

Diabetes research in India and China today: From literature-based mapping to health-care policy

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We have mapped and evaluated diabetes research in India and China, based on papers published during 1990–1999 and indexed in PubMed, Science Citation Index (SCI) and Biochemistry and Biophysics Citation Index (BBCI) and citations to each one of these papers up to 2000. We have identified institutions carrying out diabetes research, journals used to publish the results, subfields in which the two countries have published often, and the impact of the work as seen from actual citations to the papers. We have also assessed the extent of international collaboration in diabetes research in these two countries, based on papers indexed in SCI and BBCI. There is an enormous mismatch between the disease burden and the share of research performed in both countries. Although together these two countries account for 26% of the prevalence of diabetes, they contribute less than 2% of the world's research. We argue that both India and China need to (i) strengthen their research capabilities in this area, (ii) increase investment in health-care research considerably, (iii) facilitate substantive international collaboration in research, and (iv) support cross-disciplinary research between basic life sciences researchers and medical researchers. As data such as those presented here should form the basis of health policy, India and China should encourage evaluation of research.

DIABETES mellitus is a major and growing health problem in most countries and an important cause of prolonged ill health and early death¹. It was the sixteenth leading cause of global mortality in 1990, accounting for 571,000 deaths². Diabetes is predicted to continue to grow worldwide at epidemic proportions in the first quarter of the 21st century. The growth will be particularly strong in India and China^{3,4}, which lead the world in the prevalence of diabetes, with 14.3% and 11.8% of prevalence, respectively in 1995. In USA, which ranks third after India and China in the prevalence of diabetes, the growth rate is expected to be much smaller: from 13.9 million in 1995 to 21.9 in 2025 (ref. 3). The growth in number of people with diabetes is expected to be fast in Pakistan, Indonesia, Egypt and Mexico, and somewhat slow in Japan³. Recent studies of geographical and ethnical influences have shown that people of Indian origin are highly prone to diabetes⁵. The number of adults suffering from diabetes in India is expected to increase three-fold, from 19.4 million in 1995 to 57.2 million in 2025. During the

same period, China's diabetic adult population is slated to grow from 16 million to 37.6 million³. These figures are based on estimated population growth, population ageing, and urbanization, but they do not take into account changes in other diabetes-related risk factors. For this reason, Roglic and King⁴ believe that the figures are likely to be conservative estimates. And yet, the contribution of both India and China to the research literature of diabetes, based on papers indexed in *PubMed*, is rather meagre – 1.11% by India and 0.63% by China. (However, one must note that scientific articles in developing countries are under-represented in international databases and in general papers published by developing countries are not indexed comprehensively^{6,7}. As far back as 1982, Eugene Garfield assembled about thirty experts to examine how best the Institute for Scientific Information could capture a large proportion of papers published by developing-country researchers⁸. A few years ago WHO took the initiative to bring out *ExtraMed*, a secondary service to index developing-country medical journals that are not indexed by *PubMed*. However, it did not prove very useful.)

The mismatch is indeed glaring. Earlier studies have shown that India's priorities in medical research do not necessarily match the country's needs based on mortality

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and morbidity data^{9,10}. But then the quantum of research carried out in a country is not determined by needs alone. The country should be able to afford it as well as have the capacity to carry out such research. The United States and to some extent the G7 and OECD countries perform substantial quantities of research in diseases that are not their major concerns, as they have both the high quality manpower needed for research and the financial resources.

This paper is focused on mapping and evaluating diabetes research carried out in India and China in the ten-year period 1990–1999, based on data collected from three databases, viz. *PubMed* (web edition), *Science Citation Index (SCI)* on CD and *Biochemistry and Biophysics Citation Index (BBCI)* (CD-ROM edition) using carefully chosen keywords. There is some overlap among the three databases. For example, more than 40% of papers from India indexed in *SCI* are also indexed in *PubMed*.

Research design and methods

Papers published from addresses in India and China were downloaded from three databases, viz. *PubMed* (web edition), *SCI* and *BBCI* (both CD rom version). While consulting all three databases is better than depending on any one of them, one is still bound to miss some papers published in sources not indexed in any of them. For example, none of the three databases indexes *Indian Journal of Clinical Biochemistry*, which carried an excellent review article on vanadium complexes as a second line of protection against diabetes¹¹. The fields downloaded are: names of authors with initials, address, title of the paper, document type, source (journal title, volume, year, page, conference title, etc.) and language. While *SCI* and *BBCI* list the names and addresses of all authors of papers they index, *PubMed* gives the address of only one (usually the first) author. Therefore, a *PubMed* search for Indian papers will miss all multi-authored papers in which the Indian author's address is not given. We used the following keywords in the title field to download papers on diabetes: *diabet**, *NIDDM*, *IDDM*, *MODY*, *FCPD*, *Hyperglycem**, *Hypoglycem**, *Hyperglycaem**, *MRDM*, *Hypoglycaem**, *Islet transplant**, *Islet encapsulation*, *Insulin resist**, and *Retinopath**. (Use of additional keywords such as *Pancreatic regeneration*, *Islet culture*, *Islet cryopreservation*, and *Islet neogenesis* did not result in any additional paper, but resulted in a large number of papers unrelated to diabetes.) As merely giving India (or China) as the search term in the address field will not identify all papers from the country in *PubMed*, we gave the names of all possible cities, towns and states/provinces in India (or China) in the address field, while searching *PubMed*. Such precaution was not necessary when searching *SCI* and *BBCI*, as these databases invariably include country names in the address field. For our analysis, we considered all papers

published during 1990–1999. The way bibliographic data are presented differs from database to database, and some papers would have been indexed in more than one database. Therefore, special efforts were made to unify the data and to eliminate duplicates. Certain journals changed names during the period under study and certain others merged with other journals. For example, *Annals of Ophthalmology* was renamed *Annals of Ophthalmology – Glaucoma*, *Acta Diabetologica Latina* was renamed *Acta Diabetologica*, and *Diabetes/Metabolism Reviews* was renamed *Diabetes/Metabolism Research and Reviews*. These changes were taken care of and the variants of the concerned journals brought under a single entry. For each entry, journal impact factor (IF) and journal publishing country were added by looking up *Journal Citation Reports (JCR)* 1997 (CD-ROM edition). Information about country of publication of journals which are not listed in *JCR* was found in *Publist*, a web source of information on serials. For each paper, citations were looked up from the year of publication till the end of 2000 from both *SCI* and *BBCI*, and the information merged and duplicates eliminated. The extent of international collaboration was estimated by analysing information on multi-authored papers, available for papers indexed in *SCI* and *BBCI*. Based on the number of countries in the byline of each paper, we determined the extent of international collaboration and the countries collaborating often with India and China. This is a macroscopic study and the analysis stops at the level of institutions. We have not looked at publications at the individual author's level.

