**SLEEP BREATHING PHYSIOLOGY AND DISORDERS • REVIEW** 



# Top 100 influential manuscripts in obstructive sleep apnea: a bibliometric analysis

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#### Abstract

**Objective** This study aimed to explore the characteristics of the top 100 influential manuscripts on obstructive sleep apnea (OSA).

**Methods** All manuscripts in English were searched from the Thomson Reuters Web of Science database by using OSA-related terms and ranked based on citation frequency. The top 100 influential manuscripts were selected and further analyzed by author, subject, journal, year of publication, country of origin, and institution.

**Results** A total of 42,878 manuscripts were searched from the Web of Science. The top 100 influential manuscripts were published from 2005 to 2017, with a total citation frequency of 38,463 and a median citation frequency of 303 (range: from 210 to 2, 707). The *American Journal of Respiratory and Critical Care Medicine* published the largest number of manuscripts from the top 100 (n = 18; 5340 citations), followed by *Sleep* (n = 11; 3516 citations) and *Chest* (n = 7; 1784 citations). The most cited manuscript (Marin, J.M et al., *Lancet* 2005; 2707 citations) mainly analyzed long-term cardiovascular outcomes in men with OSA with/without continuous positive airway pressure. The most prevalent subject was associated diseases (n = 41), followed by treatments (n = 40). Most of the manuscripts were original articles (n = 63) based on observational clinical studies and published from American institutions (n = 60).

**Conclusions** Our study identified the top 100 influential manuscripts on OSA and provides insights into the characteristics of the most highly cited manuscripts to improve our understanding and management of OSA.

Keywords Obstructive sleep apnea · Citations · Bibliometric analysis

## Introduction

Obstructive sleep apnea (OSA) is a common sleep-associated respiratory disorder characterized by nocturnal intermittent hypoxia (IH) and fragmented sleep caused by airflow limitation or airflow interruption due to recurrent episodes of upper airway obstruction during sleep [1–3]. Epidemiological studies have indicated that the prevalence of OSA is 9–38% in adults and is higher in males, the elderly, and obese people [4–6]. The prevalence of OSA may further increase

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Qiao-ling Yao 49165627@qq.com in the near future due to the increase in the incidence of obesity. Patients with OSA also have high risk of death (about 3.5%), and such risk increases as the disorder progresses [2, 7–9]. Many studies have reported that OSA can significantly increase the risks of diseases, such as cardiovascular diseases [10, 11], cognitive disorder [12], cancer [13], and metabolic syndrome [14]. Although continuous positive airway pressure (CPAP) has been the most effective method for treating OSA, how to maintain patients' compliance has been a challenge. At present, OSA has been a public health issue and an extensive concern of medical practitioners. The number of OSA-associated studies has gradually increased annually, of which 6896 were published accumulatively in SCOPUS database from 1991 to 2012 [15]. In this era of big data, scholars have increasingly focused on how to identify the most influential scientific achievements from an abundance of literature and analyze hot topics and development tendency in OSA-related research field.

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Bibliometrics was initially proposed by bibliographer Pritchard A in 1969. This interdisciplinary science is used to quantitatively analyze all knowledge carriers by using mathematical and statistical methods to provide rational methods and approaches for evaluating and assessing scientific research. In scientific quantitative analysis, citation frequency is applied to reflect the degree to which academic papers are valued as well as the roles and status of these papers in academic communication. The higher the citation frequency of an academic paper is, the greater its influence will be in the corresponding field [16]. The contribution and influence of a country, an institution, and an author on the development of a specific field should be investigated by analyzing the most cited academic papers. At present, analysis of the most cited academic papers has been extensively used in surgical and medical specialties, such as dermatology [17], neurointerventional surgery [18], emergency abdominal surgery [19], Parkinson's disease (PD) [20], oncology [21, 22], and medical imaging [23]. Huamani et al. [15] analyzed scientific research on OSA published from 1991 to 2012 in SCOPUS database. However, the characteristics and hot topics of the top 100 influential manuscripts on OSA have not been identified in any study to date [23]. Our research aimed to confirm the top 100 most influential manuscripts in the OSA field under global view. We also analyzed the country, institution, author, journal, and subject distributions of the manuscripts by using bibliometrics to provide important references for researchers to decide and implement scientific research interests and to understand OSA-related research institutions, personnel, and important scientific achievements.

