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A Bibliometric Analysis on Top-Cited Articles in Pain Research

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Abstract

Objective. The field of pain-related research has gained more attention as the prevalence of chronic pain increased over the years. The objective of this research was to identify highly cited papers, as well as contributors, to pain-related research.

Design. Pain-related articles published from 1900 to 2011 were screened, and highly cited papers, with at least 100 citations since publication, were identified and selected for a bibliometric analysis. The total number of papers, authorship, and collaboration statistics are presented for countries, institutions, and authors. To assess contributions, a new indicator, the major contributor index (*MCI*), was used. Citation trends for all papers, as well as for top papers, are presented.

Results. A total of 7,327 articles, 2.4% of all pain-related articles, had received at least 100 citations since publication. In recent decades, top-cited articles have reached a citation peak more quickly, and have shown a more-rapid decreasing trend, compared with top-cited articles from earlier decades. The leading countries were United States, UK, Canada, and Germany. The leading institutions were Harvard University, University of California, San Francisco, University of Texas, and University of Washington. *MCI* varied among leading institutions, as well as among individual authors.

Conclusions. An indicator like the *MCI* can provide a proxy for the contributions made by an individual or institution. It reflects the independent research ability and leadership. In future evaluations of institution or individual performances, the *MCI* should be included, together with the number of total papers, to provide a better profile of research performance.

Key Words. Scientometrics; Web of Science; Pain Research; Article Life; Highly Cited; Major Contribution Index

Introduction

The field of pain-related research has gained greater attention as the prevalence of chronic pain has increased over the years [1,2]. Research showed that 6,360 papers were published on pain in three Thomson Scientific databases: *Current Contents—Clinical Medicine*, *Life Sciences*, and *Social and Behavioral Sciences*, in 2006 alone [3]. Several recently published articles focused on the bibliometric characteristics of pain-related research. Some focused on a specific syndrome, such as neonatal pain [4], headaches [5], and orofacial pain [6]. Some focused on a specific journal including *Pain* [7,8] and *Clinical Journal of Pain* [9]. Some articles even focused on pain research in certain countries [3,10]. In general, previous bibliometric research on pain-related articles made significant contributions to the field of bibliometric analyses, but tended to limit its study sample to either a year of publication, a journal of publication, or a country.

As the amount of scientific literature on pain is rapidly accumulating, top-cited articles are of particular importance, as a high citation count is an indication of a high impact or visibility in the research community [11]. A paper of higher quality is more likely to be found in the most-cited quintile than in the least cited [12]. Analysis of top-cited articles citation rates reveals useful and interesting information about scientific progress in a research field [13]. Top-cited articles can provide insights into how research fields have evolved over time, and identify those researchers who have had high impacts in a research field. Although the citation rate is not a direct measure of the impact or importance of a particular scholarly work, it does provide a marker of its recognition within the scientific community [14]. Frequently, the best manuscript can be considered the one most cited in peer-reviewed journals [15]. The analysis of citation characteristics has been accepted as a popular method for measuring the impact of an article [16], a researcher [17], a country [18], and a year [19]. A number of studies investigated top-cited articles in the *Journal Citation Reports* (JCR), particularly in medicine, such as in anesthesia [20], surgery [21], Parkinson's disease [22], depression [23], ophthalmology [24], urology [25], obstetrics and gynecology [26], rehabilitation [14], orthopedics [27], and dentistry, oral surgery, and medicine [13].

In this research, pain-related articles published from 1900 to 2011 were screened, and highly cited papers were identified and selected for a bibliometric analysis. To assess the extent of contribution, a new indicator, the major contributor index (*MCI*), was used, and its implications are discussed.

Methodology

Data used in this study were retrieved from the Thomson Reuters Web of Science, the online version of the Science Citation Index Expanded (SCI-Expanded) on February 15, 2013. To identify pain-related research, documents with at least one of the following keywords in the title, abstract, author keywords, or *KeyWords Plus* were downloaded: allodyn*, analg*, arthralg*, brachialg*, causalg*, cephalalg*, cervicodyn*, colic, eudyn*, fibromyalg*, headache, hyperalg*, hypoalg*, maldyn*, migraine, neuralg*, nocicept*, odontalg*, ophthalmodyn*, vulvodyn*, otalg*, pain, painful, painkiller, painless, radiculalg*, and toothache, where an asterisk replaces any string of characters [28]. This search yielded 416,759 documents in 24 document types, published from 1900 to 2011. Non-article-type documents were excluded. In this research, only top-cited articles were selected for further analysis. The number of citations of an article in a single year, for example, 2011, is referred to as the *C2011* [29], and the total number of citations since publication to 2011 is referred to as the *TC2011* [30,31]. The advantage of this indicator was that it was a invariable parameter to ensure repeatability to provide more scientific and accurate information, in comparison with the index of citation from Web of Science which was updated as time goes on [32]. A top-cited article (*TC2011* ≥ 100) was defined as an article with at least 100 citations since its publication to 2011. In total, 7,327 articles, 2.4% of 311,619 pain-related articles, had received at least 100 citations since publication. The impact factor (IF) of a journal was based on the *JCR* 2011.

The collaboration type was determined by the addresses of the authors. An article could be either a single-country article, in which all authors' addresses were from the same country, or an international collaborative article, which was co-authored by researchers from multiple countries [33]. In the SCI-Expanded, the corresponding author is designated as the "reprint" author; this study uses as the term "corresponding author" [33]. In a single author article where authorship is unspecified, the single author is both first author and corresponding author [29]. Similarly, in a singly institutional article, the institution is classified as the first author institution and the corresponding author institution [34]. In addition, only the first affiliation of corresponding author was considered when the author had multiple affiliations. Due to changes in country names or institution names over the years, some countries or institutions were grouped together. The Federal Republic of Germany and Germany were grouped together as Germany [29]. The Czechoslovakia and Czech Republic were reclassified as Czech Republic [35]. The Yugoslavia and Croatia were reclassified as Croatia [35]. The USSR and Russia were also reclassified as Russia [29]. England, Scotland, Northern Ireland, and Wales were grouped together as the United Kingdom (UK) [33]. Articles from Hong Kong published before 1997 were included in the Chinese category [30]. Similarly, Mayo Clin & Mayo Fdn, Mayo Clinic and Mayo Foundation, Mayo Clin, Mayo Clin Jacksonville, Mayo Clin Scottsdale, Mayo Clin & Mayo Grad Sch Med, Mayo Grad Sch Med, Mayo Clin & Mayo Med Sch, Mayo Clin Arizona, and Mayo Fdn were reclassified as Mayo Clinic and Mayo Foundation. In terms of authorship, it is clear that equal credit was not given to all of the contributors. At the individual level, a non-alphabetical name order sends a clear signal to the market that the author who is listed first actually contributed more [36]. The first author is the person who contributed most to the work and writing of the article [37]. The corresponding author is perceived as the author contributing significantly to the article independent of the author position [38]. The corresponding author supervised the planning and execution of the study and the writing of the paper [39]. It is generally assumed that the first author and the corresponding author played significant roles, and they are the major contributors in producing a research paper. Thus, in this research, a newly developed indicator, the *MCI*, was used to assess the extent a researcher or an institution contributed to publishing an article. The *MCI* is calculated as the sum of first-author articles and corresponding articles divided by 2-times the total number of articles. It implies the percentage of instances one takes on the leadership role (first author or corresponding author) out of the total possible available opportunities. The equation is:

$$MCI = \frac{FP + RP}{2TP};$$

where FP is the number of first-author articles, RP is the number of corresponding-author articles, and TP is the number of total articles. When the $MCI = 0$, there is not a first- or corresponding-author article. When the $MCI = 1$, all articles are either first- or corresponding-author articles.

