Mapping neuroscience research in India – a bibliometric approach

Sheikh Mohammed Shahabuddin

Neuroscience research in India has been mapped for the years 1992–2005 using Neuroscience Citation Index (NSCI) and PubMed. A total of 18,138 papers, with 1.31 times citations, have been published in 1975 journals from 47 different countries. Fourteen out of the top 18 productive journals are from India; of which only 6 have Impact Factor 2009 (IF-2009). Interestingly, only 4 out of the 25 highly cited journals are Indian. And 322 papers have appeared in 28 Letters and Communication journals. The dataset has been found to be a perfect fit for the Bradford law of scattering – both verbal and graphical formulations of the law. About 20% of the papers are published in journals which are having no IF, and 61% papers in journals having IF < 3. However, only 128 papers are published in journals having IF > 10, out of which 15 papers have not been cited at all. Papers have authors from 1401 Indian institutions; but only 9.2% institutions contribute 80.1% papers. Also, papers are authored by 1 to 27 authors; multi-author papers are better cited. Collaborations have been studied for papers indexed in NSCI only and not PubMed. Indian authors have international collaborations in only 12% papers indexed in NSCI with authors from 75 different countries – predominantly G7 nations and the internationalization index is 16.14. More than 70% papers have not been cited at all and those published in 1998 have been better cited. Papers drew maximum citations 4–5 years after publication. Papers having international collaborations are cited more often.

Keywords: Bibliometrics, Bradford's Law of Scattering, collaboration study, citation analysis, journal impact factor, neuroscience research.

NEUROSCIENCE is the scientific study of the nervous system. Highly interdisciplinary in nature, neuroscience includes different approaches to study the molecular, cellular, structural, functional, evolutionary, computational and medicinal aspects of the nervous system. Neurological disorders are one of the greatest threats to public health and constituted 6.3% of the total disease burden in 2005. Among neurological disorders, more than half of the burden in DALYs (disability adjusted life years) is contributed by cerebrovascular disease, 12% by Alzheimer and other dementias and 8% each by epilepsy and migraine[1]. Although a dedicated mental health policy is present in approximately 60% of countries covering roughly 72% of the world's population, India has no such policy[2]. However, there is a belief that the National Mental Health Programme practically serves as the mental health policy[3]. Globally, spending on mental health is less than two US dollars per person per year and less than 25 cents in low-income countries[2]. A substantial gap exists between the disease burden due to neurological disorders and the resources available to prevent and treat them. The clarion call by the US President George H. W. Bush declaring 1990s as the 'decade of the brain' triggered neuroscience research globally. '… it is worth mentioning that the last two decades have witnessed an explosion of interest in the field primarily due to the advances in diverse disciplines like molecular biology, immunology, genetics, biotechnology on one hand and microelectronics, computers, newer imaging techniques on the other. Not surprising, it is claimed that 90 per cent of all we know about neurosciences has accumulated during of this period.'[4] In this study we have attempted to view the status of neuroscience research in India during 1992–2005 (14 years) using the published literature as the source, and analysing the same using scientometric tools and techniques.

Sheikh Mohammed Shahabuddin is in the National AIDS Research Institute, Pune 411 026, India. e-mail: sm.shahab@gmail.com

Research methodology

We have downloaded papers in the field of neuroscience from the *Neuroscience Citation Index* (*NSCI*) and *PubMed* so that we have a comprehensive collection of the published literature on neuroscience research in India from 1992 to 2005. The only exception being papers for the year 2005, which we have downloaded from *Science Citation Index Expanded* (*SCI-Expanded*) instead of *NSCI*, as the *NSCI* annual CD for 2005 was not available.

NSCI is the specialty citation index from the publishing house of Thomson Reuters, which publishes *SCI-Expanded* (citation index – web edition for science in general) as well. In this article we consider papers downloaded from *NSCI* and *SCI-Expanded* as one and the same dataset and use the same name *NSCI* to describe both.

