

Bibliometric Analysis of the Orthopedic Literature

ZHAOYANG HUI, MD; ZHONGMEI YI, MD; JUN PENG, PHD

abstract

Full article available online at Healio.com/Orthopedics. Search: 20130920-11

Bibliometric indicators are used to assess research performance. The goal of this study was to explore publication output to construct a picture of orthopedics that may be beneficial to researchers and orthopedic specialists. All orthopedics articles published in 61 journals from 2000 to 2011 were retrieved from the Science Citation Index Expanded database. The numbers of articles, citations, authors, institutions, and journals were analyzed and subjected to quantitative and qualitative comparisons. The number of published orthopedics articles increased between 2000 and 2011. Articles published by authors from the United States always ranked first in number, although the United States' share is decreasing in the world literature. Authors from the United States published the most-cited articles and the most articles in journals with top-10 impact factors; moreover, the United States also had the greatest share of experts and highly ranked institutions. The United Kingdom, Germany, and Japan were always within the world's top 4 in terms of numbers of articles and citations. The shares of Germany, South Korea, and China among total orthopedics articles increased, especially that of China. In 2011, China ranked the fifth in the world, with its world share increasing from 0.64% in 2000 to 5.05% in 2011. However, China lags behind in average citations per article, top research institutions, and most prolific authors. According to the total citations per article, the University of Pittsburgh, Harvard University, and the Hospital for Special Surgery were the most prolific institutions.

The authors are from the Library of the Second Military Medical University, Shanghai, China.

The authors have no relevant financial relationships to disclose.

The Library of the Second Military Medical University provided research support for this study.

Drs Hui and Yi contributed equally to this article.

The authors acknowledge the valuable cooperation of Ellen Detlefsen in preparing this article.

Correspondence should be addressed to: Jun Peng, PhD, Library of the Second Military Medical University, No. 800 Xiangyin Rd, Shanghai 200433, China (pengjun@smmu.edu.cn).

doi: 10.3928/01477447-20130920-11

The quantity and quality of scientific literature are measurements of scientific achievement. The contents and quantity of scientific literature can be used to analyze the history and current status of science and technology and to forecast trends. Bibliometric techniques are a useful tool for appraising research output quality.¹ The purpose of the current study was to evaluate scientific productivity in orthopedics research using bibliometric methods to provide a general picture of orthopedic research for researchers and clinicians. The study used data from *Journal Citation Reports 2010*, published by the Institute for Scientific Information since 1975 and considered the most comprehensive citation index of scientific literature, with coverage of 8288 journals in 2011.² Citation analyses and the calculation of a journal's impact factor are frequently used to evaluate the achievement of scientists.

MATERIALS AND METHODS

A total of 61 orthopedics-related journals were selected from the orthopedics category of the Science Citation Index Expanded (SCIE) database.³ A computerized literature search was conducted using the SCIE database on February 20, 2012, and the orthopedics articles published from January 2000 to December 2011 in these journals were retrieved. The full journal titles of the 61 journals were used to perform searches in the SCIE database.

Three methods were used to evaluate the quality of the research articles. First, the impact factor was generated according to *Journal Citation Reports 2010*. Second, the distribution of articles by authors' country of origin and the total number of citations were analyzed. Third, the articles published in orthopedics journals with top-10 impact factors were also quantified.

Statistical analyses were performed using SAS version 9.1.3 statistical software (SAS Institute Inc, Cary, North Carolina).

The nonparametric test for trends was used to determine significant changes in the total number of articles over the study period. The Kruskal-Wallis test was used to determine the differences in the proportion of yearly world contributions to orthopedics by the United States, the United Kingdom, Germany, Japan, China, and South Korea, and the rank sum test was used to detect the difference in the growth rate between China and the world, if needed. The test for significance was 2-sided, and a *P* value less than .05 was considered significant.⁴

RESULTS

A total of 91,216 articles were published in the 61 orthopedics journals from 2000 to 2011. Table 1 shows the year-by-year output. The outputs in 2010 (10,276 articles) and 2011 (10,087 articles) were approximately twice that of 2000 (5161 articles), a growth rate of approximately 40%. In calculating the annual growth rate for each year, 2004 had the fastest growth (14.02%), followed by 2007 (11.39%) and 2006 (11.24%); 2001 had the lowest growth (1.88%), followed by 2009 (2.20%) and 2003 (2.70%).

Authors' Countries of Origin

The contributions of authors from different countries were plotted, with a focus on the top 10 countries according to publication count and those in Asia.