### Methods

We searched the Thompson Reuters Web of Science citation indexing (SCI) database on May 18, 2020. Appropriate retrieval terms were compiled and combined to identify all relevant manuscripts. The following retrieval terms were used: "obstructive sleep APN\*," "sleep apnea hypopnea syndrome," "OSAH," "obstructive APN\*," "OSAS," and "OSA." The abstracts of all manuscripts were screened by two reviewers (ZZL and DD) independently to establish a list of the top 100 manuscripts most cited on OSAS. A third reviewer (YQL) was appointed to independently review the abstracts to achieve a consensus in cases of discrepancy. The articles whose main focus was indirectly related to OSAS were excluded according to independent assessment. The studies selected were limited in English and ranked by citation number. The top 100 manuscripts most cited were further assessed based on manuscript type, authorship, theme, year of publication, journal, country of origin, and institution. The Journal Citation Reports dataset was used to identify the 2019 impact factor (IF) of each journal. Citation rate was an additional metric which was calculated by dividing the citation frequency based on the number of years since publication. The relationship between the number of the top-cited manuscripts and a journal's IF was analyzed by Pearson's correlation coefficient. P < 0.05 was considered to be statistically significant.

#### Results

The SCI database was accessed on May 8, 2020, from which 42,878 manuscripts were selected. The manuscripts were screened based on inclusion and exclusion criteria and ranked by citation frequency. The top 100 influential manuscripts were acquired. The general information is specified in Table S1. The total citation frequency of the top 100 influential manuscripts was 38,463 (ranging from 210 to 2707), with mean citation frequency of 384.6 and median citation frequency of 303. In the 100 manuscripts, 15 were cited by 500 times and 85 were cited by 200 to 499 times. The most cited manuscript, with a total of 2707 citations, was that by Marin et al. reporting the incidence of fatal and non-fatal cardiovascular events in males with OSA-hypopnoea with or without treatment with CPAP, published in LANCET in 2005 [24].

Citation rate was used to reflect the influence of the manuscripts and to rule out the influence of the year of publication on citation frequency. The citation rate of the top 100 influential manuscripts ranged from 14 to 169.19. The top 10 manuscripts ranked by citation rate are shown in Table 1; of which, 6 manuscripts ranked the top 10 in terms of citation frequency and citation rate. The manuscript with the highest influence ranked by citation rate was compiled by Senaratna, C.V et al. and published on Sleep Medicine Reviews in 2017 [25], which reported the prevalence of OSA in the general population. It ranked 72nd due to the total citation of 245, and the rank increased from 72nd to 9th since the citation rate was 61.25. In addition, in the top 10 manuscripts ranked by citation rate, 4 manuscripts were published by the USA (no. 1), 3 by Australia, 1 by Spain, 1 by the UK, and 1 by Canada respectively.

The top 100 influential manuscripts were published from 2005 to 2017, and the number of manuscripts published in 2005 and 2006 was the highest, about 15 papers per year. The manuscript published the earliest was compiled by Caples, S M et al. and published on *Annals of Internal Medicine* in 2005; this paper was cited 264 times [26]. This manuscript was a review on OSA and mainly reported the OSA's epidemiology, diagnosis, clinical presentation, pathophysiologic mechanisms, and cardiorespiratory physiology as well as cardiovascular diseases and management. The

