International Collaboration of Clinical Medicine Research in Taiwan, 1990–2004: A Bibliometric Analysis

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Background: The number of publications in journals indexed in the Institute for Scientific Information (ISI) database of the Thomson Corporation is generally used to assess the research performance of individuals, institutions and countries in scientific fields. The aim of this study was to analyze the trends in Taiwan's ISI publications in clinical medicine from 1990 to 2004. Special attention was paid to internationally collaborated works that were identified based on the countries of co-authors' affiliations.

Methods: The bibliographic records of articles with an author's affiliation in Taiwan were downloaded from the Web of Science on the Internet. The analysis was then limited to the journals of clinical medicine defined as such in the ISI Essential Science Indicators. International collaboration was deemed to exist in an article if any co-author's affiliation was located outside Taiwan. The impact factors in the 2004 Journal Citation Reports Science Edition were arbitrarily adopted to estimate the quality of articles.

Results: Taiwan's ISI publications in clinical medicine increased from 315 articles in 1990 to 2,636 in 2004. Only 7.4% (n = 1,494) of the 20,207 articles published during the study period were published in journals with an impact factor equal to or greater than 5. The share of articles with international collaboration was 13.6% (n = 2,752) on average. Taiwan's researchers collaborated with colleagues in 76 countries. The USA, as the most important collaborating partner of Taiwan's clinical medicine researchers, had contributed to 69.9% of articles with international collaboration. Generally, articles with international collaboration were published in journals with higher impact factors or had more citations than those without international collaboration. The number of articles published in each year, in each of selected subject categories and from each of selected domestic institutions did not correlate with the percentage of articles with international collaboration, respectively.

Conclusion: Taiwan has achieved a significant increase in the number of ISI publications in clinical medicine. Yet there exists opportunity for improvement in international collaboration. [*J Chin Med Assoc* 2007;70(3):110–116]

Key Words: bibliometrics, clinical medicine, international cooperation, publishing, Taiwan

Introduction

Along with its socioeconomic development, Taiwan's ability in scientific research has received much attention.[1,2] According to the Thomson Corporation, Taiwan ranked the 21st among the 149 countries for papers indexed in the Institute for Scientific Information (ISI) database (ISI Essential Science Indicators) in an 11-year period from 1993 to 2003 (http://www.in-cites.com/countries/taiwan.html, accessed on December 26, 2005). Actually, Taiwan was the 3rd country after the USA and the Netherlands to begin officially publishing bibliometric statistics as one of the scientific and engineering indicators of the nation.[3] The National Science Council (NSC) and many universities in Taiwan have, for years, also adopted standardized and rigid criteria to evaluate the research performance of scientists and faculty members in terms of papers indexed in the Science Citation Index (SCI) database.[4] In recent years, the NSC has collaborated with Leiden

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University in the Netherlands to conduct a series of bibliometric studies on the research capacity of Taiwan and some neighboring countries on the basis of the ISI database.[5,6] However, these extensive analyses at the macro level could not provide detailed data for specific fields.

The aim of this study was to analyze the trends in Taiwan's SCI publications in clinical medicine from 1990 to 2004. Special attention was paid to internationally collaborated works that were identified based on the countries of the authors' affiliations.

Methods

Data sources

From the Web of Science® (including SCI Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index) on the Internet (http://isi01.isiknowledge.com/, accessed on June 13, 2005), we downloaded the records belonging to Taiwan based on the addresses of the authors' affiliations. The time period of our analysis was limited to the publication years between 1990 and 2004. Because the year in the search fields referred to the year in which a paper was indexed, we extended the searched time-spans to 1989–2005, and extracted those eligible records. Because some records of Taiwanese authors might be erroneously indexed with the People's Republic of China as the country name in the address field,[7] we additionally retrieved such records by searching for major Taiwanese cities in combination with the People's Republic of China.

We also downloaded a journal list that was compiled by the Thomson Corporation for the ISI Essential Science Indicators® (http://www.in-cites.com/journal-list/index.html, accessed on July 22, 2005). Each of the 11,857 journals (status: March 2005) in the list was categorized under only 1 of 22 fields. The field of clinical medicine contained 2,103 journals; these journals were used to identify bibliographic records belonging to clinical medicine.