Results and Discussion

Among top-cited articles, "The treatment of persistent pain of organic origin in the lower part of the body by division of the anterolateral column of the spinal cord" [40] was the earliest top-cited article (*TC2011* = 176), published in 1912. The most recent top-cited articles were published in 2010, including "Inhibition of mutated, activated BRAF in metastatic melanoma" [41] with a *TC2011* of 344; "Sipuleucel-T immunotherapy for castration-resistant prostate cancer" [42] with a *TC2011* of 253; "Nilotinib versus imatinib for newly diagnosed chronic myeloid leukemia" [43] with a *TC2011* of 158; and "The American College of Rheumatology preliminary diagnostic criteria for fibromyalgia and measurement of symptom severity" [44] with a *TC2011* of 112. Three articles were published in *New England Journal of Medicine*, and one was published in *Arthritis Care & Research*.

Journals and Web of Science Categories

In total, 7,327 top-cited articles were published in 718 journals and are listed in 102 Web of Science categories in the science edition. About one third of all top-cited articles were published by 12 (1.7% of 718 journals) core journals. Another one third of articles were published by 46 (6.4%) journals. A further 660 (92%) journals published another one third of the articles. The leading 12 core journals which published at least 110 articles were *Pain* with 553 articles and an *IF* of 5.777, followed by *Spine* (275 articles; *IF* = 2.078), *New England Journal of Medicine* (236 articles; *IF* = 53.298), *Journal of Neuroscience* (205 articles; *IF* = 7.115), *Lancet* (186 articles; *IF* = 38.278), *Neurology* (159 articles; *IF* = 8.312), *JAMA-Journal of the American Medical Association* (152 articles; *IF* = 30.026), *Proceedings of the National Academy of Sciences of the United States of America* (151 articles; *IF* = 9.681), *Arthritis and Rheumatism* (138 articles; *IF* = 7.866), *Anesthesiology* (130 articles; *IF* = 5.359), *Journal of Pharmacology and Experimental Therapeutics* (121 articles; *IF* = 3.828), and *Circulation* (112 articles; *IF* = 14.739). As expected, top-cited articles were published in journals with high *IF*s, similar to previous studies [20,45]. The leading journals attracted top-cited publications, which in turn helped maintain the high *IF* for these journals [46]. Among the 718 journals, 56% (399) of all these journals were from the United States, followed by the UK with 183 journals (25%), and the Netherlands with 37 journals (5.2%). Ten of the top 12 productive journals were from the United States, while *Pain* and *Lancet* were from the Netherlands and the UK, respectively.

The leading Web of Science categories were neurosciences with 1,613 articles (22.0% of all top-cited articles), followed by clinical neurology with 1,592 (21.7%) articles, general and internal medicine with 955 (13.0%) articles, anesthesiology with 852 (11.6%) articles, surgery with 586 (8.00%) articles, orthopedics with 569 (7.77%) articles, and pharmacology and pharmacy with 481 (6.56%) articles.

Leading Articles

Table 1 shows the 14 articles with a *TC2011* of >2,000. Both citation numbers and rankings for the *TC2011* and *C2011* are displayed. The top article, "The medical outcomes (MOS) 36-item short-form health survey (SF-36) I. conceptual-framework and item selection" [47], was published by J.E. Ware, from New England Medical Center Hospitals, Massachusetts, and C.D. Sherbourne, from the RAND Corporation, California was published in 1992 and had a *TC2011* of 11,352. This article was the only one in pain-related research that had been cited more than 10,000 times. The 36-tem short-form health survey (SF-36) has been the most widely applied to clinical practice and research, health policy evaluations, and general population surveys since its publication. This indicates researchers' attention to the impact of pain research by the MOS SF-36 [48,49]. Out of these 14 articles, five (36%) were published before 1990, and nine (64%) were published after 1990. The first article cited more than 2,000 times was published in 1941, and the latest one was published in 1999. Journals in which these articles were published were *Pain* (*IF* = 5.777) with three articles, followed by *Nature* (*IF* = 36.280) and *New England Journal of Medicine* (*IF* = 53.298) with two articles, and one for each of *Science* (*IF* = 31.201), *JAMA* (*IF* = 30.026), *Journal of the National Cancer Institute* (*IF* = 13.757), *Arthritis and Rheumatism* (*IF* = 7.866), *Controlled Clinical Trials* (*IF* in 2006 = 4.025), *Journal of Pharmacology and Experimental Therapeutics* (*IF* = 3.828), and *Medical Care* (*IF* = 3.411). *Controlled Clinical Trials* became *Contemporary Clinical Trials* in 2005 (*IF* = 1.814).

Citation frequency curves of individual articles can exhibit one of the following patterns: 1) initially much praised articles, 2) basic recognized work, 3) scarcely reflected work, 4) well-received but later erroneous qualified work, and 5) general work [50]. Figures 1 and 2 show the citation pattern of 10 articles with at least 3,000 citations (*TC2011* ≥ 3,000). Two types of citing patterns can be observed including initially much praised articles and basic recognized work. Patterns showed a high impact after publication with sharply increased citations such as articles published in the 1990s, especially the article published by Ware and Sherbourne in 1992 [47]. Articles published by Jadad et al. in 1996 [51], Aaronson et al. in 1993 [52], and Wolfe et al. in 1990 [53] had a similar pattern. Another pattern, scarcely reflected work, had an impact for a long period of time such as articles published by Melzack and Wall in 1965 [54] and D'Amour and Smith in 1941 [55]. These articles showed no significant peak but a slow and steady rise.

Past research showed that, with increasing years, a paper has an increasing chance of being forgotten [56]. Moreover, as time passes, even "true classics" are gradually cited less often because their substance has been absorbed by the current knowledge, by a phenomenon called "obliteration by incorporation" [57]. Thus, the ranking of top-cited papers will fluctuate over time. Previous research found that since 1988, 94% of the 50 most

Table 1 Fourteen most frequently cited pain research articles (*TC2011* > 2,000)