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Citation rate rank	Original rank	Citation rate	First author	Senior author	Title	Corresponding author institution	Country
1	1	169.19	Marin, JM	Agusti, AGN	Long-term cardiovascular outcomes in men with obstructive sleep apnoea- hypopnoea with or without treatment with continuous positive airway pressure: an observational study	Hospital Universitario Miguel Servet	Spain
2	3	119.58	Epstein, L.J	Weinstein, MD	Clinical Guideline for the Evaluation, Management and Long-term Care of Obstructive Sleep Apnea in Adults	Sleep HealthCenters	UK
3	11	112.8	McEvoy, R.D	Anderson, CS	CPAP for Prevention of Cardiovascular Events in Obstructive Sleep Apnea	Flinders Univ S Australia	Australia
4	2	103.75	Yaggi, H.K	Mohsenin, V	Obstructive sleep apnea as a risk factor for stroke and death	Yale Ctr Sleep Med	USA
5	47	79.5	Kapur, V.K	Harrod, CG	Clinical Practice Guideline for Diagnostic Testing for Adult Obstructive Sleep Apnea: An American Academy of Sleep Medicine Clinical Practice Guideline	University of Washington	USA
6	5	72.09	Dempsey, J.A	O'Donnell, CP	Pathophysiology of Sleep Apnea	University of Wisconsin	USA
7	4	68.46	Chung, F	Shapiro, CM	STOP questionnaire—A tool to screen patients for obstructive sleep apnea	University of Toronto	Canada
8	7	67.09	Gottlieb, D.J	Shahar, E	Prospective Study of Obstructive Sleep Apnea and Incident Coronary Heart Disease and Heart Failure The Sleep Heart Health Study	Boston University	USA
9	72	61.25	Senaratna, C.V	Dharmage, SC	Prevalence of obstructive sleep apnea in the general population: A systematic review	Monash Med Ctr	Australia
10	21	59.71	Jordan, A.S	Malhotra, A	Adult obstructive sleep apnoea	University of Melbourne	Australia

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#### Table 1 Citation rate of top 10 manuscripts

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manuscript published the latest was completed by Javaheri, S et al. and published in the Journal of The American College of Cardiology in February, 2017 [27].

As shown in Table 2, the top 100 influential manuscripts had been published in 28 journals, about 1 to 18 manuscripts in each journal. The American Journal of Respiratory and Critical Care Medicine was the top 1 in the number of manuscripts published and in terms of citation frequency (n=18; 5340 citations), whose IF was 17.452 in 2019, followed by Sleep (n = 11; 3516 citations; 2019 IF: 4.805) and Chest (n=7; 1784 citations; 2019 IF: 8.308). More than onethird of the 100 manuscripts had been published on above 3 journals (n = 36; 10,640 citations). In addition, among the 28 journals, the New England Journal of Medicine had the highest 2019 IF (2019 IF: 74.699), and 6 manuscripts had been published in this journal, with a total of 3840 citations. About 5 manuscripts were published in the Jo of Clinical Sleep Medicine (3160 cit ), Circulation (2147 citations; 2019 r\_ nal of The American College of Ca s; 2019 IF: 20.589) respectively, whil ts had been published in the remain the number of manuscripts publis ferent IFs was analyzed. Althoug S

 Table 2
 Journals in which the top 100 most cited manuscripts were published, ranked according to number with corresponding impact factor at time of review

