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ORIGINAL ARTICLE

Scientific research in obstructive sleep apnea syndrome: bibliometric analysis in SCOPUS, 1991–2012

Charles Huamaní · Jorge Rey de Castro · Gregorio González-Alcaide · Daniel Ninello Polesel · Sergio Tufik · Monica Levy Andersen

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Abstract
Purpose The research in obstructive sleep apnea (OSA) may be beneficial from the collaboration between countries and researchers. In this study, we aimed to analyze the scientific research on OSA from 1991 to 2012 and to evaluate the collaboration networks between countries.
Methods We conducted a bibliometric study in the SCOPUS database. The systematic search was limited to "articles" published from 1991 to 2012. Articles are results of original research; we evaluated the following criteria: number of countries represented, number of authors, number of citations, and journal names. We determined which countries were the most productive (more articles published) and the number of collaborations between these countries. The probability of citation was evaluated using adjusted odds ratios in a logistic regression analysis.
Results We found a total of 6,896 OSA-related articles that had been published in 1,422 journals, 50 % of these articles were concentrated in 41 journals. Of the 74 different countries associated with these articles, the USA had the highest involvement with 23.8 % of all articles published. The probability of citation increased by 1.23 times for each additional author, and by 2.23 times for each additional country represented; these findings were independent of time since publication, journal, or the country of the author.
Conclusions Scientific production on OSA is increasing with limited international collaboration. The country with the greatest production in this period (1991–2012) was the USA, which concentrated the international collaboration network on OSA. We recommended that articles should be produced with international collaboration to improve the quantity of scientific publications and their chances of publication in high impact journals.

Keywords Obstructive sleep apnea · Bibliometrics · Cooperative behavior · Network analysis · Research groups

C. Huamaní (✉)
Instituto Nacional de Salud, Lima, Peru
e-mail: huamani_ca@hotmail.com

J. Rey de Castro
Centro de Trastornos Respiratorios del Sueño, Clínica Anglo Americana, Lima, Peru

G. González-Alcaide
Universitat de València, Valencia, Spain

D. N. Polesel · S. Tufik · M. L. Andersen
Department of Psychobiology, Universidade Federal de São Paulo, São Paulo, Brazil

Introduction

Obstructive sleep apnea (OSA) is a common sleep disorder and is present in 10 % of middle-aged men and 3 % of middle-aged women [1]. The OSA is considered a disease of global interest due to its impact on a patient health, including potentially causing daytime sleepiness, difficulty concentrating, frequent oxygen desaturation, and increased risk of cardiovascular problems [2]. However, how severe the consequences are that are caused by this sleep disorder on the patient's body are still unknown because this disease is typically not diagnosed until more advanced stages. Thus, the rate of undiagnosed patients remains high.

Scientific research in sleep medicine has increased in recent decades, and one of the subjects on which scientific production has increased more is related to OSA [3]. There are few countries with a strong scientific production regarding OSA, although the number of sleep laboratories has increased exponentially around the globe in the last decades [4]. As a result, the research in the subject has also increased, and the USA leads the world with respect to scientific activity on OSA [5].

Bibliometrics analyzes scientific publications in a given field as a proxy for understanding development of the field as a whole. The basic premise for bibliometrics is that scientific knowledge is mainly transmitted through publications that report research results; thus, its study allows us to analyze the development of the scientific field in question [6]. By carrying out a quantitative analysis of scientific publications in a given field, we can draw conclusions on how that research field evolves and develops. Likewise, bibliometrics studies the scientific agents that produce, transmit, and use research and provides a resource for research managers and investors to guide decision-making with regard to funding and other issues [7]. Nonetheless, previous scientific studies on sleep medicine have not analyzed the collaboration between countries, the potential domain, or independence of other countries with regard to scientific production on OSA, and the impact that collaboration has on the quality of the published research.

The analysis of collaboration between countries is important because it indicates whether scientific production on OSA is at an incipient level, or whether the scientific production of other countries occurs independently, forming collaboration networks. The current dynamic for research on scientific collaboration uses bibliometric analysis, an area of study from the social sciences, to illustrate the scientific relations that dynamically occur in certain thematic areas. For this reason, our goal was to analyze the scientific research on OSA from 1991 to 2012 and to identify the collaboration networks with other countries.

Methodology

We conducted a bibliometric study. The data encompassing the period 1991 to 2012 was extracted from the SCOPUS database, and only articles related to OSA were included. We selected this database because it includes all MEDLINE journals, and it registers the country affiliations of all authors, which were necessary for this network's analysis. We only include an on-line search that was performed in September 2013. SCOPUS is the main world multidisciplinary bibliographic database, produced by Elsevier and accessible online by subscription, it covers nearly 20,000 peer review journals including the 100 % of Medline coverage [8].