We looked for papers with an Indian address in the byline from both *NSCI* and *PubMed*. While *NSCI* indexes addresses of all authors, *PubMed* lists the addresses of only the first author of papers. Thus our *PubMed* search would have missed papers in which Indians are not the first authors. Similarly, as *PubMed* indexes only 42 Indian journals and there are more journals from India in biosciences, some papers might have been missed.

While all papers found in *NSCI* were considered related to neuroscience, we have used the following keywords for searching *PubMed* under the field 'Title/Abstract' for papers in neuroscience: Alzh*, Aneurysm*, Anxi*, Apn*, Ataxia, Brain*, Cerebe*, Cerebra*, Cerebro*, Chorea, CNS, (Cortex NOT Adrenal), Crani*, Dementia*, Depres*, Down S*, Droso*, Dysautonomi*, Encephali*, Epilep*, Gangli*, Glia*, Glio*, Headache*, Hydroceph*, Medull*, Meninge*, Meningi*, Myastheni*, Nerv*, Neura*, Neuri*, Neuro*, Paraly*, Parkin*, Schiz*, Sclero*, Seiz*, Sensory*, Strok*, Synap*, Thrombo*, Tremo*, Tumo* and Vasc*. These keywords were selected consulting medical dictionaries and glossaries.

In case of *PubMed*, the affiliation field does not necessarily include the name of the country. As such we had to search for papers from India indexed in *PubMed* using Boolean OR string containing 'India' and the names of major Indian cities and towns where some research activity takes place. For *SCI-Expanded*, we have downloaded all the papers covered under the subject-category '*Neuroscience*' and affiliation country '*India*'.

Aggregating all the papers thus collected from the above sources and removing duplicates (removal made from the *PubMed* subset) we arrived at our own database, which was analysed further.

We have accounted for changes in the name of journals, merged journals, split journals and other variations. The countries of origin for the journals were added consulting *PubMed* and the Master List of journals from ISI-Thomson. We have added impact factor 2009 (IF-2009) (released in *Journal Citations Report* 2010) to the journals.

Efforts were made to standardize the names of the institution. In cases, such as Seth GS Medical College and King Edward Memorial Hospitals, Sasoon General Hospital and BJ Medical College, etc. where papers may appear either in the name of Medical College or Hospital or both, we have grouped them together because we understand that the institutions may appear different but they are one and the same entity.

For collaborative studies, we have segregated papers into three lists – no collaborations, where papers are either single-authored or multi-authored with all authors belonging to the same department of the same institution; national collaborations, where authors are all Indian but may either belong to different departments of the same institution or belong to different institutions; foreign collaborations, where at least one of the authors is from a foreign country. The lists have been analysed to understand the nature of collaboration in Indian neuroscience research.

We have also looked for citations received by all papers (irrespective of the database) up to 2004, as seen from *NSCI* annual CDs.

In order to have a comparative view of the Indian neuroscience research vis-à-vis world neuroscience research, publication data pertaining to the G7 countries and some developing countries were collected using the annual CDs of *NSCI*.

Results

Between 1992 and 2005, both years inclusive, there were 18,138 papers published in neuroscience as found indexed either in *NSCI* or *PubMed* or both. There are 5234 papers indexed in *NSCI* but not in *PubMed*, 9516 papers indexed in *PubMed* but not in *NSCI* and 3388 papers indexed in both the databases. It is evident that we would have missed out a major portion of the contributions if we had resorted to using any single database. Merging and duplicate removal of papers obtained from two relevant secondary sources thus help compile a comprehensive database of almost all the research papers published in neuroscience in India during 1992–2005. The technique of using two or more databases for mapping research has been used effectively for many other disciplines by Arunachalam and Gunasekaran[5,6].

Growth of literature

In the 14 years (1992–2005) there are 18,138 documents from India, of which 17,026 belong to the categories of articles, letters, notes and review articles. Among these, only 4867 (~ 28.6% papers) were cited on an average 1.31 times. Articles accounted for more than 91.5% of the citable items. As expected, barring nine papers in Chinese and other European languages, virtually all have been written in English.

The number of papers in neuroscience grows steadily, except in 1995, 2004 and 2005, when it falls slightly compared to the previous years. However, the downtrend in 2005 can be attributed to the use of *SCI-Expanded* instead of *NSCI*.

