

# Bibliometric Analysis of Exercise and Chronic Obstructive Pulmonary Disease

Mengtong Chen<sup>1,2,\*</sup>, Yuting Zhang<sup>1,2,\*</sup>, Yuqiao Mao<sup>1</sup>, Yunwen Lian<sup>1</sup>, Peng Ye<sup>1</sup>, Chunlong Liu<sup>2</sup>, Zhijie Zhang<sup>3</sup>, Xihua Fu<sup>1</sup>

<sup>1</sup>Department of Infectious Diseases Unit, Panyu Central Hospital, Guangzhou, People's Republic of China; <sup>2</sup>College of Acupuncture Moxibustion and Rehabilitation, Guangzhou University of Chinese Medicine, Guangzhou, People's Republic of China; <sup>3</sup>Department of Rehabilitation, Luoyang Orthopedics Hospital of Henan Province, Luoyang, People's Republic of China

\*These authors contributed equally to this work

Correspondence: Xihua Fu, Email 455170667@qq.com

**Background:** Chronic Obstructive Pulmonary Disease (COPD) is the leading cause of death in the world. Pulmonary rehabilitation includes, but is not limited to, exercise training and education, which aim to improve the physical and psychological conditions of patients with chronic respiratory diseases through self-management interventions.

**Objective:** The aim of this study was to perform a bibliometric analysis of studies on exercise and COPD published from 2000 to 2021 using VOSviewer and CiteSpace.

**Methods:** All included literature was obtained from the Web of Science core collection. VOSviewer was used to analyze country or region, institution, major co-cited journals, and keywords. CiteSpace was used to analyze centrality, author and co-cited authors, journals, the strongest citation bursts of references, and keywords.

**Results:** A total of 1889 articles meeting the criteria were obtained. The United States has the largest number of publications. *The American Journal of Respiratory and Critical Care Medicine* is the most influential in this field, and the most published research institution is Queen's University. Denis E. O'Donnell has made significant contributions to exercise and COPD research. Association, impact, and statement are hot spots of research in this field.

**Conclusion:** A bibliometric analysis of exercise interventions for COPD over the past 22 years provides direction for future research.

**Keywords:** bibliometrics, visualization, exercise, COPD, research hotspots

## Introduction

Chronic obstructive pulmonary disease (COPD) is a common, preventable, and treatable global health problem characterized by persistent airflow limitation and respiratory symptoms, the most common of which include dyspnea, cough, or sputum. According to the World Health Organization (WHO), COPD is the third leading cause of death worldwide,<sup>1</sup> with more than 80% of deaths occurring in low- and middle-income countries.<sup>2,3</sup> According to the Burden of Obstructive Lung Disease (BOLD) program and other large-scale epidemiological studies, the prevalence of COPD is expected to increase over the next 40 years as smoking rates increase in developing countries and populations in high-income countries age. As a result, more than 5.4 million people may die annually from COPD and related diseases by 2060.<sup>4,5</sup> COPD poses a significant economic and social burden to the public health sector, and therefore effective therapeutic interventions for COPD are currently a research hotspot in the medical field.

It has been found that COPD patients have significantly lower than normal exercise levels in daily life for long periods of time, with a corresponding decrease in muscle mass and strength and associated disuse atrophy,<sup>6</sup> leading to a decrease in exercise capacity and quality of life. On March 12, 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a global pandemic.<sup>7</sup> The coronavirus attacks the human respiratory system and causes severe respiratory syndrome.<sup>8</sup> The pandemic raises questions about the management and treatment of patients with COPD.

There is no clear evidence of an increased risk of novel coronavirus infection in COPD patients, and more clinical trials are needed.<sup>9</sup> To reduce the virus's transmission risks, hospital visits for pulmonary rehabilitation for COPD patients are suspended, and COPD patients should be encouraged to stay at home and engage in moderate exercise under professional guidance. Therefore, we believe that in the context of the COVID-19 pandemic, more resources will be devoted to exercise and COPD in the future.

In addition to pharmacological treatments, non-pharmacological treatments can be used as a complement to manage the health of COPD patients. Globally, it is estimated that one in three people currently have a health condition that could benefit from rehabilitation,<sup>10</sup> and pulmonary rehabilitation is an important component of non-pharmacological treatment, and pulmonary rehabilitation has been shown to be the most effective treatment strategy for improving shortness of breath, health, and exercise tolerance.<sup>11</sup> Exercise is a core component of pulmonary rehabilitation and the most appropriate option for patients in their home conditions. Exercises include endurance training, resistance training, interval training, and flexibility training.<sup>12</sup> Multiple lines of evidence suggest that long-term exercise-based pulmonary rehabilitation is better at improving dyspnea, muscle strength, exercise capacity, and quality of life in COPD patients compared to non-exercise programs,<sup>13</sup> while reducing the psychological impact of COPD. The Global Initiative for Chronic Obstructive Lung Disease (GOLD) recommends that people with COPD participate in supervised exercise training at least three times a week for 20–30 minutes per exercise session, with a combination of moderate-intensity constant-load or interval training and strength training.<sup>14</sup> Moderate-intensity exercise can produce a wide range of health benefits, including reduced inflammation, improved immunity, and reduced respiratory viral infections.<sup>15</sup> Therefore, active exercise interventions should be considered a treatment priority for this population.

Bibliometric analysis is a method of statistical analysis of research results from the perspectives of authors, institutions, keywords, countries, cited authors, journals, and references using analysis software, which helps researchers have a clear understanding of the research field and grasp the research basis, hot issues, and frontier trends in the field.<sup>16</sup> In recent years, bibliometrics has been widely used in medical fields such as acupuncture, pain, and regenerative medicine.<sup>17–19</sup> Although there have been many publications on exercise interventions and COPD, to the best of our knowledge, these publications have not been analyzed bibliometrically with a visual approach to exercise interventions in COPD. Therefore, this study aims to help researchers understand the research progress and emerging research hotspots in this field by surveying the important collaborative forces, classic conferences, key conferences, and research hotspots in the field of exercise interventions for COPD in the past 22 years, in order to provide better exercise guidance and recommendations for COPD patients.

## Materials and Methods

### Search Strategy

All publication papers were searched from the Web of Science core collection database. We also used the Science Citation Index Expanded (SCI-Expanded) database of Web of Science (WOS) as the source of available databases. We set the period of publication paper retrieval from January 1, 2000, to December 31, 2021. The data search strategy was “TI = (exercise\* OR kinesitherapy OR training OR “physical activity\*” OR sport\* OR fitness OR walk\* OR run\* OR swim\* OR jog\* OR cycling OR pilates\* OR yoga OR qigong OR “tai chi”)<sup>20</sup> AND TI = (“Pulmonary Disease, Chronic Obstructive” OR “Chronic Obstructive Lung Disease” OR “Chronic Obstructive Pulmonary Diseases” OR “COAD” OR “COPD” OR “Chronic Obstructive Airway Disease” OR “Chronic Obstructive Pulmonary Disease” OR “Airflow Obstruction\*Chronic” OR “Chronic Airflow Obstruction\*”) AND Language = English”. The publication types were restricted to “article” or “review”, letters, meeting abstracts, published editorials, materials, book reviews, conference presentations, news items, and corrections were excluded.