Results

There were 837 unique papers from India consisting of 667 articles, 111 meeting abstracts, 31 letters, 25 notes and three editorials. Of the 427 unique papers from China, 355 were articles, 67 meeting abstracts, two notes, two editorials and one letter. A large proportion of meeting abstracts, both from India and China, appeared in 1997. Most of these meeting abstracts had appeared in *Diabetologia*. But for two papers, one each in French and German, all Indian papers were written in English. In the case of Chinese papers, 210 were written in Chinese and one each was written in Japanese, French and German, the other 223 being in English. For both India and China, *PubMed* indexes a larger percentage of diabetes research papers than either *SCI* or *BBCI* (Figure 1). Nearly 59.6% of Indian papers and 44% of Chinese papers are covered by *SCI*. The 531 papers from India indexed in *PubMed* amount to 1.11% of the 47,877 papers from all over the world, and China's 303 papers in *PubMed* amount to 0.63%. India's share of diabetes papers in *SCI* is 0.98% and in *BBCI* is 1.61%. Thus India seems to be publishing a greater share in basic sciences-oriented papers (assuming that papers indexed in *BBCI* are of this kind), even if

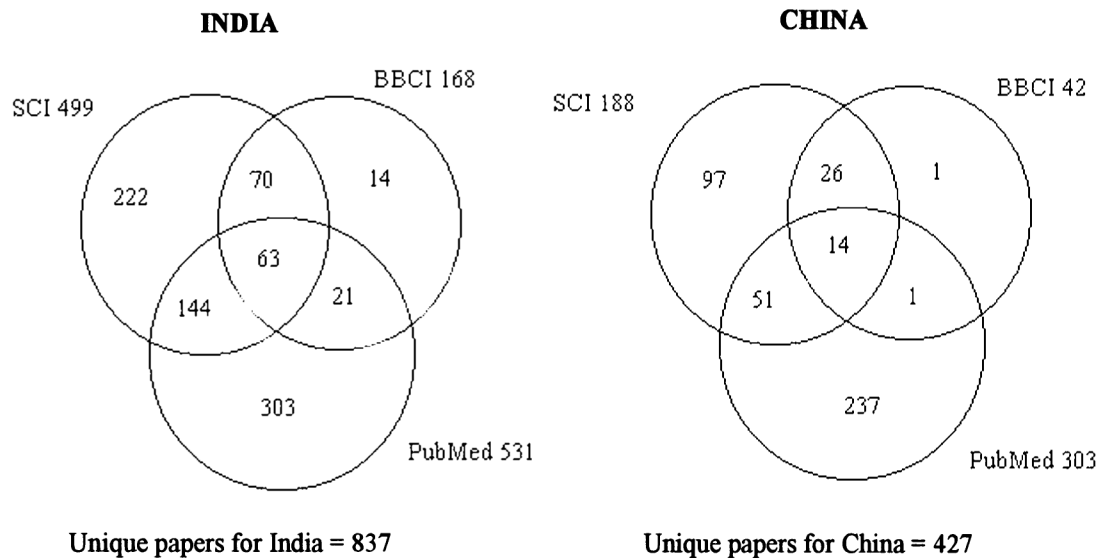


Figure 1. Coverage of Indian and Chinese diabetes research papers in three databases.

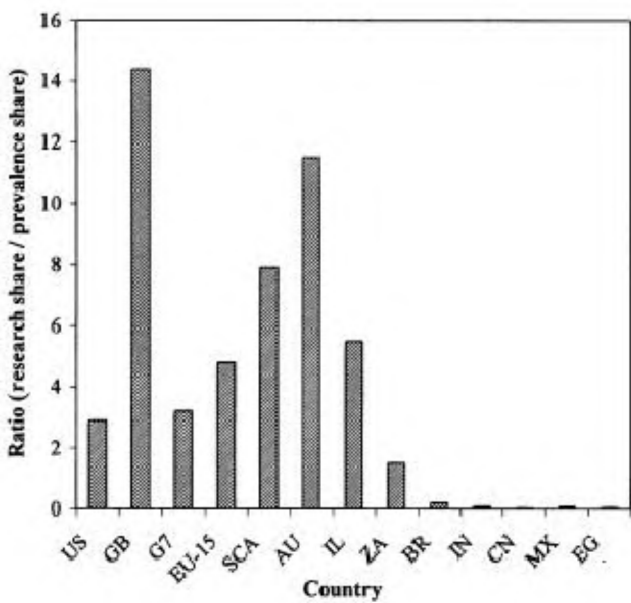


Figure 2. Research share/prevalence ratio for selected countries.

the number of papers is rather small. In tuberculosis also, India's share of papers in *BBCI* is higher than its share in *PubMed*¹². Indeed, if we had not searched *BBCI*, we would have missed only 14 diabetes papers from India and one paper from China. One might ask why then did we include *BBCI* in our study. We are looking at several areas of medical research and we want to capture basic research papers as well. After all, as Juan Rodés of the Liver Unit of the Hospital Clinic of Barcelona points out, the incorporation of new knowledge from molecular and cellular biology into clinical practice and the coordination of both clinical and basic research with medical practice can improve the implementation of scientific

Table 1. Contribution of India and China to the world literature in diabetes[†] and per cent share of prevalence[‡] compared with other countries

