India's Research on Covid-19: A Scientometric Assessment of Publications 2019-21

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ABSTRACT

Background: As a global pandemic, Covid-19 has aroused great concern and garnered research interest world-wide In India a growing number of related researches have been published in the last few months. Therefore, a bibliometric analysis of these publications may provide indication of current status and future research trends in the field. **Methods:** The India's literature about Covid-19 published during 2019-2021 were searched in the Scopus database using a well- defined search strategy. The following keywords "Covid 19" or "2019 novel coronavirus" or "coronavirus 2019" or "coronavirus disease 2019" or "2019-novel CoV" or "2019 ncov" or covid 2019 or covid19 or "corona virus 2019" or ncov-2019 or ncov2019 or "nCoV 2019" or 2019-ncov or covid-19 or "Severe acute respiratory syndrome coronavirus 2" or "SARS-CoV-2"were used in "Keyord" and "Title" (Title of articles) tags to reach the relevant publications. VOSviewer was applied to perform the bibliometric analysis of these articles. **Results:** The bibliometric analysis of India's literature on Covid-19 indicates that there were 10,233 indexed publications in Scopus database until April 2021. Of all these publications, 52.87% were original articles and 11.75% (1202) publications received external funding from more than 150 agencies and 27.41% (2805) involve international collaboration with more than 150 countries. USA contributed the largest share (38.47%) in India's international collaborative papers, followed by U.K. (22.89%), China (11.55%), Saudi Arabia (11.44), Australia (11.23%), etc. In the geographical distribution, Delhi tops the publication list (with 21.86% share), followed by Mumbai (7.30%), Chennai (7.27%), Pune (6.44%) and Kolkata (6.04%). Among population age groups, "Adults" accounts for the largest publication share (9.98%), followed by "Middle Aged" (5.07%), "Children" (3.65%), "Aged" (3.65%) and "Adolescents" (2.82%). "Treatment studies" among prominent topics, account for the largest publication share (34.12% share), followed by "Clinical Studies" (13.13%), "Epidemiology" (10.54%),

"Imaging and Diagnostics" (9.64%), "Pathophysiology" (6.27%), and etc. The 1311 organizations and 3413 authors participated in India's research on Covid-19, of which the top 30 organizations and authors contributed 43.50% and 11.57% national publication share and 45.62% and 32.14% national citation share. AIIMS-New Delhi and PGIMER-Chandigarh were the most productive organizations (with 623 and 468 papers). IVRI-Bareilly (21.32 and 4.44) and IIT-New Delhi (12.37 and 2.58) were the most impactful organizations. V. Wiwanitkit and K. Dhama were the most productive authors (with 182 and. 107 papers). R. Sah (42.89 and 8.93) and A. Misra (41.93 and 8.74) were the most impactful authors. *International Journal of Research in Pharmaceutical Sciences* (270 papers) and *Indian Journal of Ophthalmology* (210 papers) were the most productive journals. *Science of the Total Environment* (43.98) and *Asian Journal of Psychiatry* (19.19) were the most impactful journals. **Conclusion:** The paper provides a deeper understanding of the current Covid-19 research milieu in India, by identifying key players (and their collaboration linkages) and key sub-fields, while highlighting potential patterns that could assist future researchers in their scientific pursuits.

Key words: Covid-19, SARS-CoV-2, India, Publications, Bibliometrics, Scientometrics.

INTRODUCTION

The Covid-19 virus cases worldwide has surpassed more than 2 billion (223, 022,538) resulting in more than four million (4,602, 882) deaths in 234 countries of the world as on 5 September 2021. The global surge in cases is highlighting the widening gap in inoculation rates between wealthy and poor nations. Cases are still rising in about in about one third of the world countries, many of which have not even given half of the population their first vaccine dose.[1]

At least, 2.6% of the world population has been infected since the pandemic started. It took over a year for cases to hit the 100 million mark, while the next 100 million were reported in the just over next 6 months.

Globally USA reported the largest number of cases (4.0330 million), followed by India (3.3174 million), Brazil (2.0928 million), U.K. (0.7132 million), Russia Federation (0.7102 million), France (0.6675 million), etc. Globally, the largest number of deaths (649,292) are reported by USA, followed by Brazil (584, 421), India (442,009), Russia Federation (191,165), U.K. (133,841), Columbia (129, 766), France (113, 441), etc.[2]