### Analytical Tools

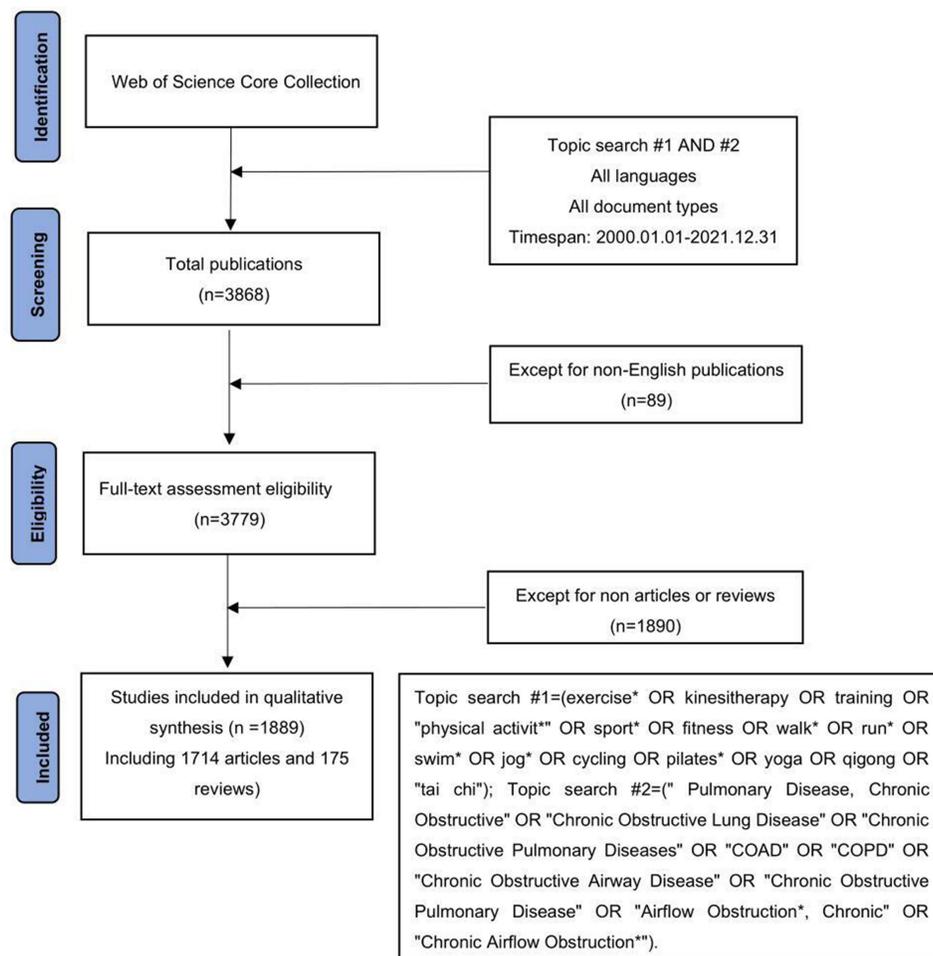
The data was cleaned up before the analysis, including removing duplicate documents and merging similar words. Graphs of the annual number of publications, the annual cumulative number of publications, and the annual total number of citations were produced by Microsoft Excel 2019 to analyze the global outputs and trend of articles related to COPD and exercise.

VOSviewer (1.6.17) (Leiden University, Leiden, Netherlands)<sup>21</sup> was used to identify productive countries or regions, institutions, the main co-cited journals, co-occurring keywords, and related visual networks. The network map was produced by VOSviewer; the size of nodes reflected the number of articles or the frequency of co-occurrence; the different colors of nodes represented different categories of research topics; the link between nodes represented the co-occurrence relationship, and the size of the link represented the co-occurrence frequency of two nodes. CiteSpace (5.8.R3) (Drexel University, Philadelphia, PA, USA)<sup>22</sup> was used to analyze authors and co-cited authors, journals, the strongest citation bursts of references, and keywords. The strongest citation bursts show the growing interest of researchers in potential research at a given time and are a key indicator for identifying emerging hot trends.<sup>23</sup> To obtain key clusters, three specialized measures were used: latent semantic indexing (LSI), logarithmic likelihood test (LLR), and the mutual information test (MI). Modular Q values > 0.3 mean that the delineated clustering structure is significant, average silhouettes > 0.5 are considered reasonable for clustering, and average silhouettes > 0.7 indicate that the clustering results are convincing. CiteSpace can help researchers understand the development trend of a field and find research hotspots. CiteSpace was also used to identify centrality, high centrality is often considered a pivotal point in a field.

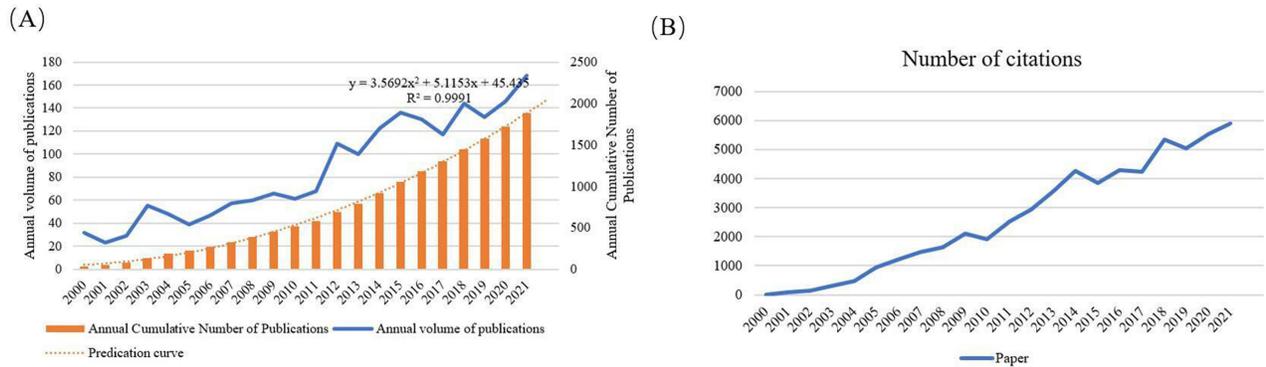
## Results

### Annual Publication Outputs and Growth Trend

From 2000 to 2021, a total of 1889 publications met the inclusion criteria, including 1714 articles and 175 reviews (Figure 1), with an average annual production of 85. Graphs of the number of articles and frequency of citations were obtained using Microsoft Excel (Figure 2). Although there were fluctuations during the period, there was an overall



**Figure 1** The flow chart of study screening process.

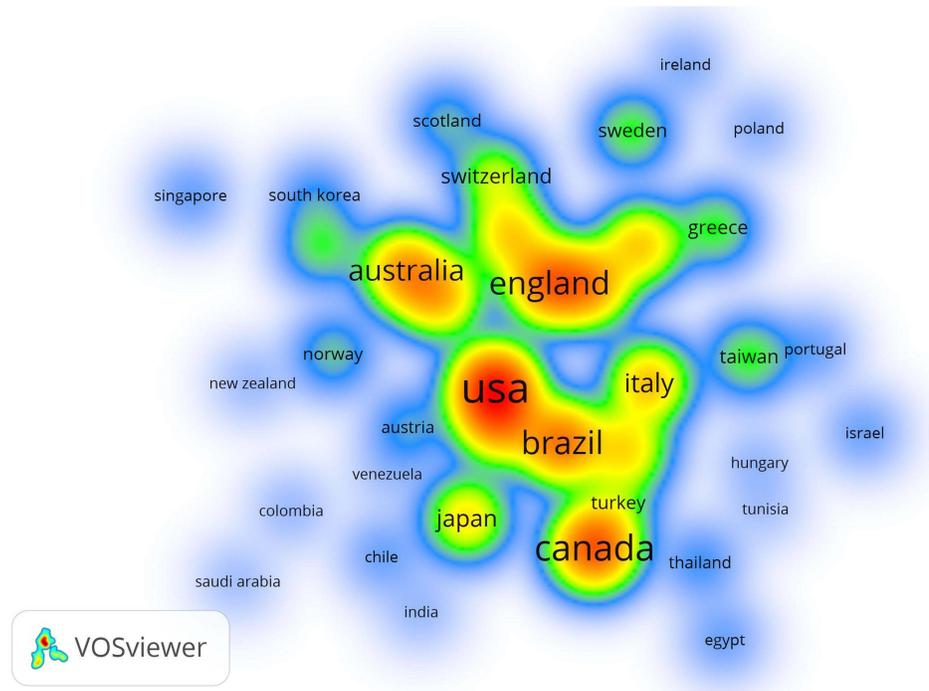


**Figure 2** Number of publications and citations.  
**Notes:** (A) The number of publication outputs and growth trend from 2000 to 2021. (B) The number of annual citations from 2000 to 2021.

upward trend in the annual volume of publications on exercise and COPD. We fitted a polynomial to the annual cumulative volume of publications in Figure 2A, with a growth trend model  $R^2 = 0.9991$ , predicting that more articles on COPD and exercise will be published in the future. Figure 2B shows that 1889 articles were cited 57,747 times (H-index 106), with an average annual citation frequency of 2624 and an all-time high of 5906 citations in 2021. These results suggest that interest in exercise and COPD continues to grow, and the intensity of research will continue to increase.

### Analysis of Country

The 1889 articles were published in 69 countries. For better visualization, we only selected 38 countries with more than 5 articles via VOSviewer (Figure 3). Each node represents a country, and the size of the node represents the number of posts in that country. The larger the node, the greater the number of articles published in this field in that country. In addition, the lines between the nodes represent the connections between countries, and the closer the connections, the thicker the lines. The countries or regions are presented on the world map in Figure 4.



