.

Objectives:
To investigate the effectiveness of stretching on the COPD patients.

Methods:
The PRISMA guideline was used to perform the review. We searched on six online databases (Web of Science, PubMed, Embase, Cochrane Library, CNKI and Wanfang Database) from inception until March 2022. The quality of the studies was appraised by PEDro scale. The pooled effect sizes of exercise capability, lung function parameters, dyspnea, psychological status and quality of life were reported.

Result: Of 422 studies, 11 studies (424 participants) met the inclusion criteria. The overall effect size of the 6MWT showed statistical difference between stretching group and the control group (P<0.00001). Among the lung function parameters, only respiratory rate (RR) and expiratory time (Te) showed superior statistical effect. The data about the psychological state, dyspnea and quality of life were too scant to conclude.

Conclusion: Stretching seemed to have strong effectiveness on improving the exercise capacity, and the breathing temporal parameters could be changed through stretching.

Background
Chronic obstructive pulmonary disease (COPD) is characterized by non-curable and progressive airflow limitation, with high prevalence of disability and mortality \(^1\). It is thought to be the third leading cause of death worldwide by 2030. In China, there are about 100 million people suffering from COPD, and the overall prevalence in adults above 20 years old was 8.6% in 2015, which had increased by 67% within 10 years \(^2\).

Individuals with COPD suffer from the progressive damage of respiratory function and dyspnea. Due to the progresses of those symptoms above, their exercise tolerance was negatively affected, which limited their daily living activities, resulting in poor health-related quality of life. Along with it came the adverse psychological states, such as depression and anxiety \(^3\), and it was very common in the COPD participants.
Pulmonary rehabilitation has been suggested as Class A method to improve symptoms in COPD patients according to the GOLD (the Global Initiative for Chronic Obstructive Lung Disease guidelines) statement. However, the pulmonary rehabilitation regimen was multifarious with different time setting, frequency setting and exercise type etc. Many previous clinical trials were attempted to prove the efficiency of the pulmonary rehabilitation program, such as the breathing exercise, the aerobics, Tai Chi, singing respectively or combined. Whereas, back to the essential change after the occurrence of COPD, except the change of the lung parenchyma, the relevant respiratory muscle fibers shorten, which increase the workload of breathing. Given the condition above, the targeted rehabilitation intervention should be able to modify the shorten muscle fibers, so as to improve the general lung function from the organic level.

Stretching is a commonly used technique to relax the tense muscles, joints and soft tissue in both clinical scenarios or the athletic training. It includes passive stretching and active stretching. As the name suggest, the passive stretching depends on external force from other people, while the active stretching relax the aimed muscle through the antagonist muscle contractile activities. Sometimes, stretching would be classified as the static stretching and the dynamic stretching, and those muscle stretch gymnastics of all kinds are categorized as the dynamic. Regardless of the type of stretching, it is a maneuverable therapeutic method to make the muscles relaxed, that is lengthen the muscle fibers or relieve the muscle stiffness. Hence, stretching has been used to ameliorate the symptom of muscle hyper-shortened or the dysfunction along with it.

Clinically, the application of stretching involved in many diseases of different human body systems. For musculoskeletal disorders, the stretching of the calf muscle and plantar fascia has been proven to improve the symptom of plantar fasciitis and the related muscle stretching could relieve chronic neck pain, subacromial impingement syndrome, patellofemoral pain and so on. In addition, stretching could be utilized to resolve some problems in neurological disease, such as spasticity after stroke, stiff in the Parkinson’s disease and hypertonia after cerebral palsy. By comparison, the usage of stretching on the respiratory disease seemed rather concentrated, most researchers chose the stretching as the intervention for COPD. It might be caused by the interaction between the shorten of the respiratory muscles and the lung dysfunction.

Based on the current studies, stretching was proven to improve the result of 6 minutes walking distance and several index about the lung function, such as respiratory rate (RR), tidal volume (VT), FEV₁ % pred, FVC and so on. The rehabilitation regimen was various, and home-based program was popular amongst these researches, since both the intervention and the progression would last for a long time. While, an immediate respiratory muscle stretching therapy that cost 20 minutes was identified to enhance the inspiratory time and expiratory time immediately.