Journal title	2019 impact factor	Number of manuscripts in the top 100	Total number of citations
American Journal of Respiratory and Critical Care Medicine	17.452	18	5340
Sleep	4.805	11	3516
Chest	8.308	7	1784
New England Journal of Medicine	74.699	6	3840
Circulation	23.603	5	2147
Journal of Clinical Sleep Medicine	3.586	5	3160
Journal of The American College of Cardiology	20.589	5	1609
Anesthesiology	7.067	4	1904
Archives of Internal Medicine	17.333	4	1146
European Respiratory Journal	12.339	4	1207
Hypertension	7.713	3	1008
JAMA-Journal of The American Medical Association	45.54	3	1043
Lancet	60.392	3	3813
Sleep Medicine Reviews	9.613	3	889
Annals of Internal Medicine	21.317	2	476
Otolaryngology-Head and Neck Surgery	2.341	2	436
Pediatrics	5.359	2	979
Sleep Medicine	3.038	2	602
Thorax	8.834	2	496
British Journal of Anaesthesia	6.88	1	362
Canadian Journal of Anesthesia-Journal canadien d anesthesie	3.779	1	305
Cochrane Database of Systematic Reviews	7.89	1	397
Diabetes Care	16.019	1	289
Journal of Pediatrics	3.7	1	213
Journal of Thoracic Disease	2.046	1	220
Nature Reviews Cardiology	20.26	1	259
Physiological Reviews	25.588	1	793
Stroke	7.19	1	230

The IF of Archives of Internal Medicine recorded above is 2014 IF since it had been updated to 2014

had been published in journals with IFs > 20, the total citation frequency was 13,980, accounting for 36.35% of the total citations of all manuscripts. The remaining 74% of the manuscripts had been published in journals with IFs  $\leq$  20, with 24,483 citations in total (63.65%). However, there was insignificant association between the journal's IF and the number of the top-cited manuscripts (P=0.54).

As shown in Fig. 1, the top 100 influential manuscripts were completed by authors from 19 countries. The USA contributed the most manuscripts (n=60), followed by Canada (n=13) and Spain (n=12). Australia (n=9), Brazil (n=6), and the UK (n=6) contributed more than 5 journals. The top 100 influential manuscripts were from 5 continents, where North America (n=73) contributed the most manuscripts, followed by Europe (n=35) and Oceania (n=9). Six manuscripts were conducted in South America and Asia, but none of the studies was from Africa or Antarctica, respectively.

The top 100 influential manuscripts originated from 269 institutions. According to the statistics of the corresponding authors' institutions, Univ Penn contributed the most manuscripts (n = 12; 5855 citations), followed by Mayo Clinic (n = 11; 4605 citations), John Hopkins University (n = 9; 4798 citations), University of Pittsburgh (n = 8; 4744 citations), and University of Toronto (n = 8; 3041 citations) (Table 3).

A total of 549 authors participated in the authorship of the top 100 influential manuscripts. Nine authors, including Gozal D (n=8), Somers VK (n=7), and Barbe F (n=6), had published more than 3 manuscripts (Table 4). Bradley TD, Drager LF, Duran-Cantolla J, Marcus CL, Marin JM, and Redline S had participated in the authorship of 5 manuscripts, respectively. Besides, Chung F, Garcia-Rio F, Malhotra A, McNicholas WT, Polotsky VY, Sanders MH, and Stradling JR had participated in the authorship of 4



Fig. 1 Bar graph demonstrating the top 100 cited manuscripts according to country of origin

manuscripts, respectively. The remaining authors had participated in the compilation of no more than 3 manuscripts, respectively. Drager LF, Marcus CL, Marin JM, Chung F, and Gami AS had published the most manuscripts as the first author (n=3 respectively) while Somers VK as the corresponding author (n=5).

As to the study design, the top 100 influential manuscripts (Fig. 2) contained 63 original research articles, 23 reviews, 9 guidelines, and 5 meta-analyses. In the 63 original research articles, 34 manuscripts (53.97%) reported the observational clinical studies, while 26 (41.27%) studied the interventional clinical methods, and 3 (4.76%) analyzed the findings of basic scientific work.