	No. of papers 1990–1999	Percentage world share in research [A]	Percentage world share diabetes prevalence [B]	Ratio (research share/ prevalence) [A/B]
World	53523			
US	15967	29.8	10.2	2.9
GB	5403	10.1	0.7	14.4
G7	35621	66.5	20.8	3.2
EU-15*	22218	41.5	8.62	4.8
Scandinavia [#]	4652	8.7	1.1	7.9
Australia	1254	2.3	0.20	11.5
Israel	609	1.1	0.2	5.5
South Africa	137	0.3	0.2	1.5
Brazil	392	0.7	3.6	0.2
India	521	1.0	14.3	0.07
China	188	0.4	11.8	0.03
Mexico	103	0.2	2.8	0.07
Egypt	74	0.1	2.4	0.04

[†]Source: *Science Citation Index*, CD-ROM edition (disk years);

[‡]Calculated from the data for the year 1995 provided by King *et al.*³;

*Luxembourg not included;

[#]Denmark, Finland, Norway and Sweden.

advances in the prevention, diagnosis, and treatment of diseases, and guarantee better health-care services¹³. In our study on mapping cardiovascular disease research, we found that *BBCI* does cover a sizable number of papers not indexed in *PubMed* and *SCI* – 32 of 1903 Indian papers and 33 of 3015 Chinese papers published during 1990–1999¹⁴. In Figure 2, we compare the research outputs of India and China with those of many other countries, based on data from *SCI*, and match the per cent share of world research in diabetes, as seen from *SCI*, with the per cent world share of prevalence of

diabetes. In 1995, over 14% of the world's diabetes patients were in India and yet India accounted for about 1% of research in diabetes (Table 1). Close to 12% of diabetes patients were in China and yet China accounted for less than half a per cent of world's research in diabetes. In contrast, the UK with about 0.7% of the world's diabetes population accounts for more than 10% of the world's research and USA with about 10% of the diabetes population accounts for close to 30% of the world's research. The G7 countries perform two-thirds of the world's research in diabetes, although only about one in five diabetes patients lives in these countries. The Scandinavian countries also perform relatively large volumes of research considering the low levels of prevalence of the disease. The ratio of share of disease burden/share of research is low for most developing countries – Egypt 0.04, Mexico 0.07, Brazil 0.2, Argentina 0.25, Thailand 0.2. This ratio is usually large for the richer countries – Denmark 15.5, the Netherlands 11.5, Australia 11.5, Belgium 11.0, Finland 10.5, Austria 9.0, Ireland 6.7, France 6.3, Sweden 6.2 and Germany 5.3.

The distribution of Indian and Chinese papers over the years is shown in Figure 3. We see a sudden spurt in the number of papers in 1997. This is largely due to the coverage of many meeting abstracts from the two countries, mostly in the journal *Diabetologia*. We have noticed such a spurt in 1997 for most countries, with Canada, the Netherlands, Spain and Belgium being the notable exceptions.

Distribution of papers by journal

Indian researchers have published their work in 197 journals (including 305 papers in 23 Indian journals) from 18 countries in the ten years. Chinese researchers have used 104 journals (including 279 papers in 31 Chinese jour-

nals) published from 13 countries. Apart from home country journals, both Indian and Chinese researchers publish their work often in American, German, British and Dutch journals. Table 2 lists journals in which Indian and Chinese researchers have published their better-cited work. In all, 371 Indian diabetes papers have been cited 1657 times and 65 Chinese papers have been cited 402 times. More than 55% of Indian papers and 84% of Chinese papers were not cited at all. 100 Indian papers published in 68 journals and 178 Chinese papers published in 55 journals have not been cited even once. Journals often used by Indian researchers to publish their findings are *Diabetologia* (IF 5.347, eight papers, two letters and 78 meeting abstracts), *Journal of the Association of Physicians of India* (72 papers), *Indian Journal of Experimental Biology* (54 papers), and *Diabetes Research and Clinical Practice* (42 papers). Chinese researchers publish many of their papers in *Chinese Medical Journal* (IF 0.127, 55 papers), *Chung Hua Nei Ko Tsa Chih* (36 papers), *Diabetologia* (34 papers, including 33 meeting abstracts), and *Chung Hua I Hsueh Tsa Chih* (30 papers).

Distribution of papers by journal country

Indian researchers have published 147 papers in 66 US journals, and of these 78 papers were cited 456 times; 93 papers in 39 UK journals and of these 64 were cited 373 times; 116 papers in 13 German journals, of which 24 were cited 185 times; and 76 papers in 16 Netherlands journals, of which 54 papers were cited 175 times. Chinese researchers have published 68 papers in 33 US journals, 16 papers in 14 UK journals, and seven papers in four Netherlands journals. Of these 22 papers in US journals were cited 211 times, 10 papers in UK journals were cited 89 times and four papers in Netherlands journals were cited 27 times.

Distribution of papers by subfield

We classified the journals into more than 30 subfields using the deluxe classification provided by the Research Department of Institute for Scientific Information (Table 3). Classification at the individual paper level would have been better, but that would have required reading each paper. Unfortunately, 54 journals carrying 301 Indian papers and 42 journals carrying 238 Chinese papers were not found in the deluxe classification of ISI, probably because these are non-SCI journals. India appears to be strong in endocrinology, metabolism and nutrition (clinical) (180 papers in 11 journals); pharmacology and toxicology (66 papers in 19 journals); medical research, general topics (46 papers in nine journals); and endocrinology, nutrition and metabolism (biology and bio-

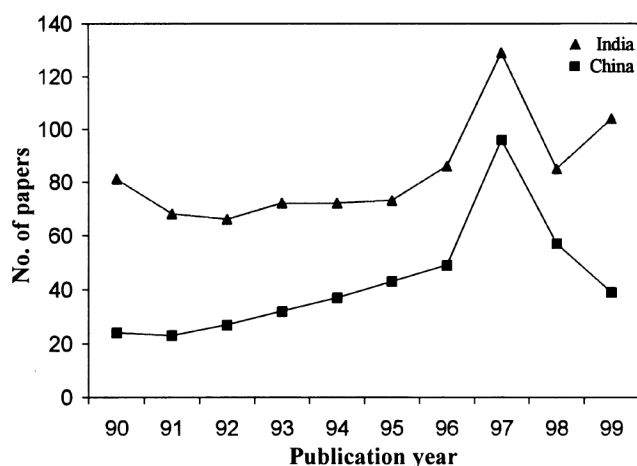


Figure 3. Year-wise distribution of diabetes research papers from India and China.

chemistry) (38 papers in 12 journals). China publishes many papers in general and internal medicine journals (55 papers in one journal); endocrinology, metabolism and nutrition (clinical) (48 papers in six journals); and endocrinology, nutrition and metabolism (biology and biochemistry) (16 papers in ten journals). In both India and China, papers under endocrinology, metabolism and nutrition are better cited: 88 Indian papers were cited 562 times and 14 Chinese papers were cited 193 times. Thirty-six Indian papers in pharmacology and toxicology were cited 171 times, and one Chinese paper in molecular biology and genetics was cited 71 times.

