

A scientometric analysis of Indian research output in medicine during 1999–2008

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Abstract

Objective: This study analyzes the research activities of India in medicine during 1999–2008, based on the total publication output, its growth rate, quality of papers published and rank of India in the global context. Patterns of international collaborative research output and the major partner countries of India are also discussed. This study also evaluates the research performance of different types of Indian medical colleges, hospitals, research institutes, universities and research foundations and the characteristics of published literature in Indian and foreign journals. It also analyzes the medical research output by disease and organs. **Materials and Methods:** The publication data on medicine has been retrieved by using SCOPUS database. **Results:** India holds 12th rank among the productive countries in medicine research consisting of 65,745 papers with a global publication share of 1.59% and registering a growth rate of 76.68% for the papers published during 1999–2003 to 2004–2008. **Conclusion:** High quality research in India is grossly inadequate and requires strategic planning, investment and resource support. There is also a need to improve the existing medical education system, which should foster research culture.

Key words: India, medical research, publication output, scientometric

INTRODUCTION

India is presently facing a triple burden of diseases: communicable diseases, non-communicable diseases and the emergence of new infections. During the last three decades, more than 30 new organisms have been identified worldwide including HIV, *Vibrio cholera* 0139, Nipah virus, SARS coronavirus and highly pathogenic avian influenza virus A. With the rapid health transition in the country, large and rising burdens of chronic diseases are estimated to account for 53% of all deaths. Non-communicable diseases, especially Diabetes Mellitus, cardiovascular diseases, cancer, stroke and chronic lung diseases, have emerged as a major public health problem. The World Health Organization (WHO) estimates that Indians – who make up 17% of

the world's population – suffer 28% of the world's total years lost to respiratory infections, 25% of the years lost to tuberculosis, 24% of the years lost to diarrhea diseases, 21% of the years lost to measles, and 45% of the years lost to leprosy. In addition, 2.5 million people in India are living with HIV/AIDS. To tackle the menace of communicable and non-communicable diseases, the Ministry of Health and Family Welfare continues to implement National Health Programs throughout the country for vector borne diseases, filaria, leprosy, tuberculosis, blindness, iodine deficiency disorder, mental health, AIDS, cancer, diabetes, cardiovascular diseases and stroke, etc. Central institutions and organizations engaged in health care, medical education and research are continuously being strengthened to tackle the emerging diseases. The strategies put in place in respect of communicable diseases, particularly leprosy and TB, have met with sufficient success. In the case of Vector Borne Diseases program, concerted efforts are being made, while under AIDS, the key strategy has been to build infrastructure and go in for targeted interventions.^[1,2]

There are at present 11,613 hospitals having 540,328 beds in the country, 6281 hospitals in rural areas with 143,069 beds and 3115 hospitals in urban areas with 369,351 beds

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during 2009–2010. The public expenditure on health is 25% and private expenditure is 75%. External assistance to health sector has always been low, ranging from 1 to 3%. There is an urgent need to expand India's medical education system while keeping the issues of quality in consideration. Currently, there are around 300 medical colleges (increasing from 146 in 1991–1992), 290 colleges for BDS courses and 140 colleges conduct MDS courses, with total admissions of 34,595 (increasing from 12,199 in 1991–1992), 23,520 and 2644 students, respectively, during 2009–2010.^[3]

According to a recent survey, India is found to be the fifth largest public funding of neglected disease RandD globally with an investment of \$32.5 million in 2008, 60.1% of which was contributed by Indian Council of Medical Research. Another \$5.1 million (15.6%) was invested by Department of Biotechnology (DBT), while Department of Science and Technology (DST) and Council of Scientific Research (CSIR) contributed \$4.0 million (12.3%) and \$3.8 million (11.7%), respectively. Overall, the diseases receiving the most funding during 2008 were malaria (\$12.5 million or 38.5%), diarrhea diseases (\$4.2 million or 12.9%), tuberculosis (\$4.0 million or 12.4%), leishmaniasis (\$3.1 million or 9.6%), leprosy (\$2.7 million or 8.3%), HIV/AIDS (8.0%), helminthes (worms and flukes) (2.8%), dengue (2.1%), *Salmonella* infections (0.2%) and bacterial pneumonia and meningitis (less than 0.1%).^[4,5]

REVIEW OF LITERATURE

Few quantitative studies have been carried in the past analyzing Indian overall medical or biomedical research. Reddy *et al.*^[6] analyzed the extent of research activities in major Indian medical colleges and concluded that only a few medical colleges (10 out of 128) are active in research. Arora *et al.*^[7] examined the extent of research undertaken in Indian medical colleges and concluded that majority of the 88 Indian medical colleges receiving research grants from ICMR did not produce any research paper in 1991. Only 10% of the projects funded to Indian medical colleges ended up in publications in indexed journals. Deo^[8] examined the current status of undergraduate Indian medical education and research and discussed the steps that need to be taken to promote research at grassroot level.

Satyanarayana^[9] examined Indian contribution in biomedical research (3605 papers in 1990 and 3241 papers in 1994) as indexed in three databases, such as Index Medicus, Excerpta Medica and Tropical Disease Bulletin. Srivastava and Diwakar^[10] provided a comparative analysis of Indian biomedical papers (4732 in 1999 and 6088 in 2007), using SCI database. Kundra^[11] analyzed the research collaboration

(as reflected in co-authored papers) in Indian medical research from 1900 to 1945, by focusing on the pattern of collaboration in basic and applied research, multiplicity of authors and types of collaboration. Dutt *et al.*^[12] analyzed 2183 papers by Chinese researchers and 1034 papers by Indian researchers in the field of plant-based medicine during 1990–2004 as indexed by PubMed. Arunachalam^[13] examined the relevance of Indian medical research during 1981–1985 using Science Citation Index database and concluded that Indian global share of research in medical sciences is very small compared to our contribution in other SandT fields. Arunachalam^[14] re-examined the relevance of Indian medical research by repeating the above study by using MEDLINE database from 1987 to 2004. He examined 19,916 Indian medical papers in 1440 journals, of which 14,822 were published in journals with impact factor less than 1.0 in contrast to only 58 papers in journals with impact factor more than 8.0. Dandona *et al.*^[15] assessed the health research output and concluded that both the magnitude and distribution of research output are not commensurate with the disease profile and burden. In the later much broader study, Dandona *et al.*^[16] examined Indian medical publications in PubMed database and unpublished research reports available in the public domain from 2001 to 2008. According to this study, public health research in India has grown in the past decade, but continues to be inadequate in scope and quality, considering the country's daunting disease burden.

Based on a survey undertaken, Sahni *et al.*^[17] examined various aspects of 75 (out of 113) major published Indian medical journals, of which 22 are included in Index Medicus. Of these journals, only eight were judged by Indian and foreign referees to be of international standard. Jain^[18] examined the visibility and extent of coverage of Indian biomedical and life sciences journals in global alerting services. Pandya^[19] examined the Indian medical research output and discussed the factors for low output of Indian authors and institutions and also indicates that although the number of Indian medical journals is rising rapidly over the years, their contents, regularity and quality leave much to be desired.

