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

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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
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.[10]

According to a recent survey, India is found to be the fifth largest public funding of neglected disease R&D 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 grassroots 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].

| 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 | 12,679 | 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 (961 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 (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 (8.33), dengue (8.05), *V. cholera* (8.03), West Nile virus (7.89), *Vibrio cholera* (7.78), *Filariasis* (7.17), tetanus (7.03), and leprosy (6.96); (ii) between 3 and 3.99 – cholera (3.57), dengue (3.55), *V. cholera* (3.54), *Filariasis* (3.52), diabetes (3.51), polio (3.50), cancer (3.49), tuberculosis (3.48), asthma (3.47), leprosy (3.46), and swine flu (3.45); and (iii) between 2 and 2.99 – leprosy, enteric fever, diabetes, *Filariasis* and *Chikungunya* [Table 5].

| Disease* | Number of papers, 1999–2008 | India | World | India’s world share |
|----------|-----------------------------|-------|-------|---------------------|
| West Nile virus | 29 | 1834 | 1.58 |
| *Vibrio cholera* | 130 | 877 | 14.82 |
| Polio | 350 | 5691 | 6.15 |
| Cardiovascular disease* | 6801 | 57,073 | 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 | 3796 | 5.96 |
| Asthma | 538 | 51,629 | 1.04 |
| Tuberculosis | 3660 | 46,359 | 7.89 |
| *Malaria* | 1162 | 19,242 | 6.04 |
| *Diabetes* | 2848 | 17,971 | 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 | 69,042 | 1.42 |
| *Swine flu* | 63 | 9344 | 0.67 |

*Note: Data are presented in Table 4. The research output has been grouped under the following three groups: (i) above 4 – chikungunya, Kala Azar, dengue, *V. cholera*, West Nile virus, *Vibrio cholera*, *Filariasis*, tetanus, and leprosy; (ii) between 3 and 3.99 – cholera, dengue, *V. cholera*, *Filariasis*, diabetes, polio, cancer, tuberculosis, asthma, leprosy, and swine flu; and (iii) between 2 and 2.99 – leprosy, enteric fever, diabetes, *Filariasis*, and *Chikungunya*. 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, Kala Azar, dengue, *V. cholera*, West Nile virus, *Vibrio cholera*, *Filariasis*, tetanus, and leprosy; (ii) between and 2.99 – leprosy, enteric fever, diabetes, *Filariasis*, and *Chikungunya*. The number of papers and their share in India’s total international collaborative papers are presented in Table 4.*
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    |
| Vibrio cholera       | 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).
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), Saifdarjung 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 Eye 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), Saifdarjung 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 5.52, 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

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

| Organ   | Number of publications 1999–2003 | Number of publications 2004–2008 | Growth from 1999–2003 to 2004–2008 |
|---------|----------------------------------|----------------------------------|------------------------------------|
| Brain   | 1543                             | 2870                             | 4413                               |
| Heart   | 1743                             | 2843                             | 4586                               |
| Artery  | 1158                             | 1890                             | 3048                               |
| Vein    | 550                              | 944                              | 1494                               |
| Lung    | 1128                             | 2302                             | 3430                               |
| Muscle  | 1109                             | 1967                             | 3076                               |
| Eye     | 1207                             | 2026                             | 3233                               |
| Nose    | 356                              | 530                              | 886                                |
| Ear     | 281                              | 385                              | 666                                |
| Throat  | 174                              | 170                              | 274                                |
| Neck    | 566                              | 1085                             | 1651                               |
| Skin    | 1477                             | 3009                             | 4486                               |
| Breast  | 504                              | 1007                             | 1511                               |
| Stomach | 364                              | 722                              | 1086                               |
| Intestine | 465                          | 817                              | 1282                               |
| Pancreas| 219                              | 423                              | 642                                |
| Kidney  | 1299                             | 2108                             | 3407                               |
| Genital | 248                              | 436                              | 684                                |
| Hormone| 1                                | 2                                | 3                                  |
| Arm     | 243                              | 547                              | 790                                |
| Feet    | 268                              | 550                              | 818                                |

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].

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Gupta and Bala: Indian publication output in medicine

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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 (616 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, Bangalore                   | 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      |
| Panjab University              | 231 | 496 | 2.15 | 12      |
| Lucknow University             | 192 | 303 | 1.58 | 11      |
| University of Delhi            | 157 | 346 | 2.20 | 12      |
| Jawadpur 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).

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.

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, 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 | H-index |
|--------------------------|------------------------------------------------------------------------------------|-----|-----|------|------|--------|
| A. Goel                  | King Edward Memorial Hospital, Mumbai                                             | 210 | 328 | 1.56 | 16   | 7.62   |
| S. C. Arya               | Sant Parmanand Hospital, Delhi                                                    | 181 | 68  | 0.38 | 22   | 12.15  |
| Kanjaksha Ghosh          | National Institute of Immunohaematology, Mumbai                                  | 173 | 348 | 2.01 | 10   | 5.78   |
| A. K. Mahapatra          | All India Institute of Medical Sciences, New Delhi                               | 183 | 274 | 1.50 | 2    | 1.09   |
| N. P. Gupta              | Army Referral Hospital, Delhi Cantt.                                             | 173 | 640 | 3.70 | 14   | 8.09   |
| A. K. Gupta              | Dr. B. R. Ambedkar University, Agra                                              | 180 | 154 | 0.86 | 7    | 3.89   |
| A. Kumar                 | All India Institute of Medical Sciences, Delhi                                   | 161 | 391 | 2.43 | 8    | 4.97   |
| D. M. Thappa             | Jawaharlal Institute of Postgraduate Medical Education and Research, Pondicherry | 171 | 192 | 1.12 | 0    | 10     |
| A. K. Hemal              | All India Institute of Medical Sciences, New Delhi                               | 150 | 461 | 3.07 | 21   | 14     |
| B. Kumar                 | Postgraduate Institute of Medical Education and Research, Chandigarh             | 146 | 429 | 2.94 | 2    | 1.37   |
| J. Biswas                | Sankara Nethralaya, Chennai                                                      | 138 | 291 | 2.11 | 21   | 15.22  |
| C. Sarkar                | All India Institute of Medical Sciences, New Delhi                               | 137 | 422 | 3.08 | 8    | 5.84   |
| S. K. Kabra              | All India Institute of Medical Sciences, New Delhi                               | 141 | 335 | 2.38 | 9    | 6.38   |
| D. Mohanty               | Institute of Immunohaematology, Mumbai                                            | 135 | 374 | 2.77 | 10   | 7.41   |
| R. B. Vajpayee           | All India Institute of Medical Sciences, New Delhi                               | 135 | 380 | 2.81 | 22   | 16.30  |

Total output 1999–2008

| Year        | TP    | TC    | ACPP | %ICP | H-index |
|-------------|-------|-------|------|------|--------|
| 1999–2003   | 2414  | 5087  | 2.11 | 172  | 7.13   |
| 2004–2008   | 1093  | 2659  | 2.43 | 187  | 10.93  |
| 2009–2010   | 1321  | 2428  | 1.84 | 172  | 7.13   |

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

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

| Name                                                 | Number of papers from Indian journals |
|------------------------------------------------------|---------------------------------------|
| 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 Otology                            | 115 139 254                           |
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, Parma, 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 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 an 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 subfields 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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