**Figure 3** The item density visualization of active countries.  
**Notes:** The higher the density, the closer it is to red. Conversely, the lower the density, the closer it is to blue.

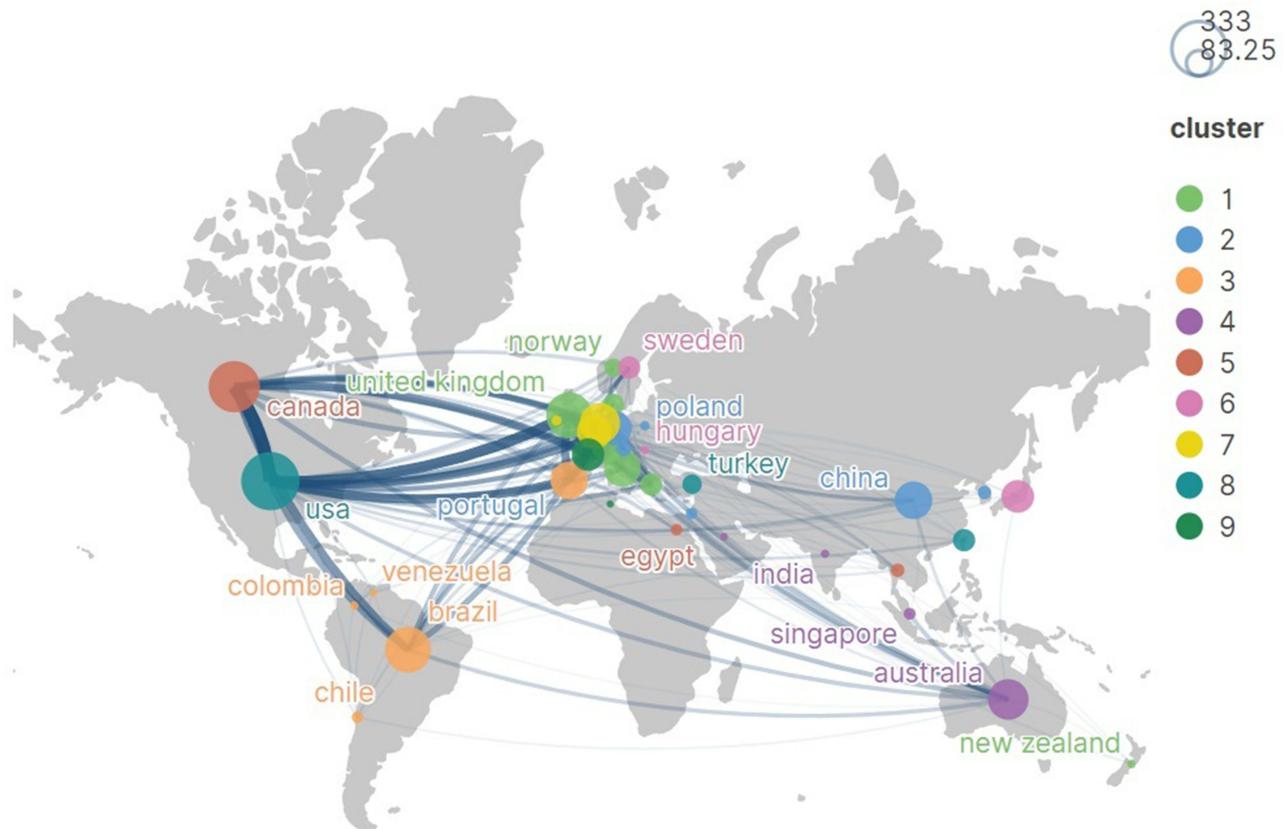


Figure 4 World Map of active countries.

The list of the top 5 countries is presented in Table 1. The USA ranked first with 333 publications, followed by Canada and the United Kingdom, followed by Brazil, and finally Australia. The top five countries in terms of centrality were the USA, followed by the United Kingdom, Canada, Brazil, and Australia.

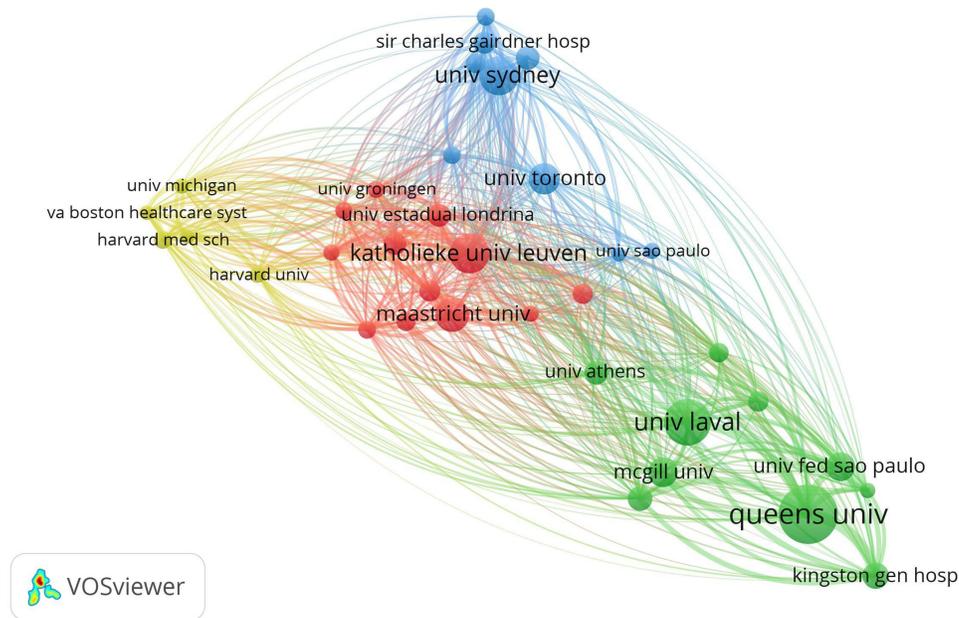
### Analysis of Institution

Overall, 1889 publications on exercise and COPD were coauthored by 2289 institutions. To obtain a better visualization, we only included institutions with at least 20 publications (Figure 5).

The list of the top 5 institutions was presented in Table 2. Queens University has published the largest number of publications (80), followed by the University of Laval (63), the Katholieke University Leuven (54), the University of Sydney (53), and the Maastricht University (46). The University of Laval showed the highest centrality (0.18). From the timeline of articles published by the institution using VOSviewer, the Hasselt University and the Harvard medical school pay more attention to exercise and COPD around 2016.

Table 1 Top 5 Active Countries with Count and Centrality

Rank	Country	Count	Country	Centrality
1	United States	333	United States	0.60
2	Canada	258	United Kingdom	0.29
3	United Kingdom	206	Canada	0.13
4	Brazil	206	Brazil	0.09
5	Australia	162	Australia	0.09