The systematic search included the following keywords only included in the titles: "sleep apnea hypopnea syndrome," "obstructive sleep apn*," "obstructive apn*," "OSAH," "OSA," and "OSAS". The search was limited by the SCOPUS filter field for "articles" published for the period 1991 to 2012. We selected this period because the previous publications may confuse the presentation of collaborations that no longer exist.

Articles are results of original research, with peer review, whose structure is the IMRaD (Introduction, Methodology, Results and Discussion) format. From each article, the following variables were obtained automatically by SCOPUS: journal name, year published, number of authors and their country of origin, and number of citations in SCOPUS. We only evaluated the collaborative research by country. No collaborations between authors were evaluated because this variable would have presented more variants, such as appearing differently in their articles or changing institutional affiliations within the same period as our analysis.

Research collaboration is a complex phenomenon which can take various forms. Bibliometric analyses are able to distinguish different levels or types of collaboration [6]. In this paper, we analyze international collaboration, that is, collaboration between authors from two different countries. If a paper had authors from the same country, we only counted one country; and the number of collaborations is the different combination of collaborations between countries. We considered the different number of collaborative countries as the degree of collaboration by country. For example, if the paper had "n" authors from four countries, the number of the collaborative countries are four, but this paper generates six collaborations between countries (A with B; A with C; A with D, B with C; B with D, and C with D), and the degree of collaboration is three by country.

We identified the most productive (with most articles published) countries and the international collaboration networks between these countries using the signatures that are related to each author, number of publications per year, journals with the most publications, number of authors, and citations. Additionally, the journals' impact factors were obtained from Journal Citation Reports 2012. We performed the correlation between the numbers of authors with citations per article using Spearman's rho.

We established two article categories: cited or not cited. Then, we evaluated whether the number of authors or number of collaborative countries increased the probability of citation, using odds ratio (OR) with a respective 95 % confidence intervals (95 % CI) in a logistic regression. The adjusted multivariate model included the time since publication, number of publications in the journal, and number of publications of each country. We choose these variables for shown if the collaboration increases the impact independent, if the country had more articles, or if the paper was published in a journal with more papers. All analyses were performed with STATA 12.1 (STATA Corp, College Station, TX, USA).

To illustrate the collaboration between countries, we constructed a network with the countries that had more than five collaborative articles by using Pajek v.3.0.2 visual representation software and applying the Kamada-Kawai algorithm. This function allowed for a graphic illustration of the networks, which weighed the collaborative intensity for each article [9]. This methodology is common for bibliometric studies and network representations [10]. Furthermore, we analyze the degree of collaboration by country (number of collaborative countries).

Results

From 1991 to 2012, 6,896 OSA-related articles were published and indexed in the SCOPUS database. For the network analysis, we excluded 256 (3.7 %) from the 6,896 identified because we could not identify the author's country of origin. The year with more number of articles published was the year 2012, with 685 articles; in contrast to the 103 articles published in 1991 (Fig. 1).

We identified 6,896 articles published in 1,422 journals. Over a third of the articles analyzed, (34.8 %) were published in 15 journals (Table 1). Eleven journals published more than 100 articles each and collectively comprised 30 % of all OSA scientific production in this analysis. The *Chest* was the journal with the most articles on OSA (311 articles, 4.51 %), with an average citation of 49.4±57.7, and 94.5 % articles had citations. The results concerning to other journals are shown in Table 1.

The average number of authors per article was 5.0±2.8; which increased from 4.1±1.9 authors in 1991, to 5.6±3.8 authors in 2012. The number of articles with a single author was 431 (6.3 %). Most of the articles, 5,338 (77.4 %) were cited, with an average of 21.0±49.7 citations per article. The number of citations received had a positive correlation with the number of authors (Spearman's rho=0.185, $p<0.001$). And the number of citations was negatively correlated with the time since publication (Spearman's rho=−0.361, $p<0.001$).

Of the 6,640 (96.3 %) articles included in the network analysis, we identified 74 different country affiliations. In the year 1991, 28 countries were included, and this number increased to 54 countries in 2012. The USA was involved in the publication of 1,758 (23.8 %) of OSA-related articles published from 1991 to 2012. The USA annual scientific production of OSA-related articles increased from 54 articles in 1991 to 168 articles in 2012. However, articles affiliated with Canada had the highest average number citations, with 45.2±67.5 citations per article.