Objectives

The main objective of this study is to analyze the research performance of India in medicine in national and global context, as reflected in its publication output during 1999–2008. In particular, the study focuses on the following objectives: (i) the Indian research output, its growth, rank and global publications share and impact, (ii) the patterns of international collaboration and major collaborative partners, (iii) the distribution of Indian medicine publications by disease and organs, (iv) the publications' productivity and impact of leading institutions of India,

(v) the characteristics of most prolific authors and (vi) the patterns of research communication in most productive journals.

MATERIALS AND METHODS

This study is based on the Indian publication data in medicine, retrieved from the Scopus Citation database for 10 years (1999–2008). A 3-year citations window has been used for counting the citations received and to access the impact of Indian research output, leading Indian institutions and authors. The process used in keyword selection was as follows: “affil (India) and pubyear aft 1998 and pubyear bef 2009 and (limit-to (subjarea, “medi”))”. For generating research output on disease and organs, research strategies were developed which primarily used disease name in title, abstract and keywords. For few diseases, like diabetes, malaria, tuberculosis, AIDS and enteric fever, search strategies were developed which used a set of keywords. For calculating the total international collaborative papers in medicine, a separate search strategy, which combines India’s collaboration with 140 major countries, was prepared and this string was combined with the main string to generate India’s total international collaborative output. For analyzing institutional, authors’ and journals’ output, separate institutional, author and journal output strategies strings were evolved and these strings were later combined with the main string.

RESULTS

World research output in medicine, its publication share and rank in global context

The global publication share of top 20 most productive countries in medicine varies from 0.30 to 26.19% during 1999–2008. United States scored the 1st rank with a global publication share of 26.19% (1,079,626 papers) during 1999–2008, followed by the United Kingdom (8.56% share, 352,689 papers), Germany (6.43% share, 265,134 papers), and Japan (6.05% share, 249,310 papers) at 2nd, 3rd and 4th positions, respectively. France, Italy, Canada, China, Spain, Australia and the Netherlands ranked from 5th to 11th positions with their global publication share ranging from 4.47 to 2.47%. India, Sweden, Switzerland, Brazil, Belgium, Taiwan, South Korea, Poland and Russia contributed less than 2% share in world research output in medicine [Table 1]. Among the most productive countries, China witnessed the highest increase of 4.3% in its publication share from the year 1999 to the year 2008 and correspondingly its world ranking improved from 16th in 1999 to 4th in 2008. A marginal increase in the publication share (ranging from 0.05 to 0.88%) was registered by Italy, Canada, Spain, Australia, the Netherlands, India, Brazil, South Korea, Taiwan and Poland during the same period. India ranks 12th position among the top 20 most productive countries in medicine, with a global publication share of 1.59% during 1999–2008 and witnessed a marginal increase of 0.71% in its publication share and achieved a growth rate of 164.15% from the year 1999 to the year 2008 [Table 1].

Table 1: World output and ranking of productive countries in medicine, 1999–2008

Countries	Number of papers			% Share of papers			Rank		
	1999–2008	1999	2008	1999–2008	1999	2008	1999–2008	1999	2008
United States	1,079,626	93,552	12,6795	26.19	27.94	23.01	1	1	1
United Kingdom	352,689	29,783	43,455	8.56	8.90	7.89	2	2	2
Germany	265,134	23,000	29,765	6.43	6.87	5.40	3	4	3
Japan	249,310	24,298	26,881	6.05	7.26	4.88	4	3	5
France	184,260	17,564	22,500	4.47	5.25	4.08	5	5	7
Italy	167,051	13,670	22,746	4.05	4.08	4.13	6	6	6
Canada	145,232	11,158	21,097	3.52	3.33	3.83	7	7	8
China	139,156	3131	28,882	3.38	0.94	5.24	8	16	4
Spain	115,582	9108	16,170	2.80	2.72	2.94	9	8	9
Australia	108,418	7862	16,011	2.63	2.35	2.91	10	9	10
The Netherlands	101,817	7861	13,877	2.47	2.35	2.52	11	10	11
India	65,745	3930	10,381	1.59	1.17	1.88	12	14	12
Sweden	64,157	5756	7959	1.56	1.72	1.44	13	11	16
Switzerland	62,986	5176	8284	1.53	1.55	1.50	14	12	14
Brazil	57,874	3235	9939	1.40	0.97	1.80	15	15	13
Belgium	50,217	4269	6673	1.22	1.28	1.21	16	13	17
Taiwan	42,557	2694	6386	1.03	0.80	1.16	17	17	18
South Korea	40,822	1897	7966	0.99	0.57	1.45	18	19	15
Poland	38,686	2093	4598	0.94	0.63	0.83	19	18	19
Russia	12,197	1196	1516	0.30	0.36	0.28	20	20	20
World	4,122,373	334,793	550,932						

India's research output, its growth and international collaboration in medicine

India's cumulative publication output during 1999–2008 consists of 65,745 papers with an average of 6574.5 papers per year and achieved an average annual publication growth rate of 11.57% and an h-index of 97. The cumulative publication output of India increased from 23,762 papers to 41,983 papers from 1999–2003 to 2004–2008, witnessing a growth of 76.68% [Table 2]. Considering the international collaboration, India contributed 11.87% share

of international collaborative papers (7824 papers) in the cumulative publication output of India during 1999–2008, which rose from 9.04 to 13.51% from 1999–2003 to 2004–2008 [Table 2].

Among the major international collaborative partners of India, as reflected in its international co-authored papers, 32 countries were found to have published more than 75 collaborative papers with India during 1999–2008 [Table 3]. United States became the largest collaborating partner of

Table 2: Medicine: India's research output, its growth and international publications share, 1999–2008

Year	TP	ICP	%ICP	Year	TP	ICP	%ICP
1999	3930	368	9.36	2006	8363	1055	12.62
2000	4057	374	9.22	2007	9061	1259	13.89
2001	4379	348	7.95	2008	10,381	1464	14.10
2002	5074	363	7.15	Total	65,745	7824	11.87
2003	6322	696	11.00				
2004	6621	874	13.20				
2005	7557	1023	13.54				

TP, total papers; ICP, international collaborative papers

Table 3: India's international collaborative papers with leading countries in medicine, 1999–2008