**Figure 5** Map of active institutions.

## Distribution of Journals and Co-Cited Journals

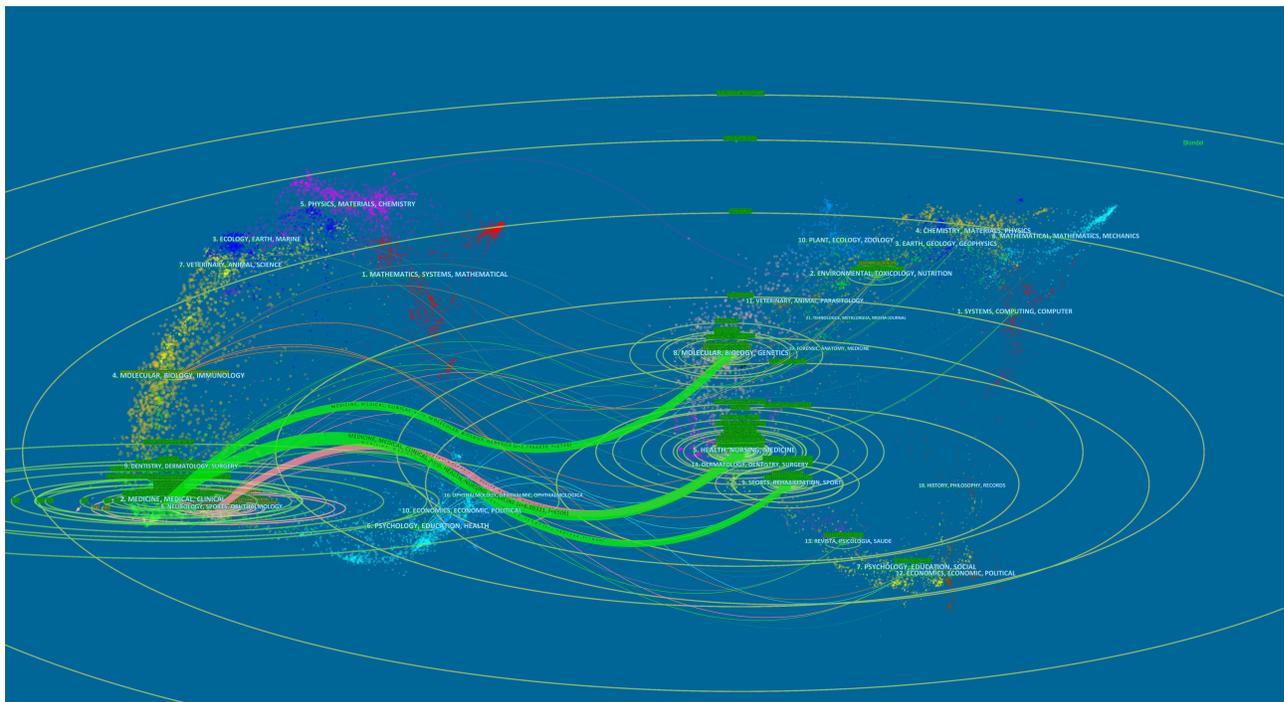
A total of 310 journals published papers on exercise and COPD. [Figure 6](#) shows a dual-map of journals. Citing journals were represented on the left, and cited journals were represented on the right. A line connects the reference logs on the left and the right. In a double-map overlay, the labels are labeled according to the subject discipline. The dual map shows that most journals are from the fields of medicine, medical and clinical. At the same time, most of the journals are cited in the fields of health, nursing, and medicine. [Table 3](#) shows the top 10 academic journals publishing articles related to exercise and COPD research. *Respiratory Medicine* led the way with 149, followed by the *International Journal of Chronic Obstructive Pulmonary Disease* with 137, followed by *CHEST* with 105, *European Respiratory Journal* with 95, and finally the *Journal of Chronic Obstructive Pulmonary Disease* with 80. The average impact factor of the top 10 journals by the number of publications was 7.67, with the highest impact factor being the Sixth Ranked American Journal of Respiratory and Critical Care Medicine (IF=21.405). We only included 50 co-cited journals with at least 150 times via using VOSviewer ([Figure 7](#)). Ranked by co-citations, the *American Journal of Respiratory and Critical Care Medicine* ranked first with 1722, followed by the *European Respiratory Journal* with 1693, *CHEST* with 1622, *THORAX* with 1345, and *Respiratory Medicine* with 1157 ([Table 4](#)). The centrality was calculated by CiteSpace, and the journal with the highest centrality was *JAMA-Journal of the American Medical Association* (0.06).

## Analysis of Authors and Co-Cited Authors

The authors' map was generated using CiteSpace, and 1889 papers were published by 6805 study authors ([Figure 8](#)). Each node represents an author, and the larger the node, the more papers were published. The connections between nodes represent cooperation, and the more extensive the connections, the closer the cooperation. The authors' cooperation map was generated by Cite Space with 770 nodes and 1212 links ([Figure 8](#)). The network density was 0.0041. [Table 5](#) lists the

**Table 2** Top 5 Active Institutions with Count and Centrality

Rank	Institution	Count	Institution	Centrality
1	Queens University	80	University of Laval	0.18
2	University of Laval	63	Harbor UCLA Medical Center	0.10
3	Katholieke University Leuven	54	Hasselt University	0.09
4	University of Sydney	53	Queens University	0.06
5	Maastricht University	46	Katholieke University Leuven	0.06



**Figure 6** The dual-map overlay of journals with publications.

top 10 authors who have published papers related to exercise and COPD. They are active professional writers from Canada, the Netherlands, the United Kingdom, Australia, and Spain. The collaboration between authors can be seen in Figure 8. Among the authors, O’Donnell DE, Maltais F, and Neder JA from Canada are closely related, as are Spruit MA and Wouters EFM from the Netherlands, which are mainly related to the region, but there is little connection between the authors from different countries. It indicates that scientific research exchanges and cooperation among countries should be strengthened.

A total of 852 authors had been cited. To get better visualization, we obtained a simplified network structure diagram (Figure 9, N = 852, E = 1246) by pruning the map through Pathfinder. Among all co-cited authors, anonymous authors had been cited 437 times. We would not discuss anonymously cited authors in this part. In addition, Denis E. O’Donnell ranked first, followed by Robert O. Crapo, Spruit Martijn A, Thierry Troosters, and Francois Maltais (Table 5).

In CiteSpace, the importance of nodes is highlighted through centrality. In other words, nodes with higher centrality play a greater role in the network. Griffiths, Timothy L, ranked first with the highest centrality (0.26), and he came from the University Hospitals of North Midlands.

**Table 3** Top 10 Academic Journals

Rank	Publications	Journal (Abbreviations)	IF (2020)
1	149	Respiratory Medicine (RESP MED)	3.415
2	137	International Journal of Chronic Obstructive Pulmonary Disease (INT J CHRONIC OBSTR)	3.355
3	105	CHEST	9.41
4	95	European Respiratory Journal (EUR RESPIR J)	16.671
5	80	Journal of Chronic Obstructive Pulmonary Disease (COPD)	2.409
6	60	American Journal of Respiratory and Critical Care Medicine (AM J RESPIR CRIT CARE MED)	21.405
7	59	Journal of Cardiopulmonary Rehabilitation and Prevention (J CARDIOPULM REHABIL)	2.081
8	57	Respiratory Care (RESP CARE)	2.258
9	45	Respirology	6.424
10	43	Thorax	9.25

**Note:** Impact factor (IF) according to Journal Citation Reports (2020).

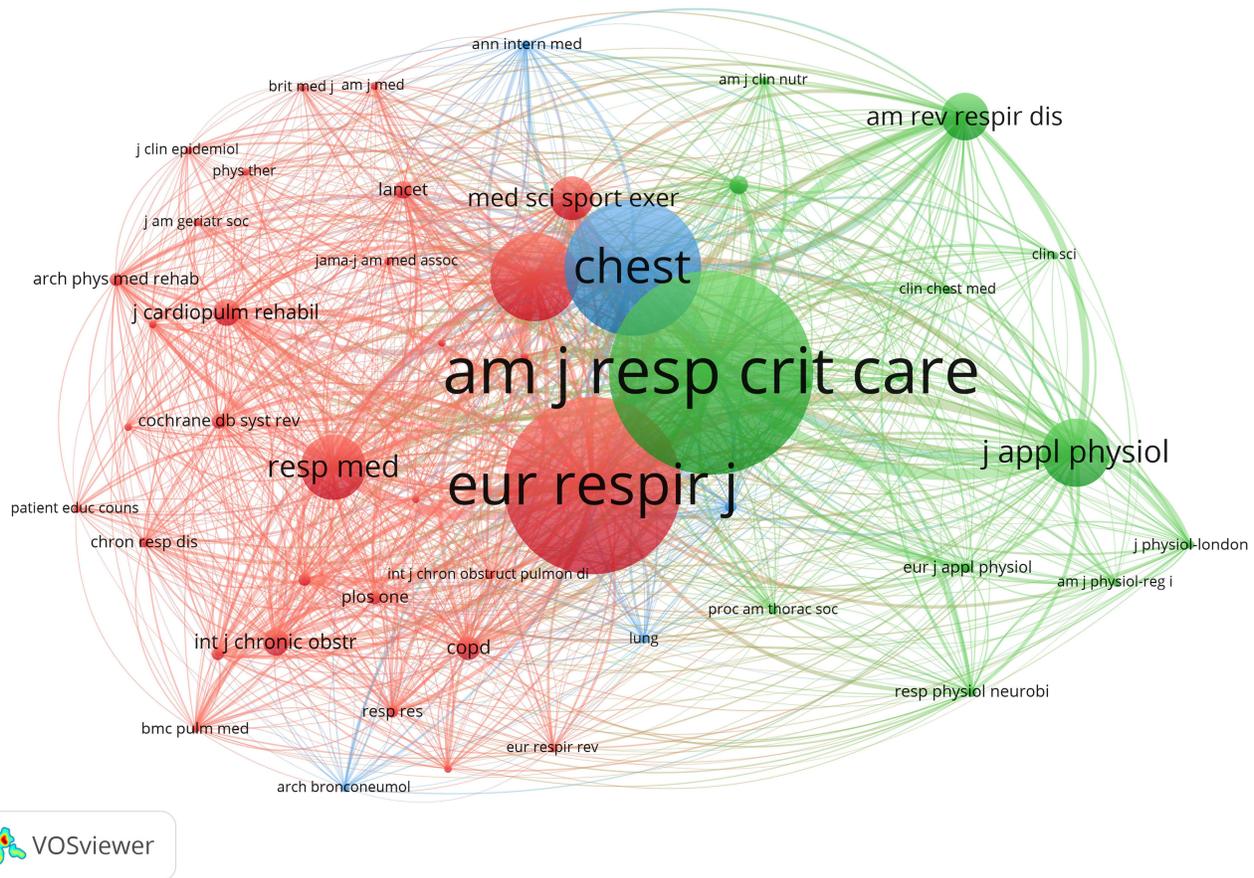


Figure 7 Map of co-cited journals with publications.