The impact factors of 5,968 journals listed in the 2004 Journal Citation Reports Science Edition® (http://isi01.isiknowledge.com/portal.cgi/jcr, accessed on July 26, 2005) were arbitrarily adopted to estimate the quality of articles.

Study design

Our analysis was limited to the "articles" in journals of clinical medicine covered in the ISI database. Reviews, notes, letters, editorials, news and meeting abstracts were excluded. We identified the authors' affiliations and countries from the fields of affiliation and corresponding address. International collaboration was deemed to exist in an article if any co-author's affiliation was located outside Taiwan.

The names of affiliations were less well formatted than those of countries. Besides, an institution might change its name during the study period or have several affiliates. This required us to process affiliations manually. To compare the major groups of medical care facilities in Taiwan, some institutions were arbitrarily grouped together, e.g. Chang Gung University with the several Chang Gung Memorial Hospitals and National Yang-Ming University with the 3 Veterans General Hospitals.

We computed the publication counts and the share of articles with international collaboration in each year. The data were then stratified by journal impact factor, subject category, domestic institution and collaborating country in 5-year periods (1990–1994, 1995–1999 and 2000–2004). The subject category that was generally used in compilation of the annual Journal Citation Reports® was presented in each ISI record. One journal with its articles might be indexed with several subject categories. To accredit an article to institutions and countries, we adopted the method of "absolute country counting", in which each institution or country contributing to an article received 1 paper credit, respectively.[8]

Data processing and statistical analysis

The extraction and computation of data was undertaken with the Perl programming language (version 5.8.7, http://www.perl.com/). Besides the descriptive statistics, e.g. the frequency in count and percentage, we also computed the associations between Taiwan's number of articles and the share of articles with international collaboration in each year and between the article count of the top 20 institutions or 44 subject categories and their share of articles with international collaboration in the latest 5 years. The correlation coefficient Kendall's tau-b was calculated. Moreover, as to the number of citations received by an article and the impact factor of the journal in which an article was published, we compared the group of articles with international collaboration with that without international collaboration. Because the number of citations and the journal impact factor varied widely between articles, we chose the Mann–Whitney U test to examine the difference between 2 groups of articles. A p value < 0.05 was regarded as statistically significant (2-tailed). Statistical analyses were performed using SPSS for Windows Release 13.0 (SPSS Inc., Chicago, IL, USA).