Collaborating country	Number of international collaborative papers			Share of international collaborative papers		
	1999–2003	2004–2008	1999–2008	1999–2003	2004–2008	1999–2008
USA	1006	2581	3587	46.81	45.48	45.85
United Kingdom	438	1253	1691	20.38	22.08	21.61
Australia	147	437	584	6.84	7.70	7.46
Canada	193	407	500	8.98	7.17	6.39
Japan	151	322	473	7.03	5.67	6.05
Germany	117	330	447	5.44	5.81	5.71
France	111	309	420	5.17	5.44	5.37
Switzerland	56	266	322	2.61	4.69	4.12
Italy	54	209	263	2.51	3.68	3.36
The Netherlands	44	201	245	2.05	3.54	3.13
China	41	178	219	1.91	3.14	2.80
Nepal	45	172	217	2.09	3.03	2.77
Singapore	27	155	182	1.26	2.73	2.33
Brazil	35	123	158	1.63	2.17	2.02
Thailand	34	122	156	1.58	2.15	1.99
South Korea	16	138	154	0.74	2.43	1.97
South Africa	1	146	147	0.05	2.57	1.88
Belgium	28	118	146	1.30	2.08	1.87
Sweden	30	112	142	1.40	1.97	1.81
Spain	24	114	138	1.12	2.01	1.76
Pakistan	20	115	135	0.93	2.03	1.73
Malaysia	23	109	132	1.07	1.92	1.69
Israel	32	85	117	1.49	1.50	1.50
Bangladesh	40	73	113	1.86	1.29	1.44
Kuwait	41	56	97	1.91	0.99	1.24
Mexico	20	74	94	0.93	1.30	1.20
Denmark	28	64	92	1.30	1.13	1.18
Turkey	25	64	89	1.16	1.13	1.14
Saudi Arabia	37	50	87	1.72	0.88	1.11
Philippines	31	51	82	1.44	0.90	1.05
Indonesia	23	58	81	1.07	1.02	1.04
Taiwan	11	66	77	0.51	1.16	0.98

India during 1999–2008 by contributing 45.85% publication share in India's total international collaborative papers in medicine, followed by the United Kingdom (21.61% share), Australia, Canada, Japan, Germany, France and Switzerland (between 4 and 8% share), Italy, the Netherlands, Nepal, Singapore, China and Brazil (between 2 and 4%), and so on. On analyzing the shift in international collaborative publication share of major collaborative partner countries of India from 1999–2003 to 2004–2008, it was found that the international collaborative publications share of Canada has decreased by 1.81% (from 8.98 to 7.17%), followed by Japan by 1.36% (from 7.03 to 5.67%) and the USA by 1.33% (from 46.81 to 45.48%). Bangladesh, Kuwait, Denmark, Turkey, Saudi Arabia, Philippines, and Indonesia witnessed a marginal decrease (less than 1%) in their international publication share, while the share of all other collaborating partner countries have increased as that of South Africa by 2.52% (from 0.05 to 2.57%), Switzerland by 2.08% (2.61 to 4.69%), the UK by 1.7% (20.38 to 22.08%), South Korea by 1.69% (0.74 to 2.43%), the Netherlands by 1.49% (2.05 to 3.54%), Singapore by 1.47% (1.26 to 2.73%), China by 1.23% (1.91 to 3.14%), Italy by 1.17% (2.51 to 3.68%) and Pakistan by 1.1% (0.93 to 2.03%), and so on [Table 3].

Analysis of research publication by disease

The Indian research activities under 27 major diseases have been discussed in this section and the publication data are presented in Table 4. The research output has been grouped under the following three groups: research output between 2000 and 10,000 papers – Cancer (9830 papers), cardiovascular diseases (6801 papers), diabetes (2848 papers) and AIDS (2032 papers); (ii) research output between 1000 and 2000 papers – hepatitis (1377 papers), malaria (1162 papers), diarrheal diseases (1210 papers), pneumonia (1061 papers); and (iii) research output between 1 and 999 papers – leprosy (965 papers), respiratory infection (787 papers), asthma (538 papers), enteric fever (475 papers), filariasis (385 papers), polio (350 papers), Kala Azar (353 papers), dengue (300 papers), Japanese encephalitis (270 papers), tetanus (252 papers), leptospirosis (165 papers), *V. cholera* (130 papers), West Nile virus (29 papers), rabies (124 papers), swine flu (63 papers), chikungunya (58 papers), and Meningitis (53 papers) [Table 4].

In terms of global publication share, the contribution of India under various diseases is further divided into the following three categories: between 21 and 30% share – enteric fever (27.63%), leprosy (24.05%); (ii) between 11 and 20% share – Kala Azar (16.82%), chikungunya (15.89%), *V. cholera* (14.82%), filariasis (13.66%), leptospirosis (11.72%), Japanese encephalitis (11.37%); and (iii) less than 10% share – dengue (9.27%), tuberculosis

Table 4: Break-up of Indian research output by 27 major diseases, 1999–2008

Disease	Number of papers, 1999–2008		
	India	World	India's world share
West Nile virus	29	1834	1.58
<i>Vibrio cholera</i>	130	877	14.82
Polio	350	5691	6.15
Cardiovascular disease*	6801	57,0731	1.19
Filariasis	385	2818	13.66
Tetanus	252	6627	3.80
Rabies	154	2037	7.56
Leptospirosis	165	1408	11.72
Chikungunya	58	365	15.89
Diarrheal disease	1210	49,352	2.45
Kala Azar	353	2099	16.82
Cholera	226	3786	5.96
Asthma	538	51,629	1.04
Tuberculosis	3660	46,359	7.89
Malaria	1162	19,242	6.04
Diabetes	2848	17,9714	1.58
AIDS	2032	46,196	4.40
Meningitis	53	4453	1.19
Japanese encephalitis	270	2375	11.37
Hepatitis	1377	64,575	2.13
Pneumonia	1061	62,178	1.71
Enteric fever	475	1719	27.63
Respiratory infection	787	41,234	1.91
Dengue	300	3237	9.27
Leprosy	965	4013	24.05
Cancer	9830	69,0422	1.42
Swine flu	63	9344	0.67

(7.89%), rabies (7.56%), cardiovascular diseases (6.15%), polio (6.15%), malaria (6.04%), cholera (5.96%), AIDS (4.40%), tetanus (3.80%), diarrheal diseases (2.45%), hepatitis (2.13%), respiratory infection (1.91%), pneumonia (1.71%), diabetes (1.58%), West Nile virus (1.58%), cancer (1.42%), Meningo* meningitis (1.19%), asthma (1.04%), and swine flu (0.67%) [Table 4].

The impact of Indian research under various diseases as measured by average citation per paper on a 3-year citation window during 1999–2008 may be put under the following three groups: (i) above 4 – chikungunya (8.33), Kala Azar (6.54), malaria (6.04), West Nile virus (5.0), diabetes (4.64), swine flu (4.43), Japanese encephalitis (4.05) and AIDS (4.0); (ii) between 3 and 3.99 – cholera (3.57), dengue (3.55), pneumonia (3.29), *V. cholera* (3.28), leptospirosis (3.17), Meningo* meningitis (3.17), respiratory infection (3.05) and asthma (3.0); and (iii) between 1 and 2.99 – filariasis (2.88), enteric fever (2.84), cardiovascular diseases (2.73), cancer (2.66), diarrheal diseases (2.45), rabies (2.18) and tetanus (2.13), and leprosy (1.90) [Table 5].

