Introduction

The quantity and quality of research in the field of sleep has increased rapidly, with a 4-fold rise in the number of publications during the period from 1974 to 2007. Obstructive sleep apnea (OSA) is a sleep-related breathing disorder characterized by repetitive upper airway obstruction, which causes frequent episodes of reduced (hypopnic) or no (apneic) airflow during sleep. OSA is common in the adult population, with a prevalence of approximately 5%, and it may negatively affect multiple organs, resulting in the development of cardiovascular diseases and neurocognitive problems. OSA can be treated using continuous positive airway pressure (CPAP), which has been shown to result in improved quality of life.

Bibliometric analysis is a research method used in library and information science to evaluate research performance. This method uses quantitative and statistical analyses to describe patterns of publication on a given topic, in a given field, institute, or country. The increasing use of bibliometric analysis by institutes and journals indicates its importance. Close examination of the literature provides information to researchers, and publication output in a certain discipline or topic can represent its previous, current, and future research trends or focus. One common method for carrying out bibliometric research is to use the Science Citation Index online version. We analyzed selected documents with “obstructive sleep apnea”, “obstructive apnea”, or “OSA” as a part of the title, abstract, or keywords and reported the following parameters: trends of publication output, journal pattern, country of publication, authorship, author-generated keywords, and KeyWords Plus.

Results: The annual number of articles on OSA grew at a faster rate than did the number of general scientific publications, from approximately 200 in 1991 to 650 in 2006. The main subject categories in which research on OSA was conducted were the respiratory system and clinical neurology, each of which accounted for >10% of total articles. Most of the research was conducted in the major industrial countries, with most international collaborations involving the United States and Canada. Certain terms were identified by KeyWords Plus but not by author-generated keywords, and some terms increased in frequency of use over time.

Conclusion: This study provides a bibliometric analysis showing that the annual number of publications related to OSA has been increasing at a much faster rate than the overall scientific literature during the past 16 years in a growing number of specialized journals. Analysis of key words (KeyWords Plus) suggests research trends and areas for future research. [J Chin Med Assoc 2009;72(3):117–123]

Key Words: bibliometric analysis, MEDLINE, obstructive sleep apnea, sleep disorder
Index (SCI) or Social Science Citation Index (SSCI), which are published by the Institute for Scientific Information (ISI), Philadelphia, PA, USA, to trace citations. Numerous medical topics such as sleep research, severe acute respiratory syndrome, patent ductus arteriosus, and asthma research have been analyzed using the SCI and SSCI to assess the performance in each research topic and indicate the authors’ impacts on and contributions to their respective fields. However, despite the importance of OSA, there have been no published bibliometric analyses of the research on this disorder. In this investigation, we attempted to gain insights into the quantity and quality of research in the area of OSA by analyzing the SCI database. The results of this study will be of value to researchers in various fields, including clinical neurology, who seek information about the current trends and future directions in sleep-related research.

Methods

Publications containing abstracts were extracted with a literature search performed in August 2007 using the online version of the SCI® (http://scientific.thomson.com/products/sci/)–ISI Web of Knowledge Service (version 3.1). Author-generated key words, such as “obstructive sleep apnea”, “obstructive apnea”, and “OSA”, and KeyWords Plus® were analyzed. KeyWords Plus® in the SCI database supplies additional search terms extracted from the titles of articles cited by authors in their bibliographies and footnotes. Data collected from the online searches were extracted and manipulated in Excel spreadsheets to provide the input for the analysis, and the search results were checked to verify that all entries were related to OSA. Documents were analyzed according to trends of publication output, subject category, journal pattern, country of publication, authorship, author-generated key words, and KeyWords Plus®. The trend of annual publication output was determined from 1991, the first year in which abstracts were available in ISI, to 2006, the last year for which complete information was available at the time of the search; and the analysis was performed for 4-year periods within this 16-year time span. Articles originating from England, Scotland, Northern Ireland, and Wales were grouped under the United Kingdom (UK) heading. The impact factor of a journal was determined for each document as reported in the Journal Citation Reports (JCR) 2005. We determined the type of collaboration for each article by the address of each author, where “independent” was assigned if no collaboration was found and “international collaboration” was assigned if researchers from more than 1 country.