Table 1

Number of Articles Per Year and Growth Rate, 2000-2011

Year	No. of Articles	Growth Rate, %	No. of Journals
2000	5161		39
2001	5258	1.88	42
2002	5750	9.36	42
2003	5905	2.70	41
2004	6733	14.02	42
2005	6977	3.62	41
2006	7761	11.24	43
2007	8645	11.39	48
2008	9230	6.77	49
2009	9433	2.20	56
2010	10,276	8.94	61
2011	10,087	21.84	61

Table 2

Top 10 Countries According to Number of Articles Plus China, 2000-2011

Rank	No. of Articles	Country	World Share, %
1	36,222	United States	39.71
2	7745	United Kingdom	8.49
3	6979	Germany	7.65
4	5686	Japan	6.23
5	4352	Canada	4.77
6	3315	France	3.63
7	2732	Austria	3.00
8	2491	Switzerland	2.73
9	2457	Netherlands	2.69
10	2262	South Korea	2.48
12	1973	China	2.16

From a total of 91,216 articles, the United States ranked first in output (36,222; 39.71%), followed by the United Kingdom (7745; 8.49%), Germany (6979; 7.65%), and Japan (5686; 6.23%). Japan ranked 1st in Asia, followed by South Ko-

Table 3

Proportion of World Contribution to Orthopedics by Year, 2000-2011

Year	%					
	United States	United Kingdom	Germany	Japan	China	Korea
2000	43.64	8.89	7.25	6.14	0.64	0.95
2001	42.49	8.55	7.24	6.67	0.87	1.18
2002	44.14	8.38	7.58	6.59	0.63	1.04
2003	45.86	8.99	7.40	6.35	1.25	1.74
2004	44.44	8.79	7.55	7.25	1.04	1.38
2005	42.01	10.06	6.74	7.38	1.46	1.99
2006	41.98	8.81	6.83	6.70	1.51	1.95
2007	38.39	9.03	7.53	6.02	1.82	2.68
2008	36.96	7.99	8.18	5.71	2.25	2.98
2009	35.87	8.45	8.44	5.83	2.79	3.52
2010	35.47	7.40	8.20	5.64	3.41	3.34
2011	35.07	7.61	7.98	5.58	5.05	4.13

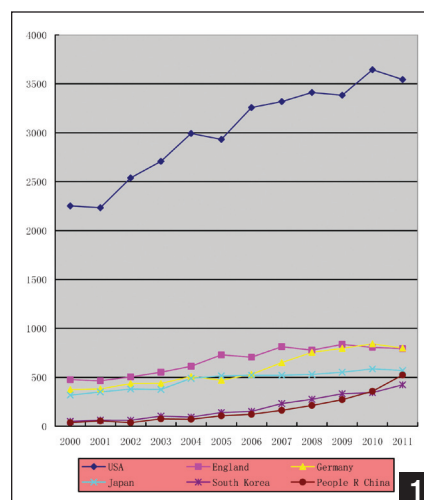


Figure 1: Line graph showing publication counts between 2000 and 2011.

rea, which ranked 10th in the world (2262; 2.48%). China ranked 12th in the world (1973; 2.16%) and 3rd in Asia (Table 2).

Although authors from the United States contributed the largest number of articles, the proportion of US articles showed a declining trend between 2000 (43.64%) and 2011 (35.07%). Before 2008, little difference existed between Germany and Japan; after 2008, Germany (8.18%) exceeded the United Kingdom (7.99%) and ranked 2nd in the world (Table 3; Figure 1).

China showed an improvement in orthopedics research, with articles published in international journals increasing significantly during the study period. In 2010, China (3.41%) overtook South Korea (3.34%) to become 2nd in Asia. In 2011, China (5.05%) narrowed its gap with Japan (5.58%) to rank 5th in the world (Tables 3 and 4; Figure 1).

Citation analysis for the retrieved articles (Table 5; Figure 2) indicated that US-authored articles were cited the highest number of times (396,797), followed by the United Kingdom (71,129), Germa-

ny (52,644), Japan (43,900), South Korea (13,863), and China (9225). Articles by US authors had the highest average per-article citation (10.96), followed by the United Kingdom (9.18), Japan (7.72), Germany (7.54), South Korea (6.13), and China (4.68) (Tables 2 and 5).