Scattering of neuroscience papers in journals

Indian researchers have used 1975 journals to publish their works in 14 years. Few generalizations, such as 50.01% of the papers were published in 3.7% of the

Table 1. Journals used to publish highly cited Indian papers

Journal	Journal country	IF-2009	Papers	Papers cited	Citations
Brain Research	The Netherlands	2.463	89	64	734
British Journal of Neurosurgery	UK	1.013	150	105	539
Journal of Neurological Sciences	The Netherlands	2.324	244	55	493
Neurology India	India	0.796	1285	278	475
Neurology	USA	8.172	29	20	415
Journal of Neurochemistry	UK	3.999	277	23	384
Indian Journal of Experimental Biology	India	0.55	460	112	342
Nature Genetics	USA	34.284	5	5	323
Journal of Neurosurgery	USA	2.594	82	29	311
Neurosurgery	USA	2.862	36	32	310
Acta Neurologica Scandinavica	Denmark	2.324	66	49	308
American Journal of Neuroradiology	USA	3.296	37	23	260
Neuroscience Letters	Ireland	1.925	71	51	260
Brain Research Bulletin	USA	2.184	34	23	257
Acta Neurochirurgica	Austria	1.472	45	33	249
Epilepsia	USA	4.052	165	27	235
Neuron	USA	13.26	6	6	233
Surgical Neurology	USA	1.382	91	45	229
Journal of Neurology, Neurosurgery & Psychiatry	UK	4.869	58	34	229
Neuroradiology	Germany	2.616	44	31	228
Indian Journal of Medical Research	India	1.516	160	64	226
Journal of Association for Physicians in India	India	No IF	696	132	223
IEEE Transactions on Neural Network	USA	2.889	48	30	223
Psychopharmacology	Germany	4.103	20	16	212
European Journal of Pharmacology	The Netherlands	2.585	36	27	211

journals and 79.6% papers got published in 22.18% journals, substantiate that the distribution of papers across journals is much skewed.

Of the top 18 journals publishing more than 100 papers each, 14 are Indian journals. Of these 14 Indian journals only 6 have IF, namely *Neurology India* (IF = 0.796), *Indian Journal of Experimental Biology* (IF = 0.55), *Indian Journal of Pediatrics* (IF = 0.539), *Indian Pediatrics* (IF = 0.962), *Indian Journal of Medical Research* (IF = 1.516) and *Journal of Postgraduate Medicine* (IF = 1.389). The *Indian Journal of Biochemistry and Biophysics* (published by the Council of Scientific and Industrial Research, India) with 69 papers has the highest citations per paper ratio (CPPR) of 1.74 and the *Indian Journal of Medical Research* (published by the Indian Council of Medical Research, India) with 160 papers has the CPPR of 1.41. The top four productive foreign journals are *Journal of Neurochemistry* (UK; IF = 3.999), *Journal of Neurological Sciences* (The Netherlands; IF = 2.324), *Epilepsia* (US; IF = 4.052) and *British Journal of Neurosurgery* (UK; IF = 1.013).

Interestingly, when journals are arranged in descending order of citations received (citations > 200), only four journals from India figure in the list (Table 1).

In all, 322 papers have appeared in 28 letters and communication journals, which contain short descriptions of important current research findings that are usually fast-tracked for immediate publication because they are considered urgent. Of these 322 papers, 121 papers have been cited 474 times. Twenty-four out of these 28 journals have IF ranging from 0.173 to 7.328. The top three journals in this list are – *Cancer Letters* (IF = 3.741, 74 papers), *Neuroscience Letters* (IF = 1.925, 71 papers), and *FEBS Letters* (IF = 3.541, 40 papers).

Seventy-nine papers from India have appeared either as book chapters or conference proceedings. All but one of these books and conference proceedings (totalling 43 documents) were published from outside India.