Results

Trends of publication output

There were a total of 6,328 articles in SCI published during the 16 years between 1991 and 2006 with “obstructive sleep apnea”, “obstructive apnea”, or “OSA” in the title. During this time period, the annual number of articles on OSA grew from approximately 200 in 1991 to 650 in 2006 (Table 1). The OSA Productivity Index, which was obtained by dividing the number of articles at each time by the number published in 1991, also grew; and the 3.25-fold increase in the Productivity Index for OSA-related articles over the 16-year period was higher than the 1.81-fold increase in the Productivity Index for all publications obtained from MEDLINE.

Subject category

A wide variety of subjects are related to sleep research. Of the 6,328 articles tabulated, 6,322 had subject category information. Clinical neurology accounted for >10% of all articles and was ranked second, behind the respiratory system, in the listing of subject categories under which research on OSA was conducted (Table 2). However, recently, more publications on OSA have been falling into categories such as pediatrics, and cardiac and cardiovascular systems. In contrast, fewer papers on OSA are being published in categories of more general interest, such as general and internal medicine, and sports sciences.

Journal pattern

Table 3 lists the 7 core journals that published more than 100 papers on OSA research, the corresponding percentage of OSA papers accounted for by each journal over the 16-year period, and impact factor for each journal indexed in the 2005 edition of the JCR. The most active journals were Sleep, Chest, and American Journal of Respiratory and Critical Care Medicine. During the period examined, these 3 journals published 8.3%, 7.5%, and 6.2% of the total number of articles, respectively. Among the journals that covered OSA, 94 had an impact factor > 10, and these journals published 1.5% of the papers on OSA. Journals that had impact factors ranging from 1 to 2 accounted for 22% of the publications, and 30% of the OSA-related articles were published in journals with an impact factor between 4 and 10.
Obstructive sleep apnea research trends

### Table 1. Characteristics of output by year of publication from 1991 to 2006

| Year | TP   | AU   | AU/P | NR   | NR/P | PG   | PG/P |
|------|------|------|------|------|------|------|------|
| 1991 | 203  | 809  | 4.0  | 4,474| 22   | 1,151| 5.7  |
| 1992 | 238  | 935  | 3.9  | 5,420| 23   | 1,385| 5.8  |
| 1993 | 241  | 969  | 4.0  | 5,548| 23   | 1,404| 5.8  |
| 1994 | 219  | 916  | 4.2  | 5,661| 26   | 1,386| 6.3  |
| 1995 | 341  | 1,417| 4.2  | 8,454| 25   | 2,103| 6.2  |
| 1996 | 349  | 1,405| 4.0  | 9,099| 26   | 2,171| 6.2  |
| 1997 | 291  | 1,288| 4.4  | 7,671| 26   | 1,977| 6.8  |
| 1998 | 324  | 1,402| 4.3  | 8,654| 27   | 2,219| 6.8  |
| 1999 | 378  | 1,615| 4.3  | 10,029|27   | 2,527| 6.7  |
| 2000 | 474  | 2,051| 4.3  | 13,737|29   | 3,160| 6.6  |
| 2001 | 405  | 1,796| 4.4  | 12,086|30   | 2,682| 6.6  |
| 2002 | 435  | 2,086| 4.8  | 13,836|32   | 2,932| 6.7  |
| 2003 | 587  | 2,758| 4.7  | 19,023|32   | 4,088| 7.0  |
| 2004 | 576  | 2,669| 4.6  | 18,518|32   | 3,844| 6.7  |
| 2005 | 594  | 2,872| 4.8  | 19,661|33   | 4,152| 7.0  |
| 2006 | 673  | 3,287| 4.9  | 21,275|32   | 4,552| 6.8  |
| Total| 6,328| 28,275|4.5 | 183,146|29 | 41,679|6.6 |

TP = total number of articles; AU = number of authors; P = publication; NR = cited reference count; PG = page count.