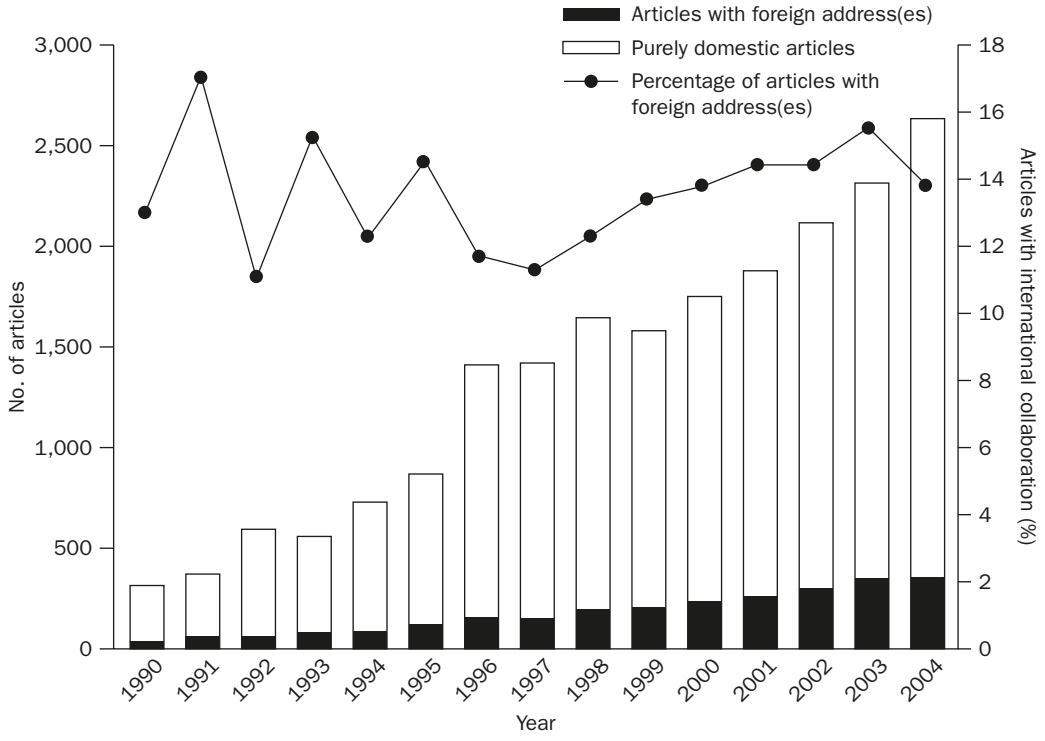

Figure 1. Trends in Taiwan's clinical medicine publications in the Web of Science.

Results

We retrieved 20,207 records of articles in which the publication years were between 1990 and 2004, the publishing journal belonged to the field of clinical medicine, and at least 1 author's affiliation was located in Taiwan, including 35 records erroneously indexed under the People's Republic of China. In 2,752 (13.6%) articles, at least 1 author's affiliation was located outside Taiwan. Taiwan's ISI publications in clinical medicine increased from 315 articles in 1990 to 2,636 in 2004, and the articles with international collaboration from 41 in 1990 to 363 in 2004. The percentage of articles with international collaboration varied between 11.1% and 17.0% annually (Figure 1). The number of articles in each year did not correlate with the percentage of articles with international collaboration (Kendall's tau-b coefficient = 0.105, $p = 0.586$).

Among the 20,207 articles in 1,031 journals, 624 articles could not be linked to any journal listed in the 2004 Journal Citation Reports Science Edition. Based on the journal impact factors in 2004, only 1,494 (7.4%) articles were published in journals with an impact factor equal to or greater than 5 (Table 1). Although the annual number of these articles with a higher journal impact factor increased from 29 in 1990 to 197 in 2004, their share did not grow correspondingly (9.2% in 1990, but 7.5% in 2004). But, the probability of international collaboration increased with the journal impact factors: 30.0% in articles with a higher journal impact factor in contrast with 7.6% in articles with a journal impact factor less than 1 (Table 1). On average, articles with international collaboration appeared in journals with higher journal impact factors than those without international collaboration (median: 2.255 *vs.* 1.567; $p < 0.001$, Mann–Whitney *U* test). On the other hand, articles with international collaboration also received more citations (median: 5 *vs.* 3; $p < 0.001$, Mann–Whitney *U* test).

Table 1. Distribution of Taiwan's clinical medicine publications in the Web of Science by journal impact factor, 1990–2004

Journal impact factor*	No. of all articles	Articles with foreign address, *n* (%)
≥ 5	1,494	448 (30.0)
≥ 4 and < 5	1,058	233 (22.0)
≥ 3 and < 4	2,170	368 (17.0)
≥ 2 and < 3	2,903	446 (15.4)
≥ 1 and < 2	6,547	758 (11.6)
< 1	5,411	409 (7.6)
NA	624	90 (14.4)
Total	20,207	2,752 (13.6)

**The journal impact factor was based on the 2004 Journal Citation Reports Science Edition. NA = Not available.*

All the articles were indexed into 91 subject categories. Table 2 displays 44 subject categories with higher

Table 2. Distribution of Taiwan's clinical medicine publications in the Web of Science by subject category (selected)