Applicability of the Bradford's law of scattering

Research has been made in library and information science (LIS) about how the literature on a particular subject is scattered across different sources. There are various laws explaining the phenomenon; the most popular and the earliest being the Bradford's law of scattering (1934). Later Vickery (1949), Leimkuhler (1967), Brookes (1977) and many others worked on his law with different datasets and presented their own ramifications of the law. While each law applies to a different specific phenomenon, they all tend to demonstrate one thing – that a few (journals, scientists, etc.) account for the many (articles, citations, etc.). In practical terms, it means that there are diminishing returns in trying to do anything exhaustively[7].

We attempted to test the appropriateness of our data into the Bradford's law of scattering. The journals have been divided into three zones in terms of decreasing productivity such that the cumulative number of papers published by journals in the three zones is approximately the

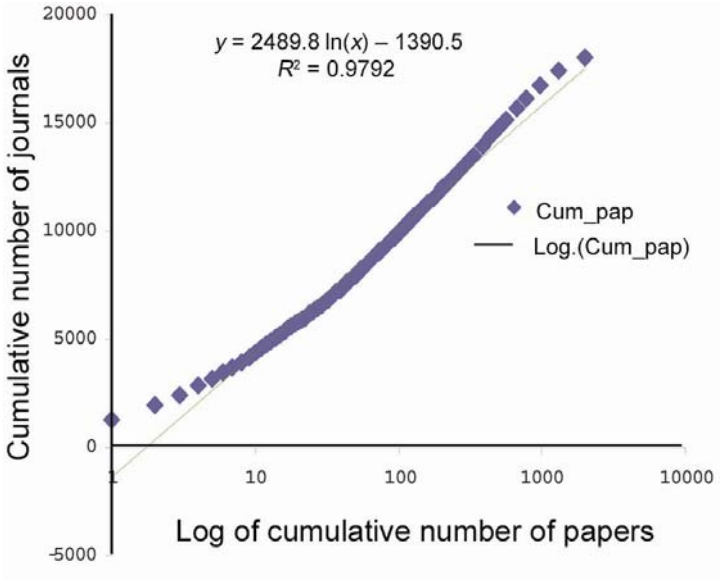

Figure 1. Bradford bibliograph.

same. Hence the first zone has 22 journals publishing 6006 articles; the second zone has 183 journals containing 6004 articles and the third zone has 1770 journals with 6049 articles. Here, 22 represents the number of journals in the nucleus and 8.995 (average of the multiplier between the first and second zone, and the second and third zone) is the Bradford multiplier.

The data yield a perfect Bradford bibliograph (Figure 1) when cumulative total number of papers has been plotted against logarithm of cumulative number of journals. On the Bradford bibliograph, the core journals are those whose points lie on the initial curved part of the graph until tangentially becoming a straight line. The sloping part at the top of the curve is called gross droop, which according to Brookes, indicates the incomplete nature of the database. It is an *S*-shaped smooth curve with almost all the points falling on the line. A simple logarithmic trendline gives the following regression equation.

$$y = 2489.8 \ln(x) - 1390.5,$$

$R^2 = 0.9792$ (close to 1) indicates that the equation fits well with the data.

Distribution of papers by journal country

The 1975 journals used by Indian researchers to publish their works are published from 47 countries. These include 67 journals from India (5902 papers), 719 journals from USA (4255 papers), 486 journals from the UK (3153 papers), 173 journals from The Netherlands (1461 papers) and 119 journals from Germany (670 papers). The citations per paper ratio (CPPR) is 0.4 for papers in Indian journals, 1.96 for papers in US journals, 1.45 for papers in UK journals, 2.08 for papers in journals from The Netherlands and 1.68 for papers in journals from Germany. The 203 papers published in 22 Danish journals were cited on an average 2.59 times. The 73 papers published in six Austrian journals were cited on an average 4.23 times.

Analyses of contributing journals by impact factor

Most Indian papers have appeared in low impact journals. About 61% of the papers have appeared in journals having IF below 3. Also, 3734 papers (~ 20%) are published in 348 journals which are not even listed in *JCR* 2010. There were 4091 papers published in 208 journals whose IF is below 1 and 3609 papers published in 493 journals whose IF is between 1 and 2. At the other extreme, only 128 papers have been published in 31 journals having IF above 10. The highest CPPR above 9 is found in the papers which are published in journals having IF in the range 8.0–8.99 and above 10.