Rank (*TC2011*)	Rank (*C2011*)	Top-cited Article Information	Journal	Year	IF	Reference
1 (11,352)	1 (1,009)	Ware and Sherbourne (1992), The MOS 36-Item short-form health survey (SF-36). I. Conceptual-framework and item selection.	Medical Care	1992	3.411	[47]
2 (4,098)	2 (557)	Jadad et al. (1996), Assessing the quality of reports of randomized clinical trials: Is blinding necessary?	Controlled Clinical Trials	1996	N/A	[51]
3 (3,875)	19 (178)	Melzack and Wall (1965), Pain mechanisms—A new theory.	Science	1965	31.201	[54]
4 (3,466)	4 (322)	Wolfe et al. (1990), The American college of rheumatology 1990 criteria for the classification of fibromyalgia—Report of the Multicenter Criteria Committee.	Arthritis and Rheumatism	1990	7.866	[53]
5 (3,301)	6 (298)	Caterina et al. (1997), The capsaicin receptor: A heat-activated ion channel in the pain pathway.	Nature	1997	36.28	[73]
6 (3,292)	3 (358)	Aaronson et al. (1993), The European organization for research and treatment of cancer QLQ-C30: A quality-of-life instrument for use in international clinical trials in oncology.	Journal of The National Cancer Institute	1993	13.757	[52]
7 (3,200)	11 (210)	Eisenberg et al. (1998), Trends in alternative medicine use in the United States, 1990–1997—Results of a follow-up national survey.	JAMA-Journal of the American Medical Association	1998	30.026	[74]
8 (3,146)	7 (260)	Pitt et al. (1999), The effect of spironolactone on morbidity and mortality in patients with severe heart failure.	New England Journal of Medicine	1999	53.298	[75]
9 (3,009)	31 (138)	Melzack (1975), McGill pain questionnaire: Major properties and scoring methods.	Pain	1975	5.777	[76]
10 (3,001)	298 (46)	D'amour and Smith (1941), A method for determining loss of pain sensation.	Journal of Pharmacology and Experimental Therapeutics	1941	3.828	[55]
11 (2,184)	28 (144)	Bennett and Xie (1988), A peripheral mononeuropathy in rat that produces disorders of pain sensation like those seen in man.	Pain	1988	5.777	[77]
12 (2,144)	20 (169)	Hargreaves et al. (1988), A new and sensitive method for measuring thermal nociception in cutaneous hyperalgesia.	Pain	1988	5.777	[78]
13 (2,123)	24 (155)	Munro et al. (1993), Molecular characterization of a peripheral receptor for cannabinoids.	Nature	1993	36.28	[79]
14 (2,098)	16 (190)	Brittberg et al. (1994), Treatment of deep cartilage defects in the knee with autologous chondrocyte transplantation.	New England Journal of Medicine	1994	53.298	[80]

C2011 = number of citations in 2011; IF = impact factor in 2011; MOS = medical outcomes; N/A = not available; *TC2011* = total number of citations at 2011 since its publication.
Controlled Clinical Trials was not listed in Web of Science after 2004.

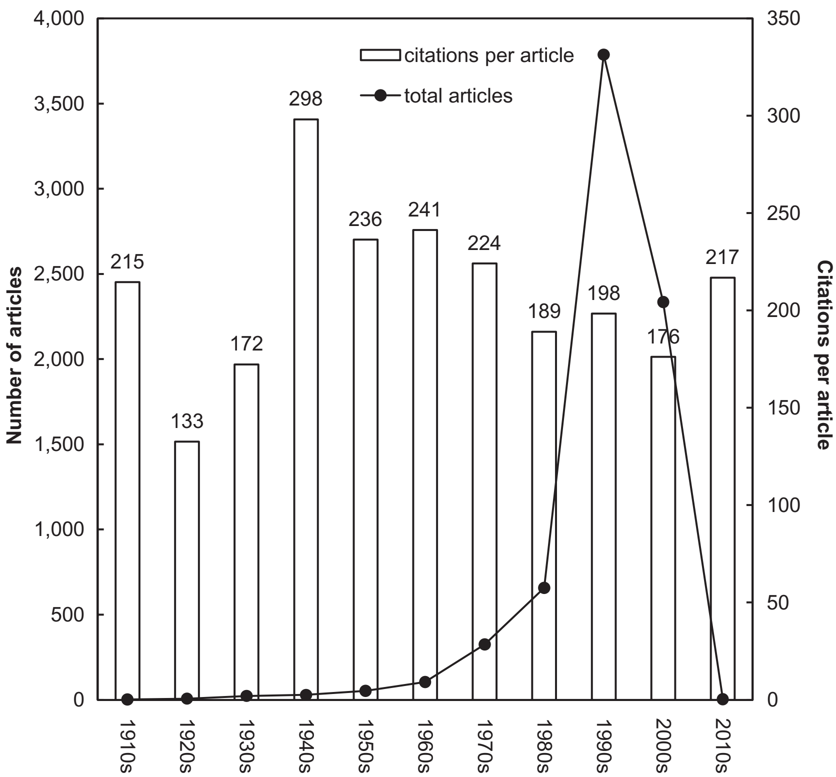

Figure 1 Number of top-cited article and citations per articles by decade of publication.

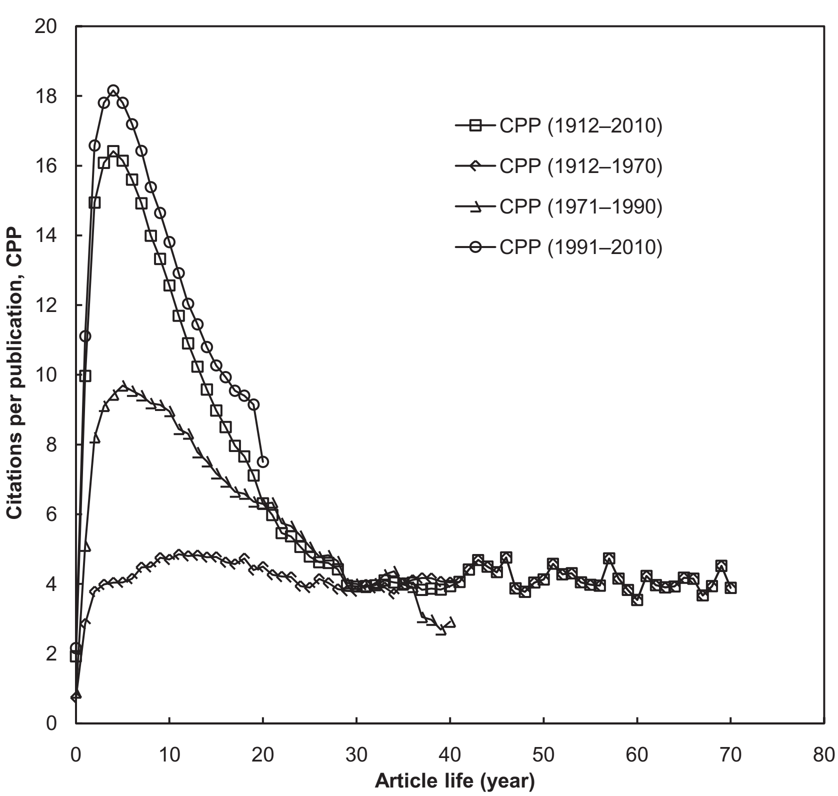

Figure 2 Variations of citations per article with article life.

frequently cited articles published in the *American Journal of Roentgenology* have changed rankings [58]. In general, among the top articles in Table 1, with the exception of the article "A method for determining loss of pain sensation" [55], by F.E. D'Amour and D.L. Smith published in 1941, all of the articles in Table 1 continued to receive high numbers of citations, as well as high rankings in 2011. Specifically, 7 of the 14 articles were still among the top 14 most-cited articles in 2011. However, for articles published before 1990, their rankings in 2011 were not as high as their all-time rankings, probably an indication of the "obliteration by incorporation" phenomenon.