### Analysis of Co-Cited References

A total of 28,049 references were generated from 1889 records for the analysis of co-cited references. According to the period from 2000 to 2021, the time slice is 1, and the top 5 items with the most citations and the highest centrality during 2000–2021 are selected by CiteSpace.

As shown in Table 6, a key literature review jointly published by author Martijn A. Spruit and other experts in 2013 ranked first with 154 co-citations. This article presented a new definition of pulmonary rehabilitation and described the science and application of pulmonary rehabilitation, including its effectiveness in acutely ill individuals with chronic obstructive pulmonary disease.<sup>12</sup> In the co-cited literature, the article with the highest centrality (0.16) was published by Henrik Watz et al in 2008 (Table 6). In a cross-sectional study, high values of systemic inflammation and left heart insufficiency in COPD patients were associated with reduced exercise.<sup>24</sup> These cited studies are landmark publications in this field, laying the foundation for future research.

Table 4 Top 5 Co-Cited Journals and Centrality

Rank	Co-Cited Counts	Cited Journal (Abbreviations)	Centrality	Cited Journal (Abbreviations)
1	1722	American Journal of Respiratory and Critical Care Medicine (AM J RESP CRIT CARE MED)	0.06	JAMA-Journal of the American Medical Association (JAMA-J AM MED ASSOC)
2	1693	European Respiratory Journal (EUR RESPIR J)	0.04	Circulation
3	1622	Chest	0.04	American Journal of Physiology-Regulatory Integrative and Comparative Physiology (AM J PHYSIOL-REG I)
4	1345	Thorax	0.04	British Journal of Sports Medicine (BRIT J SPORT MED)
5	1157	Respiratory Medicine (RESP MED)	0.04	Nursing Research (NURS RES)



Figure 8 Map of authors with publications.

## Analysis of Co-Occurring Keywords

From 2000 to 2021, a total of 4154 keywords appeared in the fields of exercise and COPD. In the VOSview software, we set the display co-occurrence frequency to at least 100 times (Figure 10). Therefore, a total of 23 keywords were frequently cited and grouped into three clusters. The green cluster represents the study of COPD disease manifestations and diagnostic evaluation measures; the blue cluster represents the study of exercise intensity, exercise type, and action site in COPD patients; and the red cluster represents the study of exercise ability, functional status, quality of life and disease prognosis in the process of COPD rehabilitation.

The centrality of each keyword was calculated using the CiteSpace software. Based on the analysis of co-occurrence frequency and centrality (Figure 10, Table 7), it was found that the maximum co-occurrence frequency was 901 times for “COPD”, followed by “obstructive pulmonary- disease” (673 times), “chronic obstructive pulmonary disease” (556 times), “exercise” (549 times), and “rehabilitation” (501 times). The highest centrality was for “lung disease” (0.07).

Table 5 Top 5 Active Authors and Co-Cited Authors

Rank	Author	Count	Co-Cited Author	Count	Co-Cited Author	Centrality
1	O'Donnell DE	54	Denis E. O'Donnell	563	Griffiths, Timothy L.	0.26
2	Maltais F	48	Robert O. Crapo	486	Bohannon, Richard W.	0.18
3	Neder JA	47	Spruit Martijn A	440	Decramer, Marc	0.16
4	Spruit MA	42	Thierry Troosters	412	Calverley, Peter M. A.	0.15
5	Wouters EFM	33	Francois Maltais	410	Ofir, Dror	0.14

CiteSpace, v. 5.8.R3 (64-bit)  
 March 13, 2022 9:24:05 PM CST  
 WoS: C:\Users\HUAWEI\Desktop\运动与COPD\data  
 Timespan: 2000-2021 (Slice Length=1)  
 Selection Criteria: g-index (k=25), LRF=3.0, L/N=5, LBY=8, e=2.0  
 Network: N=852, E=1246 (Density=0.0034)  
 Largest CC: 823 (96%)  
 Nodes Labeled: 1.0%  
 Pruning: Pathfinder

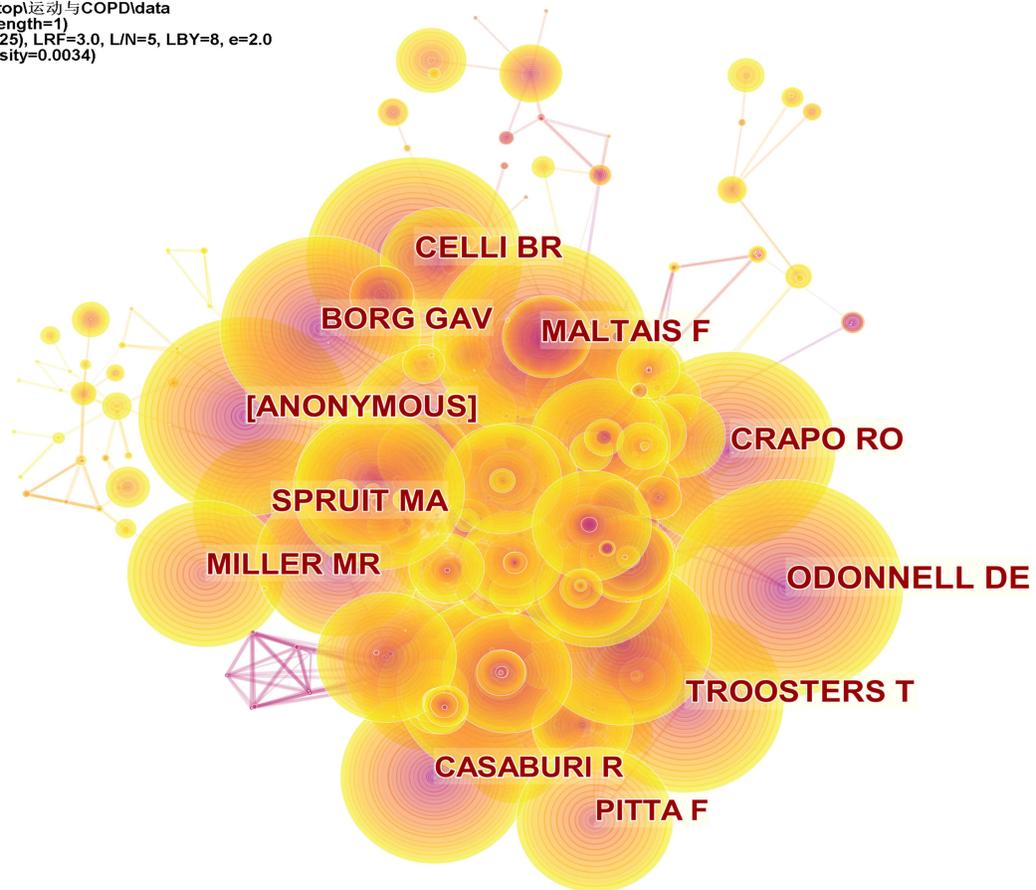


Figure 9 Map of co-cited authors with publications.