Table 5: Break-up of Indian medicine research output by disease output and quality, 1999–2008

Disease name	TP	TC	ACPP	H-index	NHCP
West Nile virus	29	145	5.0	8	0
<i>Vibrio cholera</i>	130	427	3.28	15	2
Polio	350	770	2.20	15	2
Cardiovascular disease	6801	18,594	2.73	60	80
Filariasis	385	1108	2.88	23	0
Tetanus	252	538	2.13	14	1
Rabies	154	336	2.18	11	0
Leptospirosis	165	523	3.17	15	0
Chikungunya	58	483	8.33	13	2
Diarrheal disease	1210	5990	2.45	41	28
Kala Azar	353	2310	6.54	33	17
Cholera	226	807	3.57	19	5
Asthma	538	1613	3.0	22	6
Tuberculosis	3660	11,467	3.13	47	39
Malaria	1162	19,242	6.04	33	13
Diabetes	2848	13,212	4.64	57	72
AIDS	2032	46,196	4.40	39	27
Meningitis	53	168	3.17	7	1
Japanese encephalitis	270	1095	4.05	23	3
Hepatitis	1377	4749	3.45	36	12
Pneumonia	1061	3492	3.29	28	11
Enteric fever	475	1351	2.84	21	4
Respiratory infection	787	2401	3.05	27	8
Dengue	300	1067	3.55	20	0
Leprosy	965	1833	1.90	23	
Cancer	9830	26,128	2.66	56	73
Swine flu	63	272	4.43	12	0

TP, total papers; TC, total citations; ACPP, average citations per paper; NHCP, number of high cited papers (with 50 or more citations)

Analysis of research publication by different organs of the body

In this section, organ-wise Indian research output during 1999–2008, as shown in Table 6, has been presented, which also indicates the nature and trend of disease prevalent in India. The Indian research output under 21 organs may be grouped under the following categories based on the output: 4001–5000 papers – heart (4586 papers), skin (4486 papers) and brain (4413 papers); (ii) 3001–4000 papers – kidney (3407 papers), eye (3233 papers), muscle (3076 papers), artery (3048 papers); (iii) 1001–2000 papers – neck (1651 papers), breast (1511 papers), vein (1494 papers), intestine (1282 papers), stomach (1086 papers); and (iv) 1–999 papers – nose (886 papers), feet (818 papers), arm (790 papers), genital (684 papers), ear (666 papers), pancreas (642 papers), throat (274 papers) and hormone (3 papers). The growth of Indian research output under 21 organs from 1999–2003 to 2004–2008 varies from –2.35% to 125.10% and may be grouped as follows: (i) above 100% – feet (125.10%), lung (104.08%), skin (103.72%), feet (105.22%) and hormone (100%); (ii) 75–99% – breast (99.80%), stomach (98.35%), pancreas (93.15%), neck (91.70%), brain (86.0%), muscle (77.37%), genital (75.81%) and intestine (75.70%); (iii) 50–74% – eye (67.85%), artery

(63.21%), heart (63.11%) and kidney (62.28%); and (iv) 1–49% – nose (48.87%) and ear (35.59%) [Table 6].

Research profile of different types of indian productive medical institutions

The productive Indian institutions engaged in research activities in medicine are classified into five categories, viz., medical colleges, hospitals, research institutes, universities and foundations. The research output, impact and patterns of international collaboration of these five types of institutions are presented in Tables 7–11.

Medical colleges

The top most productive 31 medical colleges together contributed 36,242 papers in medicine during 1999–2008, accounting for 55.13% share in the cumulative publication output of India in medicine, with an average of 1169 papers per institution. Four medical colleges have registered higher publication output than the group average of all medical colleges (1169 papers). These are All India Institute of Medical Sciences, New Delhi, with 8021 papers, followed by Postgraduate Institute of Medical Education and Research, Chandigarh (8001 papers), Christian Medical College, Vellore (2259 papers), and Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow (2204 papers).

Table 6: Organ-wise break-up of Indian research papers in medicine, 1999–2008

Organ	Number of publications			Growth from 1999–2003 to 2004–2008
	1999–2003	2004–2008	1999–2008	
Brain	1543	2870	4413	86.00
Heart	1743	2843	4586	63.11
Artery	1158	1890	3048	63.21
Vein	550	944	1494	71.64
Lung	1128	2302	3430	104.08
Muscle	1109	1967	3076	77.37
Eye	1207	2026	3233	67.85
Nose	356	530	886	48.87
Ear	281	385	666	35.59
Throat	174	170	274	-2.35
Neck	566	1085	1651	91.70
Skin	1477	3009	4486	103.72
Breast	504	1007	1511	99.80
Stomach	364	722	1086	98.35
Intestine	465	817	1282	75.70
Pancreas	219	423	642	93.15
Kidney	1299	2108	3407	62.28
Genital	248	436	684	75.81
Harmone	1	2	3	100.0
Arm	243	547	790	125.10
Feet	268	550	818	105.22

The cumulative output of these 31 medical colleges registered an average citation per paper of 2.11. Eight medical colleges have registered higher average citations per paper than the group average. These are LV Prasad Eye Institute, Hyderabad, with an average citation per paper of 3.64, followed by Institute of Post Graduate Medical Education and Research, Kolkata (3.15), Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow (2.77), All India Institute of Medical Sciences, New Delhi (2.54), Postgraduate Institute of Medical Education and Research, Chandigarh (2.53), King George Medical College, Lucknow (2.50), Christian Medical College, Vellore (2.27), and Banaras Hindu University Institute of Medical Science, Varanasi (2.20). These 31 medical colleges have registered an average h-index of 19.81 for all their papers during 1999–2008. Twelve medical colleges have achieved higher h-index value than the group average [Table 7].

Medical hospitals

The cumulative publication output of top 23 hospitals consists of 8226 papers, which accounts for 12.51% share in the total publication output of India in medicine during 1999–2008, with an average publication per institute being 357. Seven hospitals contributed more than the average productivity of all hospitals. These are King Edward Memorial Hospital, Bombay, with 1483 papers, followed by Tata Memorial Hospital, Bombay (1293 papers), GB Pant Hospital, Delhi (636 papers), Safdarjung Hospital,

New Delhi (625 papers), Sir Ganga Ram Hospital, Delhi (517 papers), Lok Nayak Hospital, Delhi (462 papers), and PD Hinduja National Hospital and Medical Research Centre, Mumbai (382 papers). The cumulative output of these 23 hospitals registered average citations per paper of 1.87. Seven hospitals have scored higher citations than the group average. These are GB Pant Hospital with average citations per paper of 2.74, followed by Aravind Eyed Hospital (2.66), Tata Memorial Hospital (2.41), Jaslok Hospital and Research centre (2.24), King Edward Memorial Hospital (2.02), and PD Hinduja National Hospital and Bai Jerbai Wadia Hospital for children (1.93 each). These 23 hospitals scored an average h-index of 12.91 for all their papers published during 1999–2008. Of these, 11 hospitals scored higher h-index than the group average. These are Tata Memorial Hospital, Bombay, with an h-index of 27, followed by King Edward Memorial Hospital, Bombay (26), GB Pant Hospital, Delhi (24), PD Hinduja National Hospital and Medical Research Centre, Mumbai (17), Aravind Eye Hospital, Madurai (17), Escorts Heart Institute and Research Centre, Delhi (16), Safdarjung Hospital (15), Bombay Hospital and Medical Research Centre, Mumbai (15), Sir Ganga Ram Hospital, Delhi (14), Lok Nayak Hospital, Delhi (14), and Jaslok Hospital and Research Centre, Mumbai (13) [Table 8].