### Table 2. Ten ISI subject categories with the most publications

| Subject category                              | 1991–2006 R (TP) | 1991–1994 R (TP) | 1995–1998 R (TP) | 1999–2002 R (TP) | 2003–2006 R (TP) |
|-----------------------------------------------|------------------|------------------|------------------|------------------|------------------|
| Respiratory system                            | 1 (1,545)        | 1 (273)          | 1 (324)          | 1 (426)          | 1 (522)          |
| Clinical neurology                            | 2 (1,061)        | 2 (140)          | 2 (248)          | 2 (266)          | 2 (407)          |
| Otorhinolaryngology                           | 3 (857)          | 4 (103)          | 4 (172)          | 3 (239)          | 3 (343)          |
| Psychiatry                                    | 4 (706)          | 3 (107)          | 3 (196)          | 4 (205)          | 6 (198)          |
| Physiology                                    | 5 (583)          | 6 (87)           | 5 (139)          | 6 (150)          | 5 (207)          |
| Surgery                                       | 6 (481)          | 8 (55)           | 9 (81)           | 7 (117)          | 4 (228)          |
| General & internal medicine                   | 7 (441)          | 5 (95)           | 6 (110)          | 10 (101)         | 9 (135)          |
| Critical care medicine                        | 8 (416)          | 10 (35)          | 7 (106)          | 5 (152)          | 11 (123)         |
| Neurosciences                                 | 9 (372)          | 12 (28)          | 8 (96)           | 8 (115)          | 10 (133)         |
| Pediatrics                                    | 10 (371)         | 9 (50)           | 11 (65)          | 9 (102)          | 7 (154)          |
| Sport sciences                                | 11 (309)         | 7 (61)           | 10 (66)          | 11 (91)          | 14 (91)          |
| Cardiac & cardiovascular systems              | 12 (278)         | 14 (18)          | 13 (47)          | 14 (62)          | 8 (151)          |
| Research & experimental medicine              | 13 (258)         | 11 (29)          | 15 (46)          | 12 (74)          | 12 (109)         |
| Dentistry, oral surgery, & medicine           | 14 (220)         | 13 (22)          | 12 (53)          | 13 (68)          | 15 (77)          |
| Peripheral vascular disease                   | 15 (205)         | 16 (13)          | 16 (35)          | 15 (61)          | 13 (96)          |
| Anesthesiology                                | 16 (131)         | 15 (17)          | 19 (15)          | 17 (34)          | 16 (65)          |
| Endocrinology & metabolism                    | 17 (111)         | 19 (10)          | 20 (12)          | 16 (35)          | 17 (54)          |

R = ranking; TP = total publications.

### Table 3. Seven core journals publishing the most obstructive sleep apnea research articles

| Journal                                      | TP  | %   | IF  |
|----------------------------------------------|-----|-----|-----|
| Sleep                                        | 524 | 8.3 | 4.95|
| Chest                                        | 477 | 7.5 | 4.008|
| American Journal of Respiratory and Critical Care Medicine | 395 | 6.2 | 8.689|
| Journal of Applied Physiology                | 276 | 4.4 | 3.037|
| Laryngoscope                                 | 174 | 2.7 | 1.617|
| Otolaryngology-Head and Neck Surgery         | 147 | 2.3 | 1.218|

TP = total publications; IF = impact factor.
Distribution of research among countries

Table 4 shows the ranking for the top 11 countries in terms of output for the 6,296 OSA-related publications that provided addresses for authors. The major industrial countries ranked highest, with the United States first producing 41% of the papers, and Canada second with 7.2%. The United States and Canada also produced the greatest number of papers that were determined to be international collaborations by author addresses.

Authorship

The average number of authors per article was 4.5 from 1991 to 2006. The 6,328 published articles were authored by 15,084 authors, among which 11,011 (73%) contributed just 1 article, 1,998 (13%) authored 2 articles, 767 (5.1%) authored 3 articles, 385 (2.6%) authored 4 articles, and 223 (1.5%) authored 5 articles.

Author-generated key words and KeyWords Plus®

Table 5 summarizes the most frequently used author-generated key words. A total of 6,413 key words were listed by authors in the 4,233 articles with records of author-generated key words in the SCI database. Most of the key words (73%) were used just once, and 11% were used twice. Table 6 shows the distribution of key words obtained from KeyWords Plus®. The ranking of most terms identified by KeyWords Plus® is similar to that for the key words determined by the authors.
However, KeyWords Plus® identified additional terms among the top 15, such as “daytime sleepiness”, “children”, “therapy”, and “men” that were not apparent among the authors’ key words.

Terms that relate specifically to the field of clinical neurology, such as “sympathetic nervous system” and “stroke”, are shown in Table 7. The analysis in Table 7 also shows that some terms, for example “stroke”, have risen in rank over time, with an increase from the overall ranking of 55 to 40 for the period 2003–2006.

**Discussion**

This study provides a bibliometric analysis showing that the annual number of publications related to OSA has been growing at a much faster rate than the overall scientific literature during the past 16 years. This study was limited because only publications that were contained and ranked within SCI were analyzed. Nevertheless, our results for the specific area of OSA are consistent with those obtained from a similar analysis of the literature of sleep science in general, which reported a 4-fold increase in the productivity index for sleep-related publications compared to a 2-fold increase in that for all scientific publications over the period from 1974 to 2004.