## Discussion

### Research Trends for Exercise and COPD

Based on data collected from the Web of Science core collection database from 2000 to 2021, a total of 1889 articles on exercise and COPD were published in 310 journals. A total of 2289 institutions participated in the research and published

Table 6 Top 5 Co-Cited References in Terms of Counts and Centrality

Counts	Cited Reference	Centrality	Cited Reference
154	An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. <sup>12</sup>	0.16	Extrapulmonary effects of chronic obstructive pulmonary disease on physical activity: a cross-sectional study. <sup>24</sup>
104	Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. <sup>25</sup>	0.13	The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. <sup>26</sup>
98	Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. <sup>27</sup>	0.13	Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. <sup>28</sup>
96	Pulmonary rehabilitation for chronic obstructive pulmonary disease. <sup>11</sup>	0.12	American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation. <sup>29</sup>
93	An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. <sup>30</sup>	0.12	Are patients with COPD more active after pulmonary rehabilitation? <sup>13</sup>

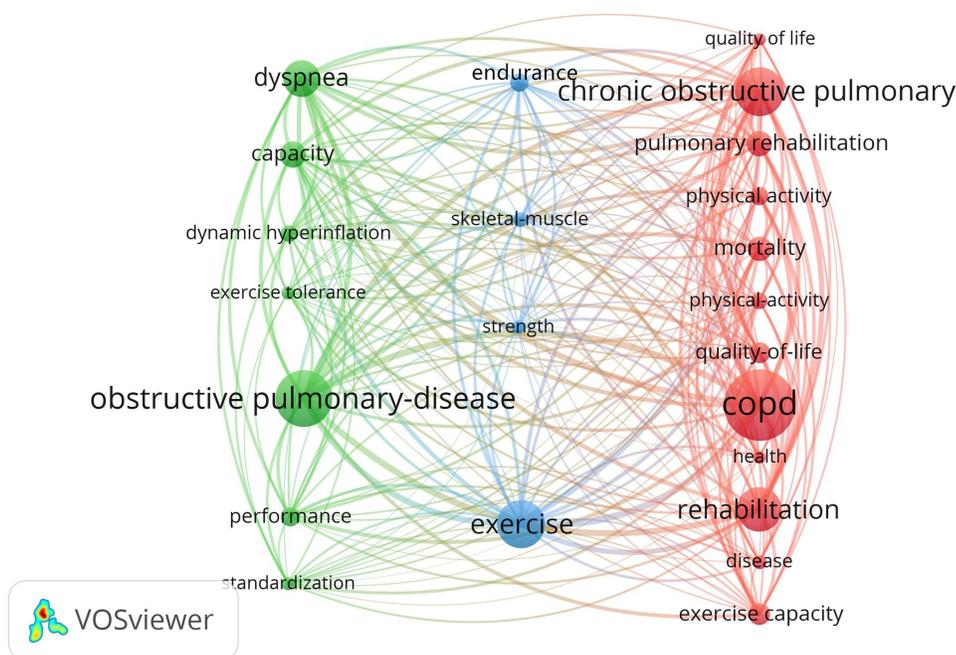


Figure 10 Map of co-occurring keywords with publications.

papers, which were distributed in 69 countries around the world. From 2000 to 2021, the 1889 papers were cited 57,747 times. To the best of our knowledge, this is the first study using bibliometrics and visual analysis to evaluate trends in exercise and COPD, prospective outcomes, and research hotspots, which may provide directions for future research.

As shown in Figure 2, although the number of publications decreased in 2005, 2013, 2017, and 2019, the number of publications per year increased dramatically from 2019 to 2021, reaching 168 papers and 5906 citations in 2021. With the spread of the idea of “exercise as medicine”,<sup>31</sup> appropriate exercise is essential to improving the daily living abilities of COPD patients. In addition, most COPD patients are elderly and have multiple comorbidities such as cardiovascular disease and diabetes, making them more vulnerable to serious complications of COVID-19.<sup>32</sup> However, home isolation can delay COPD patients’ recovery. For COPD patients, in addition to regular medication, increased exercise at home for cardiopulmonary rehabilitation is necessary. For example, tai chi increases lung capacity by counteracting the formation of fibrotic scars, thus improving the quality of life and mental status of COPD patients,<sup>33</sup> and it is also considered an effective rehabilitation tool for people affected by post-COVID-19. Many countries are gradually starting to focus on the field of exercise interventions for COPD research. The growing trend in the number of papers indicates that this research area has received increasing attention in recent years, and we predict great potential for growth in this research area.

Table 7 Top 10 Keywords

Rank	Occurrences	Keyword	Centrality	Keyword
1	901	COPD	0.07	Lung disease
2	673	Obstructive pulmonary- disease	0.06	Air flow obstruction
3	556	Chronic obstructive pulmonary disease	0.05	Skeletal muscle
4	549	Exercise	0.05	Intensity
5	501	Rehabilitation	0.05	Breathlessness
6	389	Dyspnea	0.05	Pressure
7	259	Capacity	0.04	Endurance
8	253	Pulmonary rehabilitation	0.04	Strength
9	236	Mortality	0.04	Exercise tolerance
10	202	Exercise capacity	0.04	Limitation

## Quality of Global Publications on Exercise and COPD Countries

As shown in [Table 2](#), the United States ranked first in the exercise and COPD topic studies with the highest number of publications (333) and the highest centrality (0.6). COPD poses a significant economic threat to the United States, and it is the second leading cause of disemployment-adjusted life years (DALY) loss in the United States<sup>34</sup>, after ischemic heart disease.

In item density visualization ([Figure 3](#)), each node on the graph fills in with the color based on the density of the elements surrounding that node. The higher the density, the closer it is to red. Conversely, the lower the density, the closer it is to blue. The density depends on the number of elements in the surrounding area and the importance of those elements. As can be seen from [Figure 3](#), the countries with the most frequent cooperation with the United States include the United Kingdom, Brazil, Canada, Australia, Italy, and Japan, and the countries with the most close cooperation are all developed countries. A strong research culture underpinned by significant public and private funding no doubt supports this. In addition, the top five countries in terms of the number of publications also have high centrality, which indicates that these countries are more active in the international community and have closer cooperation with other countries. It can also be seen from [Table 1](#) that, among the top five countries, only Brazil is a developing country, indicating that developed countries have invested a lot in this aspect.

### Institutions

In [Table 2](#), Queens University and Laval University, both from Canada, are ranked first in several publications and centrality respectively. As can be seen from [Figure 5](#), Queens University has the closest connection with Kingston General Hospital, but it still needs to strengthen cooperation with other institutions. The University of Laval has the highest centrality, this shows that the University of Laval is active in this field and works closely with other institutions. Collaboration helps researchers who investigated exercise and COPD share resources and exchange knowledge and ideas, which is crucial for further development. Thus, stronger collaboration networks should be established among more institutions.

### Journals and Co-Cited Journals

A total of 310 journals have published papers on exercise and COPD. From the dual map of the journals ([Figure 6](#)), most journals focus on the fields of medicine, medical, and clinical, while most of the co-cited journals focus on the fields of health, nursing, and medicine. [Table 3](#) showed that *Respiratory Medicine* has published more exercise and COPD papers over the past 22 years, with 149 papers, and is the favorite journal of exercise and COPD researchers (IF = 3.415). However, from the perspective of publications, it is not enough to consider only the most influential journal on exercise and COPD. As shown in [Figure 7](#) and [Table 4](#), the most frequently cited journal is the *American Journal of Respiratory and Critical Care Medicine*, with 1722 co-citation counts and three of the top five citations. We found that the first paper cited in terms of counts was also from the *American Journal of Respiratory and Critical Care Medicine*. Therefore, we can say that the *American Journal of Respiratory and Critical Care Medicine* has the greatest influence in this field (IF = 21.405). In terms of centrality, the journal active in exercise and COPD is *JAMA-Journal of the American Medical Association* ([Table 4](#)), which works closely with other journals. Future scholars should pay more attention to these journals to obtain international information and the latest advances in exercise and COPD.

### Authors and Co-Cited Authors

In this study, CiteSpace helped to identify the top authors in terms of numbers of publications and the number of citations ([Figures 8](#) and [9](#)), and the information about author citations in the field contributed to establishing potential co-authorships. As shown in [Table 5](#), Denis E. O'Donnell has the highest number of publications (54) and co-citation counts (563). Griffiths Timothy L. is ranked as the first co-cited author in terms of centrality (0.26). Two authors have made outstanding contributions to this field. Denis E. O'Donnell comes from the department of Respiratory and Critical Care Medicine at Queen's University and Kingston General Hospital. Robert O. Crapo is from the Division of Pulmonary and Critical Care Medicine at the University of Utah and LDS Hospital. Spruit Martijn A and Thierry Troosters are from the Katholieke Universiteit Leuven, specializing in respiratory rehabilitation and rehabilitation science. Francois Maltais is from the University of Laval.