Most Prolific Authors

An author analysis was conducted for the retrieved articles to determine the top 100 authors according to publication counts. Researchers were ranked based on their number of articles and citations (Tables 6-8). Among the top 100 most prolific authors, 43 were American, 19 were Japanese, 6 were Korean, 5 were German, 4 were English, and 23 were from other countries. Table 7 shows that among the top 10 most published authors, 4 were American, 2 were English, 2 were Japanese, 1 was Canadian, and 1 was Korean. The number of publications for the top 10 authors ranged from 258 (1st place) to 185 (10th place). Table 8 shows the citation ranking of the top 10 authors, ranging from 4672 (1st) to 2261 (10th).

P.V. Giannoudis, from the United Kingdom, was the most prolific author, publishing 258 articles during the study period; Freddie Fu, from the United States, was the most-cited author (4672 citations). The top 5 prolific authors all had citations within the top 10, including P.V. Giannoudis (United Kingdom), J. Parvizi (United States), A.R. Vaccaro (United States), M. Bhandari (Canada), and L.G. Lenke (United States). Citation rates for authors not in the top 10 were not necessarily low. For example, the 112 articles by R. Ganz (Switzerland) ranked him in 35th place overall, but his articles ranked 3rd in total number of citations (n=4447). K.H. Bridwell (United States) ranked 16th (n=169) in number of articles and 4th (n=3728) in total number of citations.

Most Prolific Institutions

An analysis of academic institutions was conducted for the retrieved articles to determine the top 100 institutions according to publication counts. The institutions were ranked according to the numbers of articles and citations (Tables 9-11).

Among the top 100 most prolific institutions, 59 were in the United States, 5 in Germany, 5 in the United Kingdom,

Table 4

Top 10 Countries According to Number of Articles per Year, 2000-2011

Year	1	2	3	4	5	6	7	8	9	10
2000	US	UK	GER	JPN	CAN	FRA	SUI	SWE	AUS	NED
2001	US	UK	GER	JPN	CAN	FRA	SWE	AUS	SUI	NED
2002	US	UK	GER	JPN	CAN	FRA	SUI	AUS	NED	SWE
2003	US	UK	GER	JPN	CAN	FRA	AUS	SUI	NED	TUR
2004	US	UK	GER	JPN	CAN	FRA	AUS	SUI	TUR	NED
2005	US	UK	GER	JPN	CAN	FRA	AUS	NED	TUR	SUI
2006	US	UK	GER	JPN	CAN	FRA	SUI	SWE	AUS	NED
2007	US	UK	GER	JPN	CAN	FRA	AUS	NED	KOR	TUR
2008	US	GER	UK	JPN	CAN	FRA	TUR	KOR	NED	AUS
2009	US	UK	GER	JPN	CAN	FRA	KOR	TUR	NED	CHN
2010	US	GER	UK	JPN	CAN	FRA	NED	AUS	CHN	KOR
2011	US	GER	UK	JPN	CHN	CAN	KOR	AUS	FRA	SUI

Abbreviations: AUS, Australia; CAN, Canada; CHN, China; FRA, France; GER, Germany; JPN, Japan; KOR, South Korea; NED, the Netherlands; SUI, Switzerland; SWE, Sweden; TUR, Turkey; UK, United Kingdom; US, United States.

Table 5

Total Citations of Articles per Year, 2000-2011

Year	No. of Citations					
	United States	United Kingdom	Germany	Japan	Korea	China
2000	288	62	57	31	1	0
2001	2096	354	267	217	25	18
2002	5490	841	720	609	118	62
2003	10,034	1547	1348	1109	221	136
2004	16,518	2563	2111	1774	406	221
2005	24,129	3761	2984	2577	563	350
2006	33,062	5433	4110	3518	858	500
2007	42,243	7222	5522	4767	1288	710
2008	51,662	9186	6778	5929	1727	1176
2009	61,534	11,251	8147	6833	2275	1425
2010	73,000	13,588	9945	7952	2823	1998
2011	76,741	15,321	10,655	8584	3558	2629
Total	396,797	71,129	52,644	43,900	13,863	9225

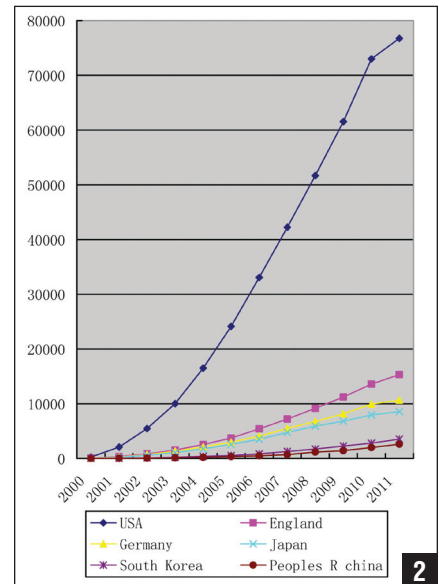


Figure 2: Line graph showing numbers of citations between 2000 and 2011.