Research institutes

The cumulative research output of top 15 most productive research institutes in medicine consists of 3210 papers, accounting for 4.88% of the total Indian medical research output and with an average of 214 papers per institute. Six institutes registered higher number of papers than the group average. They are Bhabha Atomic Research Centre, Mumbai, with 363 papers, followed by Indian Institute of Science, Bangalore (313 papers), Central Drug Research Institute, Lucknow (273 papers), Indian Institute of Chemical Biology, Kolkata (258 papers), Centre for Cellular and Molecular Biology, Hyderabad (253 papers), and National Institute of Cholera and Enteric Diseases, Kolkata (246 papers). The total papers published by these 15 research institutes received 11,106 citations, with an average of 3.46 citations per paper. Nine institutes scored higher citations than the group average. These are: Centre for DNA Fingerprints and Diagnostics, Hyderabad, with average citations per paper of 5.32, followed by Centre for Cellular and Molecular Biology, Hyderabad (4.59), National Institute of Immunology, New Delhi (4.41), Institute of Genomics and Integrative Biology, New Delhi (4.26), National Institute of Cholera and Enteric Diseases, Kolkata (4.00), Tuberculosis Research Centre, Chennai (3.89), Indian Institute of Science, Bangalore (3.82), Indian Institute of Chemical Biology, Kolkata (3.74), and Central Food Technological Research Institute, Mysore (3.50). The average h-index value of these 15 research institutes

Table 7: Research productivity and impact of top 31 most productive Indian medical colleges during 1999–2008

Name	TP	TC	ACPP	H-index
All India Institute of Medical Sciences, New Delhi	8021	20,338	2.54	52
Postgraduate Institute of Medical Education and Research, Chandigarh	8001	20,235	2.53	51
Christian Medical College, Vellore	2259	5132	2.27	34
Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow	2204	6113	2.77	34
Maulana Azad Medical College, Delhi	1149	1861	1.62	20
Kasturba Medical College, Manipal	1131	1770	1.56	21
Banaras Hindu University Institute of Medical Science, Varanasi	1119	2461	2.20	29
Sree Chitra Tirunal Institute of Medical Science and Technology, Thiruvananthapuram	998	1745	1.75	22
JIPMER, Pondicherry	991	1278	1.29	15
University College of Medical Sciences, Delhi	937	1377	1.47	20
Governmental Medical College and Hospital, Chandigarh	782	933	1.19	15
Pandit Bhagwat Dayal Sharma Postgraduate Institute of Medical Sciences, Rohtak	696	614	0.88	15
King George Medical College, Lucknow	670	1673	2.50	26
Kasturba Medical College, Mangalore	656	546	0.83	13
LV Prasad Eye Institute, Hyderabad	639	2327	3.64	32
Armed Forces Medical College, Pune	627	390	0.62	12
Lady Harding Medical College, New Delhi	607	810	1.33	15
Medical College and Hospital, Kolkata	485	839	1.73	19
BYL Nair Charitable Hospital and TN Medical College, Mumbai	449	380	0.85	12
Government Medical College, Srinagar	440	116	0.26	6
Amrita Institute of Medical Sciences, Kochi	416	487	1.17	12
Nizam's Institute of Medical Sciences, Hyderabad	400	814	2.04	16
Institute of Post Graduate Medical Education and Research, Kolkata	331	1044	3.15	22
St. John's Medical College, Bangalore	323	690	2.14	16
Government Medical College, Nagpur	306	608	1.99	17
SMS Medical College, Jaipur	298	276	0.93	11
Sri Ramachandra Medical College and Research Institute Deemed University, Chennai	279	419	1.50	13
Indira Gandhi Medical College, Shimla	277	376	1.36	11
Government Medical College, Mysore	252	264	1.05	11
MS Ramaiah Medical College, Bangalore	250	268	1.07	10
Grant Medical College, Mumbai	249	307	1.23	12

TP, total papers; TC, total citations; ACPP, average citations per paper

is 20.53. Eight institutions scored higher h-index value than the group average. These are Centre for Cellular and Molecular Biology, Hyderabad, with an h-index of 27, followed by Indian Institute of Science, Bangalore, and National Institute of Cholera and Enteric Diseases, Kolkata (25 each), Tuberculosis Research Centre, Chennai (24), Indian Institute of Chemical Biology, Kolkata (23), National Institute of Immunology, New Delhi (22), Centre for DNA Fingerprints and Diagnostics, Hyderabad (22), and Central Drug Research Institute, Lucknow (21) [Table 9].

Universities

The research output of 16 most productive Indian universities in medicine consists of 3886 papers, accounting for 5.91% of the total Indian medical research output and with an average of 242.88 papers per university. Five universities have published higher number

of papers than the group average. These are: Banaras Hindu University with 961 papers, followed by Annamalai University (361 papers), University of Delhi (346 papers), Aligarh Muslim University (339 papers), and Madras University (336 papers). The average citations received per paper registered by these universities was 2.44. Eight universities registered higher citations per paper than the group average. These are Jawaharlal Nehru University with average citations per paper of 3.71 citations, followed by Annamalai University (3.30), Jadavpur University (3.21), University of Delhi (3.18), University of Pune (3.07), Madras University (2.72), University of Rajasthan (2.71), and Osmania University (2.50). The average h-index value registered by these universities was 14.13. Six universities have registered higher h-index than the average h-index of all universities. These are Banaras Hindu University with an h-index of 25, followed by Annamalai University (19), University of Rajasthan (19), University of Delhi (18),

Table 8: Research productivity and impact of top 23 most productive Indian hospitals during 1999–2008