This growth may reflect the increasing awareness of the importance of sleep in modern society and the rapid rise in the number of sleep centers and laboratories that can diagnose sleep disorders.

This analysis of OSA-related publications has revealed a trend toward specialization in the area of OSA-related research. For example, a decrease in the number of publications was noted in subject areas such as general and internal medicine, psychiatry, and sports sciences. Furthermore, among the 7 core journals that published the most OSA-related research, the highest ranking (Sleep) focuses exclusively on sleep research. The wide variety of subject categories that contained publications on OSA also reflects the impact of OSA on many aspects of health, including the respiratory, cardiovascular, and nervous systems.

The subject category of clinical neurology ranked second in terms of the number of publications related to OSA. This suggests that OSA is a research area of increasing concern to neurologists. Within the category of clinical neurology, the current focus of OSA research is indicated by the terms “autonomic nervous system”, “quality of life”, “depression”, “serotonin”, “stroke”, and “epilepsy”. From the perspective of frequency of use of key words, it is apparent that the

### Table 6. Top 22 most frequently used key words from KeyWords Plus® during 1991 to 2006 and in each of the 4-year periods

| KeyWords Plus®                  | 1991–2006 | 1991–2006 | 1991–1994 | 1995–1998 | 1999–2002 | 2003–2006 |
|--------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Obstructive sleep apnea        | 1,360     | 1 (23)    | 1 (16)    | 1 (19)    | 1 (24)    | 1 (27)    |
| Positive airway pressure       | 706       | 2 (12)    | 6 (7.2)   | 3 (9.1)   | 2 (11)    | 2 (15)    |
| Sleep apnea                    | 593       | 3 (10)    | 2 (12)    | 2 (11)    | 3 (11)    | 4 (8.2)   |
| Hypertension                   | 461       | 4 (7.8)   | 15 (4.1)  | 6 (6.7)   | 4 (8.6)   | 3 (9)     |
| Apnea syndrome                 | 359       | 5 (6.1)   | 4 (8.6)   | 4 (7.4)   | 9 (5.7)   | 17 (4.8)  |
| Apnea                          | 357       | 6 (6)     | 3 (8.9)   | 5 (7.2)   | 13 (5.4)  | 16 (4.9)  |
| Pressure                       | 353       | 7 (6)     | 7 (6.4)   | 6 (6.7)   | 6 (6.6)   | 15 (5)    |
| Daytime sleepiness             | 351       | 8 (5.9)   | 14 (4.3)  | 12 (5.4)  | 5 (6.7)   | 9 (6.2)   |
| Prevalence                     | 340       | 9 (5.7)   | 13 (4.5)  | 13 (5)    | 12 (5.5)  | 7 (6.6)   |
| Blood pressure                 | 335       | 10 (5.7)  | 30 (3)    | 10 (5.8)  | 10 (5.7)  | 8 (6.4)   |
| Children                       | 314       | 11 (5.3)  | 23 (3.4)  | 16 (4.4)  | 8 (5.8)   | 10 (6)    |
| Therapy                        | 313       | 12 (5.3)  | 17 (3.9)  | 17 (4.2)  | 7 (6.5)   | 11 (5.5)  |
| Uvulopalatopharyngoplasty      | 296       | 13 (5)    | 8 (6.2)   | 8 (6.3)   | 10 (5.7)  | 22 (3.5)  |
| Men                            | 295       | 14 (5)    | 5 (7.7)   | 9 (6.1)   | 14 (5.1)  | 23 (3.4)  |
| Association                    | 294       | 15 (5)    | 45 (2)    | 39 (2.1)  | 16 (4.5)  | 5 (7.7)   |
| Disease                        | 289       | 16 (4.9)  | 9 (5.6)   | 19 (3.9)  | 17 (4.4)  | 11 (5.5)  |
| Adults                         | 281       | 17 (4.7)  | 79 (1.2)  | 35 (2.2)  | 15 (4.8)  | 6 (7.1)   |
| Disorders                      | 254       | 18 (4.3)  | 25 (3.3)  | 21 (3.7)  | 21 (3.9)  | 13 (5.2)  |
| Population                     | 248       | 19 (4.2)  | 35 (2.7)  | 23 (3.6)  | 20 (4)    | 14 (5.1)  |
| Hypoxia                        | 242       | 20 (4.1)  | 10 (5.1)  | 11 (5.4)  | 19 (4.1)  | 27 (3)    |
| Humans                         | 227       | 21 (3.8)  | 10 (5.1)  | 14 (4.7)  | 18 (4.2)  | 33 (2.7)  |
| Mortality                      | 226       | 22 (3.8)  | 12 (4.8)  | 14 (4.7)  | 21 (3.9)  | 29 (3)    |