Out of 128 papers in high impact (IF > 10) journals, 29 have appeared in the *Lancet* and 19 papers in the *American Journal of Human Genetics*. The highest CPPRs are scored by five papers in *Nature Genetics* (64.6), two papers in *Science* (48.5) and six papers in *Neuron* (38.83). Besides, one paper in *Pharmacological Reviews* and *Cell* has received exceptionally high citations of 149 and 55 respectively. However, 15 papers have not been cited at all. Even though these papers found their way into journals with high IF (> 10), they only brought down the IF of the journals.

Years ago Arunachalam and Manorama[8] had drawn attention to the phenomenon that quite often Indian authors publish papers in journals above a certain threshold IF,

Table 2. Institutions contributing to neuroscience research

Institution	City	Papers	Papers cited	Citations
All India Institute of Medical Sciences	Delhi	183	521	2,290
Postgraduate Institute of Medical Education and Research	Chandigarh	1,001	274	1,013
National Institute of Mental Health and Neurosciences	Bangalore	984	428	2,388
Seth G S Medical College and KEM Hospital	Mumbai	668	221	1,025
Sanjay Gandhi Postgraduate Institute of Medical Sciences	Lucknow	665	240	1,572
Banaras Hindu University	Varanasi	517	213	1,122
Christian Medical College and Hospital	Vellore	504	177	1,009
Maulana Azad Medical College and Associated Hospital	Delhi	368	73	196
Sree Chitra Thirunal Institute of Medical Sciences and Technology	Thiruvananthapuram	359	103	323
Tata Memorial Hospital	Mumbai	312	54	158
King George Medical College	Lucknow	276	106	469
University College of Medical Sciences and GTB Hospital	Delhi	257	81	208
Panjab University	Chandigarh	257	97	755
Nizam's Institute of Medical Sciences	Hyderabad	248	75	256
Indian Institute of Science	Bangalore	248	79	380
Industrial Toxicology and Research Centre	Lucknow	223	90	400
Central Drug Research Institute	Lucknow	185	69	588
Kasturba Medical College and Hospital	Manipal	177	55	190
Jawaharlal Nehru University	Delhi	163	54	357
Delhi University	Delhi	155	35	177
Lady Hardinge Medical College and Associated Hospital	Delhi	154	36	87
University of Calcutta	Kolkata	151	46	190
Other institutions		10,251	2504	11,326
Total		19,960*	5631	26,479

*Here the total number of papers appears greater because papers have been counted as many times as the number of collaborating institutions.

but these papers do not get cited as often as would be expected on the basis of the IF of the journals. They have shown that Indian papers often bring down the IF of journals. Tibor Braun and colleagues have shown that in most fields the relative citation rate of India (ratio of actual citation rate/expected citation rate) is less than one[9].

Indian institutions involved in neuroscience research

Authors from 1401 institutions have contributed at least one paper in the 14 years considered. Ten institutions have contributed more than 300 papers each (Table 2). These include some prominent names like the All India Institute of Medical Sciences (AIIMS; 1837 papers, CPPR = 1.247), Postgraduate Institute of Medical Education and Research (PGIMER; 1001 papers, CPPR = 1.012), National Institute of Mental Health and Neurosciences (NIMHANS; 984 papers, CPPR = 2.427), Seth G S Medical College and KEM Hospital (668 papers, CPPR = 1.534) and Sanjay Gandhi Postgraduate Institute of Medical Sciences (665 papers, CPPR = 2.364). A large number of institutions (70.76%) have contributed one, two or three papers, most of which have received no citation at all. For majority of institutions, CPPR is below 2. The distribution of papers across different institutions is much skewed – 80.1% papers published by 9.2% institutions.

Distribution of papers by city and state

Authors from 275 cities have contributed to neuroscience research in India. Fifteen cities/towns have contributed more than 150 papers; New Delhi and Mumbai lead the list with 3990 and 2101 papers respectively. Other productive cities are Bangalore (1821 papers), Lucknow (1426 papers), Chandigarh (1372 papers) and Kolkata (1111 papers). Fifty-two cities/towns have published 30 or more papers in the 14 years. At the other extreme, 87 cities/towns have published only one paper and 36 cities/towns have accounted for two papers each.