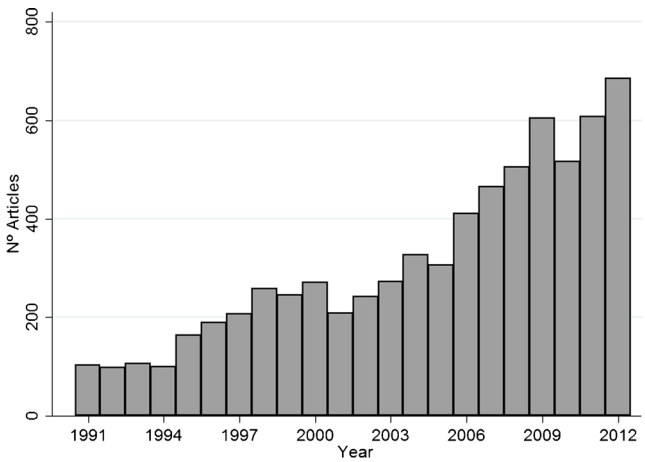

Fig. 1 Annual scientific research in obstructive sleep apnea, SCOPUS 1991–2012

The probability of citation increased by 1.23 times for each additional author on the article, or 2.23 times for each additional country affiliated with the article, independent of time since publication, papers for journal, and the country of the author (Table 2).

Of the 74 affiliated countries identified in this analysis, 24 of them published over 50 OSA-related articles each, 29 of which published less than 10 OSA-related articles each during the study period (Table 3). Of all the articles analyzed in this study, 87.3 % were not collaborative between countries, 8.4 % (580) were collaborative among authors of two countries, and 0.8 % (53) was collaborative among authors of three countries. In 2011, a multicenter study was made among 26 countries, which was published in *Sleep Medicine* involving 41 authors from various European countries [11].

The country with the greatest collaboration was the USA (47 countries), followed by Germany (34), and Canada (34). The top-producing countries collaborated with USA in at least one article. The scientific network on OSA was centralized by the USA. Finally, China, UK, Canada, Australia, and Germany collaborate to publish fewer articles than those published in collaboration with the USA (Fig. 2).

Discussion

Our study provides information on the collaboration network of OSA research; it also shows the annual growth of scientific production in this field. Our findings are consistent to those shown by a similar study performed using the Science Citation Index of Institute for Scientific Information (SCI-ISI) database [5], and a similar study was also based on a researched theme of sleep medicine [3]. Scientific collaboration between countries for research in sleep medicine is still scant, which is evident in the collaboration network as well as in the percentage of independent articles. For instance, Brazil produces 12 % of its articles in collaboration with other countries; however, in regard to Clinical Medicine, the international collaboration is approximately 30 % [12]. This finding may explain why the production of sleep medicine is low because the countries that had increased their international collaboration, have obtained a larger growth in quantity and with respect to quality of their research [13].

Some of the findings are similar to those reported in previous studies in other fields, particularly the fact that the USA dominates scientific production and the international collaboration networks. The researchers from the USA, together with Canada, UK, and some other European countries, also have the highest citation rates [14, 15]. Despite the fact that countries such as China or Brazil have emerged as leading research countries, they are still far away from them in terms of citation rates [16]. A final point to be emphasized in accordance with previous

Table 1 Scientific research and citations in obstructive sleep apnea by journal in SCOPUS, 1991–2012

Journal	No. of articles (%)		Citations[a] Citations/article	No. of cited articles (%)[b]		Impact factor[c]
Chest	311	(4.5)	49.4±57.7	294	(94.5)	5.25
Sleep	276	(4.0)	38.4±47.9	273	(98.9)	5.05
Am J Respir Crit Care Med[d]	248	(3.6)	92.6±94.4	248	(100)	11.08
Sleep Breath	238	(3.5)	9.1±11.6	222	(93.3)	1.84
Sleep Medicine	208	(3.2)	16.0±18.8	186	(89.4)	3.40
Eur Respir J.	176	(2.6)	39.9±35.1	174	(98.9)	5.89
Thorax	135	(1.9)	39.8±55.7	116	(85.9)	6.84
J Clin Sleep Med	123	(1.8)	10.1±12.8	107	(86.9)	3.23
Otolaryngol Head Neck Surg	123	(1.8)	23.5±37.1	115	(93.5)	1.72
Laryngoscope	120	(1.7)	25.5±32.6	109	(90.8)	1.75
Chinese J. Otorhinolaryngol[e]	107	(1.6)	0.4±0.7	27	(25.2)	–
Chinese J. Tuberculosis Res	83	(1.2)	1.0±1.8	42	(50.6)	–
Pneumologie	83	(1.2)	2.3±4.6	39	(46.9)	–
Respir Med	78	(1.1)	18.1±19.7	76	(97.4)	2.48
J Sleep Res	75	(1.1)	23.4±25.7	73	(97.3)	3.16

[a] Mean±standard deviation

[b] Percentage of cited articles/total articles per journal

[c] Impact factor by JCR 2012

[d] *American Review of Respiratory Disease* changed its name in 1994 to *American Journal of Respiratory and Critical Care Medicine*; we merged the articles by both journals

[e] *Chinese journal of otorhinolaryngology* changed in 2004 to *Chinese journal of otorhinolaryngology head and neck surgery*

studies is the importance of international collaboration, which has a positive effect on citation rates and enhances the quality of the research [17, 18].

