A bibliometric analysis of the 100 most influential papers on COPD

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Objective: We aimed to identify the 100 top-cited articles published on chronic obstructive pulmonary disease (COPD) and to analyze their characteristics so as to provide information on the achievement and development in COPD research over the past decades.

Methods and materials: A comprehensive list of citation classics in COPD was generated by searching the Science Citation Index expanded database, using the keywords “COPD” or “chronic obstructive pulmonary disease” or “chronic obstructive pulmonary diseases”. The 100 top-cited research papers were retrieved by reading the abstract or full text if needed. All eligible articles were read for basic information, including country of origin, organizations, article type, journals, research field, and authors.

Results: The 100 top-cited articles on COPD were published between 1966 and 2010. The number of citations ranged from 254 to 2,164, with a mean of 450 citations for each article. These citation classics were from 32 countries, with 38 from the United States. The Imperial College London led the list of classics, with 16 papers. The 100 top-cited articles were distributed in 18 journals, with the American Journal of Respiratory, Critical Care Medicine, and Journal of the American Medical Association topping the list. Among the various fields, both respiratory system (63%) and general internal medicine (63%) were the most common fields of study for the 100 articles.

Conclusion: Our bibliometric analysis provides a historical perspective on the progress of scientific research on COPD. Articles originating from the United States and published in high-impact specialized respiratory journals are most likely to be cited in the field of COPD research.

Keywords: citation analysis, top-cited, chronic obstructive pulmonary disease

Introduction

Chronic obstructive pulmonary disease (COPD) continues to be an important cause of morbidity, mortality, and health care costs worldwide. As the global population ages, the burden of COPD will increase in the years to come.1–3 Numerous specialists and researchers have focused their efforts on COPD in an attempt to gain a better understanding of how comorbid diseases, different phenotypes, and risk factor affect the outcome of COPD patients. A great numbers of articles have been published annually and have given new insights into the mechanism or treatment of COPD.4–6 However, there still exists a lack of knowledge regarding the quality of scientific yield in relation to this area.

It is generally believed that publications represent the central part of a research process. In medicine, the number of times a paper is cited by other authors has been established as a widely used and logical measure of how much academic influence it has had in its subject area. The reporting of this type of citation analysis is widespread.
in the medical literature. One way to measure the academic importance of an article is the rate at which the work is quoted or referenced by other authors. The article referenced by another peer-reviewed article receives a “citation.” The total number of citations that an article receives is not necessarily a measure of its academic quality or even its influence upon the practice of the author’s or authors’ peers. Nevertheless, it does testify to the readership of the particular article and the influence of the article in generating changes in practice, controversy, discussion, or further research. Citation is viewed as a direct measure of the recognition an article has received in its field. Citation analysis in specific journals and specific subject areas has become a popular method to assess the citation impact of a journal, article, or author.

The Institute for Scientific Information (ISI) has been collecting citation and other academic impact information since 1945 and has been available electronically since 1979. ISI (now a subsidiary of Thomson Corp) calls their newest journal citation system “Science Citation Index® (SCI) Expanded,” and it is one of the databases available under the banner of Web of Science. Citation data from peer-reviewed articles are indexed from more than 10,000 high-impact journals, not only from the sciences and social sciences but also, from the arts and humanities.

This search used the electronic version of this database to determine which published articles in medical journals have been cited most often by other authors, by ranking the 100 top-cited works. By analyzing characteristics of these articles, we intended to determine what qualities make a COPD article important to the specialty.

Materials and methods
On June 30, 2014, authors searched Web of Science and identified the 100 top-cited articles relating to COPD (Table 1) published in professional journals from 1945 to date. The articles entitled using the terms “COPD” or “chronic obstructive pulmonary disease” or “chronic obstructive pulmonary diseases” were included in the research.

Each article in the most cited 100 was reviewed, and the basic information collected included authors, year of publications, source journal of the article, geographic origin of the authors, and study field (general internal medicine, respiratory system, cardiovascular system cardiology, immunology, microbiology, physiology, research experimental medicine, sports science, or surgery). The full texts were mainly selected by PubMed or ScienceDirect. In addition, other methods were also used to search for articles that were not found in the aforementioned database, for example, interlibrary lending and requests for help on the PubMed.cn website (http://paper.pubmed.cn/). This website is a Chinese language–based platform used by scholars to request and share literatures. Several articles were cited more often than others because of the difference in time since publication. Thus, a citation index was also determined for each article to control this error. The citation index was defined as the mean number of citation times per year.

Statistical analysis was performed using SPSS 17 (SPSS Inc., Chicago, IL, USA). Spearman correlation analysis was used to test the total citation times and number of citation times per year, with an alpha level of 0.05. Descriptive statistics were quantified as counts or percentages of parameters.

