

Assessing stem cell research productivity

Y. S. HO^{1,4}, C. H. CHIU², T. M. TSENG³, W. T. CHIU²

¹*School of Public Health, Taipei Medical University, Taipei (Taiwan)*

²*Taipei Medical University – Wan-Fang Hospital, Taipei (Taiwan)*

³*School of Medicine, Taipei Medical University, Taipei (Taiwan)*

⁴*Bibliometric Centre, Taipei Medical University – Wan-Fang Hospital, Taipei (Taiwan)*

Honour Index (HoI), a method to evaluate research performance within different research fields, was derived from the impact factor (IF). It can be used to rate and compare different categories of journals. HoI was used in this study to determine the scientific productivity of stem cell research in the Asian Four Dragons (Hong Kong, Singapore, South Korea and Taiwan) from 1981 to 2001. The methodology applied in this study represents a synthesis of universal indicator studies and bibliometric analyses of subfields at the micro-level. We discuss several comparisons, and conclude the developmental trend in stem cell research for two decades.

Introduction

Researchers have discovered that stem cells are capable of self-regeneration and differentiation into unexpected cells while situating in any type of animal cells (HORWITZ, 2003). Stem cells have the potential for medical treatment in the future. Researchers have, for example, successfully developed specialized cells from stem cells and transplanted them into the nervous system of rats to develop new treatments for human neurological diseases (TOMITA et al., 2002). Continuing research on stem cell is essential for more applications.

Science would not exist if the results of scientific work were not communicated. Communication is the driving force of science (VAN RAAN, 1999). Publication to exchange research findings is an important aspect of science and is a basis of methods to evaluate scientific productivity. Many methods have been suggested to evaluate the scientific productivity of countries (BRAUN et al., 1995; BONITZ et al., 1997), universities (COLMAN et al., 1995), research institutes (UGOLINI et al., 1996), journals (BUDILOVA et al., 1997; ARKHIPOV, 1999), research teams (BORDONS & ZULUETA, 1997), and research fields (BRAUN et al., 1995). However, publication counts cannot indicate the quality of the research conducted. In a bibliometric analysis of Flemish

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Address for correspondence:

W. T. CHIU

Taipei Medical University – Wan-Fang Hospital

111 Hsing-Long Road Sec. 3, Taipei 116, Taiwan

E-mail: wtchiu@wanfang.gov.tw

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universities, the productivity of each department was determined by the number of SCI articles, and citation counts were used as an impact indicator (VAN DEN BERGHE, 1998). Bibliometric studies carried out in recent years have provided an accurate and objective method, based on the number of citations to measure a paper's contribution in advancing knowledge. Although the method has been widely discussed, there is a consensus in certain aspects (UGOLINI et al., 1996). Various citation-related indicators were introduced and the most often referred and used ones were the impact factor published in *Journal Citation Reports* (JCR) and the Relative Citation Impact (RCI). A common disadvantage of these indicators is their "unfairness" when comparing publications from different categories. GARFIELD (1977) has mentioned that due to differences between journals, it would be "unfair" to compare journals in different categories. A specific disadvantage of RCI is that the citation analysis of the whole world is required for its computation. Due to various limitations, the world citation is extremely difficult to maintain. Responding to the need of a more effective method, especially when evaluating the performance of multi-discipline research groups, Honour Index (HoI) has been developed and will be introduced in later sections.

GARFIELD (1970) indicated that proper bibliometric analysis could identify the present focus of scientific research. The objective of this study was to evaluate the development of stem cell research for the past two decades through bibliometric analysis. The research performance was focused to hematology and immunology due to numerous articles were published in these two categories. The study was centered on the four Asian countries, Hong Kong, Singapore, South Korea, and Taiwan, which were also known as the Four Asian Dragons or Tigers indicating their importance to Asian economy beside Japan. However, there is a significant bond between research and economy (SWINBANKS et al., 1997) and research is an essential part of successful economy. Comparing the pattern emerging from the citation analysis of the Asian Dragons and seven significant industrial countries, Canada, Germany, France, Italy, Japan, United Kingdom, and United States would indicate the development trend in stem cell research.

Method

The data were based on the online version of SCI, *Web of Science*. SCI is a multidisciplinary database of the Institute for Scientific Information (ISI, Philadelphia USA). It indexes more than 5,700 major journals with citation references across 164 scientific disciplines. The online version of SCI was searched under the keyword "stem cell" to compile a bibliography of all papers containing at least one corporate address from the desired countries, South Korea, Singapore, Hong Kong, and Taiwan. Only

original articles were used for analysis as relevant citable items, while all others were discarded.