4 in Japan, 2 in South Korea, and 1 in China (Table 9). Table 10 shows that the 10 most prolific institutions were all in the United States. The number of publications by the top 10 institutions ranged

from 1258 (1st place) to 640 (10th place). Table 11 shows the rankings of the top 10 institutions according to their total citations, which ranged from 17,752 to 9107. The Hospital for Special Surgery (United

States) was the most prolific institutional source of orthopedic articles, with 1258 articles about orthopedics, whereas the University of Pittsburgh ranked first in total number of citations (n=17,752). Total number of citations for the top 5 most prolific institutions—the Hospital

Table 6

Country Distribution of Top Authors According to Number of Articles, 2000-2011

Rank	No. of Authors	Country
1	43	US
2	19	Japan
3	6	South Korea
4	5	Germany
5	4	UK
	0	China

Abbreviations: UK, United Kingdom; US, United States.

for Special Surgery, Harvard University, the Mayo Clinic, Washington University (St Louis), and the University of Pittsburgh—were all in the top 10.

However, the total citations for institutions outside of the top 10 were not necessarily low. For example, the University of Bern (Switzerland) ranked 25th in number of articles (n=453) and 8th in total number of citations (n=9737).

Journal Distribution: Most Popular Orthopedic Journals

A source publication analysis was conducted for the retrieved articles to determine the top 10 most popular journals according to publication counts (Table 12). *Spine* ranked the first in number of articles (n=7902; impact factor, 2.51), *Clinical Orthopedics and Related Research* ranked second (n=6243; impact factor, 2.116), and the *Journal of Bone and Joint Surgery, British Volume* ranked third (n=5662; impact factor, 2.967).

High-impact Orthopedic Journals

The 61 journals were ranked according to their impact factor, and the number of articles published in the top 10 journals was analyzed according to the authors' country of origin (Table 13). *Osteoarthritis and Cartilage* had the highest impact factor (3.953), the *American Journal of Sports Medicine* ranked 2nd (3.821), and *Arthroscopy* ranked 3rd (3.317). As shown in Table 13, authors from the United States published the most articles (n=15,835) in the journals with a top 10 impact factor, followed by

Table 7

Top 10 Authors According to Number of Articles, 2000-2011

Rank	Author	No. of Articles	No. of Citations	H-index	Average Citations per Article	Country
1	Giannoudis	258	2817	27	10.92	UK
2	Parvizi	237	3538	30	14.93	US
3	Vaccaro	234	2812	29	12.02	US
4	Bhandari	227	2672	27	11.77	Canada
5	Lenke	208	4492	37	21.60	US
6	Lee	205	1192	18	5.81	South Korea
7	Fu	202	4672	37	23.13	US
8	Nakamura	191	1365	20	7.15	Japan
9	Yoshikawa	191	2009	24	10.52	Japan
10	Maffulli	185	2128	24	11.50	UK

Abbreviations: UK, United Kingdom; US, United States.

Table 8

Top 10 Authors According to Number of Citations, 2000-2011

Rank	Author	No. of Articles	No. of Citations	H-index	Average Citations per Article	Country
1	Fu	202	4672	37	23.13	US
2	Lenke	208	4492	37	21.60	US
3	Ganz	112	4447	31	39.71	Switzerland
4	Bridwell	169	3728	33	22.06	US
5	Parvizi	237	3538	30	14.93	US
6	Giannoudis	258	2817	27	10.92	UK
7	Vaccaro	234	2812	29	12.02	US
8	Bhandari	227	2672	27	11.77	Canada
9	Warren	134	2382	28	17.78	US
10	Berry	105	2261	28	21.53	US

Abbreviations: UK, United Kingdom; US, United States.

those from Japan (n=1928) and the United Kingdom (n=1359).

those from Japan (n=1928) and the United Kingdom (n=1359).