Distribution of papers by journal IF

Both India and China have published a very large percentage of their papers in low-impact journals: 578 (69%) Indian papers and 329 (77%) Chinese papers in journals of IF less than 1.0 (Table 4). The situation is somewhat better than in tuberculosis research (74.3%

Indian papers and 89.6% Chinese papers appearing in journals of IF lower than 1.0)¹² and cardiovascular diseases research (70.6% Indian papers and 80.7% Chinese papers appearing in journals of IF less than 1.0)¹⁴. Only 12 articles, seven letters and 86 meeting abstracts from India and five articles and 53 meeting abstracts from China have appeared in journals of IF > 5.0. From India, there were eight articles in *Diabetologia*, three in *Diabetes* (IF 8.675), and one in *Investigative Ophthalmology and Visual Science* (IF 5.250), and four letters in *Lancet* (IF 16.135). From China there were two articles and one meeting abstract in *Diabetes*, one article each in *Human Molecular Genetics* (IF 8.505) and *Journal of Bone and Mineral Research* (IF 6.695), and one article and 33 meeting abstracts in *Diabetologia*. Leading institutions take pride in publishing most of their papers in high impact journals. For example, more than half of the 1500 publications of the Institut d'Investigacions Biomèdiques August Pi i Sunyer, Barcelona (IDIBAPS), in the past four years has appeared in journals within the first quartile of their speciality¹³. In contrast, papers in almost all fields

Table 2. Journals used to publish often-cited Indian and Chinese research papers

Journal	Journal country	Impact factor (JCR 97)	No. of papers	No. of cited papers	No. of citations
India					
<i>Diabetologia</i>	DE	5.347	88	13	152
<i>Diabetes Care</i>	US	3.321	23	19	112
<i>Diabetes Research and Clinical Practice</i>	NL	0.959	42	34	99
<i>Diabetic Medicine</i>	GB	1.601	13	13	93
<i>Diabetes</i>	US	8.675	3	3	77
<i>Biochemistry International</i>	AU	A	11	9	67
<i>Indian Journal of Experimental Biology</i>	IN	A	54	23	53
<i>Clinical Science</i>	GB	1.820	2	1	49
<i>Medical Science Research</i>	GB	0.367	14	12	39
<i>Indian Journal of Medical Research Section B</i>	IN	A	13	6	38
<i>Journal of Association of Physicians of India</i>	IN	A	72	21	29
<i>Journal of Ethnopharmacology</i>	CH	0.578	18	9	29
<i>Indian Journal of Biochemistry and Biophysics</i>	IN	0.335	15	10	27
<i>Molecular and Cellular Biochemistry</i>	NL	1.345	7	6	25
<i>Pharmacological Research</i>	GB	0.470	6	5	25
114 other journals cited at least once			356	188	743
68 other journals			100	0	0
Total			837	371	1657
China					
<i>Diabetes Care</i>	US	3.321	7	7	115
<i>Human Molecular Genetics</i>	GB	8.505	1	1	71
<i>Diabetes</i>	US	8.675	3	2	54
<i>Diabetes Research and Clinical Practice</i>	NL	0.959	2	2	20
<i>Biological and Pharmaceutical Bulletin</i>	JP	0.864	2	2	15
<i>Journal of Bone and Mineral Research</i>	US	6.695	1	1	14
<i>Tissue Antigens</i>	DK	4.339	1	1	12
<i>Virchows Archiv B, Cell Pathology including Molecular Pathology</i>	DE	A	1	1	7
<i>Biological Trace Element Research</i>	US	0.745	5	3	7
40 other journals cited at least once			226	45	87
55 other journals			178	0	0
Total			427	65	402

A, not indexed in JCR 1997; Citations seen from SCI and BSCI 1990–2000.

Table 3. Indian and Chinese papers in diabetes classified by subfield based on journal title

Subfield	No. of journals	No. of papers	No. of cited papers	No. of citations
<i>India</i>				
Endocrinology, Metabolism and Nutrition*	11	180	88	562
Pharmacology and Toxicology	19	66	36	171
Medical Research, General Topics	9	46	23	119
Endocrinology, Nutrition and Metabolism [†]	12	38	23	89
Cell and Developmental Biology	5	12	9	52
Biochemistry and Biophysics	8	32	19	43
Immunology	4	8	4	42
Neurosciences and Behaviour	6	16	7	40
Urology and Nephrology	3	5	4	34
Ophthalmology	8	17	5	29
Cardiovascular and Respiratory Systems	10	15	9	28
Medical Research, Diagnosis and Treatment	6	11	6	25
Cardiovascular and Hematology Research	2	8	5	20
13 other subfields cited at least once	32	71	30	86
7 other subfields	8	11	0	0
Not indexed	54	301	103	317
Total	197	837	371	1657
<i>China</i>				
Endocrinology, Metabolism and Nutrition*	6	48	14	193
Molecular Biology and Genetics	2	6	1	71
Endocrinology, Nutrition and Metabolism [†]	10	16	12	37
Pharmacology and Toxicology	6	8	2	15
Medical Research, Diagnosis and Treatment	2	4	2	13
Neurology	1	1	1	6
Ophthalmology	2	2	1	6
General and Internal Medicine	1	55	3	6
Cell and Developmental Biology	1	1	1	5
8 other subfields cited at least once	19	33	12	22
9 other subfields	12	15	0	0
Not indexed	42	238	16	28
Total	104	427	65	402

*Clinical; [†]Biology and Biochemistry.

from most developing countries are published in journals of very low impact, many of them not indexed in *SCI*.