In terms of global share, India accounts for 14.87% share of global cases and 9.60% share of global deaths from Covid-19. Despite challenges in

terms of large population and risk groups, India has done remarkably well in managing the Covid-19 pandemic. India was quick to identify gaps and rapidly provided innovative solutions or surveillance and testing. The government ramped up testing capacity, diagnostic centers and supply of critical equipment and medicines. With ICMRs rapid intervention, India had more than 2,900 Covid-19 testing labs, more than 541 million samples have been tested and 1.5 million tests are conducted every day. The Department of Biotechnology (DBT) has launched a pan-India 1000 SARS-CoV-2 RNA genome sequencing programme. India's Covid-19 vaccination drive has shown the strength of India's vaccine manufacturing capabilities for inoculating such a large population of which many reside in the remotest villages. With the massive support of India's governments, India is able to accelerate and expand its Covid-19 vaccination drive.[3]

India has proven track record of strong pharma and vaccine manufacturing capabilities. The first indigenous developed Covid-19 vaccine (Covaxin) led by ICMR in collaboration with Bharat Biotech; Serum Institute's Covishield; Sputnik (in private hospitals) have been rolled out

across the country. ZyCoV-D. The world first placid DNA vaccine, has received EUA, and many other candidates from India companies are in advanced stage of trials.[3]

The Covid-19 pandemic has highlighted hurdles in India's quest to become a leader in translational research. The government has funded dozens of proposals from labs and companies to develop Covid-19 vaccines, drugs and diagnostics, intending to create local solutions to the pandemic. Some investments have paid off, yielding two licensed vaccines, Covaxin and Covishield, and a range of diagnostic tests.[4]

The Government of India has provided a lot of funding in Covid-19 R&D through its various scientific agencies. Under the Covid-19 research consortium, as a part of the comprehensive efforts to facilitate development of indigenous research solutions to tackle Covid-19, 107 projects were supported in thematic areas of vaccines (17), diagnostics (45), therapeutics (22) and biomedical interventions (23). To advance biomedical research, the DBT has supported five Covid-19 biorepositories. Further, the Indian SARS-CoV-2 Genomic Consortium (INSACOG), a consortium of 28 regional sequencing labs, was launched, to ascertain the status of new variants of SARS-CoV-2. Under "Mission Covid Suraksha - The Indian Covid-19 vaccine development mission" is being implemented, supporting the development of Covid-19 vaccine candidates (5), facilities for animal challenge studies (3), facilities for immunogenicity assays (3), clinical trial sites (19). Additionally, facility enhancement of Bharat Biotech and three public sector undertakings to support augmented production of Covaxin, is also being supported under the mission.[5]

Indian pharmaceutical companies are one of the leading manufacturers of vaccine in the world, are utilizing its capacity to its maximum, and are one among the forerunners in vaccine research against Covid-19 across the globe.[6]

Literature Review

Only a select few bibliometric studies have been carried output on India's contribution to Covid-19. Among such studies, Gautam, Maheshwari, Kaushal-Deep, Bhat and Jaggi[7] examined India's literature on Covid-19 as indexed in Scopus database till 10 April 2020. It explores the status of current research, the contribution of various countries, organizations and authors, the association of various authors with each other, the role of collaboration between several institutions and the position of India in current explosive ongoing research. Pathak[8] analyzed India's publications (742 records with 196 citations) on Covid-19 as covered in Dimension database till 11 May 2020. The author observed that All Institute of Medical Sciences is the most productive organization with 65 publications. Preprint servers such as MedRXiv and BiorXiv are the leading databases where Indian authors have made available their research output. Raju N and Patil[9] assessed India's publications on Covid-19, as covered in WHO Covid-19 database covering three months period (2 March 2020 to 12 May 2020. Their focus of analysis was on growth, identifications of most important organizations, authors, journals and geographical state and areas of focus in type of studies. Prajapati and Kanadia[10] studied the Indian contribution (1129 records) to Covid-19 research, with a focus on identification of important players, collaboration between countries and authors, funding received and identification and co-occurrence of keywords, etc. Ghosh[11] studied India's publications (3104 records) on Covid-19 indexed in Web of Science database till 29 April 2021. The study intends to focus on citations, *h*-index, document type, prolific authors, authorship pattern, degree of collaboration, most preferred journals, publishers, top rated research institutions and research fields under WOS categories. Raman, Vinuesa and Nedungadi[12] examined India's publication trends and citation structure in Covid-19 along with the identification of major

research clusters. By performing network analysis of authors, citations, institutions, keywords, and countries, the authors explored their semantic associations. The authors observe an increasing number of sustainable development-related studies from the Covid-19 domain, particularly concerning the topic of good health and well-being.