Denis E. O'Donnell, was the most productive author, with 54 publications. Denis E. O'Donnell mainly studied the respiratory system, general internal medicine, and physiology, including exercise measurement, medical intervention, and improvement of exercise capacity (lung capacity, lung ventilation, etc.) in COPD patients with exercise intolerance.<sup>35–39</sup> More attention to his research direction and results will help broaden our thinking and promote innovation. Griffiths Timothy L. is the co-cited author from University Hospitals of the North Midlands, ranking first in terms of centrality. His research direction is the respiratory system, focusing on effective measures to promote lung rehabilitation, such as encouraging outpatient rehabilitation programs for COPD patients, encouraging COPD patients to gradually carry out aerobic physical exercise and lung rehabilitation education to improve the respiratory and skeletal muscle function of COPD patients, and promoting the rehabilitation of lung function.<sup>40–42</sup>

Greater attention to the research findings of key authors in the field will help open up our thinking and encourage innovation in research.

## Research Hotpot for Exercise and COPD

### Co-Cited Reference and Reference with the Strongest Citation Bursts

In bibliometric studies, CiteSpace was used to identify landmark publications that are highly cited by scientists and that reflect active frontiers and developments in research.

The article with the highest co-citation counts (Table 6), published in 2013, was found by Spruit et al (154). The author introduced the pulmonary rehabilitation science to the latest data and applications, including various forms of exercise training for patients with chronic obstructive pulmonary disease (COPD), whose condition improved, was clinically safe and effective, and had a curative effect on individual random respiratory diseases, and stressed the importance of pulmonary rehabilitation in chronic disease management.<sup>12</sup> The article with the highest centrality (Table 6) was published by Watz et al in 2008 (0.16). In this paper, a cross-sectional study has found that reduced exercise in patients with COPD is associated not only with clinical stages of COPD severity but also with left heart dysfunction and systemic inflammation. The authors advocate that COPD patients should increase exercise. Regular exercise can improve the decline of lung function and reduce mortality.<sup>24</sup>

The co-cited references in Table 6 showed that the daily exercise level of COPD patients will decrease due to pulmonary dysfunction. However, reduced exercise hurts lung function. Therefore, we should pay attention to the physical management of COPD patients and emphasize the important role of exercise training in pulmonary rehabilitation therapy in COPD management. Strengthening exercise rehabilitation to reduce the degree of lung function decline and speed up the recovery of physical function, the application of home lung rehabilitation training is also increasingly supported.

The significant increase in interest in exercise and COPD is highlighted in the literature with citation bursts. Figure 11 shows the top 20 references co-citations with the strongest citation bursts from 2000 to 2021. From the bursts of cited references, literature from 2001 to 2017 has opened up a hot spot in the study of exercise in COPD.

The co-cited references with bursts first occurred in 2003. Between 2003 and 2018, most references had citation bursts. The authors of the top four strongest burst references are Spruit MA, Rabe KF, McCarthy B, and Holland AE. Starting in 2013, the strongest burst came from Spruit MA and her team,<sup>12</sup> who updated data on the scientific and applied aspects of pulmonary rehabilitation therapy and highlighted the important role of pulmonary rehabilitation therapy in the management of the chronic disease.

Labels chosen by the log-likelihood ratio test method (LLR) are used in the subsequent discussions.<sup>43</sup> The modular Q is 0.6982, the average silhouette is 0.8839, and the map consists of 1196 nodes and 5932 links. The Modular Q values and average silhouettes obtained in the map suggest that the clusters are reasonable. I have compiled six clusters related to the theme (Table 8).

“Cycle exercise” is the largest cluster, with 157 references. The cluster has a silhouette of 0.919, indicating that the results make sense. The most active participant in this group is described in a paper published by Bernard et al. This study demonstrated that weakness in COPD was due to muscle atrophy. Periods of prolonged inactivity or lower than normal activity levels in COPD patients lead to a decrease in muscle mass and strength, resulting in peripheral skeletal muscle dysfunction.<sup>5</sup>

References	Year	Strength	Begin	End	2000 - 2021
Pauwels et al. <sup>50</sup>	2001	18.45	2003	2006	
Bartolome et al. <sup>26</sup>	2004	23.6	2005	2009	
Celli et al. <sup>51</sup>	2004	20.44	2005	2009	
O'Donnell et al. <sup>38</sup>	2004	17.27	2005	2009	
Lacasse et al. <sup>52</sup>	2006	18.89	2006	2011	
Nici et al. <sup>29</sup>	2006	29.57	2007	2011	
Rabe et al. <sup>27</sup>	2007	<b>49.1</b>	2008	2012	
Ries et al. <sup>53</sup>	2007	22.34	2008	2012	
Miller et al. <sup>54</sup>	2005	18.24	2008	2010	
Watz et al. <sup>24</sup>	2008	17.58	2009	2013	
Watz et al. <sup>55</sup>	2009	26.24	2011	2014	
Troosters et al. <sup>56</sup>	2010	20.21	2011	2015	
Waschki et al. <sup>57</sup>	2011	29.75	2012	2016	
Spruit et al. <sup>12</sup>	2013	<b>52.56</b>	2014	2018	
Vestbo et al. <sup>25</sup>	2013	32.37	2014	2018	
Watz et al. <sup>58</sup>	2014	23.89	2015	2019	
McCarthy et al. <sup>11</sup>	2015	<b>34.8</b>	2016	2021	
Holland et al. <sup>30</sup>	2014	<b>32.97</b>	2016	2019	
Puente-Maestu et al. <sup>59</sup>	2016	17.22	2017	2021	
Vogelmeier et al. <sup>60</sup>	2017	17.43	2018	2021	

**Figure 11** Top 20 references co-citation with the strongest citation bursts.

**Notes:** Bold: citation burst strength >30. The light blue bar indicates that the reference has not yet appeared, the dark blue bar indicates that the reference has started to appear, and the red line represents the burst time.

The second cluster is “regular physical activity”, with a silhouette of 0.867, which is one of 134 references. The most actively cited reference in the cluster is a paper published by Rabe et al. This study updated the definition of COPD, spirometry classification, and treatment, and provided new data on COPD morbidity and mortality based on the 2001 report. In addition to smoking as a risk factor, indoor air pollution from other risk factors such as biomass cooking and heating in poorly ventilated dwellings should be considered whenever possible. The study also suggested that emphasis should be placed on establishing good health care teams to ensure that COPD patients are diagnosed and receive timely and effective treatment.<sup>27</sup>

The third cluster was “physical activity”, with a silhouette of 0.879 and 125 references. The most active reference in this group is a paper published by Vestbo et al. The study revised the original recommendations and proposed three new

**Table 8** Top-Ranked Clusters

Cluster-ID	Size	Silhouette	Label (LSI)	Label (LLR)	Label (MI)	Mean (Year)
0	157	0.919	Chronic obstructive pulmonary disease	Cycle exercise	Controlled inspiratory muscle training	1999
1	141	0.867	Chronic obstructive pulmonary disease	Regular physical activity	Community	2003
2	134	0.879	Physical activity	Physical activity	Community	2011
3	125	0.885	Chronic obstructive pulmonary disease	Systematic review	Community	2015
4	122	0.828	Chronic obstructive pulmonary disease	Progressive resistance exercise	Community	2006
5	121	0.859	Chronic obstructive pulmonary disease	High-intensity exercise	Minute walk test	2007

**Note:** Three different algorithms provided by CiteSpace are used to extract clustering labels at different locations of cited references.