Diachronous distribution of citations to highly cited papers

As many papers published in high IF journals by authors from developing countries are not cited often, we thought that besides giving data on number of papers published in journals of different IFs we should also look at the actual citations received by papers in our data set. Indeed, Garfield¹⁵, Seglen¹⁶, and Moed¹⁷ among others, have warned against the improper use of journal IFs in evaluation of research impact. We looked up citations from both *SCI* and *BBCI* and merged the two sets of data removing duplicates. Of the 837 papers from India, only 371 were cited at least once and together they were cited 1657 times. Of the 427 papers from China, only 65 were cited at least once and together they were cited 402 times. If we have not searched *BBCI*, we would have missed 152 citations to Indian papers and 25 citations to Chinese

Table 4. Distribution of Indian and Chinese papers in diabetes by journal IF range

IF range <i>JCR</i> 1997	India		China	
	No. of journals	No. of papers	No. of journals	No. of papers
0.000	53	322	42	238
> 0.0–0.5	27	114	9	67
> 0.5–1.0	40	142	16	24
> 1.0–1.5	26	53	5	5
> 1.5–2.0	15	35	8	9
> 2.0–2.5	12	16	3	4
> 2.5–3.0	8	12	4	5
> 3.0–3.5	1	23	3	9
> 3.5–4.0	4	6	–	–
> 4.0–4.5	2	8	3	8
> 4.5–5.0	1	1	–	–
> 5.0–5.5	2	89	3	38
> 5.5–6.0	1	1	1	1
> 6.0–6.5	–	–	1	6
> 6.5–7.0	–	–	1	1
> 8.5	5	15	5	12
Total	197	837	104	427

papers (Figure 4). In Table 5 we provide data on year-wise distribution of citations to some highly cited papers from the two countries. We also provide the names of the institutions publishing these papers. The three most cited papers from China are recent and are consistently cited well every year.

Distribution of papers by institution

In all, 192 Indian institutions have published at least one paper in the ten years, 21 of them having published ten papers or more; 163 Chinese institutions have published at least one paper, eight of them having contributed more than ten papers (Table 6). Two private research institutions (attached to hospitals) located in Chennai are among the leading producers of diabetes research papers in India. Diabetes Research Centre, Chennai, founded in 1972, has published 74 papers, and of these 45 were cited 289 times. Madras Diabetes Research Foundation (the parent hospital was founded in 1991) has published 27 papers, of which 16 were cited 53 times. The other leading institutions include All India Institute of Medical Sciences, New Delhi, and the Post Graduate Institute of Medical Education and Research, Chandigarh, both of them leading medical research institutions of India. Jawaharlal Nehru University, New Delhi, where there is no clinical research, has published 30 papers, mostly in basic sciences aspect of diabetes, of which 18 are quoted 151 times. National Centre for Cell Science, Pune, has published six papers, of which four were cited a total of seven times. India's output of diabetes research papers comes mainly from academia (549 papers), followed by hospitals (183 papers). Surprisingly, the research departments and councils of the central government, which are strong in physics, chemistry and to some extent engineering, contribute very little to diabetes research (66 papers). In China, much of diabetes research takes place in medical colleges and universities and hospitals. We have identified both Indian and Chinese institutions pub-

lishing papers in high IF journals. Five papers from China-Japan Friendship Hospital, Beijing were cited 109 times.

Distribution by city and state

Papers have come from 69 Indian cities and 37 Chinese cities. The leading Indian cities (Figure 5) are Chennai (159 papers), New Delhi (127), Mumbai (59), Hyderabad (41), Chandigarh (36), Pune (33), Bangalore and Lucknow (29 each), Kolkata (28) and Thiruvananthapuram (25). Tamil Nadu (191 papers), Delhi (127), Maharashtra (104), Uttar Pradesh (84) and Andhra Pradesh (58) are the leading states.

Beijing (157 papers), Shanghai (61), Guangzhou (28) and Changsha (21) are the leading Chinese cities. In China, diabetes research is concentrated in the municipalities of Beijing (157 papers) and Shanghai (61). These are followed by the provinces of Jiangsu (31), Guangdong (30), and Hunan (23 papers).

International collaboration

More than 16% of the 534 Indian papers in diabetes indexed in *SCI* and *BBCI* (86 papers from 37 institutions) and close to 30% of the 190 Chinese papers indexed in *SCI* and *BBCI* (56 papers from 40 institutions) had resulted from collaboration with foreign authors (Table 7). In all of science, technology and medicine, as seen from *SCI* 1998, 17.6% of Indian papers and 28.5% of Chinese papers were found to have foreign co-authors¹⁸. The internationalization index ($100 \times \text{number of international links} / \text{total number of papers from the country}$) for diabetes research for the ten-year period 1990–1999 in India (21.38) and China (36.31) is less than the internationalization index for all of science and technology (28.85 India and 40.13 China for the year 1998) obtained from an analysis of papers indexed in *SCI* 1998 (ref. 19). Both

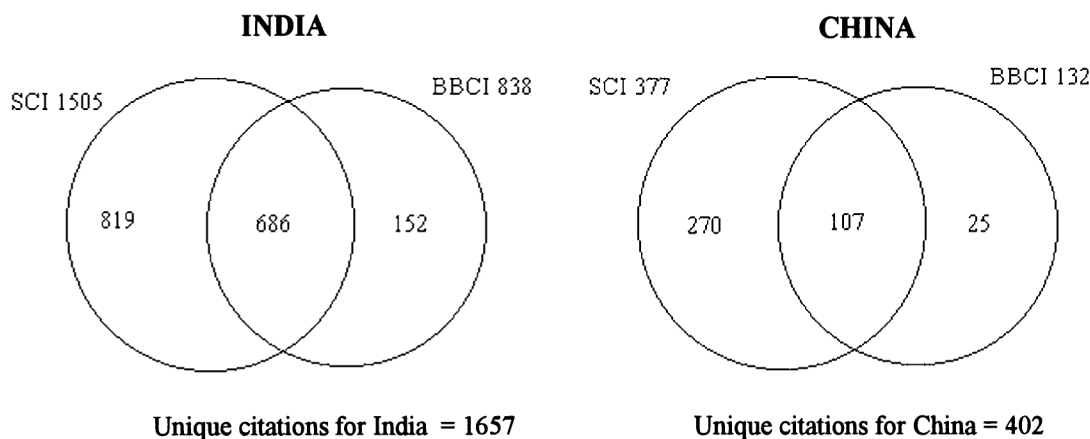


Figure 4. Citations to Indian and Chinese diabetes papers in *SCI* and *BBCI*.