Name	TP	TC	ACPP	H-index
King Edward Memorial Hospital, Bombay	1483	3001	2.02	26
Tata Memorial Hospital, Bombay	1293	3119	2.41	27
GB Pant Hospital, Delhi	636	1745	2.74	24
Safdarjung Hospital, New Delhi	625	949	1.52	15
Sir Ganga Ram Hospital, Delhi	517	639	1.24	14
Lok Nayak Hospital, Delhi	462	703	1.52	14
PD Hinduja National Hospital and Medical Research Centre, Mumbai	382	738	1.93	17
Bombay Hospital and Medical Research Centre, Mumbai	269	465	1.73	15
Aravind Eye Hospital, Madurai	269	715	2.66	17
Jaslok Hospital and Research Centre, Mumbai	256	573	2.24	13
Army Hospital Research and Referral Centre, Delhi	235	133	0.57	6
Escorts Heart Institute and Research Centre, Delhi	227	479	2.11	16
Dr. Ram Manohar Lohia Hospital, Delhi	204	359	1.76	11
Guru Teg Bahadur Hospital, Delhi	185	217	1.17	8
St. Stephens Hospital, Delhi	152	169	1.11	8
Indraprastha Apollo Hospital, Delhi	152	180	1.18	7
Bai Jerbai Wadia Hospital for Children, Mumbai	149	287	1.93	11
Kalawati Saran Children's Hospital, Delhi	138	240	1.74	10
Manipal Hospital, Bangalore	125	180	1.44	9
Dr. Balabhai Nanavati Hospital, Mumbai	124	167	1.35	8
Lokmanaya Tilak Municipal General Hospital, Mumbai	120	84	0.70	7
Government General Hospital, Chennai	120	197	1.64	11
Sant Paramanand Hospital, Delhi	103	38	0.37	3
Total output	8226	15,377	1.87	297.00

TP, total papers; TC, total citations; ACPP, average citations per paper

Table 9: Research productivity and impact of top 15 most productive Indian research institutes during 1999–2008

Research institute	TP	TC	ACPP	H-index
Bhabha Atomic Research Centre, Mumbai	363	911	2.51	20
Indian Institute of Science, Bangalore	313	1195	3.82	25
Central Drug Research Institute, Lucknow	273	764	2.80	21
Indian Institute of Chemical Biology, Kolkata	258	965	3.74	23
Centre for Cellular and Molecular Biology, Hyderabad	253	1162	4.59	27
National Institute of Cholera and Enteric Diseases, Kolkata	246	985	4.00	25
Tuberculosis Research Centre, Chennai	198	771	3.89	24
Indian Institute of Toxicology, Lucknow	188	518	2.76	17
Institute of Genomics and Integrative Biology, New Delhi	171	729	4.26	20
National Institute of Communicable Diseases, New Delhi	177	271	1.53	13
National Institute of Malaria Research, New Delhi	162	497	3.07	16
Institute of Nuclear Medicine and Allied Sciences, New Delhi	158	369	2.34	14
National Institute of Immunology, New Delhi	155	684	4.41	22
Central Food Technological Research Institute, Mysore	156	546	3.50	19
Centre for DNA Fingerprints and Diagnostics, Hyderabad	139	739	5.32	22
Total/average	3210	11,106	3.46	20.53

TP, total papers; TC, total citations; ACPP, average citations per paper

Madras University (17) and Jawaharlal Nehru University (17) [Table 10].

Medical research foundations

The research output of 11 most productive Indian research foundations in medicine consists of 851 papers, accounting for 1.29% to the national publication output and with an average of 77.36 papers per foundation, during 1999–2008.

Of these 11 medical research foundations, 3 foundations published higher number of papers than the average of 77.36 papers. These are: Vision Research Foundation, Chennai (251 papers), Medical Research Foundation, Chennai (188 papers), and Madras Diabetes Research Foundation, Chennai (154 papers). These 11 foundations have registered average citations per paper of 3.08. Four foundations have registered higher citations per paper than

Table 10: Research performances of productive Indian universities in medicine during 1999–2008

University	TP	TC	ACPP	H-index
Banaras Hindu University	961	2047	2.13	25
Annamalai University	361	1192	3.30	19
University of Delhi	346	1099	3.18	18
Aligarh Muslim University	339	457	1.35	11
Madras University	336	913	2.72	17
Jawaharlal Nehru University	233	865	3.71	17
Punjab University	231	496	2.15	12
Lucknow University	192	303	1.58	11
University of Calcutta	157	346	2.20	12
Jadavpur University	123	395	3.21	13
University of Rajasthan	115	312	2.71	19
University of Pune	109	335	3.07	13
Guru Nanak Dev University	107	222	2.07	10
Punjabi University	99	134	1.35	9
Osmania University	90	225	2.50	11
Andhra University	87	141	1.62	9

TP, total papers; TC, total citations; ACPP, average citations per paper

the group average. They are Nutrition Foundation of India, Delhi, with average citations per paper of 6.86 citations, followed by Madras Diabetes Research Foundation, Chennai (5.99 citations), Aravind Medical Research Foundation, Tamil Nadu (4.24 citations) and Schizophrenia Research Foundation, Chennai (4.14 citations). These 11 foundations have registered an average h-index of 11.45. Four foundations have scored higher h-index value than the group average. They are Madras Diabetes Research Foundation, Chennai, with an h-index of 25, followed by Vision Research Foundation, Chennai (18), Medical Research Foundation, Chennai (18), and Schizophrenia Research Foundation, Chennai (13).

Research profile of productive indian authors in medicine

The research activities of the most productive 15 Indian authors in medicine published 135 and above papers during 1999–2008 are presented in Table 12. Of these, six authors are affiliated to AIIMS, New Delhi, two to National Institute of Immunohaematology, Mumbai, and one each to other institutions. These 15 most productive authors together contributed 2414 papers in medicine during 1999–2008, with an average of 160.93 papers per author and witnessed the growth of 20.86% for the papers published from 1999–2003 to 2004–2008. Eight authors published higher number of papers than the group average. These are A. Goel with 210 papers, followed by A. K. Mahapatra (183 papers), S.C. Arya (181 papers), A. K. Gupta (180 papers), N. P. Gupta and K. Ghosh (173 papers each), D. M. Thappa (171 papers), and A. Kumar (161 papers).

The total citations received by these 15 authors for their cumulative number of papers during 1999–2008 are 5087,

Table 11: Research productivity and impact of Indian research foundations in medicine during 1999–2008

Foundations	TP	TC	ACPP	H-index
Vision Research Foundation, Chennai	251	513	2.04	18
Medical Research Foundation, Chennai	188	375	1.99	18
Madras Diabetes Research Foundation, Chennai	154	923	5.99	25
Sankara Nethralaya, Chennai	46	104	2.26	9
Aravind Medical Research Foundation, Tamil Nadu	42	178	4.24	11
Sundaram Medical Foundation, Chennai	42	71	1.69	6
Schizophrenia Research Foundation, Chennai	35	145	4.14	13
The Foundation for Medical Research India, Mumbai	30	50	1.67	5
Nutrition Foundation of India, Delhi	22	151	6.86	8
Lata Medical Research Foundation, Nagpur	21	51	2.43	5
MS Swaminathan Research Foundation, Chennai	20	56	2.8	8

TP, total papers; TC, total citations; ACPP, average citations per paper

registering an average of 2.11 citations per paper. The average citations per paper registered by these 15 authors declined from 2.43 in 1999–2003 to 1.84 citations per paper in 2004–2008. Eight authors registered higher citations per paper than the group average. These are N. P. Gupta with average citations per paper of 3.70, followed by C. Sarkar (3.08), A. K. Hemal (3.07), B. Kumar (2.94), R. B. Vajpayee (2.81), D. Mohanty (2.77), A. Kumar (2.43), and S. K. Kabra (2.38).