**Abbreviations:** LSI, Latent Semantic Indexing; LLR, logarithmic likelihood test; MI, mutual information test.

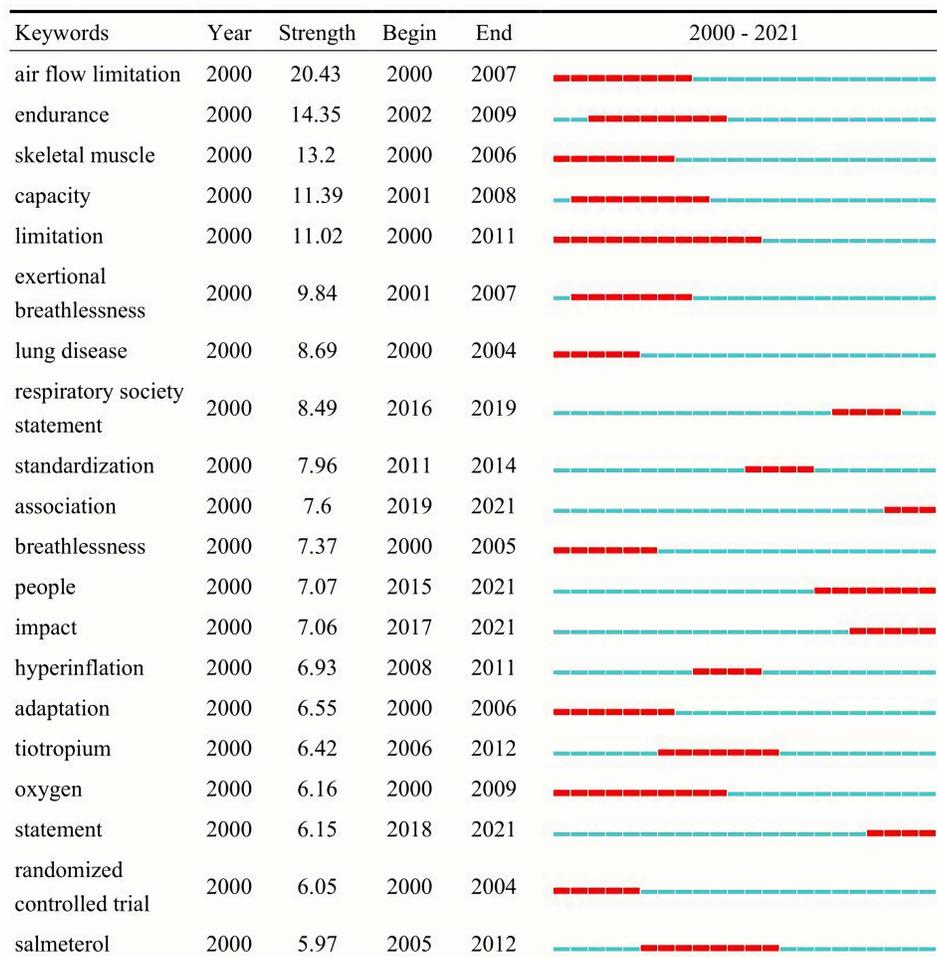
recommendations: a change in treatment goals, a change in the COPD severity classification system, advocating for a new clinical management approach, and a new assessment system.<sup>25</sup>

### Keywords with the Strongest Citation Bursts

Burst keywords are considered to be indicators of frontier topics or emerging trends. Keywords with citation bursts can reflect the development of a knowledge field. By using CiteSpace, we obtained the top 20 keywords with the strongest citation bursts (Figure 12). The keywords with earlier citation bursts could reflect the subjects that were of concern in the early stages. As can be seen from Figure 12, the words that were concerned in the early stage were lung disease (2000–2004), breathlessness (2000–2005), and randomized controlled trial (2000–2004). The emerging research keywords in recent years are association (2019–2021), impact (2017–2021), and statement (2018–2021). Figure 12 shows us that the early keywords with the strongest citation bursts included lung disease, breathlessness, and randomized controlled trial. We grouped this into three areas:

#### Disease

According to the statistics of the World Health Organization, respiratory disease is one of the three leading causes of death in the world. Chronic obstructive pulmonary diseases, as common and frequently-occurring diseases of the respiratory system, are common diseases characterized by continuous airflow restriction, with high disability and mortality rates worldwide.<sup>44</sup>



**Figure 12** Top 20 Keywords with the Strongest Citation Bursts.

**Notes:** The blue bars mean the reference was published; the red bars mean citation burstness.

## Clinical Symptoms

Common symptoms of COPD develop from mid-life on, including breathlessness or difficulty breathing, a chronic cough, often with phlegm, and tiredness.<sup>44</sup>

## Intervention

To compare the effects of different interventions on lung function in COPD patients in randomized controlled trials.

The emerging research keywords are “association”, “impact”, and “statement”. Association is defined as the connection between objects. It enables one object to know the properties and methods of another object. Scholars continue to pay attention to the relationship between changes in exercise levels and COPD. According to a study in patients with and without COPD, a decline to a low exercise level was associated with the highest all-cause mortality risk in subjects with and without COPD. Moreover, it seems that being moderately physically active may already have important beneficial consequences in subjects with and without COPD.<sup>45</sup> The Respiratory Society addressed various aspects of lung rehabilitation in its 2006, 2013, 2015, and 2018 statements.<sup>29</sup> From emphasizing the importance of pulmonary rehabilitation to strengthening pulmonary rehabilitation education for COPD patients. Pulmonary rehabilitation should be included as a primary treatment for patients with COPD.<sup>46</sup> An American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation noted that COPD patients accounted for the majority of the pulmonary rehabilitation treatment population.<sup>12</sup> Pulmonary rehabilitation is clinically proven to be effective in improving the clinical outcomes of patients with COPD, such as increased exercise endurance, improved dyspnea, and ultimately improved overall quality of life for patients with COPD. Health care systems are encouraged to provide affordable rehabilitation for COPD patients, which can reduce health care resources and ultimately achieve long-term benefits.<sup>47–49</sup> In addition, individualized treatment options, such as optimal exercise intensity and duration, should be provided for patients with COPD. Finally, patients with COPD should improve their compliance and actively participate in pulmonary rehabilitation.<sup>29</sup> While there is a lack of evidence that education has a significant effect on the treatment of patients with COPD, self-managed educational activities have a positive impact on improving patients’ quality of life compared to routine care alone, according to the 2018 Respiratory Society statement.<sup>49,52</sup> To improve the compliance of pulmonary rehabilitation in COPD patients, it is necessary to change the concept of patients’ education, so that they can actively participate in pulmonary rehabilitation treatment. We believed that a combination of strength and endurance training may be the best strategy for treating chronic respiratory diseases.

The change in focus reflects a trend in the field, with researchers now focusing more on the effects of the disease and providing better advice to patients with COPD.

## Strengths and Limitations

This study describes the research status of exercise and COPD through countries, institutions, journals, authors and co-cited authors, keywords, co-occurrence, etc. This provides a great deal of information from different perspectives, showing current and future research trends in this field. As far as we know, this is the first time that VOSviewer and CiteSpace are used for literature analysis in this field. However, there are some limitations in the accuracy of our analysis. First, this study only included literature from the WOS core collection database, which may lead to insufficient data collection and have a certain impact on the outcome. Second, we limited the language to English and omitted non-English literature, which may lead to bias in the study of language-published literature. Furthermore, recently published research is likely to be underestimated, while existing publications with real impact will largely influence the citation indicators of journals, authors, institutions, and countries in the field more significantly over time.

## Conclusion

This study analyzed trends and hot spots in exercise and COPD research from 2000 to 2021 using VOSviewer and CiteSpace. The study suggests that the number of papers published in this field will continue to increase in the future. The United States has made the largest contribution to exercise and COPD research, with Queens University and Laval University in Canada as the core institutions. Denis E. O’Donnell is an academic authority on the subject, both in terms

of the number of publications and the most cited publications. The American Journal of Respiratory and Critical Care Medicine is the most frequently cited journal (IF = 21.405) and the most influential in the field. The main research interests include COPD manifestations and diagnostic evaluation methods, exercise prescription setting for COPD patients, and changes in exercise ability, functional status, quality of life, and disease prognosis after rehabilitation intervention in COPD. Emerging research focuses on the association between exercise level and COPD and the impact of pulmonary rehabilitation on clinical outcomes and quality of life in patients with COPD, according to COPD-related statements released by the Respiratory Society. Countries, institutions, and scholars should start with exercise and COPD research hotspots, strengthen academic cooperation, and improve the quality of research. The findings of this paper lay the framework for future development of research on exercise and COPD.

## Research Ethics

All data used in this study were obtained from the Internet and no animal or human subjects were involved. Therefore, ethics committee approval is not required.

## Acknowledgments

The authors show gratitude for Van Eck and Waltman, the inventor of the VOSviewer. The authors also would like to express their appreciation to Professor CM Chen, who invented CiteSpace, which is free to use.

## Funding

This study was supported by Grant No.201904010065 from the science and technology program of Guangzhou.

## Disclosure

The authors report no conflicts of interest in this work.

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