India and China had foreign co-authors in a higher proportion of papers in diabetes than in cardiovascular disease research (11.3% for India, and 23.1% for China)¹⁴. However, in tuberculosis research China had collaborated with foreign institutions in 45% of the 40 papers indexed

in *SCI* and *BBCI*, whereas India had collaborated with foreign institutions in only 7.7% of the papers¹². In diabetes research, India had collaborated with the UK in 40 papers and USA in 22 papers, whereas China had collaborated with USA in 27 papers and Japan in 7 papers in

Table 5. Diachronous distribution of citations to the highly cited diabetes papers from India and China

Paper No.	Year											Total
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	
India												
1							1	11	9	20	8	49
2							1	14	13	5	6	39
3			6	8	2	4	6	6		3		35
4						2	8	7	4	8	3	32
5								3	9	9	10	31
6			2	2	1	3	6	3	4	3	3	27
7					2	3	2	2	3	5	5	22
8				2	4	4	1	3	1	4	3	22
9							2	7	1	4	7	21
10	1	3	2	2	2	2	3	1	3	1		20
11								1	11	1	7	20
12									5	5	10	20
Total	1	3	10	14	11	18	30	58	63	68	62	338
China												
13								2	20	29	30	81
14									16	28	27	71
15									11	22	15	48
16						4	1	4	3		2	14
17					1	2	2	3	4	1	1	14
18		1		1		2	1	2	2	2	2	13
19		1	1	2		3	2			3		12
20					1	2	1	1	1	1	3	10
21									2	4	4	10
Total		2	1	3	2	13	7	12	59	90	84	273

Bibliographic details of Nos 1–21

No.	Cited paper	Times cited	Institution
<i>India</i>			
1	Sundaram, R. K. <i>et al.</i> , <i>Clin. Sci.</i> (GB), 90 , 1996, 255–260	49	Dr A.L.M. Post Graduate Institute of Basic Medical Sciences, Chennai
2	Niki, T. <i>et al.</i> , <i>Diabetes</i> (US), 45 , 1996, 675–678	39	Sir Hurkisondas Nurrotumdas Medical Research Centre, Mumbai
3	Kumari, K. <i>et al.</i> , <i>Diabetes</i> (US), 40 , 1991, 1079–1084	35	Central Drug Research Institute, Lucknow
4	Hitman, G. A. <i>et al.</i> , <i>Diabetologia</i> (DE), 38 , 1995, 481–486	32	Diabetes Research Centre, Chennai
5	Ramachandran, A. <i>et al.</i> , <i>Diabetologia</i> (DE), 40 , 1997, 232–237	31	Diabetes Research Centre, Chennai
6	Sanjeevi, C. B. <i>et al.</i> , <i>Diabetologia</i> , (DE), 35 , 1992, 283–286	27	Madras Medical College, Chennai
7	Saxena, A. K. <i>et al.</i> , <i>Biochem. Pharmacol.</i> (US), 45 , 1993, 539–542	22	Jawaharlal Nehru University, New Delhi
8	Saxena, A. K. <i>et al.</i> , <i>Eur. J. Pharmacol.</i> (NL), 216 , 1992, 123–126	22	Jawaharlal Nehru University, New Delhi
9	Mukherjee, B. <i>et al.</i> , <i>Immunol. Cell Biol.</i> (AU), 72 , 1994, 109–114	21	Jadavpur University, Kolkata
10	Ramachandran, A. <i>et al.</i> , <i>Diabetic Med.</i> (GB), 7 , 1990, 331–334	20	Diabetes Research Centre, Chennai
11	Das, U. N. <i>et al.</i> , <i>Prostag. Leukotr. Ess.</i> (GB), 52 , 1995, 387–391	20	Nizam's Institute of Medical Sciences, Hyderabad
12	Ahmad, J. <i>et al.</i> , <i>Diabetes Care</i> (US), 20 , 1997, 1576–1581	20	Aligarh Muslim University, Aligarh
<i>China</i>			
13	Pan, X. R. <i>et al.</i> , <i>Diabetes Care</i> (US), 20 , 1997, 537–544	81	China–Japan Friendship Hospital, Beijing
14	Marron, M. P. <i>et al.</i> , <i>Hum. Mol. Genet.</i> (GB), 6 , 1997, 1275–1282	71	China Medical University, Shenyang
15	Anderson, R. A. <i>et al.</i> , <i>Diabetes</i> (US), 46 , 1997, 1786–1791	48	Beijing Medical University, Beijing
16	Epstein, S. <i>et al.</i> , <i>J. Bone Miner. Res.</i> (US), 9 , 1994, 557–566	14	Guangdong Medical College, Guangdong
17	Pan, X. R. <i>et al.</i> , <i>Diabetes Care</i> (US), 16 , 1993, 150–156	14	China–Japan Friendship Hospital, Beijing
18	Dowse, G. K. <i>et al.</i> , <i>Diabetes Res. Clin. Pr.</i> (NL), 10 , 1990, 265–279	13	Medical Center of Fudan University, Shanghai
19	Ju, L. Y. <i>et al.</i> , <i>Tissue Antigens</i> (DK), 37 , 1991, 218–223	12	Beijing Children's Hospital, Beijing
20	Kiho, T. <i>et al.</i> , <i>Biol. Pharm. Bull.</i> (JP), 16 , 1993, 1291–1293	10	China Pharmaceutical University, Nanjing
21	Pan, X. R. <i>et al.</i> , <i>Diabetes Care</i> (US), 20 , 1997, 1664–1669	10	China–Japan Friendship Hospital, Beijing