Stretching could be used in those undeveloped and developing areas widely as a simple and affordable technique. However, its efficiency and the details of the regimen were still uncertain. We need the result
from the higher-level evidence. Based on the present search, the effectiveness of manual therapy on COPD was the only relevant topic among reviews. Stretching had not been singled out for a review. Hence, the purpose of our review was to summarize the previous clinical trials and evaluate the efficiency of stretching on the lung function, exercise ability, psychological state, quality of life and provide some suggestions on the setting of stretching strategy.

Methods

This study was reported according to the PRISMA guidelines and the review protocol was registered on PROSPERO (CRD42022297474). English and Chinese language studies were eligible for inclusion if the publication type was randomized controlled trial that conducted in patients with stable COPD, comparing stretching exercise with other interventions (including usual care). It was enrolled that the trial regarded the stretching exercise (be executed separately) as the main intervention. The attribution of the stretching duration in total intervention time should be more than 40%. Stretching exercise could be active stretching like the Calisthenics or passive stretching. Usual care was defined as any other formal intervention such as exercise, education, or self-management programs. Studies must have reported an outcome related to symptoms of COPD.

Search Strategy

We searched six electronic databases (Web of Science, PubMed, Embase, Cochrane Library, Chinese National Knowledge Infrastructure and Wanfang Database) from inception until 17 March 2022. We also searched manually for additional studies by cross-checking the reference lists of all included primary studies and lists of relevant systematic reviews. Keywords used are as follows: (1) COPD or chronic obstructive pulmonary disease; (2) stretch or stretching or muscle stretching*; (3) passive stretching or active stretching or PNF stretching. The references of the articles selected also needed to be searched manually in order to find out eligible studies. The full search strategy is given in Appendix 1.

Inclusion Criteria and Study Selection

Potentially eligible studies would be included in this review if they met the inclusion Criteria below: (1) published in a peer-reviewed journal; (2) randomized controlled trials (RCTs); (3) study subjects were human beings diagnosed with stable COPD; (4) stretching exercise (be executed separately) was used as main intervention, combined with other interventions or not; (5) have at least one outcome (health-associated quantitative parameters). While, those studies that did not meet the following criteria were excluded from this review: (1) participants with other diagnosis except for COPD; (2) published abstract only or data unreported; (3) research not in English or Chinese. Two investigators independently screened all the articles according to their abstracts and titles, then evaluated the selected articles with full-text reading, in order to remove irrelevant articles. If they had different opinions on one article, the eligibility would be judged by a third reviewer.

Study Quality Assessment for Included Studies
The study quality assessment was evaluated through the Physical Therapy Evidence Database (PEDro) scale [16]. Eleven items were involved as follows: (1) eligible Criteria; (2) randomization; (3) allocation concealment; (4) similar baseline; (5) blind method of participants; (6) blind method of instructors; (7) blind method of assessors; (8) more than 85% retention; (9) intention to treat analysis; (10) between-group comparison; (11) point measure and measures of variability. Two researchers graded articles independently to ensure its accuracy.

**Data Extraction and Statistical Analysis**

Two reviewers extracted data independently. A standardized form was utilized in this process, and the detail information included: the reference information (author, location, language and year of publication), subjects (sample size and attrition rate, mean age/age range, and course of COPD), intervention (exercise dosage weekly and duration), measuring outcomes (lung function, exercise capacity and etc.), adverse event and follow-up evaluation. The Review Manager 5.3 was applied to synthesize the sample size and the quantitative data of participants in selected articles (mean and standard deviation) at baseline and post-intervention. Pooled effect size (Hedge's g) was defined as: small effect size=0.2, medium effect size=0.5, large effect size=0.8. A random-effects model with 95% confidence interval (CI) was applied. The value of $I^2$ was applied to reveal the heterogeneity between studies (small=25%, moderate=50%, large=75%). The random effect model would be used when heterogeneity<50%, otherwise, the fixed effect model would be used. Besides, if the heterogeneity was found moderate to large, the subgroup analysis or the sensitivity test were implemented. And the forest plot was utilized to illustrate the overall effect visually. Sensitivity analysis were performed for achieving high quality studies. For all the results, $p<0.05$ was considered to indicate a statistical difference. Publication bias was detected by the egger’s test in Stata SE 12.0.