As this was a bibliometric analysis, it was not necessary to obtain Internal Review Board approval.

Results
A total of 22,210 papers were identified in the initial search for the period from 1960 to present, with 12,098 published as “article” and 1,436 classified as “review”. Among them, 623 articles were cited more than 100 times. One hundred selected articles were published from 1966 to 2010, of which about 55% were published after 2000. The mean number of citations was 450 (range 254 to 2,164), and seven papers were cited more than 1,000 times (Table 1). Annual average number of citations were correlated by total number of citations ($r_s=0.659, P<0.0001$).

The most cited paper, published by Rabe et al in 2007, was an executive summary describing the global strategy for the diagnosis, management, and prevention of COPD. Interestingly, the second most cited paper, by Celli et al received 1,659 citations and was also a summary of standards for the diagnosis and treatment of patients with COPD, published in 2004. The third article, by Hogg et al was a randomized controlled trial (RCT) – the paper proved that 1) progression of COPD is associated with the accumulation of inflammatory mucous exudates in the lumen and infiltration of the wall by innate and adaptive inflammatory immune cells that form lymphoid follicles, and 2) these changes are coupled to a repair or remodeling process that thickens the walls of these airways. The most recent paper came from 2010 and was cited 367 times. This paper proposed use of the “frequent exacerbation phenotype” to predict COPD exacerbations, implicating an important target of exacerbation-prevention strategies across the spectrum of disease severity. The last paper on the most cited list was a cohort study, authored by Marquis et al from 2002 and cited 254 times to date, which
| Rank | First author | No of citations | Publication year | Citations/Year | New rank |
|------|--------------|-----------------|------------------|---------------|----------|
| 1    | Rabe KF      | 2,164           | 2007             | 270.50        | 1        |
| 2    | Celli BR     | 1,659           | 2004             | 150.82        | 2        |
| 3    | Hogg JC      | 1,246           | 2004             | 113.27        | 4        |
| 4    | Celli BR     | 1,177           | 2004             | 107.00        | 5        |
| 5    | Calverley    | 1,146           | 2007             | 143.25        | 3        |
| 6    | Anthonisen   | 1,129           | 1987             | 40.32         | 23       |
| 7    | Siafakas NM  | 1,006           | 1995             | 50.30         | 15       |
| 8    | Brochard L   | 834             | 1995             | 41.70         | 21       |
| 9    | Keatings VM  | 791             | 1996             | 41.63         | 22       |
| 10   | Seemungal    | 768             | 1998             | 45.18         | 17       |
| 11   | Burge PS     | 765             | 2000             | 51.00         | 12       |
| 12   | Tashkin DP   | 669             | 2008             | 95.57         | 6        |
| 13   | Donaldson    | 663             | 2002             | 51.00         | 13       |
| 14   | Barnes PJ    | 654             | 2000             | 43.60         | 19       |
| 15   | Gan WQ       | 597             | 1994             | 54.27         | 10       |
| 16   | Barnes PJ    | 556             | 2003             | 46.33         | 16       |
| 17   | Cooper JD    | 555             | 1995             | 27.75         | 50       |
| 18   | Calverley    | 540             | 2003             | 45.00         | 18       |
| 19   | Bestall JC   | 518             | 1999             | 32.38         | 36       |
| 20   | Buist AS     | 510             | 2007             | 63.75         | 8        |
| 21   | Pauwels RA   | 501             | 1999             | 31.31         | 39       |
| 22   | Schols AJ    | 484             | 1998             | 28.47         | 48       |
| 23   | Ries AL      | 482             | 1995             | 24.10         | 57       |
| 24   | Repine JE    | 457             | 1995             | 25.39         | 55       |
| 25   | Casaburi R   | 456             | 1997             | 35.08         | 30       |
| 26   | Mannino DM   | 440             | 2007             | 55.00         | 9        |
| 27   | Rahman IA    | 432             | 1996             | 22.74         | 59       |
| 28   | Sethi S      | 431             | 2002             | 33.15         | 34       |
| 29   | Plant PK     | 430             | 1997             | 28.67         | 45       |
| 30   | Sin DD       | 428             | 2003             | 35.67         | 29       |
| 31   | Seemungal    | 428             | 2000             | 28.53         | 47       |
| 32   | Altose MD    | 422             | 2000             | 28.13         | 49       |
| 33   | Vestbo J     | 414             | 1999             | 25.88         | 53       |
| 34   | Vincken W    | 407             | 2002             | 31.31         | 40       |

**Notes:**
- The "new rank" was sorted by the average annual number of citations.
- **Abbreviation:** COPD, chronic obstructive pulmonary disease.
found that the mid thigh muscle cross-sectional area was a better predictor of mortality than body mass index (BMI) in COPD patients; these findings suggest that the assessment of body composition may be useful in clinical practice.28

The 100 top-cited articles were published in 18 journals, predominantly in American Journal of Respiratory and Critical Care Medicine (n=30), followed by European Respiratory Journal (n=14) and New England Journal of Medicine (n=12) (Table 2).