the ten years considered (Table 8). In both cardiovascular diseases research and tuberculosis research, India and China had collaborated with USA in more papers than with any other country. In cardiovascular diseases research, of the 136 internationally co-authored papers from India in the ten years 1990–1999, 75 were co-authored with US researchers and 20 with UK researchers¹⁴. Of the 347 internationally co-authored Chinese papers in cardiovascular diseases research, 155 were co-authored with researchers from USA and 53 were co-authored with Japanese scientists¹⁴. During the same ten years, India had 41 internationally co-authored papers in tuberculosis, including 18 co-authored with US scientists and 14 with UK scientists, and Chinese researchers had published 18 internationally co-authored papers, including nine with US scientists and four with those from Belgium¹². In some papers in diabetes India (and China) had collaborated with institutions in more than one other country. Diabetes Research Centre, Chennai and Madras Diabetes Research Foundation, Chennai had collaborated with foreign laboratories in 30 and 11 papers, respectively. In particular, Diabetes Research Centre, Chennai had collaborated with St Bartholomews and Royal London School

of Medicine and Dentistry, London, in 20 papers, and Madras Diabetes Research Foundation, Chennai had collaborated with the same London hospital in five papers. Diabetes Research Centre, Chennai had collaborated with National Public Health Institute, Helsinki, Finland in nine papers. SCB Medical College, Cuttack had collaborated with Karolinska Institute, Stockholm in five papers, and with University of Perugia, Italy in four papers. Chinese Academy of Preventive Medicine had collaborated with the University of Pittsburgh, USA in four papers. Peking Union Medical College Hospital, Beijing had collaborated with Allegheny University of Health Sciences, USA in four papers.

Collaborative research between advanced and developing-country scientists has increased dramatically in recent years²⁰. In all of science, technology and medicine, India had collaborated with 87 countries during 1986–1988 and during the same period China had collaborated with 54 countries²¹. These numbers increased to 109 countries for India and 107 for China during the period 1995–1997. Per cent share of internationally co-authored Indian papers in all of science rose from 9.5 in 1986–1988 to 15.7 in 1995–1997, but the per cent share of

Table 6. Institutions contributing to diabetes research, number of papers published and citations received

Institution	No. of papers	No. of cited papers	No. of citations
<i>India</i>			
Diabetes Research Centre, Chennai	74	45	289
Jawaharlal Nehru University, New Delhi	30	18	151
Dr A.L.M. Post Graduate Institute of Basic Medical Sciences, Chennai	13	10	109
All India Institute of Medical Sciences, New Delhi	73	22	63
Central Drug Research Institute, Lucknow	12	11	63
Christian Medical College and Hospital, Vellore	18	11	62
King Edward Memorial Hospital and Research Centre, Pune	16	14	60
National Institute of Nutrition, Hyderabad	8	7	54
Madras Diabetes Research Foundation, Chennai	27	16	53
Post Graduate Institute of Medical Education and Research, Chandigarh	29	12	46
Sir Harkisondas Nurrotumdas Medical Research Centre, Mumbai	7	4	44
University of Madras, Chennai	17	9	44
Nizam's Institute of Medical Sciences, Hyderabad	12	6	43
Madras Medical College, Chennai	7	4	38
87 other institutions cited at least once	374	182	538
91 other institutions	120	0	0
Total	837	371	1657
<i>China</i>			
China–Japan Friendship Hospital, Beijing	18	5	109
China Medical University, Shenyang	6	1	71
Beijing Medical University, Beijing	21	5	63
Medical Center of Fudan University, Shanghai	7	4	18
China Pharmaceutical University, Nanjing	3	2	15
Guangdong Medical College, Guangdong	1	1	14
Beijing Children's Hospital, Beijing	1	1	12
Hunan Medical University, Changsha	14	3	11
Peking Union Medical College Hospital, Beijing	27	3	9
32 other institutions cited at least once	128	40	80
122 other institutions	201	0	0
Total	427	65	402

Citations seen from *SCI* and *BBCI* 1990–2000.

internationally co-authored biomedical research papers from India had remained lower throughout: 7.4 in 1986–1988 and 13.2 in 1995–1997. Not only did China have a much higher per cent share of internationally co-authored papers in all of science, technology and medicine (22.9 in 1986–1988 and 28.8 in 1995–1997), but the per cent share of internationally co-authored biomedical research papers remained higher (27.5 in 1986–1988 and 38.7 in 1995–1997) than that for all of science²¹.

While talking about international collaboration, it is pertinent to ask what are the factors that govern such collaboration. The most obvious factor is the knowledge or expertise gradient that exists between the partner countries. The greater the difference, the greater will be

the interest of the poorer partner. Surely shared interest is a major factor. Language could be another determinant. That explains why USA and UK are among the most preferred partners for India. And it also throws up the question of how, despite its distinctly poorer abilities in English compared to India, China manages a much higher level of international collaboration. One pertinent question to ask is whether these collaborations are in areas of research most pertinent to the urgent needs of the developing countries, including research that addresses the most prevalent diseases²².

From the point of view of scientists from the richer countries, availability of data, specimen and trained people to collect them are attractive features. In 33 of the 40 papers in which Indian authors have collaborated with authors from the UK, the latter were first authors. In nine of the 22 Indo-US papers, US authors were first authors. In six of the eight Indo-Swedish papers, Swedish authors were first authors. In 13 of the 27 US–Chinese papers, five of the seven Chinese–Japanese papers, and in four of the six Chinese–French papers, Chinese were not the first authors. If, following Acosta-Cazares *et al.*²³, we classify papers with first authors from a developed country as ‘Safari research’, then a large proportion of Indian and Chinese papers co-authored with developed-country authors fall under this category. Does it mean that diabetes research in India and China continues to remain peripheral?²⁴ Do scientists from the advanced countries view India and China as a source merely of data-



Figure 5. Indian cities contributing to diabetes research.

Table 7. Distribution of diabetes papers from India and China by number of nations in the byline

No. of nations in the byline	No. of papers	
	India	China
2	67	47
3	10	5
4	9	4
Total No. of papers	534	190
No. internationally collaborated	86	56
Percentage papers internationally collaborated	16.13	29.47
No. of international links	114	69
Internationalization Index	21.38	36.31

Table 8. Nations collaborating with India and China in diabetes research

Nation	No. of papers	
	India	China
USA	22	27
Japan	3	7
France	3	6
Hong-Kong	–	6
Australia	6	4
Germany	3	4
Denmark	5	3
Sweden	8	3
Great Britain	40	2
Canada	1	1
India	–	1
Israel	–	1
Mauritius	–	1
Slovakia	–	1
South Korea	–	1
Taiwan	–	1
Finland	9	–
Italy	8	–
Iran	1	–
China	1	–
Kuwait	2	–
The Netherlands	1	–
Bangladesh	1	–
Total No. of links	114	69

gathering and survey-related research and not as partners in the tasks of theoretical synthesis and proposing new theoretical configurations²⁵? These are questions worth investigating.