**Results**

**Study Selection**

Initially, we yielded 442 studies through electronic and manual database searching. After duplicate, 162 articles were removed. Among the remaining articles, 75 irrelevant articles were excluded; 11 articles were excluded because of no full-text; 43 research protocol articles were excluded; one article was removed since qualitative research; 20 articles were excluded because of not RCT. The full-text of these remaining 12 articles were carefully read and screened. Finally, the number of eligible studies reduced to 11 (Shown in the Figure 1).

**Study Characteristics and Methodological Quality**

The characteristics of the 11 eligible studies are listed in Table 1. The published year was between 1988 and 2021. There were 424 COPD patients all together, with the age range from 53.13 to 72.50. The range of sample size across studies were from 15 to 67. The severity level was from GOLD I to GOLD IV. The intervention duration of stretching exercise ranged from 5 days to 24 weeks, with the frequency ranging
from 2 to 5 sessions per week, lasting 20 to 60 minutes per session. Once treatment for immediate effect was involved also.

**Risk of Bias**

The PEDro scales of the included studies ranged from 5 to 11 (11 in total). The average PEDro score of the included studies was 7.63 out of 11, which indicated general moderate-above quality of those studies. One study got full score, eight scored 10; one scored 9; four scored 7; one scored 6 and two scored 5. Publication Bias was tested through the egger's test in Stata 12.0 and the result showed \( p=0.317 \), which illustrated the low risk of the publication bias. (Figure 2)

**Effects of stretching on lung function**

**Effects of stretching on FEV\(_1\)%pred**

Two studies\(^{26,29}\) with a total of 122 patients were included for FEV\(_1\)%pred analysis. The results showed that FEV\(_1\)%pred of COPD patients in stretching group was not significantly higher than that in the control group (WMD=1.04, 95% CI: -1.97 to 4.05, \( I^2=0\% \), \( p=0.50 \), Fig. 3a).

**Effects of stretching on FVC**

One study\(^{26}\) with a total of 67 patients were included for FVC analysis. The results showed that the FVC of COPD patients in stretching group was not significantly higher than that in the control group (\( p=0.29 \), Fig. 3b).

**Effects of stretching on Respiratory Rate (RR)**

Two studies\(^{14,30}\) with a total of 62 patients were included for RR analysis. The results showed that RR of COPD patients in stretching group was significantly lower than that in the control group (WMD=-3.16, 95% CI: -5.51 to -0.81, \( I^2=0\% \), \( p=0.008 \), Fig. 3c).

**Effects of stretching on Tidal Volume (VT)**

Two studies\(^{14,30}\) with a total of 28 patients were included for VT analysis. The results showed that VT of COPD patients in stretching group was not significantly higher than that in the control group (WMD=0.10, 95% CI: -0.08 to 0.28, \( I^2=67\% \), \( p=0.27 \), Fig. 3d).

**Effects of stretching on expiratory time (Te)**

Only one study\(^{14}\) with a total of 28 patients were included for Te analysis. The results showed that Te of COPD patients in stretching group was significantly higher than that in the control group (WMD=1.12, 95% CI: 0.58 to 1.66, \( p=0.0001 \), Fig. 3e).