The greatest number of top-cited articles were published in 1996, 2000, and 2002 (n=8 each). The least number of articles was published in the 1960s (n=1 [decade]). Articles on the list were divided into three periods, 1960 to 1989 (n=8), 1990 to 1999 (n=37), and after 2000 (n=55) (Table 3).

The country origins of the articles included: the United States (n=38), England (n=34), Canada (n=20), Netherlands (n=12), Italy (n=10), Belgium (n=9), Spain (n=8), Denmark (n=7), Australia (n=6), and Scotland (n=5). The rest of the countries had less than five publications. Table 4 shows the distribution of top-cited articles over the countries of origin. Given some articles were authored with multiple sources of origin, especially those in the form of international research collaborations, the total number of countries of origin exceeded 100. The leading institutions are shown in Table 5. Imperial College London was found to be the most productive institution (n=16), followed by the University of London (n=10) and GlaxoSmithKline (n=9).

Among the 100 top-cited articles in COPD, the overwhelming majority (n=63 each) were studies belonging to “general internal medicine” and “respiratory system”, followed by two studies in “cardiovascular system cardiology”. Other fields, like “immunology”, “microbiology” and “physiology” only had one article each (Table 6).

The top-cited papers were written by 749 authors and ranged from 1 to 70 per article. Three articles had one author, followed by eight articles with two authors, and eight articles with three authors. Table 7 presents a list of the most productive authors, showing that Barnes and Wedzicha each authored ten articles, followed by Vestbo (n=8), Jones (n=7), Buist (n=6), Calverley (n=6), Hogg (n=6), Anthonisen (n=5), Celli (n=5), Maltais (n=5), and Seemungal (n=5) (Table 7).

**Discussion**

In medical literature, the number of times other authors reference an article is one measure of the influence of the publication, and this type of citation analysis strategy is widely used as a bibliometric study. The evaluation of specialty-wide citation analyses has been reported in other areas of medicine.7–9,18–21,23 However, the establishment of a citation rank list across a specialty, comprising many journals specific to an area of medicine, is a more complex process than citation analysis for one journal, although such analyses have been reported in some other areas of medicine.21–34

In this review, researchers ranked the top 100 articles by number of citations, in the specialty of COPD. The top article had 2,164 citations. Seven papers were cited more than 1,000 times, of which three were summaries of the most well-known international COPD management guidelines, by different research institutions or in different periods. However, they all represented the latest achievements of COPD development in their period and have played profound influence in COPD treatment and research development around the world. While the third-place paper was classic RCT research, the findings created a new therapy targets for COPD treatment. The fourth paper also was classic; the authors proved a multidimensional grading system (the BODE [BMI, airflow obstruction, dyspnea, and exercise] index) assessing the respiratory and systemic expressions of COPD would better categorize and predict outcome in COPD patients than the forced expiratory

| Table 2 Top-ten sources that contribute most articles to the top-100 papers |
|-----------------|-----------------|
| **Journal**     | **Number** |
| American Journal of Respiratory and Critical Care Medicine (Am J Respir Crit Care Med) | 30 |
| European Respiratory Journal (Eur Respir J) | 14 |
| New England Journal of Medicine (N Engl J Med) | 12 |
| Lancet | 10 |
| Thorax | 8 |
| American Review of Respiratory Disease (Am Rev Respir Dis) | 7 |
| Annals of Internal Medicine (Ann Intern Med) | 4 |
| Chest | 3 |
| Archives of Internal Medicine (Arch Intern Med) | 2 |
| Journal of the American Medical Association (J Am Med Assoc) | 2 |

| Table 3 Decades distribution of the top-100 most cited papers |
|-----------------|-----------------|-----------------|-----------------|
| **Year**        | **Number** | **Mean number of citations** | **Minimum number of citations** | **Maximum number of citations** |
| 1980s           | 8            | 412             | 258             | 1,129             |
| 1990s           | 37           | 413             | 259             | 1,006             |
| 2000s           | 55           | 481             | 254             | 2,164             |
volume in one second (FEV\textsubscript{1}). The fifth and sixth papers were specialized in the exploration of COPD drug therapy, and both of their groundbreaking discoveries have provided new directions for COPD treatment. In sum, the main reason for being so widely referenced is that the findings or conclusions reported in these papers have produced historical influence in COPD treatment and research history. However, every article on the list can be considered a citation “classic” by the frequently used, but somewhat arbitrary, marker of 100 pieces as the benchmark.\textsuperscript{29}

This review of the most cited articles in COPD may be worthwhile for several reasons. First, the observations suggest the authors of citation classics in COPD have produced more highly cited articles than many of their colleagues in other specialties. Second, this study has successfully identified several attributes of articles in citation, indicating that journal and country of origin are very important factors. Finally, this paper might be considered as the first report on the most cited papers in COPD.