Subject category	1990–1994		1995–1999		2000–2004	
	Total no.	Articles with IC, *n* (%)	Total no.	Articles with IC, *n* (%)	Total no.	Articles with IC, *n* (%)
Surgery	503	20 (4.0)	1,136	106 (9.3)	1,654	150 (9.1)
Oncology	263	53 (20.2)	717	118 (16.5)	1,190	238 (20.0)
Medicine, general & internal	98	12 (12.2)	833	49 (5.9)	1,027	88 (8.6)
Gastroenterology & hepatology	256	27 (10.5)	596	43 (7.2)	692	64 (9.2)
Cardiac & cardiovascular systems	278	26 (9.4)	558	33 (5.9)	699	76 (10.9)
Radiology, nuclear medicine & medical imaging	227	19 (8.4)	514	72 (14.0)	766	134 (17.5)
Urology & nephrology	147	12 (8.2)	339	45 (13.3)	610	55 (9.0)
Obstetrics & gynecology	82	10 (12.2)	399	27 (6.8)	594	34 (5.7)
Clinical neurology	104	10 (9.6)	250	49 (19.6)	463	107 (23.1)
Immunology	133	8 (6.0)	245	34 (13.9)	401	78 (19.5)
Pediatrics	103	13 (12.6)	262	17 (6.5)	408	33 (8.1)
Hematology	151	25 (16.6)	214	30 (14.0)	368	66 (17.9)
Medicine, research & experimental	68	15 (22.1)	183	37 (20.2)	437	75 (17.2)
Peripheral vascular disease	108	19 (17.6)	243	33 (13.6)	308	76 (24.7)
Transplantation	91	0 (0.0)	208	22 (10.6)	336	44 (13.1)
Respiratory system	119	12 (10.1)	187	23 (12.3)	314	28 (8.9)
Dentistry, oral surgery & medicine	78	18 (23.1)	203	59 (29.1)	335	42 (12.5)
Orthopedics	70	5 (7.1)	188	29 (15.4)	291	44 (15.1)
Public, environmental & occupational health	78	15 (19.2)	168	42 (25.0)	293	84 (28.7)
Pathology	78	12 (15.4)	176	34 (19.3)	275	65 (23.6)
Otorhinolaryngology	40	12 (30.0)	122	22 (18.0)	324	42 (13.0)
Ophthalmology	42	12 (28.6)	136	21 (15.4)	290	33 (11.4)
Critical care medicine	63	2 (3.2)	154	16 (10.4)	229	22 (9.6)
Pharmacology & pharmacy	43	9 (20.9)	139	24 (17.3)	198	31 (15.7)
Infectious diseases	29	6 (20.7)	104	8 (7.7)	233	37 (15.9)
Engineering, biomedical	22	3 (13.6)	143	9 (6.3)	194	16 (8.2)
Dermatology	62	4 (6.5)	100	10 (10.0)	171	28 (16.4)
Microbiology	23	6 (26.1)	117	16 (13.7)	186	32 (17.2)
Acoustics	46	1 (2.2)	103	3 (2.9)	175	13 (7.4)
Sport sciences	20	3 (15.0)	100	10 (10.0)	196	45 (23.0)
Genetics & heredity	20	5 (25.0)	97	15 (15.5)	197	38 (19.3)
Anesthesiology	29	8 (27.6)	92	12 (13.0)	152	25 (16.4)
Endocrinology & metabolism	31	6 (19.4)	68	19 (27.9)	154	46 (29.9)
Cell biology	28	5 (17.9)	76	17 (22.4)	139	37 (26.6)
Rheumatology	27	5 (18.5)	69	6 (8.7)	145	21 (14.5)
Integrative & complementary medicine	46	0 (0.0)	71	0 (0.0)	112	7 (6.3)
Neurosciences	23	6 (26.1)	56	8 (14.3)	150	27 (18.0)
Reproductive biology	12	2 (16.7)	81	13 (16.0)	124	13 (10.5)
Medical laboratory technology	33	5 (15.2)	49	12 (24.5)	134	29 (21.6)
Rehabilitation	13	2 (15.4)	61	10 (16.4)	135	33 (24.4)
Neuroimaging	27	3 (11.1)	63	18 (28.6)	74	21 (28.4)
Biochemistry & molecular biology	15	5 (33.3)	58	15 (25.9)	87	32 (36.8)
Emergency medicine	7	0 (0.0)	37	0 (0.0)	106	9 (8.5)
Allergy	27	3 (11.1)	42	5 (11.9)	63	7 (11.1)
Total	2,585	347 (13.4)	6,923	865 (12.5)	10,699	1,540 (14.4)

IC = international collaboration.

article counts in 5-year intervals. The number of articles in each of these 44 subject categories did not correlate with their percentage of articles with international collaboration (Kendall's tau-b coefficient = −0.194, p=0.064).