**Effects of stretching on exercise capability**
Six studies\textsuperscript{25,26,29,31-33} with a total of 251 patients examined the effects of stretching exercise on 6 minutes walking distance (6MWD). Compared to the control group, there was a significant increase in the stretching group, and it had statistical difference (WMD=30.92, 95% CI: 17.75 to 44.09, $I^2=41\%$, $p$ 0.00001, Fig. 4). In addition, two of the six studies adopted home-based rehabilitation program, while the intervention of the rest studies were implemented in the clinic or hospitals. As the Figure 4 shows, the heterogeneity among studies in each subgroup decreased and the overall effect of the Not Home-based subgroup was higher than that of the Home-based subgroup.

**Effects of stretching on dyspnea**

There were two studies utilizing modified BORG to evaluate the dyspnea level of the participants, but only one of them reported the specific data. The result of the modified BORG revealed superior score in the respiratory muscles stretching group after the intervention\textsuperscript{32,33}. In addition, dyspnea Visual Analog Scale was also a choice for dyspnea assessment\textsuperscript{29}, and the result was the same as the former.

**Effects of stretching on quality of life**

Among the selected articles, only De Sousa Pinto\textsuperscript{25} focused on how the quality of life influenced by stretching through London Chest Activity of Daily Living and St. George's Respiratory Questionnaire (SGRQ). Both of the scales showed statistical difference after three months' intervention with no statistical different baseline.

**Effects of stretching on psychological states**

Few clinical trials concentrated on the psychological states affected by stretching. A very early study in 1988\textsuperscript{34} assessed the depression level by Zung self-Rating Depression Scale and the anxiety level by Spielberger state-trait anxiety inventory (STAI). Based on the result, stretching combined with walking exercise could improve the anxiety but not depression.

**Patient Compliance**

The acceptable rate and the drop-out rate of some included articles were calculated to reveal the patient compliance to stretching. It was obvious that the drop-out rate of the stretching group was lower than that of the control group, which showed better patient compliance to stretching. Nevertheless, of the 11 included articles, there were five articles not reporting the relevant data (eligible participants, consented participants and drop-out participants), so the calculated rate following was shown for reference only (Shown in the Table 2).

**Table 2** The Acceptable Rate and The Drop-out Rate of partial included articles
<table>
<thead>
<tr>
<th>Study</th>
<th>Acceptance rate</th>
<th>Drop-out rate (E)</th>
<th>Drop-out rate (C)</th>
<th>Drop-out rate (Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borghi-Silva, 2009</td>
<td>0.82</td>
<td>0</td>
<td>0.3</td>
<td>0.15</td>
</tr>
<tr>
<td>de Sá, R. B. 2017</td>
<td>1</td>
<td>0.07</td>
<td>0</td>
<td>0.26</td>
</tr>
<tr>
<td>de Sousa Pinto, J. M. 2014</td>
<td>0.90</td>
<td>0.21</td>
<td>0.14</td>
<td>0.29</td>
</tr>
<tr>
<td>Khoshkesht, S. 2015*</td>
<td>-</td>
<td>0.03</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td>Liu, K. 2021</td>
<td>1</td>
<td>0.1</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>Wada, J. T. 2016</td>
<td>1</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Total (unweight)</td>
<td>0.93</td>
<td>0.08</td>
<td>0.11</td>
<td>0.10</td>
</tr>
</tbody>
</table>

* Khoshkesht, S. did not report the number of the eligible participants.

**Adverse events**

No adverse events or side effects were reported by any of the included studies. In addition, in some research, participants indicated that stretching was considered as an easily performed activity. Compared to high-intensity exercise, low-intensity exercise\(^{35}\) like active stretching also had the benefit\(^{26}\) and brought less psychological burden.