The analysis of subject disciplines demonstrated that the top 100 influential manuscripts on OSA involved 13 disciplines, in which respiratory system ranked the top (n=32), followed by critical care medicine (n=25) and clinical neurology (n=22). As shown in Fig. 3, the top 100 influential

**Table 3** Institutions with  $\geq$  5 articles in the top 100 manuscripts

Institution	Number of publica- tion in top 100	Total number of citations
Univ Penn	12	5855
Mayo Clin	11	4605
Johns Hopkins Univ	9	4798
Univ Pittsburgh	8	4744
Univ Toronto	8	3041
Harvard Univ	7	4038
Brigham and Women Hosp	6	3553
Case Western Reserve Univ	6	2735
Univ Louisville	5	1318
Univ Sao Paulo	5	1894
Univ Wisconsin	5	1820

**Table 4** Authors with  $\geq$  4 articles in the top 100 manuscripts

Author	Number of publications	Citations
Gozal D	8	2763
Somers VK	7	2371
Barbe F	6	2106
Bradley TD	5	1871
Drager LF	5	1894
Duran-Cantolla J	5	1422
Marcus CL	5	2098
Marin JM	5	4043
Redline S	5	2613
Chung F	4	1858
Gami AS	4	1584
Garcia-Rio F	4	1236
Malhotra A	4	2418
McNicholas WT	4	1650
Polotsky VY	4	972
Sanders MH	4	1410
Stradling JR	4	976

manuscripts focused on different topics, such as associated diseases (n=41), treatments (n=40), pathobiology (n=22), clinical guidelines (n=9), screening and diagnosis (n=8), epidemiology (n=7), prognosis (n=7), all aspects (n=2), and other (n=1).

#### Discussion

Bibliometrics can be used to quantitatively analyze a researcher's individual achievements and even the contributions and international influences of a country or an institution in a clinical field via the statistical analyses of the total number and total citation frequency of the academic papers published in this field. This study initially confirmed the top 100 influential manuscripts in OSA field based on their global citation frequency using the bibliometric analysis. The most cited manuscript was compiled by Marin J.M et al. [24], with a total of 2707 citations. This study was an original article published in Lancet in 2005 and mainly assessed long-term cardiovascular outcomes among male subjects with OSA hypopnea with/without treatment with CPAP. In that study, 264 healthy males, 403 males with untreated mild-moderate OSA hypopnea, 377 simple snorers, 372 individuals with CPAP-treated OSA, and 235 individuals with untreated severe OSA were followed up for 10.1 years in average to observe differences in the risks of fatal cardiovascular events and non-fatal cardiovascular events. The results demonstrated that the risks of fatal and non-fatal cardiovascular events increased prominently in males with severe OSA hypopnea, which could be reduced by CPAP

**Fig. 2** Pie chart demonstrating distribution of the top 100 most cited manuscripts according to manuscript type and study design of the 63 original research articles



treatment. The manuscript ranked the second was also an original research article compiled by Yaggi H.K et al. [28] and published on the New England Journal of Medicine in 2005, with a total of 1660 citations. In this study, a large-scale observational cohort study was developed, in which the independent effect of OSA on the increased incidence of all-cause death and stroke was initially interpreted. The results revealed more pronounced risk of the composite end point in patients with severer OSA at baseline. The earlier the manuscripts are published, the higher the citation frequency will be, and vice versa. Therefore, citation rate was adopted in this study to assess differences in the influence of the



Fig. 3 Bar graph demonstrating the theme within the topic of OSA in the top 100 most cited manuscripts

manuscripts to rule out the influence of the year of publication on citation frequency. Although the citation rates of 2 manuscripts compiled respectively by Marin J.M and Yaggi H.K ranked in the top 10 (1st and 4th, respectively), 3 manuscripts were published within 5 years. These manuscripts included 1 original study (McEvoy R.D et al. [29]), which concluded that CPAP treatment could not prevent the prevalence of major cardiovascular events, 1 clinical practice guideline (Kapur V.K et al. [30]) for diagnostic testing in adults with OSA, and 1 review (Senaratna C.V et al. [25]), which reported on the prevalence of OSA in the general population. These studies were included not only in the top 100 influential manuscripts on OSA but also in the top 10 ranked by citation rate (3rd, 5th, and 9th, respectively). It indicated that the above 3 manuscripts will play important roles in academic communication in the future and will receive more attention and be cited by more peer scholars.