Effect of Time on Citation Analysis

Figure 3 shows the number of articles and the average number of citations per article by decade. The 1990s had the most number of top-cited articles with 3,787, followed by the 2000s with 2,335. There was a significant peak in the number of top-cited articles in the 1990s. One speculation is that the recent significant growth in numbers of journals and papers has contributed to the increase in top-cited papers. It was found that 709,747 papers including 523,373 articles were published in 1991, 985,265 papers including 716,308 articles were published in 2001, and 1,536,602 papers including 1,119,792 articles were published in 2011 in SCI-Expanded. In addition, references cited in a paper were also found to have increased [59]. As more papers were being published, there were more opportunities to be cited, and hence, a greater likelihood to accumulate citations. Another reason could possibly be attributed to the lack of "abstract" section for most articles published before 1991 in the SCI-Expanded database. Hence, articles published before 1991 would have a less chance to be identified using the same keyword, as a keyword search would also include contents in the abstract.

Top-cited articles in the 2010s had higher citations per article than articles in the 1980s, 1990s, and 2000s, despite having a much shorter article life. One speculation is that recently popular open-access journals have changed the effect of time, or article life, on citations. It was reported that open-access articles in general receive more citations [60]. Changes in journal publishing practices have allowed articles to receive more citations within a shorter period of time. Another possible reason is that the increasing number of pain-related articles in recent years has also provided more citation opportunities.

The citation of an article usually follows a time course. The article lifespan demonstrates the influence of the article on scientific research. Forty-eight percent of all top-cited articles had no citations, 20% articles had one citation, and 9.3% articles had two citations during the year of publication. In recent year (2011), 5.0% of all top-cited articles had no citations, 5.4% articles had one citation, and 5.8% articles had two citations. Figure 4 shows the citation life of articles published in three time periods: 1912~1970, 1971~1990, and 1991~2010. Three distinctive patterns can be observed. Articles published in 1912~1970 had the lowest citations per publication (*CPP*). This increased sharply in the first 2 years and leveled off, but never showed a decreasing trend and

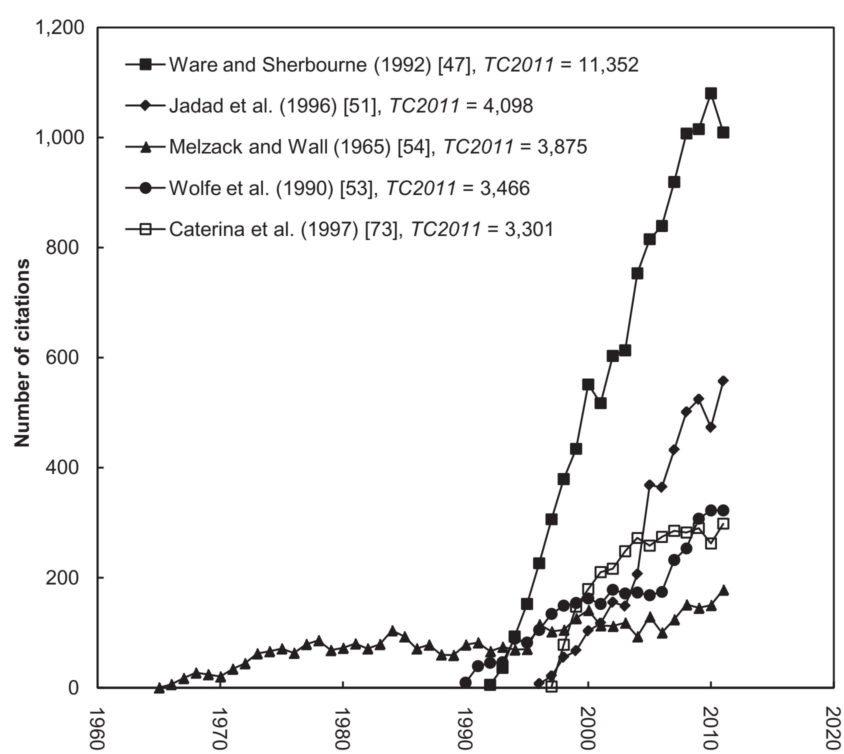

Figure 3 Annual citations of the top one to five articles (*TC2011* > 3,000).

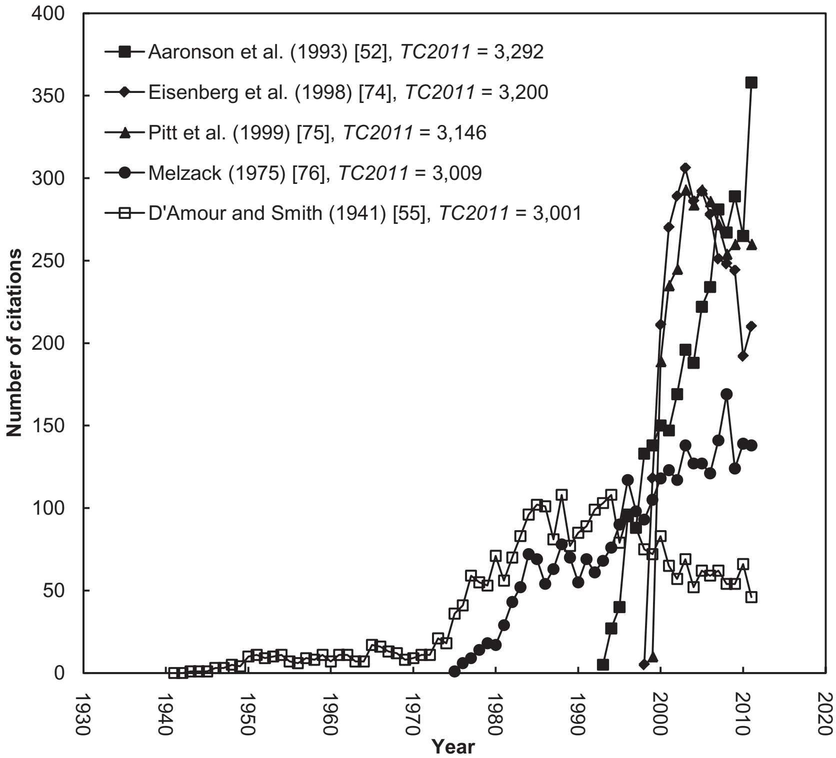

Figure 4 Annual citations of the top 6–10 articles (*TC2011* > 3,000).

remained constant. On the contrary, it showed a small increasing trend over the first 20 years. Values of the *CPP* for articles published in 1971~1990 also sharply increased over the first 2 years, reached a peak in the 5th year, and showed a slowly decreasing trend thereafter. Values of the *CPP* for articles published in 1991~2010 significantly increased over the first 2 years and reached a peak in the 4th year, but showed a rapidly decreasing trend thereafter. Overall, articles published in later years had a more-rapid rise in citation numbers, needed fewer years to reach a citation peak, but also decreased more rapidly after the citation peak. If such a trend continues, it is expected in the future that top-cited articles will show an even steeper rise in citation and reach the citation peak within a shorter time, but will also decline more rapidly. Nevertheless, the peak year of the *CPP* was found to be longer than other medical-related research disciplines where the peak could be in the 2nd year [33,61].