**Discussion**

**Stretching improved the walking ability**

Six studies utilized the six minutes walking distance, 6MWD (or six minutes walking test, 6MWT) to evaluate the exercise capability and obtained remarkable positive change. Among the six studies, there were five studies assessing the separate efficiency of stretching. Of them, PNF stretching was the most popular choice and Calisthenics was the last one. No matter the type of the stretching, all the targeted muscles were respiratory muscle groups. Rehman\(^{31}\) reported increased chest expansion with improved 6MWD, which might be caused by decreased stiffness of the chest wall after the stretching intervention. Mechanistically, it was found in Danny A Riley's research that passive stretching could reduce the muscle tissue stiffness, since the enough lengthening of muscle fibers would raise the cytoplasmic calcium through stretch-active calcium channels, and then induce sarcomere addition\(^{16}\). The change of respiratory muscle and chest wall might result in the reduction of dyspnea sensation when walking, which contribute to the longer walking distance or time\(^{33}\). Except for the benefit of the improved respiratory muscles, the patient compliance with the stretching intervention was good. Takahashi, H.\(^{26}\) observed that the active stretching (Calisthenics) did not require the tools or specific weathers like the outdoor strength exercise, and it could be performed easily indoors at any time. That promote the sustained implementation for the program. Besides, the acceptable rate and drop-out rate in parts of
these included articles also illustrated the superior patient compliance to the stretching exercise. That might be a reason for the statistical improvement of the exercise capacity, since the intervention of COPD usually needs to last for a long time.

**The temporal parameter of the lung function improved by stretching**

According to the result, Te and RR were the only two parameters in the lung function that showed positive change. It was interesting to note that Te and RR are the parameters about time, while the parameters of volume like FEV$_1$ pred%, FVC and VT etc. did not show the statistical difference. The reduction of the respiratory rate (RR) might indicate that the increase of respiratory stability, and that minimized the respiratory workload$^{14}$. The time of expiratory rose through stretching, which was mentioned by Ito et al$^{36}$ in a clinical trial. Longer expiratory time would make it easier to implement the pulmonary gas exchange between alveolus and capillary adequately. With unaltered FVC and FEV$_1$ % pred, the increase of the Te caused the reduction of the expiratory flow, which prevent the airway collapse too early$^{36}$. So, even the FVC or FEV$_1$ % pred did not have a significant change, the improvement of the expiratory time and frequency optimized the respiratory pattern to alleviate the respiratory effort and relieve the symptom. However, although the flexibility changes of soft tissue provide more space for the activities of respiratory muscles, the acquisition of the correct respiratory pattern is necessary. Cancelliero-Gaiad KM$^{37}$ suggested that lung volume and SpO$_2$ increased after the diaphragmatic breathing training, and also the reduction of respiratory rate. In Ying Yang et al’s meta-review$^{38}$, the purse-lip breathing combined with the diaphragmatic breathing training was found to improve FVC, FEV$_1$ and FEV$_1$/FVC statistically. In general, based on the result of this review, the improvement of the lung function was limited in the temporal parameters and more randomized clinical trials were warranted for its effectiveness. For the improvement of the symptoms, the combination utilization of stretching and other training was recommended.

**Home-based program or hospital-based program**

More than half selected articles adopted home-based program to implement the stretching training. Generally speaking, the home-based rehabilitation program ensured the compliance via the regular group education program$^{26}$, the counseling session$^{25}$, the phone contact$^{39}$, the home visit$^{40}$ and so on. It was reasonable that home-based was the preferred program, since the symptom of COPD would last for a long time and those patients usually were ordered to receive the sustained training. However, in a review$^{41}$ from Cochrane Database, the hospital-based pulmonary rehabilitation program was found to have a superior result than that of the home-based program. In another review$^{42}$, the home-based program shown the comparable short-term benefits compared with the outpatient-program. Actually, the nonadherence of the home-based pulmonary rehabilitation depends on many factors, and it was proved that frequent exacerbation and smoking would increase the nonadherence rate$^{43}$. Furthermore, from the perspective of cost-effectiveness, the community-based pulmonary rehabilitation had a 50% probability compared with hospital-based in the UK$^{44}$. The development of remote communication promoted the feasibility of home-based rehabilitation and the social media (like WeChat) was proved to reduce the risk
of exacerbation effectively\textsuperscript{45}. Back to our intervention, stretching was much simpler and had more immediate effect than other exercise, which was fit for the home-based rehabilitation. In general, we need to find a balance between the patient compliance and the patient safety, especially during the Covid-19 pandemic time.