In Table 3, the top 20 institutions in clinical medicine publications from 1990 to 2004 are shown. Although National Taiwan University was most productive during the 15 years, the Chang Gung group

Table 3. Distribution of Taiwan's clinical medicine publications in the Web of Science by institution (selected)

Institution	1990–1994		1995–1999		2000–2004	
	Total no.	Articles with IC, *n* (%)	Total no.	Articles with IC, *n* (%)	Total no.	Articles with IC, *n* (%)
National Taiwan University	586	69 (11.8)	1,868	199 (10.7)	2,602	341 (13.1)
Chang Gung University	545	33 (6.1)	1,656	148 (8.9)	2,654	369 (13.9)
National Yang-Ming University + Veterans General Hospitals	718	87 (12.1)	1,608	176 (10.9)	2,378	302 (12.7)
National Cheng Kung University	121	11 (9.1)	559	56 (10.0)	864	126 (14.6)
National Defense Medical Center	194	48 (24.7)	452	91 (20.1)	757	129 (17.0)
Kaohsiung Medical University	183	20 (10.9)	339	44 (13.0)	681	96 (14.1)
China Medical University	25	3 (12.0)	185	16 (8.6)	711	65 (9.1)
Taipei Medical University	22	7 (31.8)	145	20 (13.8)	549	72 (13.1)
Mackay Memorial Hospital	54	5 (9.3)	198	22 (11.1)	368	60 (16.3)
Chung Shan Medical University	22	0 (0.0)	101	8 (7.9)	407	39 (9.6)
Academia Sinica	87	17 (19.5)	200	29 (14.5)	216	44 (20.4)
Taipei City Hospital	44	6 (13.6)	112	11 (9.8)	167	26 (15.6)
Tzu Chi University	16	2 (12.5)	83	11 (13.3)	212	36 (17.0)
Chi Mei Hospital	1	0 (0.0)	50	7 (14.0)	252	27 (10.7)
Shin Kong Wu Ho-Su Memorial Hospital	4	0 (0.0)	81	5 (6.2)	198	18 (9.1)
National Health Research Institutes	1	0 (0.0)	27	7 (25.9)	218	52 (23.9)
Cathay General Hospital	25	5 (20.0)	64	7 (10.9)	152	32 (21.1)
National Tsing Hua University	39	4 (10.3)	57	5 (8.8)	97	8 (8.2)
Changhua Christian Hospital	5	0 (0.0)	33	6 (18.2)	152	19 (12.5)
Far Eastern Memorial Hospital	5	1 (20.0)	7	0 (0.0)	170	9 (5.3)

IC = international collaboration.

had taken the leading role in research quantity since 2002. The number of articles in each of these 20 institutions did not correlate with their percentage of articles with international collaboration (Kendall's tau-b coefficient = –0.228, $p = 0.162$).

According to the co-authorship of articles, the researchers of clinical medicine in Taiwan had collaborated with colleagues in 76 countries or regions (e.g. Hong Kong). Only in 12 countries did the number of articles with collaboration surpass 50 articles during the 15 years (Table 4). The USA, as the most important collaborating partner of Taiwan's clinical medicine researchers, contributed to 69.9% of articles with international collaboration.