Discussion

There is a yawning gap between the disease burden and the share of research performed in both India and China. Also, despite the large population sizes, little is known about the epidemiology of diabetes in these two countries.

The Diabetes Research Working Group, appointed by the US Congress, has identified several research areas that present unique opportunities for major advances and changes that will have to be made in the scientific infrastructure to implement this research endeavour, and sees extraordinary opportunities²⁶. Olefsky²⁷ expects to see major accomplishments over the next 25 years that will alter the prevention, treatment and cure of diabetes. But what role India and China are likely to play, one wonders. Given their past performance and current level of interest, one doubts if they will become major players at all in the near future. One thing is certain – they cannot entirely depend on research performed elsewhere for long. As recommended by the International Conference on Health Research for Development, Bangkok²⁸, ‘Each country needs to be able to generate knowledge relevant to its own situation, to allow it to determine its particular health problems, appraise the measures available for dealing with them, and choose the actions likely to produce the greatest improvement in health.’ Most diabetes patients in developed countries are in the 65 + age group, whereas in India and other developing countries the majority of people with diabetes are in the age range 45–64 years³. As Andrew Hattersley²⁹ has put it, what works in the UK may not work in India and vice versa, as environmental and genetic factors can make a world of difference. Genetic influences are important in the aetiology of diabetes. To date the majority of advances in our understanding have been in the rare monogenic subgroups like MODY (maturity onset diabetes of the young). In MODY, description of the genes has led to new clinical insights and diagnostic testing. The major predisposing genes for Type-2 diabetes will be much more difficult to define, but in the next few years several studies should lead to considerable progress in this area²⁹. Such studies would naturally call for close collaboration between clinical researchers and basic sciences researchers. India and China would do well to promote such cross-disciplinary research.

According to Hattersley²⁹, future work on Type-2 diabetes will be considerably helped by very large collaborative collections of DNA from patients and modern high throughput genetic analysis methods. ‘There are many differences between people with Type-2 diabetes in

Europe and UK. In Chennai they are younger, slimmer and respond differently to diabetes and other drugs. I think these differences are fascinating and personally think that these mainly reflect genetic differences and not malnutrition. It certainly needs researching.’ (Andrew Hattersley, pers. commun., 8 December 2001). Indian and Chinese researchers and authorities should come forward to join such international collaborative programmes.

Michaud and Murray³⁰ have shown that in the past the returns on investment on health research have been excellent. The 25-year increase in life expectancy in the US and the enormous gains in the quality of life over the past century confirm the value to human health of new knowledge deriving from biomedical and public health research. ‘The 20th century health revolution appears to have resulted far more substantially from the generation and application of new knowledge,’ says the *World Health Report* 1999 (ref. 31). Unfortunately, less than 4% of global research was devoted to diseases that dominate the burden of disease in developing countries. Funding for research on such essentially developing country diseases (malaria, tuberculosis, acute respiratory tract infections, etc.) is utterly inadequate. It is, therefore, necessary for countries like India and China, leaders of the developing world, to play a more active role in research into diseases that affect them the most. At present there is a mismatch between the burden of disease and health problems and the technical capacity of developing countries to make use of existing knowledge or generate new knowledge to combat this³². It is necessary for developing countries to develop the research capacity necessary to deal with their own health problems through evidence-based decision making³². However, this is easier said than done. But it need not be. After all, both India and China have made very large investments in nuclear and space research, and it should not be difficult for them to increase investment on health research. The citizens’ health is as important as, if not more than a nation’s capability to produce weapons and satellites.

Both India and China account for a much higher world share of research in fields other than medicine. As seen from *MathsciNet*, the web database of the American Mathematical Society, in 2000 researchers from China and India authored more than 10% and 2%, respectively of the world’s papers in mathematics. Chinese scientists authored 9.8% of papers indexed in *Chemical Abstracts* in 2001 and Indian researchers authored 2.5% of papers. In new biology, as seen from *BBCI* 2000, China’s share was 2.03% and India’s share 1.35%. In all of science and technology, as seen from *SCI* 2000, the shares of China and India were 2.83% and 1.55%, respectively. It is difficult to explain why these two Asian giants are not paying adequate attention to health research. There are a few exceptions. As Hicks *et al.*³³ had pointed out, India’s

share in malaria research was 5% in 1989 and 10% in 1990 and 1991, and India's share in leprosy research was above 30% during the three years, and China's share in schistosomiasis research was 9% in 1991. In the 1990s, as seen from *PubMed*, India's share of tuberculosis research was over 5% (ref. 12). The silver lining to the cloud is that at least a few institutions are active in diabetes research. Also worth noting is that the Hyderabad-based Dr Reddy's Research Foundation is actively involved in producing new molecules as potential diabetes drugs and licensing them to major world pharmaceutical companies, such as Novartis and Novo Nordisk. DRF-2593, licensed to Novo Nordisk in March 1997, had entered Phase-2 clinical trials in March 2000. Another compound licensed to Novo Nordisk, DRF-2725, a PPAR (peroxisome proliferator-activated receptor) alpha and gamma agonist, which in preclinical, early clinical and also in Phase-2 trials had shown potential to regulate blood glucose and diabetic dyslipidaemia, has cleared the proof of concept stage and is poised to enter Phase-3 studies. The compound is expected to be among the first to reach the market from a new generation of dual-acting sensitizers currently in development. Novartis has completed preclinical trials of another antidiabetic compound from Dr Reddy's, DRF-4158, meant to treat insulin resistance and associated metabolic disorders.

We believe our findings will stimulate the governments and the medical establishments in these countries to look at health policy more critically, reorient their research priorities and help bring more funds for research in areas of immediate relevance. We believe research on evaluating health research and health policy is as important as medical research per se.

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