Publication Performances: Countries, Institutions, and Authors

The geographical distribution of top-cited articles is presented in Figure 5. North America and Western Europe were the main areas that produced top-cited pain research. Japan and Australia were showed high output. In general, Southeast Asia, the Middle East, Africa, and Eastern Europe were areas with low production. This result was consistent with other previous research [29]. In recent years, indicators of performance of first authors [62], both first and corresponding author [29], institutions [63], and countries [64] were reported to compare publication performances. The contributions provided by different countries were estimated by the affiliation of at least one author of top-cited articles. There were 262 articles without author address information on the Web of Science. Of all articles with author's addresses, 5,769 (82%) top-cited articles were single-country publications from 43 countries, and 1,296 (18%) articles were internationally collaborative publications from 68 countries. Table 2 shows the leading countries. The top 20 countries were ranked according to the number of total top-cited articles published with their affiliations. It includes five indicators such as numbers of total articles, single-country articles, internationally collaborative articles, first-author articles, and corresponding-author articles. Moreover, the percentage of single-country articles among total articles for each country (*S*%) is also presented. The United States tops the list with 4,154 articles, followed by the United Kingom, Canada, and Germany. The G7 countries (the United States, UK, Canada, Germany, France, Italy, and Japan) had high productivity in top-cited articles, which included 6,053 (86% of 7,065 top-cited articles with affiliations). Domination in publication is not surprising from mainstream countries, as this pattern has occurred in many medical-related topics, for example patent ductus arteriosus [65], asthma in children [66], stem cells [67], *Helicobacter pylori* [68], and human papillomavirus [69]. Furthermore, previous studies on "citation classics" in obstetrics and high-impact anesthetic journals showed similar results [20,26]. In terms of independent research, the United States again tops the list, with 79% of its articles being single-country articles, followed by Japan (72%), Denmark (64%), and the UK (60%). High

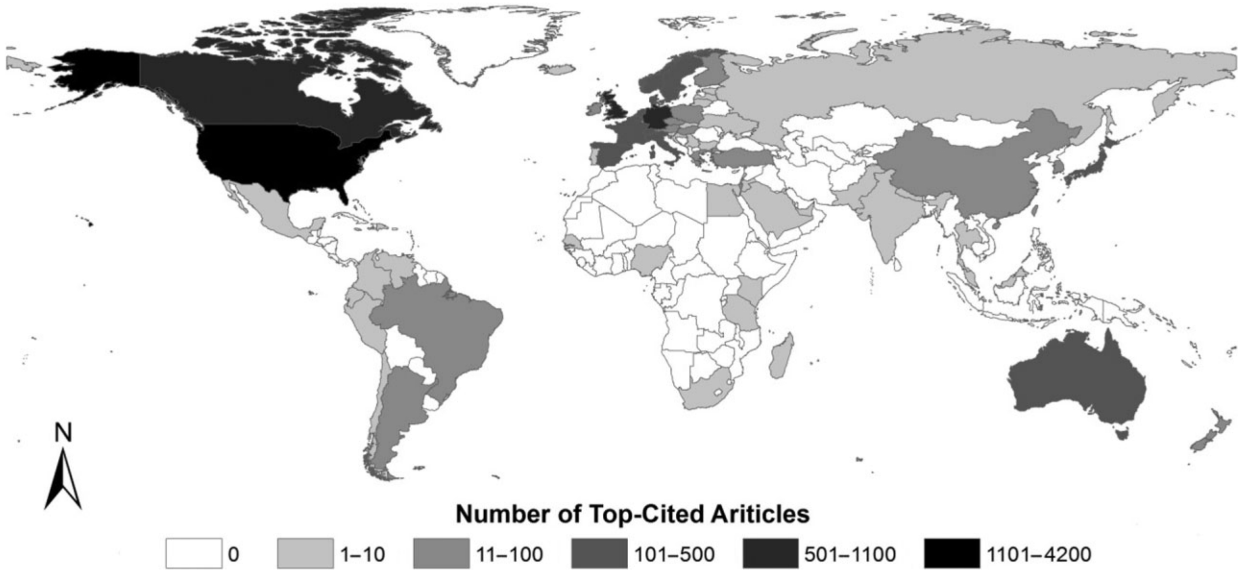

Figure 5 Distribution of top-cited articles in the world.

independent research by the United States, Japan, and the UK was also found in top-cited articles in environmental sciences [70] and chemical engineering [29]. Similarly the United States, Japan, and the UK had high independent publications in medical-related research, for example, Parkinson's disease [71], stem cells [67], *H. pylori* [68], and human papillomavirus [69].

In order to analyze institutions and author publications, the *MCI* was firstly applied. Only 6,121 top-cited articles had affiliation information on both first- and corresponding-author, and only 5,712 top-cited articles with names of both first- and corresponding-author in the Web of Science were further analyzed in subsequent analysis. In total, 5,038 institutions had published a top-

Table 2 Top 20 countries with top-cited articles

Country	*TP*	*TPR* (%)	*SPR* (%)	*CPR* (%)	*FPR* (%)	*RPR* (%)	*S*%
USA	4,154	1 (59)	1 (57)	1 (66)	1 (53)	1 (52)	79
UK	1,030	2 (15)	2 (11)	2 (32)	2 (11)	2 (11)	60
Canada	581	3 (8.2)	3 (4.7)	3 (24)	3 (5.5)	3 (5.4)	47
Germany	507	4 (7.2)	4 (3.8)	4 (22)	4 (4.7)	4 (5.0)	43
France	381	5 (5.4)	5 (3.3)	5 (15)	5 (3.5)	5 (3.5)	51
Sweden	307	6 (4.3)	6 (2.8)	8 (11)	6 (3.0)	6 (3.0)	53
Italy	298	7 (4.2)	9 (2.0)	6 (14)	7 (2.3)	7 (2.4)	38
Netherlands	257	8 (3.6)	11 (1.9)	7 (12)	9 (2.2)	9 (2.3)	42
Australia	226	9 (3.2)	8 (2.1)	10 (8.0)	8 (2.2)	8 (2.3)	54
Denmark	206	10 (2.9)	7 (2.2)	12 (5.9)	10 (2.1)	10 (2.1)	63
Switzerland	192	11 (2.7)	12 (1.0)	9 (10)	12 (1.5)	12 (1.5)	31
Belgium	160	12 (2.3)	13 (1.0)	10 (8)	13 (1.1)	13 (1.1)	35
Japan	155	13 (2.2)	10 (1.9)	17 (3.3)	11 (1.8)	11 (1.9)	72
Spain	104	14 (1.5)	16 (0.59)	13 (5.4)	17 (0.64)	17 (0.69)	33
Norway	103	15 (1.5)	15 (0.88)	15 (4.0)	14 (0.91)	14 (1.0)	50
Finland	100	16 (1.4)	14 (0.92)	16 (3.6)	15 (0.89)	15 (0.93)	53
Israel	93	17 (1.3)	16 (0.59)	14 (4.6)	16 (0.75)	16 (0.75)	37
Austria	57	18 (0.81)	19 (0.31)	18 (3.0)	18 (0.37)	18 (0.38)	32
Brazil	38	19 (0.54)	21 (0.23)	19 (1.9)	20 (0.28)	20 (0.29)	34
China	37	20 (0.52)	18 (0.33)	22 (1.4)	19 (0.33)	19 (0.31)	51

TP = total number of articles.
TPR (%), *SPR* (%), *CPR* (%), *FPR* (%), and *RPR* (%), the rank and percentage of total articles, single-country articles, internationally collaborative articles, first-author articles, and corresponding-author articles among total articles, respectively; *S*%, the percentage of single-country articles among total articles for a country.