Bibliometric analysis is an indispensable statistic tool to map the state of the art in a given area of scientific knowledge and identify essential information for various purposes, such as prospecting research opportunities and substantiating scientific researches. The present paper uses a method of bibliometric analysis for mapping the state of the art and identifying gaps and trends of research. The method encompasses instruments to identify and analyze the scientific performance of articles, authors, institutions, countries, and journals based on the number of citations, to reveal the trends of the field studied through the analysis of keywords, and to identify and cluster scientific gaps from most recent publications.[13]

Methodology

Published papers were retrieved via a topic search (title/keyword) in Scopus database on 6 June 2021. The Scopus database currently is the world's largest abstract and citation database of peer-reviewed scientific literature compared with PubMed or Web of Science.

Regarding Covid-19, the key terms used in the search engine of Scopus were either in Title or Keyword ("Covid 19" or "2019 novel coronavirus" or "coronavirus 2019" or "coronavirus disease 2019" or "2019-novel CoV" or "2019 ncov" or covid 2019 or covid 19 or "corona virus 2019" or ncov-2019 or ncov2019 or "nCoV 2019" or 2019-ncov or covid-19 or "Severe acute respiratory syndrome coronavirus 2" or "SARS-CoV-2".

Covid-19 related relevant data were downloaded from the Scopus database and then analyzed the retrieved data through Excel to collect the following indicators: (1) publication output; (2) document type; (3) country/region; (4) institute and authors; (5) journal; (6) citation.

VOSviewer v.1.6.14 (https://www.vosviewer.com/) is used here to construct and visualize network terms used in title/abstract articles to detect hot topics in this field.

TITLE ("Covid 19" OR "2019 novel coronavirus" OR "coronavirus 2019" OR "coronavirus disease 2019" OR "2019-novel CoV" OR "2019 ncov" OR covid 2019 OR covid 19 OR "corona virus 2019" OR ncov-2019 OR ncov2019 OR "nCoV 2019" OR 2019-ncov OR covid-19 OR "Severe acute respiratory syndrome coronavirus 2" OR "SARS-CoV-2") OR KEY ("Covid 19" OR "2019 novel coronavirus" OR "coronavirus 2019" OR "coronavirus disease 2019" OR "2019-novel CoV" OR "2019 ncov" OR covid 2019 OR covid 19 OR "corona virus 2019" OR ncov-2019 OR ncov2019 OR "nCoV 2019" OR 2019-ncov OR covid-19 OR "Severe acute respiratory syndrome coronavirus 2" OR "SARS-CoV-2") AND (LIMIT-TO (AFFILCOUNTRY,"India"))

Objectives

The main objectives of the current study is to assess the India's scientific output of Covid-19 research from its early stage of the outbreak till 6 June 2021 using bibliometric methods and techniques. In particular, it aims to study the distribution of India's publications by type and source, to identify funded papers and agencies, to identify international collaborative papers, most important collaborative countries, organizations and authors, distribution of papers by broad subjects and identification of important keywords, to identify the top organizations and authors and study their collaborative network linkages, to identify important sources of research and to identify the top cited publications and to study their bibliometric characteristics

ANALYSIS AND RESULTS

The global research on Covid-19 constitutes 144256 publications, as indexed in Scopus database. Among top 10 countries contributing to global publications, the largest number and share is contributed by USA (38332 publications and 26.59% share), followed by U.K. (16065 publications and 11.13% share), China (14998 publications and 10.39% share), Italy (12812 publications and 8.88% share), India (10233 publications and 7.09% share), Spain (6356 publications and 4.40% share), Canada (6248 publications and 4.33% share), Germany (6225 publications and 4.31% share), France (5569 publications and 3.86%)) and Australia (5541 publications and 3.84% share). The combined out of top 10 countries constitute 101277 publications which account for 70.16% share of global output.

The 10233 Indian publications (2019=3, 2020=6037 and 2021=4193) on Covid-19 received 49168 citations, averaging 4.80 citations per publication. Of the 10233 Indian publications, 1202 received funding support from more than 150 external national and international funding agencies. These 1202 funded publications have received 10602 citations, averaging 8.82 citations per publication. Table 1 lists top 12 Indian and foreign funding agencies supporting Indian research on Covid-19 along with their output. Of the total output, articles, reviews and letters contributed the largest publications share (52.87%, 17.5% and 16.59%), followed by conference papers, notes and editorials (4.33%, 3.62% and 3.01%), book chapters (1.33%), erratum and data paper (0.18% and 0.10%).