**Limitation**

During the searching process, only English and Chinese articles were included, which could cause the missing of similar articles in other language. Besides, the quality of the included articles was low to mild, especially the blind method was ignored in most articles. That would affect the accuracy of the result. Focused on the result, the effectiveness of stretching on dyspnea, quality of life and psychological states remained unclear because of the small sample size. The parameters of the lung function used in the included articles were distributed so the overall effect and the statistical significance were of low validity.

**Conclusion**

Stretching have a positive influence on relieve the symptoms of stable chronic obstructive pulmonary disease, especially on the exercise ability. The lung function could be partially improved. Therein, the respiratory rate and the expiratory time were improved statistically.

**Abbreviations**

COPD: Chronic obstructive pulmonary disease; PEDro: Physical Therapy Evidence Database; SMD: (Standardized mean difference; RR: respiratory rate; Te: expiratory time; GOLD: the Global Initiative for Chronic Obstructive Lung Disease guidelines; VT: tidal volume; RCTs: randomized controlled trials; PEDro: Physical Therapy Evidence Database; CI: confidence interval; SGRQ: St. George's Respiratory Questionnaire; STAI: Spielberger state-trait anxiety inventory.

**Declarations**

**Ethics Approval and Consent to Participate**

Not Applicable.

**Consent for Publication**

Not Applicable

**Availability of data and materials**

All data generated or analysed during this study are included in this published article [and its supplementary information files].
Competing interests

No conflict of interest existed in this study.

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Not applicable.

Authors’ contributions

RJT and KL performed the systematic review of databases, study data abstraction. RJT, ZTQ, ZLZ, JZZ, SYS, KL contributed to the study design and interpretation of results. RJT and ZTQ wrote the manuscript. All authors read and approved the final manuscript.

References


Table

Table 1 is available in the Supplementary Files section.

Figures
Figure 1

Flow Diagram
Figure 2

risk of bias across included studies
Figure 3a FEV$_1$% pred

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Experimental Mean</th>
<th>SD</th>
<th>Total</th>
<th>Control Mean</th>
<th>SD</th>
<th>Total</th>
<th>Weight</th>
<th>IV, Fixed, 95% CI</th>
<th>Mean Difference IV, Fixed, 95% CI</th>
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<tr>
<td>Liu, K. 2021</td>
<td>49.08</td>
<td>6.5</td>
<td>28</td>
<td>47.59</td>
<td>6.45</td>
<td>27</td>
<td>77.5%</td>
<td>1.49 [-1.93, 4.81]</td>
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</tr>
<tr>
<td>Takahashi, H. 2014</td>
<td>45.4</td>
<td>13.7</td>
<td>35</td>
<td>45.9</td>
<td>12.8</td>
<td>32</td>
<td>22.5%</td>
<td>-0.50 [-6.65, 5.65]</td>
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<tr>
<td>Total (95% CI)</td>
<td></td>
<td></td>
<td>63</td>
<td></td>
<td></td>
<td>59</td>
<td></td>
<td>100.0%</td>
<td>1.04 [-1.97, 4.05]</td>
</tr>
</tbody>
</table>

Heterogeneity: Chisquare = 0.29, df = 1 (P = 0.59); I$^2$ = 0%
Test for overall effect: Z = 0.88 (P = 0.50)

Figure 3b FVC

<table>
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<tr>
<th>Study or Subgroup</th>
<th>Experimental Mean</th>
<th>SD</th>
<th>Total</th>
<th>Control Mean</th>
<th>SD</th>
<th>Total</th>
<th>Weight</th>
<th>IV, Fixed, 95% CI</th>
<th>Mean Difference IV, Fixed, 95% CI</th>
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<tr>
<td>Takahashi, H. 2014</td>
<td>3.07</td>
<td>0.75</td>
<td>35</td>
<td>2.85</td>
<td>0.64</td>
<td>32</td>
<td>100.0%</td>
<td>0.18 [0.15, 0.51]</td>
<td></td>
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</tbody>
</table>