Delhi, Maharashtra, Uttar Pradesh, Karnataka, Tamil Nadu, Chandigarh, West Bengal and Andhra Pradesh have accounted for more than 1000 papers in the 14 years. There is a tremendous concentration of research institutions and funding in the capital city and few selected states. Fifteen states have accounted for more than 150 papers.

Collaborations and co-authorship

As *NSCI* gives the addresses of all authors in the byline, we could examine international collaboration involving Indian researchers. However, collaborations for 9516 papers from *PubMed* could not be determined as affiliations for only the first authors of papers are given. Of the 8622 papers indexed in *NSCI*, 7580 papers were entirely

Table 3. Countries with which Indian authors collaborate in neuroscience research

Collaborating country	Papers	Papers cited	Citations	CPPR
USA	612	296	3624	5.92
UK	148	65	767	5.18
Germany	75	36	463	6.17
Canada	67	44	468	6.99
Japan	60	31	222	3.7
France	26	13	302	11.62
People's Republic of China	24	6	36	1.5
Australia	24	10	153	6.38
Singapore	22	9	28	1.27
Italy	22	11	95	4.32
Other countries (65)	312	130	1677	5.38
Total	1392*	651	7835	5.63

*This number exceeds the number of internationally collaborated papers (1040), as many papers have collaborators from more than one country.

by Indian authors. In 862 papers there was at least one author from one other country, 109 papers have authors from two other countries and 34 papers have authors from three other countries. At the other extreme, 1 paper has authors from 11 other countries and 6 papers have authors from 9 other countries.

Papers in neuroscience have been authored by 1 to 27 authors in the byline. More than 8% of Indian research papers in neuroscience are single-author papers. About 76% papers have two to five authors. Multi-author papers get more citations than single-author papers. Papers having ten or more authors are better cited than those with less number of authors.

Indian researchers collaborate largely with researchers from the G7 countries (Table 3). Some other notable countries include Brazil (17 papers, CPPR = 10.88), Sweden (13 papers, CPPR = 10.62), Spain (11 papers, CPPR = 9.09) and New Zealand (9 papers, CPPR = 25.78). In all, Indian researchers have had 1040 papers (12.08%) in collaboration with co-authors from 75 countries. Internationalization index (= 100 × No. of international links/ Total number of papers from the country)[10] for neuroscience research in India is 16.14. For diabetes research in India, the internationalization index is 21.35 where 16.1% papers are with foreign collaboration[5], while for science (as a whole) research in India, the internationalization index is 28.85 where 17.62% papers are with foreign collaboration[11]. This clearly shows the relative underperformance of neuroscience research in India.

Co-authored papers tend to be cited more frequently[12] and neuroscience research in India is no exception to this. Papers where Indian authors have foreign co-authors draw more citations than those having no international collaborations. More than 1072 papers have resulted from multi-institutional collaboration within the country.

Citations analysis

The number of citations received each year starting from 1992 to 2004 for papers published in different years from 1992 to 2004 has been worked out. Here we have excluded papers published in 2005. The same set of data has been reoriented as a time series starting from citations received in the same year (designated as the zeroeth year) as publication year to 12 years after publication. In terms of citations won, papers published in 1998 seemed to have done well. These were cited consistently more often than papers published during earlier years and 2000 onwards. However, we could have done a better justification to the data, had we collected citation data for all the papers to the same number of years. Citations to papers rise during the period 2–6 years after the year of publication, peaking out during the fourth and fifth years, and then dropping subsequently. Since IF calculation involves the first two years of citations by papers, the impact of Indian papers seems missed out. This may be further studied in proper perspective to see if Indian papers really make any difference in the IF of journals, if it is calculated for more number of years (say 5 year IF). A recent report[13] shows that average citation received by Indian papers in the field of neuroscience has improved over the last decade. The report also shows that the citations received by Indian papers in neuroscience is 0.59 times the citations received by the total neuroscience papers published across the world.