The study characteristics revealed here echo those found in similar reviews. The majority of articles originated in the United States. This result is in line with previous studies and is in accordance with the reported strong influence of the United States in research related to health science,\textsuperscript{8,12,14} indicating that American authors may be at an advantage. On the contrary, in Asian countries, although the scientific research has achieved rapid development in recent years, authors did not have a place in the COPD research field since their contribution in research productivity was rather disappointing. European countries, like England, Netherlands, Italy, etc, also showed a higher productivity. This finding seems to conform to the phenomenon “the better the economic ranking of a country, the higher the quantity and quality of its biomedical publications”.\textsuperscript{30}

Financial support from public foundations or commercial companies has evolved over time in response to changes in professional codes, laws, and markets. Public funds have given a great push to the development of medical research and public health. Industry-funded science has been widely debated because of the susceptibility to various kinds of biases. Nevertheless, it has played and will continue to play a critical role in the research process. Although this research did not analyze financial support separately, our findings showed that there was a commercial company ranked among the top-ten prolific institutions, which contributed a total of nine articles.

Although researchers were expecting a higher number, only 18% of the papers were review articles, whereas the majority were original research articles, which might be attributable to a preference for referencing experimental evidence rather than review articles or expert opinion.

It has been reported that scientific articles begin to be cited 1 or 2 years after publication and reach a maximum citation rate 7 to 10 years later after publication.\textsuperscript{26–28} It has also been reported that the “older” articles are, the greater the likelihood that they have attained more citations, purely because their citable period was longer. However, in our study, the citation rate gradually rose over the last decade and is indicative of an increasing consideration for the field of COPD.

Table 5 The top-ten institutions contributing to the most cited articles in COPD

| Institute                        | Number |
|----------------------------------|--------|
| Imperial College London          | 16     |
| University of London             | 10     |
| GlaxoSmithKline                  | 9      |
| St Georges University London     | 8      |
| University of British Columbia   | 8      |
| University of California System  | 8      |
| Oregon Health Science University | 7      |
| Oregon University System         | 7      |
| Queen Mary University London     | 7      |
| University of Copenhagen         | 7      |

Table 6 Research field of the most cited articles in COPD

| Field                              | Number |
|------------------------------------|--------|
| General internal medicine          | 63     |
| Respiratory system                 | 63     |
| Cardiovascular system cardiology   | 2      |
| Immunology                         | 1      |
| Microbiology                       | 1      |
| Physiology                         | 1      |
| Research experimental medicine     | 1      |
| Sport sciences                     | 1      |
| Surgery                            | 1      |

Abbreviation: COPD, chronic obstructive pulmonary disease.
survey was restricted with the word “COPD” or “chronic obstructive pulmonary disease” or “chronic obstructive pulmonary diseases” in their titles. In other words, some significant COPD articles published under other titles might not have been included, and it is possible that these were good-quality articles with a high number of citations. Second, the journals have different approaches to accept or reject a submitted manuscript. Thus, particular journals could have stricter selection criteria that might have affected the clinical applicability or quality of their publications. The criteria could be a reason why most top-cited papers were found in one journal. Also, there are some intrinsic problems in using this method alone to evaluate the academic importance of one article, an author’s or authors’ publications, or the performance of a journal overall. First, this type of citation analysis does not account for self-citation, citations in textbooks and lectures, and an author’s or authors’ potential preference to cite articles in the journal in which they seek to publish their work.29 Second, language of publication plays a major role, with an obvious bias for articles published in English language journals. Third, there are biases inherent in the age of the database as any articles published in the 19th or early 20th century would be excluded, which likely causes some true “classic” articles to be excluded. Finally, previous study16 would tell us that in a scientific community, there is a tendency for adherence to a paradigm. In this context, this would mean that there is “snowball effect” to citations and that other authors are more likely to cite it because of previous citations, rather than for its content or quality. Despite these obvious defects, the data presented here do provide insight into the achievement and development of COPD research over the past decades.

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Author contributions
Xiaoyan Jin and Wenchao Gu participated in the study design. Wenchao Gu, Yaping Yuan, Hua Yang, Guangsheng Qi, Xiaoyan Jin, and Jin Yan performed the data extraction and analysis. Hua Yang, Yaping Yuan, Guangsheng Qi and Jin Yan drafted the article. Xiaoyan Jin and Wenchao Gu wrote the manuscript.

Disclosure
The authors report no conflicts of interest in this work.

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