DISCUSSION

According to classical bibliometric theory, an increase or decrease in the publication of scientific literature indicates the speed of progress of science

Table 9

Country Distribution of Top Affiliations According to Number of Articles, 2000-2011

Rank	No. of Affiliations	Country
1	59	United States
2	5	Germany
3	5	United Kingdom
4	4	Japan
5	2	South Korea
6	1	China

and technology, and the period needed for the doubling of scientific literature can be used to measure scientific development. An acute change in the number of published articles likely reflects a turning point in the development of the science.⁵ The current study found that the number of orthopedics articles published dramatically increased between 2000 and 2011, when the number doubled, indicating an important turning point for the rapid development of orthopedics and the achievements that have been made. Another reason for the increase is the increase of orthopedics journals found in the SCIE database.

The geographic and language distributions of scientific literature can mirror the research capabilities and technological developments of different countries.⁵ This study found that the top 10 countries' authors published 81.39% of the total orthopedics articles, indicating that the worldwide research efforts in orthopedics were actually concentrated, with the United States publishing the most articles and making the greatest contribution, followed by the United Kingdom and Germany.

The contribution rankings of countries underwent variation in the past decade, but the variation was mild. The United States still ranked first but showed

Table 10

Top 10 Institutions According to Number of Articles, 2000-2011

Rank	Institution	No. of Articles	No. of Citations	H-index	Average Citations per Article	Country
1	Hospital for Special Surgery	1258	15,312	52	12.17	US
2	Harvard U	1134	17,198	56	15.17	US
3	Mayo Clinic	1100	9874	40	8.99	US
4	Washington U	1097	14,882	50	13.57	US
5	U of Pittsburgh	1065	17,752	62	16.67	US
6	U of Toronto	763	11,587	53	15.19	US
7	U of Washington	742	11,243	49	15.15	US
8	Massachusetts General Hospital	688	9176	42	13.34	US
9	U of California San Francisco	686	9094	45	13.26	US
10	U of Pennsylvania	640	7665	41	11.98	US

Abbreviations: U, University; US, United States.

a declining trend year by year, a trend that was also true for other traditionally strong countries, such as the United Kingdom and Japan. However, Germany, Korea, and China showed an increase in orthopedics publishing. In 2011, China ranked 5th in the world, with the proportion increasing from 0.64% in 2000 to 5.05% in 2011.

Researchers believe that the total citation rate for an article can reflect the quality and value of the research it reports. Citation analysis can thus be used to evaluate and compare the academic position of different countries and research institutions.⁵ An investigation of the citation rates for the orthopedic articles under analysis showed that the United States ranked first in terms of total citations and average citations per article. Although the number of articles published by Japanese authors was lower than those published by German authors, their total citations and average citations per article were both higher than those of German authors, indicating a stronger influence for Japanese articles. China also

witnessed a rapid increase in the number of published orthopedics articles, but its total citations and average citations per article were small.

An analysis of prolific authors in orthopedics showed that the United States and Japan had the most prolific authors because these 2 countries had the most-cited orthopedics researchers. Analysis of the top research institutions found that the United States had the greatest number of top research institutions for orthopedics, demonstrating that the United States is currently the strongest power in orthopedics research. If the impact factor is the most important quality indicator for scientific journals, then US authors published the most articles in the top 10 orthopedics journals.

The results of the analyses of number of articles, citation status, top researchers, and top institutions all showed that the United States is the strongest country in orthopedics research, and the United Kingdom, Germany, and Japan were always within the world's top 4 in terms of number of articles and citation status. Chi-

na has shown a rapid increase and is now ranked fifth in terms of number of articles. However, China is lagging behind in terms of citations per article, top research institutions, and most prolific authors.

Current changes in Chinese orthopedic research are due to several factors. First, the number of research institutions has grown and clinical orthopedic practice and research capabilities have improved with recent advances in China's economy. Chinese orthopedic researchers now have more chances to communicate with their international partners.⁶ Second, the Chinese government and various academic and research institutions now regard the number of articles indexed in the SCIE database as an important indicator of the research ability and achievements of a researcher or an institution, and these evaluation outcomes are now typically related to an author's technical title, salary, bonus, and other important benefits, which stimulates an interest in research. However, these changes seem to have resulted only in an increase in number of articles and not in their quality, as indicated by the current citation rates for Chinese-authored articles.

One of the limitations of this study is that only the 61 orthopedics journals covered by the SCIE database were analyzed; some orthopedics articles are also published in multispecialty medical journals.