The manuscripts published on a journal with higher IF will receive increasing attention and be cited by more researchers. Similar to this opinion, our study revealed that although only 26% manuscripts were published in journals with IF > 20, the total citation frequency was 13,980, accounting for 36.35% of all total citations. Additionally, in the top 100 influential manuscripts on OSA, most manuscripts (about 74%) were published in journals with IF  $\leq 20$ . The possible reasons are described as follows: Firstly, a journal with higher IF has more requirements on the innovativeness of a study achievement and the forwardness of a study technique, so the number of published manuscripts is limited. Secondly, a journal with higher IF may prefer to publish profound studies on pathogeneses. However, in the top 100 influential manuscripts on OSA in this study, only 3 manuscripts analyzed the findings of basic scientific research, which might be associated with insufficient attention from researchers involved in OSA and related pathogenesis, unskilled techniques in the study of pathogeneses, and absence of proper animal models. Thirdly, the maximum citation rates were 399.70, 255.00, and 190.50 respectively in manuscripts on bladder cancer [21], gastric cancer [22], and PD [20]. The rate was 169.19 in manuscripts on OSA in the top 100 influential manuscripts, which indirectly indicated that scientific researchers might have paid less attention on OSA than on neoplasm-related diseases and PD. The limited study population may affect the yields of achievements published in journals with higher IFs. A metrologic analysis specific to OSA published in 2012 suggested that the USA contributed the largest number of manuscripts [15]; consistently, according to the analysis of the top 100 influential manuscripts on OSA in the present study, the USA (n=60) had absolute advantages in OSA research and held a leading position worldwide.

Several studies revealed that OSA is closely associated with many diseases [10, 12-14, 31, 32]. Although CPAP has been the most effective method for treatment of OSA, its therapeutic efficacy in different populations [33–35]. how to promote the treatment compliance [36-38] and finding a new and better therapeutic approach more advisable for children with OSA have been positively explored [39, 40]. Whether CPAP can reduce the prevalence of OSArelated diseases and promote the therapeutic efficacy of OSA-related diseases has become a topic highly concerned by researchers [29, 41–43]. Moreover, profound studies on the pathogeneses of OSA and OSA-related diseases will provide new insights for clinical treatments and prognoses. The topic analysis of bibliometrics found that in the top 100 influential manuscripts, 66 focused on the pathobiology, treatment, and OSA-associated diseases, indicating that they are still hot topics in the present OSA field.

Citation frequency is mainly used in bibliometric analysis to quantitatively analyze study achievements and development tendency in a study field. However, paper citation is a subjective thinking process of an author; as such, bibliometric analysis has been influenced by many factors and has some limitations. Firstly, the objectively existing system prejudice, gender discrimination, and language prejudice may cause differences in citations. Secondly, the Matthew effect may affect paper citation, and "authority" has always been considered the standard for paper citation, which may affect the authenticity of the citation. Thirdly, other factors, such as self-citation, coauthors, similar or alien author names, and availability of the cited manuscripts, may be blind spots for citation analysis. Although this study adopted citation rate index to rule out the influence of year of publication on citation frequency, paper citation is influenced by the date of publication and accumulating the citation frequency of a newly published manuscript takes time. Finally,

the importance of the cited manuscripts to the original ones varies, but it has not been differentiated in the present citation analysis because different contents from the manuscripts were cited by the authors.

#### Conclusions

Bibliometric analysis was used to determine the top 100 influential manuscripts on OSA as well as the distributions of country of origin, institution, authorship, and journal worldwide based on citation frequency. Pathobiology, treatment, and OSA-associated diseases remain hot topics in the OSA field. These findings may serve as valuable references for investigators to direct and implement scientific research interests in the OSA field.

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