The bibliometric impact of a publication is usually assessed in terms of the number of citations it has received relative to other outputs in the same journal or field. For entity i , let total papers be P_i and let numbers of citations be C_i . The average number of citations per publications (CPP) is defined as:

$$CPP = \frac{C_i}{P_i} .$$

Average impact factor (IF_H) is a composite indicator designed to measure the quality of the papers under evaluation. It is based on the impact factor (IF) of the top one journal in a group of category of SCI and number of journals in a group of category of SCI (n_i), for papers in a given subfield that includes numbers of categories. The average impact factor is calculated as follows:

$$IF_H = \sum_i \frac{IF_i \times n_i}{\sum_i} .$$

The HoI of an institute or a scientific field is calculated as follows:

$$HoI = \frac{CPP}{IF_H} .$$

Since HoI normalizes the size of publication output by country, university, department and researcher as well as the size of output in the subject field, it is a valid indicator for making cross nation – department and – researcher comparisons.

Results

Figure 1 gives the total number of SCI papers in stem cell research worldwide from 1981 to 2001. As shown in Figure 1, the stem cell research suddenly emerged in the World. The extrapolation from this graph suggested that the development in this field would most likely continue after 2001. Table 1 shows the number of SCI papers in stem cell research for G7 (U.S.A., Japan, Germany, U.K., France, Italy, and Canada) from 1981 to 2001. In the past 20 years, the researchers in G7 published approximately 70% of SCI papers in all research fields across the world. Interestingly, in this particular field of stem cell, G7 scientists published for over 90% of world SCI papers.

In recent years, people in the countries around the Pacific Rim have begun to focus on scientific research. The officials of the research institutions of these countries recognized that creativity and innovation in their research systems were essential to their future economical success and were adopting Western techniques to assess research productivity. In the past few years the number of scientific papers produced by the region stretching from Japan to Singapore has been increasing (SWINBANKS et al., 1997). Although the contributions made from these countries were not as great compared with the G7, their motivation to keep up the development can be observed from the number of published papers.

This study focused on the Asian Four Dragons (Figure 2, Table 2). Although Taiwan was the earliest country to publish a paper in this field in 1987, the termination of some studies eventually delayed its development. One of the most outstanding countries in the stem cell research was South Korea. Since 1998, the development in stem cell research in South Korea has been increasing and the developmental trend, as seen from graphs in Figure 1 and 2, has remains consistent with that in the world. Both Hong Kong and Taiwan also have an average increase in their research development.

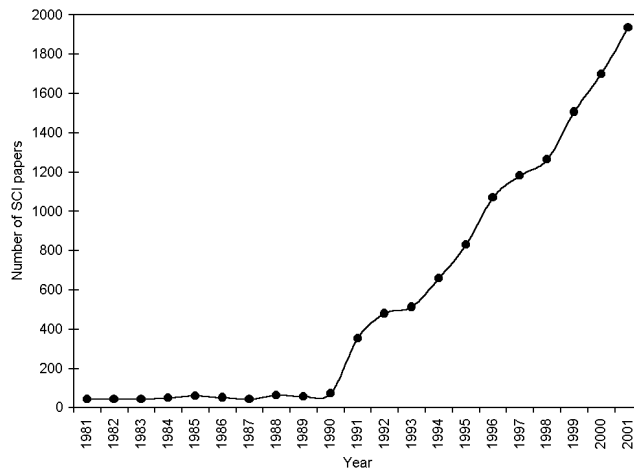


Figure 1. World stem cell research development, 1981–2001

Table 1. Percentage relative to world total

	1981–2001 Total publications	% of world total
World	12025	100.00
USA	5106	42.50
Japan	1306	10.90
Germany	1299	10.80
UK	1194	9.93
France	922	7.67
Italy	742	6.17
Canada	506	4.12
South Korea	63	0.52
Taiwan	42	0.35
Hong Kong	25	0.21
Singapore	14	0.12