Table 4. Distribution of Taiwan's clinical medicine publications with international collaboration in the Web of Science by collaborating country (selected)

Country	1990–1994	1995–1999	2000–2004	All
USA	258	625	1,040	1,923
Japan	40	86	201	327
England	14	50	89	153
Canada	15	42	73	130
PR China	12	39	78	129
Hong Kong	6	25	69	100
Australia	4	24	63	91
South Korea	3	17	68	88
Germany	9	19	50	78
France	7	24	44	75
Singapore	6	18	47	71
Sweden	3	10	46	59
Total	347	865	1,540	2,752

Discussion

Our current study was a purely descriptive analysis about Taiwan's SCI publications in clinical medicine research since 1990 and arbitrarily adopted co-authorship as an indicator of collaboration. Research collaboration might exist in several forms and levels: individual, group, department, institution, sector and nation.[9] Our study was focused only on collaboration between institutions in different countries. Besides, we implicitly accepted the popular assumption that research collaboration is good and should be encouraged.[9] Our results showed that the proportion of internationally co-authored articles in Taiwan's clinical medicine publications remained low during the study period.

Some bibliometricians reported that 15.6% of the records in the SCI database in 2000 were internationally co-authored.[10] In another extensive report on SCI publications in 50 countries, the share of international papers in Taiwan's national output was 17.5% in 1995/96 and ranked the 48th lowest, slightly lower than the USA (18.1%) but higher than India (15.2%) and Japan (14.4%).[11] The top in the ranking list was Thailand (64.2%), and the top among the developed countries was Switzerland (47.5%). In contrast, the share of articles with international collaboration in Taiwan's clinical medicine publications was merely 13.6% on average from this study.

In this study, we adopted "absolute country counting" in accrediting an article to countries and might have overlooked the indirect collaboration relationships. Only if some kind of "relative country counting" is adopted will the relationships resulting from indirect collaboration be leveraged off.

Unlike studies on basic medicine, natural science and engineering, the research topics and materials in clinical medicine are usually patient-oriented and possibly have more local features, resulting in less international collaboration. Herein, although articles with international collaboration were averagely published in journals with higher impact factors, the causality was uncertain. Possibly, the researchers sought foreign involvement only for the "better" themes that were of broader interest and suitable for journals with higher impact factors. The clinical medicine studies with international collaboration might include some multinational clinical trials. Because the ISI database, as a comprehensive bibliographic database of the sciences, is not limited to clinical medicine, its indexing of clinical trials is not as detailed and systematic as that of MEDLINE. To test the hypothesis, linkage from ISI records to MEDLINE would be more adequate. On the other hand, articles with international collaboration also received more citations on average. But the distribution of citation counts was highly skewed among these articles, i.e. a few articles with a considerable citation count. It demands further analyses to better understand the real situation.

Special attention should be paid to the data in Table 2 about publications in selected subject categories. The 22 fields in the ISI Essential Science Indicators also included biology & biochemistry, immunology, microbiology, molecular biology & genetics, neuroscience & behavior, psychiatry/psychology and pharmacology & toxicology. A journal was categorized only under 1 field. But in practical cataloging within the SCI database, 1 journal with its articles could be indexed with several subject categories. A journal in the clinical medicine field might also be indexed under a subject category of basic medicine.

Another caution is needed when adopting a single impact factor value to judge a journal, as was done in this study. The journal impact factor changes from year to year. Moreover, the impact factor was calculated on the basis of 2-year citations a journal received divided by 2-year articles the journal published. Therefore, the 2004 Journal Citation Reports reported the performance (in terms of impact factor in our current study) of journals published in 2002 and 2003. However, the articles that were retrieved from the Web of Science were distributed from 1990 to 2004. Some discrepancies existed.

The major limitation in analyzing the institutional research performance in Taiwan was that the number of research staff in each institution was unknown. On the other hand, the research productivity should not be confined to the field of clinical medicine. Many publications might be in other biomedical fields. Research collaboration in terms of co-authorship represented only the outcome. It would be a challenge to study the process and individual contributions.

In conclusion, Taiwan achieved a significant increase in the number of SCI publications in clinical medicine from 1990 to 2004. Yet there exists opportunity for improvement in international collaboration. Moreover, the impact of collaboration on the diffusion of scientific knowledge and the quality of medical care in the long term deserves examination and monitoring.

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