The cumulative collaborative publications (172) share of these authors to their total research output constitutes only 7.13%. Seven authors registered higher collaborative publications share than the group average of 7.13%. These are R. B. Vajpayee with an international collaborative publications share of 16.30%, followed by J. Biswas (15.22%), A. K. Hemal (14.0%), S. C. Arya (12.15%), N. P. Gupta (8.09%), A. Goel (7.62%), and D. Mohanty (7.14%).

The average h-index value of the papers of these 15 authors during 1999–2008 was 12.67. Eight authors have shown higher value of h-index than the group average. These are N. P. Gupta with an h-index value of 20, followed by A. K. Hemal (18), R. B. Vajpayee (15), A. Goel (15), B. Kumar (14), C. Sarkar (14), S. Kabra (14), and A. Kumar (13).

Patterns of research communication

The patterns of research output in medicine as reflected in publications in the most productive national and

international journals during 1999–2008 is presented in Tables 13 and 14. These 57 productive journals together contributed 41.94% share (27,572 papers) in the

Table 12: Publication productivity, impact and international collaborative papers of 15 most productive Indian authors in medicine

Name of the author	Affiliating address	TP	TC	ACPP	ICP	%ICP	H-index
A. Goel	King Edward Memorial Hospital, Mumbai	210	328	1.56	16	7.62	15
S. C. Arya	Sant Parmanand Hospital, Delhi	181	68	0.38	22	12.15	5
Kanjaksha Ghosh	National Institute of Immunohaematology, Mumbai	173	348	2.01	10	5.78	10
A. K. Mahapatra	All India Institute of Medical Sciences, New Delhi	183	274	1.50	2	1.09	12
N. P. Gupta	Army Referral Hospital, Delhi Cantt.	173	640	3.70	14	8.09	20
A. K. Gupta	Dr. B. R. Ambedkar University, Agra	180	154	0.86	7	3.89	8
A. Kumar	All India Institute of Medical Sciences, Delhi	161	391	2.43	8	4.97	13
D. M. Thappa	Jawaharlal Institute of Postgraduate Medical Education and Research, Pondicherry	171	192	1.12	0	0	10
A. K. Hemal	All India Institute of Medical Sciences, New Delhi	150	461	3.07	21	14	18
B. Kumar	Postgraduate Institute of Medical Education and Research, Chandigarh	146	429	2.94	2	1.37	14
J. Biswas	Sankara Nethralaya, Chennai	138	291	2.11	21	15.22	11
C. Sarkar	All India Institute of Medical Sciences, New Delhi	137	422	3.08	8	5.84	14
S. K. Kabra	All India Institute of Medical Sciences, New Delhi	141	335	2.38	9	6.38	14
D. Mohanty	Institute of Immunohaematology, Mumbai	135	374	2.77	10	7.41	11
R. B. Vajpayee	All India Institute of Medical Sciences, New Delhi	135	380	2.81	22	16.30	15
	Total output 1999–2008	2414	5087	2.11	172	7.13	12.67
	1999–2003	1093	2659	2.43			
	2004–2008	1321	2428	1.84			

TP, total papers; TC, total citations; ACPP, average citations per paper; ICP, international collaborative papers

Table 13: Research output published in productive Indian journals, 1999–2008

Name	Number of papers from Indian journals		
	1999–2003	2004–2008	1999–2008
Indian Pediatrics	1054	1053	2107
Journal of Association of Physicians of India	1100	720	1820
Indian Journal of Pediatrics	746	895	1641
Indian Journal of Pathology and Microbiology	461	761	1222
Neurology India	620	501	1121
Indian Journal of Otolaryngology and Head and Neck Surgery	446	543	989
Indian Journal of Radiology and Imaging	330	639	969
Indian Journal of Dermatology Venereology and Leprology	170	787	957
Journal of the Indian Medical Association	496	407	903
Medical Journal Armed Forces India	285	592	877
Indian Journal of Ophthalmology	382	425	807
Indian Heart Journal	390	325	715
National Medical Journal of India	318	353	671
JK Practitioner	394	269	663
Journal of Postgraduate Medicine	296	332	628
Indian Journal of Gastroenterology	190	400	590
Indian Journal of Medical Microbiology	85	466	551
JK Science	167	355	522
Indian Journal of Medical Sciences	128	348	476
Indian Journal of Urology	49	359	408
Indian Journal of Surgery	0	370	370
Indian Journal of Leprosy	138	138	276
Indian Journal of Cancer	118	153	271
Indian Journal of Occupational and Environmental Medicine	167	103	270
Indian Journal of Practical Pediatrics	56	208	264
Indian Journal of Otolaryngology	115	139	254

Table 14: Research output published in productive international journals in medicine, 1999–2008

Name	Number of papers from foreign journals		
	1999–2003	2004–2008	1999–2008
Journal of Anaesthesiology Clinical Pharmacology	346	363	709
Journal International Medical Sciences Academy	144	282	426
Journal of Communicable Diseases	222	169	391
Lancet	132	205	337
Acta Cytologica	131	158	289
Tropical Doctor	131	156	287
Pediatric Surgery International	167	95	262
Journal of Gastroenterology and Hepatology	101	152	253
Perinatology	85	134	219
Anesthesia and Analgesia	61	156	217
Singapore Medical Journal	87	128	215
International Journal of Gynecology and Obstetrics	87	128	215
Vaccine	59	153	212
International Journal of Dermatology	77	131	208
Journal of Ecophysiology and Occupational Health	30	170	200
International Journal of Tuberculosis and Lung Disease	65	131	196
Journal of Tropical Pediatrics	96	95	191
Asian Cardiovascular and Thoracic Annals	113	74	187
<i>In vitro</i> Cellular and Developmental Biology Plant	79	107	186
Journal of Clinical Microbiology	77	107	184
Diagnostic Cytopathology	91	92	183
Journal of Forensic Medicine and Toxicology	105	76	181
Annals of Thoracic Surgery	79	90	169
Leprosy Review	74	95	169
International Journal of Cardiology	69	99	168
Cornea	90	75	165
Journal of Cataract and Refractive Surgery	84	80	164
Paediatric Anaesthesia	29	135	164
Cytologia	61	101	162
International Urology and Nephrology	69	93	162
Journal of Cancer Research and Therapeutics	0	159	159

cumulative publication output of India during 1999–2008 and witnessed a growth rate of 34.82% for the literature published from 1999–2003 to 2004–2008 in these journals. The publications share of these total productive journals showed decline from 49.42% during 1999–2003 to 37.71% during 2004–2008. Of these, 26 Indian journals contributed 30.94% share (20,342 papers) in contrast to 11% (7230 papers) contribution of 31 international journals. International journals witnessed a higher growth rate of 37.75% than the Indian journals having 30.94% for the publication output from 1999–2003 to 2004–2008. The research output of both national and international journals shows decline in their publication share from 36.62 to 27.73% and from 12.80 to 9.98%, respectively, during 1999–2003 to 2004–2008.