Scientific production on OSA increased to a rate of 6.6 times in 2012 compared to 1996; however, this growth is more attributed to international production, which varied from 28 to 54 countries in the period of study, rather than due to the participation of one country in particular. For example, the country with most production, the USA, has only increased 3 times its production in the past two decades, even though the USA is a country where the number of sleep laboratories has increased since the 1980's [4]. This increase is likely due to the suggestion of a treatment for OSA using continuous positive airway pressure (CPAP), which has amounted to a significant improvement in patient quality of life [19].

In contrast, for many countries, interest in sleep medicine is more recent, and there is a high rate of underdiagnosis of OSA on a global scale [20, 21]. Because sleep disorders are not broadly known, more specialists or sleep laboratories are needed [22], but due to, among other factors, economics or funding in research, these countries still have not achieved this goal. In the future, it is possible that the production and the participation of more countries, as well as the implementation of more specialization programs or sleep laboratories, can be explained by the scientific collaboration networks. In other contexts, scientific collaboration networks have not only meant greater scientific production but also greater exchange of professionals and specialization [12].

One positive aspect for improving diffusion and scientific visibility is the presence of journals specialized in sleep medicine [23], which despite being recent, receive important citations. In some cases, these journals had more citations than the journals that are not exclusive to a particular specialty.

Given the multidisciplinary nature of approaches taken to examine sleep medicine, a great number of authors would be expected; thus, our results are similar to the ones reported by Huang in sleep apnea research, who indicated that the average number of authors increased from 4.1 to 4.9 from 1991 to 2006 [5]. However, in the period of 2007 to 2012, this average number varied from 5.2 to 5.6 authors per article, which suggests a rapid increase in the authorship. Spearman's correlation coefficient indicated a strong result with a level of significance between the number of authors and number of citations. Nevertheless, Spearman's correlation coefficient still suggests that the number of citations is inversely related with the time since publication of the study. Therefore, a study of more co-authors tends to be cited more as time progresses.

In this study, the number of authors or countries per article was associated with a greater probability that the papers received citations. Previous studies also show the relation between national or international collaboration with an increase of the number of citations [24, 25]. However, this relation may be due to the nature of the research: multicenter,

Table 2 Association between be cited with the number of authors or collaborative countries by article in obstructive sleep apnea by journal in SCOPUS, 1991–2012

	OR adjusted[a]	(95 % CI)	*p*
Number of authors	1.23	1.20–1.27	<0.001
Number of collaborative countries	2.23	1.89–2.63	<0.001

[a] Odds ratios adjusted by time since publication, papers for journal, and papers for country

Table 3 Scientific research and citations in obstructive sleep apnea by country. SCOPUS 1991–2012