Collaborative Linkages of India's Publication Output

Among India's output (10233) on Covid-19, 2805 publications (27.41%) involve international collaboration. These 2805 ICP received 45865 citations, averaging to 16.35 CPP. India's collaboration with 10 select countries has varied from 6.92% to 38.47% of its total Covid-19 ICP output. India's collaboration with the USA was the largest (38.47% of India's ICP output), followed by U.K. (22.89%), China (11.55%), Saudi Arabia (11.44), Australia (11.23%) and for other five countries varying from 6.92% to 9.91%. In terms of research impact, Indo-Chinese collaborative papers registered the highest citation impact per paper (CPP) of 17.71, followed by Indo-Brazil (15.40), Indo-Italy (14.16), Indo-Germany (13.61), etc. India's collaborative network linkages with top 10 countries are depicted in Table 2 and Figure 1.

Top 10 Foreign Organizations Collaborating with India Organizations

The top 10 foreign organizations collaborating with Indian organizations in Covid-19 are listed in Table 4. Among these 10 foreign organizations, Hainan Medical University, China tops the list with 92 collaborative papers, followed by King Saud University, Saudi Arabia (73 papers), University of New South Wales, Sydney, Australia (66 papers), University of Toronto, Canada (59 papers), etc. Among collaboration between top 10 foreign organizations and Indian organizations, Hainan Medical University, China and Dr D.Y. Patll VIdyapeeth, Pune registered the highest number (85) of collaborative papers, followed by Tribhuvan University, Nepal and IVRI-Bareilly (33 papers) University of New South Wales, Sydney, Australia and Georgia Institute of Global Health, New Delhi (19 papers), University of New South Wales, Sydney, Australia and MAHA-Manipal and Tribhuvan University, Nepal and College of Veterinary Science Mathura (18 papers each), etc. (Table 3)

Top 10 Foreign Authors Collaborating with Indian Authors

The top 10 foreign authors collaborating with Indian authors in Covid-19 research are listed in Table 4. Among these 10 foreign authors,

Table 1: Top 12 Indian and Foreign Funding Agencies Supporting Covid-19 Research in India.

S.No	Name of the Indian Agency	TP	TC	CPP	S.No	Name of Foreign Agency	TP	TC	CPP
1	Department of Science and Technology (DST), India	233	1974	8.47	1	National Institute of Health, USA	99	1249	12.62
2	Department of Biotechnology (DBT), India	131	1062	8.11	2	U.S. Department of Health and Human Service	90	1163	12.92
3	Council of Scientific and Industrial Research (CSIR), India	127	931	7.33	3	King Saud University, Saudi Arabia	44	148	3.36
4	Indian Council of Medical Research (ICMR), India	126	1184	9.40	4	European Commission	36	986	27.39
5	Science and Engineering Board (SEB), India	126	1347	10.69	5	National Research Foundation of Korea	32	549	17.16
6	University Grants Commission (UGC), India	133	563	4.23	6	Bangladesh Council of Scientific and Industrial Research	30	198	6.60
7	Ministry of Human Resource Development (MHRD), India	38	395	10.39	7	U.K. Research and Innovation	30	991	33.03
8	Department of Biotechnology, West Bengal	26	376	14.46	8	National Institute of Health Research	28	643	22.96
9	Department of Science and Technology, Kerala	24	386	16.08	9	World Health Organization	28	479	17.11
10	Department of Science and Technology, West Bengal	24	170	7.08	10	Bill and Melinda Gates Foundation	27	594	22.00
11	Ministry of Health and Social Welfare (MHSW), India	18	40	2.22	11	National Natural Foundation of China	27	596	22.07
12	Indian Council of Agricultural Research (ICAR), India	16	134	8.38	12	National Aeronautics and Space Administration	25	289	11.56

TP=Total papers; TC=Total citations; CPP=Citations per publication

Table 2: Contribution and Share of Top 10 Foreign Countries in India's Publication Output.

S.No	Collaborative Country	TP	%TP	TC	CPP
1	USA	1079	38.47	10561	9.79
2	U.K.	642	22.89	7253	11.30
3	China	324	11.55	5739	17.71
4	Saudi Arabia	321	11.44	4227	13.17
5	Australia	315	11.23	3479	11.04
6	Italy	278	9.91	3936	14.16
7	Canada	240	8.56	3117	12.99
8	Thailand	210	7.49	1505	7.17
9	Brazil	200	7.13	3080	15.40
10	Germany	194	6.92	2641	13.61
	India's total	2805		45865	16.35

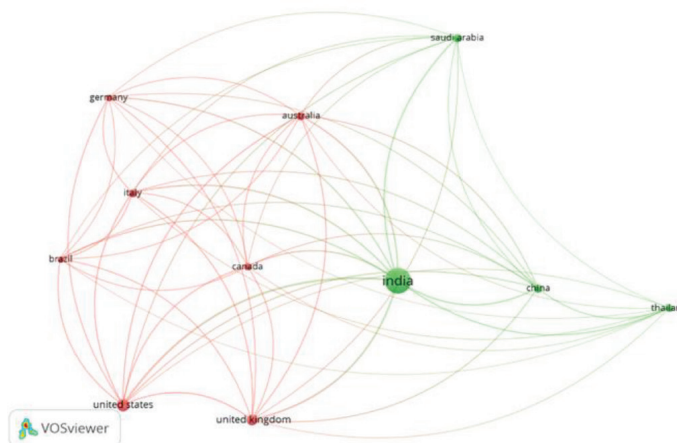TP=Total papers; TC=Total citations; CPP=Citations per publication

Figure 1: Networks Map of Top-10 highly collaborative foreign countries with India.