Table 3 Institutions with at least 60 top-cited articles

Institution	*TP*	*FP*	*RP*	*MCI*
Harvard University, USA	235	82	82	0.349
University of California, San Francisco, USA	206	114	113	0.551
University of Texas, USA	176	81	84	0.469
University of Washington, USA	176	90	88	0.506
University of California, Los Angeles, USA	150	67	65	0.440
Mayo Clinic and Mayo Foundation, USA	128	82	80	0.633
Johns Hopkins University, USA	124	43	41	0.339
Stanford University, USA	112	42	43	0.379
University of Pittsburgh, USA	108	52	51	0.477
University of Toronto, Canada	107	31	28	0.276
Duke University, USA	99	46	46	0.465
University of California, San Diego, USA	97	53	53	0.546
Massachusetts General Hospital, USA	96	41	40	0.422
University of Michigan, USA	90	45	45	0.500
University of Minnesota, USA	84	48	45	0.554
McGill University, Canada	84	36	35	0.423
Yale University, USA	81	49	49	0.605
Brigham and Women's Hospital, USA	78	33	32	0.417
University of North Carolina, USA	77	32	32	0.416
Washington University, USA	71	41	41	0.577
University College London, UK	68	33	31	0.471
Virginia Commonwealth University, USA	64	42	42	0.656
Boston University, USA	64	32	32	0.500
Veterans Administration Medical Center, USA	63	22	22	0.349
Northwestern University, USA	60	19	20	0.325
University of Pennsylvania, USA	60	25	25	0.417
University of Iowa, USA	60	41	41	0.683
University of Copenhagen, Denmark	60	45	44	0.742

FP = number of first-author top-cited articles; *MCI* = major contributor index; *RP* = number of corresponding-author top-cited articles; *TP* = total number of top-cited articles.

cited article, with 3,451 (68%) institutions publishing only one articles, 641 (13%) institutions publishing two articles, 214 (4.2%) institutions publishing three articles, 163 (3.2%) institutions publishing four articles, and 569 (11%) institutions publishing at least five articles. A small proportion of institutions accounted for a high proportion of top-cited articles, similar to previous findings in dermatologic research [17]. Table 3 shows the 28 institutions had published at least 60 articles. Harvard, with 235 articles, toped this list. Its output quantity was slightly below the Netherlands, but more than Australia. Table 3 also displays the *MCI* score for each institution. Among the 10 institutions with the highest *TP*, Mayo Clinic and Mayo Foundation (*MCI* = 0.633), University of California at San Francisco (*MCI* = 0.551), and University of Washington (*MCI* = 0.506) had high *MCI* scores of >0.500. Institutions with an *MCI* of <0.400 were the University of Toronto (*MCI* = 0.276), Johns Hopkins University (*MCI* = 0.339), Harvard University (*MCI* = 0.349), and Stanford University (*MCI* = 0.379). Among all 29 institutions, the University of Copenhagen of Denmark topped the list with an *MCI* of 0.742, while having a *TP* of 60. Table 4 shows the *TP*, *FP*, *RP*, and *MCI* of leading authors with at least 15 top-cited articles. R.B. Lipton, with 40 articles, was the leader, followed by J. Olesen (39) and W.F. Stewart (37). Those authors in Table 4 showed a wide range of variation in the

Table 4 Authors with at least 15 top-cited articles

Author	*TP*	*FP*	*RP*	*MCI*
R.B. Lipton	40	13	14	0.338
J. Olesen	39	9	9	0.231
W.F. Stewart	37	11	13	0.324
R.A. Deyo	33	15	15	0.455
C.J. Woolf	33	13	18	0.470
F. Wolfe	29	16	16	0.552
T.L. Yaksh	28	8	9	0.304
D.D. Price	28	10	11	0.375
S.F. Maier	27	5	5	0.185
F. Porreca	27	3	12	0.278
A.I. Basbaum	23	3	5	0.174
P.J. Goadsby	23	5	17	0.478
L.R. Watkins	23	7	12	0.413
D. Julius	20	0	14	0.350
R.H. Gracely	20	7	5	0.300
J.D. Levine	19	6	11	0.447
T.S. Jensen	19	3	4	0.184
H.L. Fields	19	3	3	0.158
J. Lai	19	1	1	0.053
R. Melzack	18	8	8	0.444
J.N. Wood	18	2	9	0.306
G.F. Gebhart	18	2	4	0.167
R. Dubner	18	0	0	0
M. Dougados	17	5	7	0.353
L.M. Bouter	17	0	0	0
C. Bombardier	17	2	2	0.118
S.B. Mcmahon	17	3	7	0.294
E.A. Mayer	17	2	6	0.235
D.T. Felson	16	7	8	0.469
A.H. Dickenson	16	7	7	0.438
D.C. Turk	15	6	6	0.400
I.J. Russell	15	5	4	0.300
H. Flor	15	7	10	0.567
R.K. Portenoy	15	7	8	0.500
M.B. Max	15	6	6	0.400
M.H. Ossipov	15	4	1	0.167
T.P. Malan	15	4	6	0.333

FP = number of first-author top-cited articles; *MCI* = major contributor index; *RP* = number of corresponding-author top-cited articles; *TP* = total number of top-cited articles.

MCI, from 0.567 to 0. The author with the highest *MCI* was H. Flor (*MCI* = 0.567, *TP* = 15), followed by F. Wolfe (*MCI* = 0.552, *TP* = 29), and R.K. Portenoy (*MCI* = 0.500, *TP* = 15). No other author had an *MCI* of >0.500. A high *MCI* has two implications. First, it probably indicates a higher capability or productivity in conducting independent research. Second, it could, as well, indicate a more-prominent role in collaborations. On the contrary, a low *MCI* is probably a sign of heavy reliance on collaboration, as well as relying on others to provide a leadership role in conducting research. While the authors and institutions listed in Tables 3 and 4 were all leaders in publishing top-cited articles, they did significantly differ, in their contributions, as well as in the mechanism through which they produced top-cited articles. In future evaluative research, the *MCI* can be used, along with other indicators, to provide a better profile of an individual or an institution in their roles in collaborations, as well as the extent of contribution.

Conclusions

Bibliometric research on top-cited articles in pain-related research has revealed some interesting findings. It shows that the citation life and citation pattern have changed over time for top-cited articles. In recent decades, top-cited articles have reached a citation peak more quickly and have shown a more-rapid decreasing trend, compared with top-cited articles from earlier decades. Articles from earlier decades tended to show a slowly increasing pattern after publication, and a longer time to reach a citation peak, but then leveled off instead to show a definitive downward trend after the peak. Article life would seem to be compressed or shortened as the dissemination of information has adopted an electronic form, and information has become readily retrievable through the internet. This research also provides some evidence that as information is being produced and disseminated at a quicker rate, the so-called "classic" article that continues to receive a high number of citations for a long period of time will likely become a rare commodity in the future.