More than 70% of papers have not been cited at all. This is rather depressing considering the fact that new biology papers and biomedical research papers worldwide are better cited, albeit the papers have larger references when compared to papers in most other fields. Sixteen out of the top 23 highly cited papers from India have appeared in international collaborations. A large number

Table 4. List of highly cited papers

Cited articles	No. of years for citing	Times cited	Type of collaboration
DHAWAN-BN-1996-PHARMACOL-REV-V48-P567	9	149	F
SASTRY-PS-2000-J-NEUROCHEM-V74-P1	5	140	N
GU-SM-1997-NAT-GENE4T-V17-P194	8	129	F
HUDSON-J-1995-BRAIN-RES-B-V36-P425	10	124	F
CHATTERJEE-SS-1998-LIFE-SCI-V63-P499	7	107	F
POPTANI-H-1995-AM-J-NEURORADIOL-V16-P1593	10	103	I
BHALLA-US-1999-SCIENCE-V283-P381	6	97	F
RAMASWAMI-M-1994-NEURON-V13-P363	11	97	F
PIKIELNY-CW-1994-NEURON-V12-P35	11	94	F
MAW-MA-1997-NAT-GENET-V17-P198	8	87	F
MINASSIAN-BA-1998-NAT-GENET-V20-P171	7	73	F
ARUN-P-1998-INDIAN-J-BIOCHEM-BIO-V35-P308	7	72	
SRIRAM-K-1997-BRAIN-RES-V749-P44	8	68	F
SILVEIRA-I-1996-NEUROLOGY-V46-P214	9	66	F
ARUN-P-1998-INDIAN-J-MED-RES-V107-P231	7	62	I
DELBRUTTO-OH-1996-J-NEUROL-SCI-V142-P1	9	62	F
ESTES-PS-1996-J-NEUROSCI-V16-P5443	9	59	F
KUMAR-R-1995-J-NEUROCHEM-V64-P1703	10	59	N
SHIVAKUMAR-BR-1995-J-PHARMACOL-EXP-THER-V274-P1167	10	58	N
RAJSHEKHAR-V-1993-J-NEUROSURG-V78-P402	12	58	N
ZENG-HK-2001-CELL-V107-P617	5	55	F
FONG-GCY-1998-AM-J-HUM-GENET-V63-P1117	7	51	F
MAWALDEWAN-M-1992-J-BIOL-CHEM-V267-P9705	13	51	F

F, Foreign collaboration; N, No collaboration; I, Collaboration with other institutions in India.

of highly cited papers have been written in collaboration with authors mainly from USA, followed by Brazil, Canada, UK, France, Germany and New Zealand. This reasserts our observation that papers having international collaborations are cited more often. Three out of 23 highly cited papers have been published in Indian journals. Review articles tend to draw more citations: three papers – by B. N. Dhawan *et al.* (149 citations), P. S. Sastry *et al.* (140 citations) and O. H. Delbrutto (62 citations) – are review articles (Table 4).

Neuroscience research across the world

The G7 countries are predominant players in the field of neuroscience research. Publication data collected from the *NSCI* CDs (1992–2004) show that USA contributes the majority 41% of papers, followed by Japan (8.9%), England (8.7%), France (8.69%), Germany (5.45%), Canada (5.26%) and Italy (4.83%). The total contribution from the G7 countries stands at 83.71%. On the contrary, developing countries like India (0.78%), China (0.98%), South Korea (0.75%) and Brazil (0.99%) show a meagre contribution. Among the developing nations, Israel (1.36%) has a little better share. This shows that the so-called developed countries, particularly USA, dominate the research world. Earlier we have shown that India collaborates more with the developed countries. The percentage of papers in international collaborations is somewhat less.

Conclusion

In this study, we have compiled a nearly comprehensive database of neuroscience research papers in India for the years 1992–2005. Recently, Bala and Gupta[14] have published a study on neuroscience research in India for 1999–2008 using data from *Scopus*. However, the data from *Scopus* alone do not represent the whole of neuroscience research in India and hence may be inadequate to project a correct picture.