CONCLUSION

This bibliometric analysis showed that orthopedics research witnessed rapid development between 2000 and 2011. The United States is the strongest country in terms of orthopedic research: US authors published the greatest number of orthopedics articles, and those articles have the highest total number of citations and average citations per article. Moreover, the United States has the most prolific authors and the most top research institutions. Japan is the strongest country in Asia in terms of published orthopedic research. China demonstrates rapid prog-

Table 11

Ranking of Top 10 Institutions According to Citation, 2000-2011						
Rank	Institution	No. of Articles	No. of Citations	H-index	Average Citations per Article	Country
1	U of Pittsburgh	1065	17,752	62	16.67	US
2	Harvard U	1134	17,198	56	15.17	US
3	Hospital for Special Surgery	1258	15,312	52	12.17	US
4	Washington U	1097	14,882	50	13.57	US
5	U of Toronto	763	11,587	53	15.19	US
6	U of Washington	742	11243	49	15.15	US
7	Mayo Clinic	1100	9874	40	8.98	US
8	U of Bern	453	9737	47	21.49	SUI
9	Massachusetts General Hospital	688	9176	42	13.34	US
10	U of Texas	482	9107	44	18.89	US

Abbreviations: SUI, Switzerland; U, University; US, United States.

Table 12

Top 10 Journals According to Number of Articles, 2000-2011			
Rank	Journal	IF	No. of Articles
1	<i>Spine</i>	2.51	7902
2	<i>Clinical Orthopedics and Related Research</i>	2.116	6243
3	<i>Journal of Bone and Joint Surgery, American Volume</i>	2.967	5662
4	<i>Journal of Bone and Joint Surgery, British Volume</i>	2.351	3928
5	<i>Injury: International Journal of the Care of the Injured</i>	2.269	3388
6	<i>American Journal of Sports Medicine</i>	3.821	3032
7	<i>Journal of Hand Surgery, American Volume</i>	1.439	3001
8	<i>Journal of Arthroplasty</i>	2.207	2996
9	<i>Orthopedics</i>	1.098	2913
10	<i>Osteoarthritis and Cartilage</i>	3.953	2906

Abbreviation: IF, impact factor.

ress in orthopedic research thanks to its rapid economic development and growth in research funding.

The purpose of this study was to evaluate the scientific productivity of orthopedics research by bibliometric methods. Among the benefits of this study is the potential for the professional orthopedics community to

discover a new perspective on their own discipline and its subfields. The authors' work in this area is ongoing. ■

REFERENCES

1. Middleton A. An attempt to quantify the quality of student bibliographies. *Perform Meas Metr.* 2005; 6(1):7-18.

Table 13

Top 10 Journals According to Impact Factor and Number of Articles, 2000-2011

Rank	Journal	IF	No. of Articles					
			US	UK	Germany	Japan	South Korea	China
1	<i>Osteoarthritis and Cartilage</i>	3.953	1183	332	243	212	37	49
2	<i>American Journal of Sports Medicine</i>	3.821	1599	108	190	172	97	23
3	<i>Arthroscopy</i>	3.317	1264	94	168	212	175	73
4	<i>Spine</i>	3.024	489	16	14	28	34	29
5	<i>Journal of Orthopedic Research</i>	2.976	1345	103	208	258	42	91
6	<i>Journal of Bone and Joint Surgery American</i>	2.967	3716	244	129	168	126	40
7	<i>Physical Therapy</i>	2.645	1031	45	22	9	3	13
8	<i>Journal of the American Academy of Orthopedic Surgery</i>	2.547	604	6	2	3	0	0
9	<i>Journal of Orthopedics and Sports Physical Therapy</i>	2.538	890	31	13	14	3	10
10	<i>Spine</i>	2.51	3714	380	319	852	284	352
Total			15,835	1359	1308	1928	801	680

Abbreviations: IF, impact factor; UK, United Kingdom; US, United States.

- Journal Citation Reports 2010. Institute for Scientific Information Web site. <http://isiknowledge.com>. Accessed February 20, 2012.
- Orthopedics journals. Journal Citation Reports 2010. Institute for Scientific Information Web site. <http://www.isinet.com/cgi-bin/jrnlst/jlsubcatg.cgi?PC=D>. Accessed February 20, 2012.
- May WL, Johnson WD. A SAS macro for the multivariate extension of the Kruskal-Wallis test including multiple comparisons: randomization and 2 criteria. *Comput Stat Data Anal.* 1997; 26(2):239-250.
- Qiu JP. Informetrics: application of informetrics in science of science and management of science and technology. *Inf Stud Theory Appl.* 2001; 24(6):474-478.
- 30th Anniversary of the Chinese Orthopedic Association (COA). Chinese Orthopedic Association Web site. <http://www.orthonline.com.cn/html/folder/2208222-1.htm>. Accessed February 20, 2012.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.