The use of the *MCI* can provide another important perspective in evaluating research performance. While the number of total papers has been extensively used in evaluating institutions or individuals, it can also be influenced by the extent of collaboration network of an institute or researcher. An indicator like the *MCI* can provide a proxy on contributions made by an individual or institution. It reflects the independent research ability and leadership. As shown in this research, the *MCI* showed wide variations among authors and institutions with similar total outputs. If an author is either the first- or corresponding-author in all articles, the author would have an *MCI* = 0.5, which was an extremely high value. Future research can be carried out to identify the mean and variance of *MCI* for authors and institutions, in order to establish a basis for comparisons. In future evaluations of institution or individual performances, the *MCI* can be included to provide a better profile of research performance, particularly in fields that tended to have a large number of authors listed in a single article. However, the *MCI* should not be applied independently from the number of total paper. It is likely that as the number of paper increases, the value of *MCI* would likely to decrease, considering there is a limit on resources and research capacity. Thus, the *MCI* would work best if applied to institutions or authors within the same level of total output. Another limitation on *MCI* is that it assumed that first and corresponding author were the ones that make the most contributions in producing a research paper. While this is a well-accepted assumption, it may not always be the case, such as in the practice of "gift authorship," as previously reported [72]. The practice of "gift authorship" has led to overestimation in the evaluation of research performance of individuals or institutions, and is almost impossible to be identified. Nevertheless, despite of its limitations, the *MCI* can provide additional information, and if used together with the *TP*, it can reveal important information on collaboration and the independent research capability.

References

1 Breivik H, Collett B, Ventafridda V, Cohen R, Gallacher D. Survey of chronic pain in Europe: Prevalence impact on daily life and treatment. Eur J Pain 2006;10:287–333.

2 Hardt J, Jacobsen C, Goldberg J, Nickel R, Buchwald D. Prevalence of chronic pain in a representative sample in the United States. Pain Med 2008;9:803–12.

3 Robert C, Wilson CS, Donnadieu S, Gaudy JF, Arreto CD. Bibliometric analysis of the scientific literature on pain research: A 2006 study. Pain 2008;138:250–4.

4 Banos JE, Ruiz G, Guardiola E. An analysis of articles on neonatal pain published from 1965 to 1999. Pain Res Manag 2001;6:45–50.

5 Norton PJ, Asmundson GJG, Norton GR, Craig KD. Growing pain: 10-year research trends in the study of chronic pain and headache. Pain 1999;79:59–65.

6 Robert C, Caillieux N, Wilson CS, Gaudy JF, Arreto CD. World orofacial pain research production: A bibliometric study (2004–2005). J Orofac Pain 2008;22:181–9.

7 Dubner R. A bibliometric analysis of the Pain journal as a representation of progress and trends in the field. Pain 2009;142:9–10.

8 Mogil JS, Simmonds K, Simmonds MJ. Pain research from 1975 to 2007: A categorical and bibliometric meta-trend analysis of every research paper published in the journal Pain. Pain 2009;142:48–58.

9 Turk DC. Impact of articles published in the Clinical Journal of Pain: Most frequently cited papers published from 2002 to 2009. Clin J Pain 2010;26:173–4.

10 Sapunar D, Kostić S, Banožić A, Ferhatović L, Puljak L. Pain research in Croatia: Analysis of bibliometric trends. Period Biol 2011;113:137–40.

11 Wohlin C. Most cited journal articles in software engineering. Inform Software Tech 2005;47:955.

12 Patterson MS, Harris S. Are higher quality papers cited more often? Phys Med Biol 2009;54. doi: 101088/0031–9155/54/17/E01.

13 Fardi A, Kodonas K, Gogos C, Economides N. Top-cited articles in endodontic journals. J Endod 2011;37:1183–90.

14 Shadgan B, Roig M, HajGhanbari B, Reid WD. Top-cited articles in rehabilitation. Arch Phys Med Rehabil 2010;91:806–15.

15 Robinson JK, Callen JP. The best of the best: A new section led by Henry W Lim MD. Arch Dermatol 2010;146:554.

16 Bloch S. "And the winners are": The top articles of 2001. Aust NZ J Psychiat 2002;36:157.

17 Stern RS, Arndt KA. Top-cited authors in dermatology—A citation study from 24 journals: 1982–1996. Arch Dermatol 1999;135:299–302.

18 Madhan M, Chandrasekar G, Arunachalam S. Highly cited papers from India and China. Curr Sci 2010;99:738–49.

19 Falkai P. What was new interesting and frequently cited in 2009? Eur Arch Psy Clin N 2010;260:87–9.

20 Baltussen A, Kindler CH. Citation classics in anesthetic journals. Anesth Anal 2004;98:443–51.

21 Brooke BS, Nathan H, Pawlik TM. Trends in the quality of highly cited surgical research over the past 20 years. Ann Surg 2009;249:162–7.

22 Ponce FA, Lozano AM. The most cited works in Parkinson's disease. Mov Disord 2011;26:380–90.

23 Lipsman N, Lozano AM. The most cited works in major depression: The "Citation classics. J Affect Disord 2011;134:39–44.

24 Ohba N, Nakao K, Isashiki Y, Ohba A. The 100 most frequently cited articles in ophthalmology journals. Arch Ophthalmol 2007;125:952–60.

25 Hennessey K, Afshar K, MacNeily AE. The top 100 cited articles in urology. Can Urol Assoc J 2009;3:293–302.

26 Brandt JS, Downing AC, Howard DL, Kofinas JD, Chasen ST. Citation classics in obstetrics and gynecology: The 100 most frequently cited journal articles in the last 50 years. Am J Obstet Gynecol 2010;203:355e1–7.

27 Lefaivre KA, Shadgan B, O'Brien PJ. 100 most cited articles in orthopaedic surgery. Clin Orthop Relat Res 2011;469:1487–97.

28 Robert C, Wilson CS, Donnadieu S, Gaudy JF, Arreto CD. Evolution of the scientific literature on pain from 1976 to 2007. Pain Med 2010;11:670–84.

29 Ho YS. Top-cited articles in chemical engineering in Science Citation Index Expanded: A bibliometric analysis. Chin J Chem Eng 2012;20:478–88.

30 Chuang KY, Wang MH, Ho YS. High-impact papers presented in the subject category of water resources in the Essential Science Indicators database of the institute for scientific information. Scientometrics 2011;87:551–62.

31 Wang MH, Fu HZ, Ho YS. Comparison of universities' scientific performance using bibliometric indicators. Malays J Libr Inform Sci 2011;16:1–19.

32 Fu HZ, Wang MH, Ho YS. The most frequently cited adsorption research articles in the Science Citation Index (Expanded). J Colloid Interface Sci 2012;379: 148–56.

33 Chiu WT, Ho YS. Bibliometric analysis of homeopathy research during the period of 1991 to 2003. Scientometrics 2005;63:3–23.

34 Ho YS. Classic articles on social work field in Social Science Citation Index: A bibliometric analysis. Scientometrics 2013. doi:10.1007/s11192-013-1014-8.

35 Ho YS. The top-cited research works in the Science Citation Index Expanded. Scientometrics 2013;94: 1297–312.

36 Engers M, Gans JS, Grant S, King SP. First-author conditions. J Polit Econ 1999;107:859–83.

37 Gaeta TJ. Authorship: "law" and order. Acad Emerg Med 1999;6:297–301.

38 Mattsson P, Sundberg CJ, Laget P. Is correspondence reflected in the author position? A bibliometric study of the relation between corresponding author and byline position. Scientometrics 2011;87:99–105.