There is no health without mental health. And yet till recently, mental health research was not given due importance. With recent advances in molecular level understanding of the nervous system and the processes that occur in the brain, and with the convergence of approaches from different specialties of new biology, neuroscience research may witness some exciting times. Greater government spending and funding through public–private partnership can foster greater development. More institutions and organizations like Neurological Society of India, Society for Neuroscience, NIMHANS and NBRC should be set up to create awareness through training programmes and workshops among students to take up research in neuroscience.

We suggest that scientists in India should embrace open access (OA) – publishing in OA journals and/or depositing their papers in OA archives. OA improves visibility and hence increases citability in proportion to the importance and quality of the work by removing subscription-based constraint to accessibility[15]. A summary of studies

carried out till the beginning of 2010 showed that 27 studies demonstrated a citation advantage from OA and four did not[16,17].

Collaboration increases productivity and quality of work. We suggest increase in collaboration internationally as well as within India across different institutions.

1. World Health Organization (WHO), Neurological disorders: public health challenges, 2006; http://www.who.int/mental_health/neurology/neurodiso/en/index.html
2. WHO, *Mental Health Atlas*, 2011. http://whqlibdoc.who.int/publications/2011/9799241564359_eng.pdf
3. Khandelwal, S. K., Jhingan, H. P., Ramesh, S., Gupta, R. K. and Srivastava, V. K., India mental health country profile. *Int. Rev. Psychiatry*, 2004, **16**, 126–141.
4. Tandon, P. N., The expanding frontiers of neurosciences. *Ann. Neurosci.*, 2007, **14**, 52–56.
5. Arunachalam, S. and Gunasekaran, S., Diabetes research in India and China today: from literature-based mapping to health-care policy. *Curr. Sci.*, 2002, **82**, 1086–1097.
6. Arunachalam, S. and Gunasekaran, S., Tuberculosis research in India and China: from bibliometrics to research policy. *Curr. Sci.*, 2002, **82**, 933–947.
7. Garfield, E., Bradford's law and related statistical patterns. *Curr. Contents*, 1980, **19**, 5–12.
8. Arunachalam, S. and Manorama, K., Are citation-based quantitative techniques adequate for measuring science on the periphery? *Scientometrics*, 1989, **15**, 393–408.
9. Arunachalam, S., Mapping life sciences research in India: a profile based on BIOSIS 1992–1994. *Curr. Sci.*, 1999, **76**, 1191–1203.
10. Frame, J. D. and Carpenter, M. P., International research collaboration. *Soc. Stud. Sci.*, 1979, **9**, 481–497.
11. Arunachalam, S. and Doss, M. J., Mapping international collaboration in science in Asia through coauthorship analysis. *Curr. Sci.*, 2000, **79**, 621–628.
12. Adams, J., Collaborations: the rise of research networks. *Nature*, 2012, **490**, 335–336.
13. Bound, K. and Thornton, I., Our frugal future: lessons from India's innovation system, July 2012; http://www.nesta.org.uk/news_and_features/frugal_innovations/assets/features/our_frugal_future_lessons_from_indias_innovation_system
14. Bala, A. and Gupta, B. M., Mapping of Indian neuroscience research: a scientometric analysis of research output during 1999–2008. *Neurol. India*, 2010, **58**, 35–41.
15. Gargouri, Y. *et al.*, Self-selected or mandated, open access increases citation impact for higher quality research. *PLoS One*, 2010, **5**, e13636.
16. Swan, A., Policy guidelines for the development and promotion of open access, 2012; http://unesdoc.unesco.org/images/0021/002158/215863e.pdf
17. Swan, A., The open access citation advantage: studies and results to date 2010; http://eprints.ecs.soton.ac.uk/18516

ACKNOWLEDGEMENTS. This paper is my tribute to Late Prof. Subir K. Sen, my teacher. I am highly indebted to Prof. Subir K. Sen and Prof. Subbiah Arunachalam for introducing me to scientometrics and guiding me through this study. They have been source of inspiration and constant mentoring for me. I thank Mr Jinandra Doss for helping me with computer programs used in the study. I also thank the Director, National AIDS Research Institute, for allowing me to work upon this study.

Received 19 November 2012; revised accepted 13 May 2013