High-cited Papers

The characteristics of top 100 most high-cited papers of India in medicine were also evaluated. Based on publication output of India in this area, 100 papers are identified as highly cited ones, which have received citations right from

their publication till 1 October 2009, from 87 to 543 during 1999–2008. Of these 100 papers, 77 appeared as articles, 19 as reviews, 2 each as short survey and conference paper. Of the 100 high-cited papers, 68 involve international collaboration (35 bilateral and 33 multilateral) and 19 involve national collaboration.

These 100 papers are in citations range of 87–543. Of these 100 papers, 1 paper is in citations range of 501–543, 1 paper in citations range of 401–500, 2 papers in citations range of 301–400, 19 papers in citations range of 201–300, 49 papers in citations range of 101–200, and 28 papers in citations range of 87–100. These 100 high-cited papers together have received 14,759 citations, with average citations per paper of 147.6. The authors of these high-cited papers are affiliated to 72 Indian institutions, including 14 papers from All India Institute of Medical Sciences, New Delhi; 5 papers each from GP Pant Hospital, Delhi, BHU Institute of Medical Sciences, Varanasi and KEM Hospital, Pune; 4 papers from Diabetes Research Centre, MV Hospital for Diabetes, Chennai;

3 papers each from Centre for Cellular and Molecular Biology, Hyderabad, National Chemical Laboratory, Pune, Postgraduate Institute of Medical Education and Research, Chandigarh, Sangath Centre, Goa, and Tata Institute of Fundamental Research, Mumbai; 2 papers each from Agharkar Research Institute, Pune, Balaji Uthan Sangathan, Patna, Cancer Institute, Chennai, Christian Medical College, Vellore, Central Food Technological Institute, Mysore, Indian Council of Medical Research, New Delhi, Indian Institute of Science, Bangalore, Jaslok Hospital, Mumbai, CCS University, Meerut, Kala Azar Research Centre, Muzzafarpur, KG Medical College, Lucknow, LV Prasad Eye Institute, Hyderabad, Maulana Azad Medical College, Delhi, Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow; and 1 paper each from 47 other organizations.

These 100 high-cited papers have appeared in 62 journals, including 11 papers in *Lancet*, 6 papers in *New England Journal of Medicine*, 4 papers in *Theoretical and Applied Genetics*, 3 papers each in *Bulletin of WHO*, *Circulation*, *Journal of Gastroenterology and Hepatology*, *Journal of the National Cancer Institute*, *Nature Genetics* and *Critical Reviews in Food and Nutrition*, 2 papers each in *Diabetes Care*, *Diabetologia*, *International Journal of Obesity*, *Journal of Clinical Endocrinology and Metabolism*, *Journal of Clinical Microbiology*, *Journal of Infectious Diseases*, *Journal of Nutrition*, *Journal of American Medical Association*, *Ophthalmology*, and 1 paper each in 44 other journals.

DISCUSSION AND CONCLUSION

India scored 12th position among the productive countries of the world in medicine during 1999–2008, publishing 65,745 papers, with 1.59% share in the world research output, rising from 23,762 papers in 1999–2003 to 41,983 papers in 2004–2008, and with a publication growth rate of 76.68%. The total international collaborative papers (7824) of India in medicine account for 11.87% share in its cumulative publication output during 1999–2008, increasing from 9.04% in 1999–2003 to 13.51% in 2004–2008. Among the collaborative partners, India has published the highest collaborative research output with USA.

The maximum Indian medicine research output (9830 papers) came from cancer, followed by cardiovascular diseases (6801 papers), diabetes (2848 papers), AIDS (2032 papers), hepatitis (1377 papers), malaria (1162 papers), diarrheal diseases (1210 papers), pneumonia (1061 papers), etc. Organ-wise, the maximum research output came from heart (4586 papers), followed by skin (4486 papers), brain (4413 papers), kidney (3407 papers), eye (3233 papers), muscle (3076 papers), artery (3048 papers), etc.

The research output of productive Indian medical institutions including 31 medical colleges, 23 hospitals, 15 research institutes, 16 universities and 11 research foundations contributed 36,242 papers (55.13% share), 8226 papers (12.51% share), 3210 papers (4.88% share), 3886 papers (5.91% share) and 851 papers (1.29% share), respectively, in medicine during 1999–2008. The impact of research output of medical colleges was the highest with average of 3.64 citations per paper, followed by research institutes (3.46), foundations (3.08%), universities (2.44) and hospitals (1.87). In terms of h-index, the highest (20.53) was achieved by research institutes, followed by medical colleges (19.81), universities (14.13), hospitals (12.91) and foundations (11.45).

The research performance of 15 most prolific Indian authors together contributed 2414 papers in medicine with an average of 160.93 papers per author, and received an average of 2.11 citations per paper, contributing 7.13% of collaborative publications share and average h-index value of 12.67. The research output of India in medicine published in 57 productive journals accounts for 41.94% share in the total publication output of India during 1999–2008.

The top 100 most high-cited papers of India in medicine received citations from 87 to 543 during 1999–2008. Of these 100 papers, 68 involved international collaboration (35 bilateral and 33 multilateral) and 19 involved national collaboration. These 100 high-cited papers together received 14,759 citations, with average citations per paper of 147.6. The authors of these high-cited papers are affiliated to 72 Indian institutions and appeared in 62 journals.

In order to increase the research output, improve the quality and undertake more focused research, there is an urgent need to formulate a national health research plan. There is a need to create a research culture and climate that foster health research. In addition, capacity development for human resource development and infrastructure should be taken as a priority. There is also a need to improve the existing medical education system, which should foster research culture. A clear research career structure and productivity related incentives are required for people involved in research. The efforts of the government should be to make available the tools of modern information technology and biotechnology to health professionals and researchers, which are at present not accessible to majority of researchers. High-quality research in India is grossly inadequate and requires strategic planning, investment, and resource support. There has been a low proportional output in several diseases or conditions that contribute substantially to mortality and morbidity. There is a need

to develop a critical mass of researchers in various sub-fields affecting health. Besides, the resources available for research (human, financial, and infrastructure) should be accessed and used more judiciously to address national priorities. There should be a proper resource allocation to different areas, which should also be monitored regularly. Access to national and international literature and knowledge base should be provided to contributors and users of health research.

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