39 Burman KD. Hanging from the masthead—Reflections on authorship. Ann Intern Med 1982;97:602–5.

40 Spiller WG, Martin E. The treatment of persistent pain of organic origin in the lower part of the body by

division of the anterolateral column of the spinal cord. J Am Med Assoc 1912;58:1489–90.

41 Flaherty KT, Puzanov I, Kim KB, et al. Inhibition of mutated activated BRAF in metastatic melanoma. N Engl J Med 2010;363:809–19.

42 Kantoff PW, Higano CS, Shore ND, et al. Sipuleucel-T immunotherapy for castration-resistant prostate cancer. N Engl J Med 2010;363:411–22.

43 Saglio G, Kim DW, Issaragrisil S, et al. Nilotinib versus imatinib for newly diagnosed chronic myeloid leukemia. N Engl J Med 2010;362:2251–9.

44 Wolfe F, Clauw DJ, Fitzcharles MA, et al. The American college of rheumatology preliminary diagnostic criteria for fibromyalgia and measurement of symptom severity. Arthritis Care Res 2010;62:600–10.

45 Aksnes DW. Characteristics of highly cited papers. Res Eval 2003;12:159–70.

46 Schein M, Paladugu R, Sutija VG. What American surgeons read: A survey of a thousand Fellows of the American College of Surgeons. Curr Surg 2000; 57:252–8.

47 Ware JE, Sherbourne CD. The MOS 36-Item short-form health survey: I Conceptual-framework and item selection. Med Care 1992;30:473–83.

48 Garratt AM, Ruta DA, Abdalla MI, Buckingham JK, Russell IT. The SF-36 health survey questionnaire—An outcome measure suitable for routine use within the NHS. Br Med J 1993;306:1440–4.

49 Rowbotham M, Harden N, Stacey B, et al. Gabapentin for the treatment of postherpetic neuralgia—A randomized controlled trial. J Am Med Assoc 1998;280: 1837–42.

50 Avramescu A. Actuality and obsolescence of scientific literature. J Am Soc Inf Sci Technol 1979;30:296–303.

51 Jadad AR, Moore RA, Carroll D, et al. Assessing the quality of reports of randomized clinical trials: Is blinding necessary? Control Clin Trials 1996;17:1–12.

52 Aaronson NK, Ahmedzai S, Bergman B, et al. The European organization for research and treatment of cancer QLQ-C30: A quality-of-life instrument for use in international clinical trials in oncology. J Natl Cancer Inst 1993;85:365–76.

53 Wolfe F, Smythe HA, Yunus MB, et al. The American college of rheumatology 1990 criteria for the classification of fibromyalgia—Report of the Multicenter Criteria Committee. Arthritis Rheum 1990;33:160–72.

54 Melzack R, Wall PD. Pain mechanisms: A new theory. Science 1965;150:971–9.

55 D'Amour FE, Smith DL. A method for determining loss of pain sensation. J Pharmacol Exp Ther 1941; 72:74–9.

56 Picknett T, Davis K. The 100 most-cited articles from JMB. J Mol Biol 1999;293:173–6.

57 Garfield E. 100 citation classics from the Journal of the American Medical Association. J Am Med Assoc 1987;257:52–9.

58 Bui-Mansfield LT. Whatever happened to the 50 most frequently cited articles published in AJR? AJR Am J Roentgenol 2005;185:597–601.

59 Xie SD, Zhang J, Ho YS. Assessment of world aerosol research trends by bibliometric analysis. Scientometrics 2008;77:113–30.

60 Xia JF, Nakanishi K. Self-selection and the citation advantage of open access articles. Online Inform Rev 2012;36:40–51.

61 Chuang KY, Huang YL, Ho YS. A bibliometric and citation analysis of stroke-related research in Taiwan. Scientometrics 2007;72:201–12.

62 Li Z, Ho YS. Use of citation per publication as an indicator to evaluate contingent valuation research. Scientometrics 2008;75:97–110.

63 Ho YS, Satoh H, Lin SY. Japanese lung cancer research trends and performance in Science Citation Index. Intern Med 2010;49:2219–28.

64 Wang MH, Yu TC, Ho YS. A bibliometric analysis of the performance of Water Research. Scientometrics 2010;84:813–20.

65 Hsieh WH, Chiu WT, Lee YS, Ho YS. Bibliometric analysis of patent ductus arteriosus treatments. Scientometrics 2004;60:205–15.

66 Chen SR, Chiu WT, Ho YS. Asthma in children: Mapping the literature by bibliometric analysis. Rev Fr Allergol Immunol Clin 2005;45:442–6.

67 Li LL, Ding GH, Feng N, Wang MH, Ho YS. Global stem cell research trend: Bibliometric analysis as a tool for mapping of trends from 1991 to 2006. Scientometrics 2009;80:39–58.

68 Suk FM, Lien GS, Yu TC, Ho YS. Global trends in Helicobacter pylori research from 1991 to 2008 analyzed with the Science Citation Index Expanded. Eur J Gastroenterol Hepatol 2011;23:295–301.

69 Lin HW, Yu TC, Ho YS. A systemic review of the human papillomavirus studies: Global publication comparison and research trend analyses from 1993 to 2008. Eur J Gynaecol Oncol 2011;32:133–40.

70 Khan MA, Ho YS. Top-cited articles in environmental sciences: Merits and demerits of citation analysis. Sci Total Environ 2012;431:122–7.

71 Li T, Ho YS, Li CY. Bibliometric analysis on global Parkinson's disease research trends during 1991–2006. Neurosci Lett 2008;441:248–52.

72 Smith J. Gift authorship: A poisoned chalice. Br Med J 1994;309:1456–7.

73 Caterina MJ, Schumacher MA, Tominaga M, et al. The capsaicin receptor: A heat-activated ion channel in the pain pathway. Nature 1997;389:816–24.

74 Eisenberg DM, Davis RB, Ettner SL, et al. Trends in alternative medicine use in the United States 1990–1997—Results of a follow-up national survey. J Am Med Assoc 1998;280:1569–75.

75 Pitt B, Zannad F, Remme WJ, et al. The effect of spironolactone on morbidity and mortality in patients with severe heart failure. N Engl J Med 1999;341:709–17.

76 Melzack R. McGill pain questionnaire: Major properties and scoring methods. Pain 1975;1:277–99.

77 Bennett GJ, Xie YK. A peripheral mononeuropathy in rat that produces disorders of pain sensation like those seen in man. Pain 1988;33:87–107.

78 Hargreaves K, Dubner R, Brown F, Flores C, Joris J. A new and sensitive method for measuring thermal nociception in cutaneous hyperalgesia. Pain 1988;32:77–88.

79 Munro S, Thomas KL, Abushaar M. Molecular characterization of a peripheral receptor for cannabinoids. Nature 1993;365:61–5.

80 Brittberg M, Lindahl A, Nilsson A, et al. Treatment of deep cartilage defects in the knee with autologous chondrocyte transplantation. N Engl J Med 1994;331:889–95.