Total (95% CI): 35
Heterogeneity: Not applicable
Test for overall effect: Z = 1.06 (P = 0.22)

Figure 3c RR

<table>
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<tr>
<th>Study or Subgroup</th>
<th>Experimental Mean</th>
<th>SD</th>
<th>Total</th>
<th>Control Mean</th>
<th>SD</th>
<th>Total</th>
<th>Weight</th>
<th>IV, Random, 95% CI</th>
<th>Mean Difference IV, Random, 95% CI</th>
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</thead>
<tbody>
<tr>
<td>Borges Silva, A. 2009</td>
<td>16.88</td>
<td>9.64</td>
<td>14</td>
<td>20.33</td>
<td>4.61</td>
<td>14</td>
<td>35.0%</td>
<td>-3.45 [-7.38, 0.49]</td>
<td></td>
</tr>
<tr>
<td>de Sa, R. B. 2017</td>
<td>27</td>
<td>3</td>
<td>20</td>
<td>30</td>
<td>5</td>
<td>14</td>
<td>64.4%</td>
<td>-3.00 [-5.93, -0.07]</td>
<td></td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td></td>
<td></td>
<td>34</td>
<td></td>
<td></td>
<td>28</td>
<td></td>
<td>100.0%</td>
<td>-3.16 [-5.51, -0.81]</td>
</tr>
</tbody>
</table>

Heterogeneity: Chi$^2$ = 0.03, df = 1 (P = 0.86); I$^2$ = 0%
Test for overall effect: Z = 2.63 (P = 0.08)

Figure 3d VT

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Experimental Mean</th>
<th>SD</th>
<th>Total</th>
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<th>Weight</th>
<th>IV, Random, 95% CI</th>
<th>Mean Difference IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borges Silva, A. 2009</td>
<td>1.17</td>
<td>0.31</td>
<td>14</td>
<td>0.966</td>
<td>0.2</td>
<td>14</td>
<td>44.1%</td>
<td>-0.20 [-0.33, 0.06]</td>
<td></td>
</tr>
<tr>
<td>de Sa, R. B. 2017</td>
<td>0.5</td>
<td>0.17</td>
<td>14</td>
<td>0.48</td>
<td>0.15</td>
<td>14</td>
<td>55.9%</td>
<td>0.02 [-0.10, 0.14]</td>
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<tr>
<td>Total (95% CI)</td>
<td></td>
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<td>34</td>
<td></td>
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<td>28</td>
<td></td>
<td>100.0%</td>
<td>0.10 [-0.08, 0.28]</td>
</tr>
</tbody>
</table>

Heterogeneity: Tau$^2$ = 0.81, Chi$^2$ = 2.99, df = 1 (P = 0.08); I$^2$ = 67%
Test for overall effect: Z = 1.11 (P = 0.27)

Figure 3e Te

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Experimental Mean</th>
<th>SD</th>
<th>Total</th>
<th>Control Mean</th>
<th>SD</th>
<th>Total</th>
<th>Weight</th>
<th>IV, Fixed, 95% CI</th>
<th>Mean Difference IV, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>de Sa, R. B. 2017</td>
<td>3.2</td>
<td>0.88</td>
<td>14</td>
<td>2.08</td>
<td>0.54</td>
<td>14</td>
<td>100.0%</td>
<td>1.12 [0.58, 1.66]</td>
<td></td>
</tr>
</tbody>
</table>

Total (95% CI): 14
Heterogeneity: Not applicable
Test for overall effect: Z = 4.06 (P = 0.0001)

Figure 3

Meta-analysis of the effect of stretching on lung function: a FEV$_1$% pred; b FVC; c RR; d VT; e Te.

Abbreviations: FVC, forced volume vital capacity; FEV$_1$% pred, the percentage of predicted values of FEV$_1$; RR: respiratory rate; VT: tidal volume; Te: expiratory time.
### Figure 4

Meta-analysis of the effect of stretching on exercise capability

### Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Appendix1.docx
- PRISMA2020checklist.docx
- Table1.docx