Country	No. articles (%)		No. AC (%)		No. cou.	Authors[a]	Citations[a]	No. of cited articles (%)	
USA	1,758	(23.8)	328	(18.7)	47	4.8±3.1	30.0±58.3	1,551	(88.2)
China	712	(9.6)	38	(5.3)	11	5.3±2.5	6.2±29.4	329	(46.2)
Japan	504	(6.8)	55	(10.9)	15	6.4±2.9	16.2±35.6	378	(75.0)
Germany	443	(6.0)	77	(17.4)	34	5.3±2.9	19.3±42.4	376	(84.9)
Canada	359	(4.9)	88	(24.5)	29	5.2±2.7	45.2±67.5	333	(92.8)
UK	348	(4.7)	90	(25.9)	34	4.8±3.1	35.9±71.5	293	(84.2)
Spain	326	(4.4)	55	(16.9)	26	6.2±4.8	20.2±86.4	266	(81.6)
Australia	301	(4.1)	88	(29.2)	18	5.3±2.5	28.2±48.0	273	(90.7)
Italy	264	(3.6)	45	(17.0)	27	6.4±3.6	17.1±23.7	226	(85.6)
Turkey	253	(3.4)	20	(7.9)	7	5.6±2.0	8.2±13.5	183	(72.3)
France	250	(3.4)	45	(18.0)	27	5.9±3.5	20.2±29.4	208	(83.2)
Brazil	174	(2.4)	21	(12.1)	8	6.0±2.5	12.0±26.9	145	(83.3)
Poland	157	(2.1)	11	(7.0)	22	5.4±3.4	5.9±17.5	121	(77.1)
Sweden	137	(1.9)	35	(25.5)	28	5.2±3.8	33.9±55.9	127	(92.7)
Taiwan	122	(1.7)	38	(31.1)	6	4.9±1.8	8.7±11.0	102	(83.6)
Israel	118	(1.6)	21	(17.8)	22	4.9±4.0	32.3±52.5	112	(94.9)
Greece	87	(1.2)	13	(14.9)	22	7.2±4.4	16.3±21.6	75	(86.2)
Switzerland	82	(1.1)	39	(47.6)	14	5.8±3.0	14.6±19.2	78	(95.1)
Netherlands	77	(1.0)	17	(22.1)	24	5.5±4.7	10.9±14.1	60	(77.9)
South Korea	77	(1.0)	16	(20.8)	4	6.3±2.4	10.1±12.4	64	(83.1)
Belgium	71	(1.0)	20	(28.2)	24	5.9±5.3	22.6±28.5	61	(85.9)
Finland	71	(1.0)	17	(23.9)	25	5.6±5.1	19.8±25.9	57	(80.3)
India	65	(0.9)	7	(10.8)	2	4.1±2.1	8.6±19.2	42	(64.6)
Singapore	55	(0.7)	24	(43.6)	8	4.1±2.9	11.2±13.6	47	(85.5)

No. AC number (%) of articles with collaboration with other country

No. cou number of countries in collaboration

[a] Mean±standard deviation

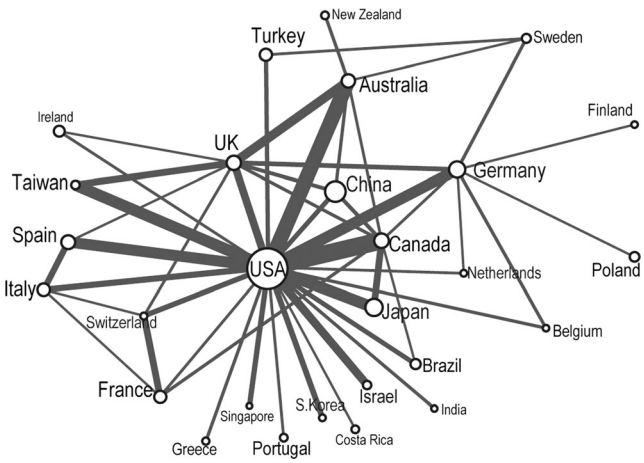

Fig. 2 Collaboration network into countries with 50 or more articles published in obstructive sleep apnea, SCOPUS 1991–2012. Note: Only plotted the relations into countries with five or more articles together, the *thickness of the lines* is proportional to the number of collaborative articles, and the *circles*' size is proportional to the number of articles published

multidisciplinary, high complexity, and large sample size. These types of studies result in a greater impact, compared to noncollaborative research. Although it is necessary more studies for demonstrate this association.

Asian journals and countries had a significant increase in scientific production on OSA. Nevertheless, these countries and journals received a smaller number of citations. Multiple factors may have contributed to this finding. For example, the citation of Chinese journals is primarily in traditional medicine in relation to Western medicine [26]. Internationally collaborative studies on sleep medicine are typically only between a few countries (Table 2), in contrast with other Asian studies that received more citations [25]. Due to the nature of an author's native language, nonnative English authors have a lower probability of citation because of difficulties for these authors to publish in English [27]. Other factors likely contribute to this finding, but these require more specified studies.

This study has limitations because studies on OSA that were indexed in databases other than SCOPUS may not have been included. In addition, some SCOPUS journals categorize

reviews or other documents as "articles." To exclude these other papers, we would have had to employ a manual selection process, which could possibly lead to bias; therefore, it is possible that other forms of publication have been included in the analysis. OSA articles that not include this term as a keyword in their titles were not included, so it is possible that not all articles for all OSA have been considered. Finally, we could not analyze all aspects of research, such as financing, number of researchers, or number of sleep laboratories.

In conclusion, scientific production on OSA is increasing; nonetheless, the international collaboration is still rare. The country with the greatest production is USA, which concentrates the international collaboration network on OSA, followed by a significant production from Asia and Europe. By knowing the benefits of international collaboration, we recommend tightening the network connections among researchers to facilitate an increase in scientific production on OSA.

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Conflict of interest The authors declare that there are no conflicts of interest.

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