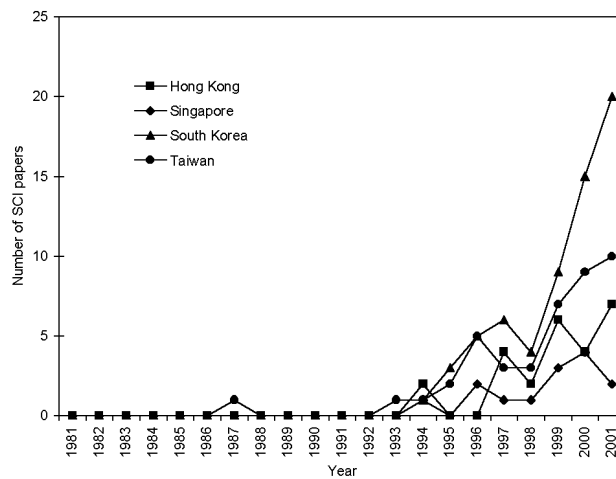


Figure 2. Stem cell research development of the Asian Four Dragons, 1981–2001

To determine the quality of papers directly is to examine its frequency of citations. In Table 2, we can observe that the quality of papers produced by Hong Kong, South Korea and Taiwan was similar since their highest citation frequencies (C_h) were 29, 26, 23 respectively. Another indicator used to determine the quality of papers published is to observe the number of papers published through international collaboration (P_{in}).

Table 2. Indicators of bibliometric studies on Asia four Dragons 1981–2001

	Hong Kong	Singapore	South Korea	Taiwan
P	25	14	63	42
P _f	1994	1994	1994	1987
P _{in}	3 (12.0%)	7 (50.0%)	22 (31.0%)	6 (13.6%)
C _h	29 times	101 times	26 times	23 times
CPP	4.13	13.7	3.32	3.48
HoI	0.178	0.645	0.165	0.147

P Number of papers published

P_f Year of first publication

P_{in} Number of papers published in international collaboration

C_h Paper with the highest frequency cited

CPP Citations per publication

HoI Honour Index

Since internationally collaborated papers combine data from around the world and the subject to be studied is viewed internationally, the analysis is considered to be more complete and often receive higher recognition than papers published nationally.

In Table 1, South Korea had the greatest number of international collaboration papers. We observed that South Korea and Hong Kong are very similar in terms of their stem cell research development. Controversially, Taiwan was slightly behind in its development. Singapore as the special case in the four Dragons, there was no notable trend in its production due to its minute amount.

A further study was made to compare the quality of two separate categories of journals that published under the same topic of stem cells using HoI. Tables 3 and 4 showed a comparison between hematology and immunology. As shown in Tables 3 and 4, the IF_i for hematology was 10.517 but was 46.233 for immunology. This finding indicated that for an immunology journal to be ranked at the same level as a hematology journal in terms of its quality, the immunology paper needed to have more citations per paper than a hematology paper. For example, the CPP values for hematology and immunology were 5.538 and 4.500 respectively for Hong Kong, which did not differ significantly. However, an outstanding paper published in the hematology category will only be considered as an average paper if published in the immunology category if CPP is the method used for an evaluation. Comparing the HoI values in both categories for Hong Kong, South Korea, and Taiwan, it was found HoI values in hematology was ten times more than HoI values in Immunology. This indicated that papers produced by Hong Kong, South Korea, and Taiwan were more cited, or had more impact in hematology than in immunology. On the other hand, Singapore has smaller difference between its HoI values compared to other three countries where Singapore showed

slightly more impact in hematology, too. This dissimilar pattern was again due to the minute paper production. None of the HoI values in both categories were above 1, which denoted none of the citation frequencies reached the average in either hematology or immunology.

Table 3. HoI comparisons of hematology ($IF_i = 10.517$)

	Hong Kong	Singapore	South Korea	Taiwan
P	13	3	25	19
C	72	3	127	75
CPP	5.538	1.00	5.080	3.947
HoI	0.527	0.095	0.483	0.375

Table 4. HoI comparisons of Immunology ($IF_i = 46.233$)

	Hong Kong	Singapore	South Korea	Taiwan
P	6	7	10	10
C	27	13	37	23
CPP	4.500	1.857	3.700	2.300
HoI	0.0973	0.0402	0.0800	0.0497

Conclusion

Citation analysis was considered an important indicator since the listing of references in publications is traditionally used by researchers to acknowledge the value of previous work (UGOLINI et al., 1996). Prior to the introduction of HoI, the bibliometric method used to perform analysis was quite limited and may have included selection bias and statistical fluctuations due to the small sample size. Most importantly, it cannot be used to make comparisons between two different subjects. Although HoI cannot reduce all the limitations of a citation analysis, it was an improved method and would definitely provide aid for other researchers. Based on the finding of our study on the development of stem cell research in the Asian Four Dragons, we would like to suggest that South Korea, Hong Kong, and Taiwan have followed the world's trend in scientific research. South Korea's performance in stem cell research was especially outstanding.

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