TP = total publications; R = ranking.
A unique aspect of this study was the use of the KeyWords Plus® feature to identify research trends. Previous bibliometric studies have used only author-generated key words, but we have analyzed with the use of KeyWords Plus® simultaneously. In general, the source title and author-generated key words supply reasonable details about an article’s subject. KeyWords Plus®, however, can reveal greater detail about an article’s content. Thus, by combining the terms from KeyWords Plus®, it is possible to glimpse more details about the subject of each individual article and to identify emerging themes within the field. The term metabolic syndrome illustrates this. Our data showed that the area of metabolic syndrome ranked 132 in the overall period of study, but that its rank rose to 54 in the most recent period of 2003 to 2006. This suggests that recognition of the association between OSA and metabolic syndrome has emerged since 2003. Therefore, articles that may not have identified OSA as a key word but may be part of a developing research trend will be captured in a bibliometric analysis using KeyWords Plus®.

Terms that were identified by KeyWords Plus®, for example “daytime sleepiness”, “children”, and “men” may confirm that most patients with OSA experience daytime sleepiness,25 that sleep disorders are important in children as well as adults, and that men are more likely to have OSA than women. The most commonly used key words after “OSA” and “sleep apnea” were “snoring” and “polysomnography”. From this observation, we might infer that current OSA research is focused on clinical symptoms, such as snoring, and frequently used methods of diagnosis, such as polysomnography. On the other hand, there is less emphasis on basic laboratory research about OSA at present. These terms may suggest areas where additional research is needed in the future.

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Table 7. Additional terms and frequency of use (rank) over time as analyzed by KeyWords Plus®

| KeyWords Plus* | 1991–2006 | 1991–2006 | 1991–1994 | 1995–1998 | 1999–2002 | 2003–2006 |
|---------------|-----------|-----------|-----------|-----------|-----------|-----------|
|               | TP        | R (%)     | R (%)     | R (%)     | R (%)     | R (%)     |
| Sympathetic nervous system | 55 | 27 (1.3) | 29 (1.4) | 21 (1.6) | 26 (1.4) | 54 (1.3) |
| Quality of life | 50 | 31 (1.2) | #N/A | 38 (0.4) | 32 (1.2) | 22 (2.6) |
| Autonomic nervous system | 40 | 40 (0.94) | 62 (0.69) | 34 (0.86) | 44 (0.95) | 46 (1.4) |
| Depression | 34 | 48 (0.8) | #N/A | 81 (0.43) | 49 (0.86) | 40 (1.6) |
| Stroke | 32 | 55 (0.76) | 203 (0.23) | 139 (0.26) | 58 (0.78) | 40 (1.6) |
| Sudden infant death syndrome | 30 | 63 (0.71) | 29 (1.4) | 56 (0.6) | 113 (0.43) | 69 (1) |
| Epilepsy | 24 | 83 (0.57) | 203 (0.23) | 81 (0.43) | 196 (0.26) | 54 (1.3) |
| Serotonin | 23 | 88 (0.54) | 45 (0.93) | 65 (0.52) | 113 (0.43) | 103 (0.68) |
| Oxidative stress | 16 | 122 (0.38) | #N/A | #N/A | #N/A | 46 (1.4) |
| Metabolic syndrome | 15 | 132 (0.35) | #N/A | #N/A | #N/A | 54 (1.3) |
| Adiponectin | 6 | 363 (0.14) | #N/A | #N/A | #N/A | 139 (0.51) |
| Brain natriuretic peptide | 6 | 363 (0.14) | #N/A | #N/A | #N/A | 139 (0.51) |
| C-reactive protein | 6 | 363 (0.14) | #N/A | #N/A | #N/A | 139 (0.51) |
| Randomized trial | 6 | 363 (0.14) | #N/A | #N/A | #N/A | 139 (0.51) |
| Atrial fibrillation | 5 | 443 (0.12) | #N/A | #N/A | #N/A | 159 (0.43) |
| Hypothalamus | 5 | 443 (0.12) | #N/A | #N/A | #N/A | 159 (0.43) |
| Laparoscopic | 5 | 443 (0.12) | #N/A | #N/A | #N/A | 159 (0.43) |
| Spatial learning | 5 | 443 (0.12) | #N/A | #N/A | #N/A | 159 (0.43) |

TP = total publications; R = ranking.
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