Table 3: List of Top 10 Most Productive Foreign Organizations Collaborating with Indian Organizations.

S.No	Name of the Foreign Organization	TP	TC	CPP	Indian Collaborating Organization (No. of papers)
1	Hainan Medical University, China	92	318	3.46	Dr D.Y. Patll VIdyapeeth, Pune (85 papers)
2	King Saud University, Saudi Arabia	73	446	6.11	Jamia Millia Islamia (7 papers); North Eastern University (5 papers0, Aligarh Muslim University (5 papers)
3	University of New South Wales (UNSW), Sydney, Australia	66	1109	16.80	Georgia Institute of Global Health (GIGH)(19 papers), MAHA-Manipal (18 papers)
4	University of Toronto, Canada	59	855	14.49	Tata Memorial Hospital (5 papers), NIMANS-Bangalore (4 papers)
5	Organisation Mondiale la Sante, Switzerland	57	838	14.70	National Institute of Virology (5 papers), Maulana Azad Medical College (3 papers)
6	Tribhuvan University, Nepal	53	1553	29.30	IVRI-Bareilly (33 papers), College of Veterinary Science Mathura (18 papers),
7	Harvard Medical School	51	940	18.43	MAHE (6), PGIMER-Chandigarh (6 papers), AIIMS-New Delhi (5 papers), KMC- Manipal (5 papers), NIHMANS (5 papers)
8	University of Oxford, U.K.	48	556	11.58	MAHE-Manipal (6 papers), GIGH-New Delhi (6 papers), AIIMS-New Delhi (5 papers), PGIMER-Chandigarh (4 papers), CMC-Vellore (4 papers)
9	Sapienza Universita di Roma, Italy	48	410	8.54	Treat well Skin Hospital, Jammu (4 papers), Wockhardt Hospital (3 papers), Jamia Millia Islamia (3 papers)
10	Chinese University of Hong Kong	46	1178	25.61	Tata Memorial Hospital (5 papers), Asian Institute of Gastroenterology (4 papers)

TP=Total papers; TC=Total citations; CPP=Citations per publication

A.J. Rodriquez-Moralesj, Columbia tops the list with 34 collaborative papers, followed by M. Goldust, Switzerland and A.A. Rabaan, USA (29 papers each), H. Harapan, Indonesia and M. Jafferany, USA (22 papers each), etc. Among collaboration between top 10 foreign authors and Indian authors, A.J. Rodriquez-Moralesj. Columbia and K. Dhama, India collaborated in 32 papers, followed by A.A. Rabaan, USA and K. Dhama, India (27 papers), A.J. Rodriquez-Moralesj. Columbia and R.Sah, India (24 papers), H. Harapan, Indonesia and K. Dhami (22 papers) (Table 4).

Geographical Distribution of Indian Output

The city-wise publication output of India's research on Covid-19 research is listed in Table 6. The top 20 cities individually contributed 1.0% to 21.86% publication share: 1 city contributing 21.86%, 4 cities

contributing (from 6.04% to 7.30%), four cities contributing (from 3.74% to 5.88%) and the rest of the 12 cities contributed (from 1.0% to 3.74%). Together, the top 10 and 20 Indian cities account for 70.25% and 85.72% share in Indian Output. In terms of citation impact, Srinagar registered the highest citation impact per paper (9.16), followed by Ahmedabad (8.29), Kolkata (7.80), Mumbai (7.01%), etc (Table 5).

Distribution of Papers by Population Age Groups

On analyzing India's research on Covid-19 by population age groups, it was observed that the maximum focus was on "Adults" (with 9.98% publication share), followed by "Middle Aged" (5.07%), "Childern" (3.65%), "Aged"(3.65%) and "Adolescents" (2.82%). The publications in "Aged" group registered the highest citation impact per

Table 4: List of Top 10 Most Productive Authors Collaborating with Indian Authors.

S.No.	Name of the Foreign Author	Affiliation of the Foreign Author	TP	TC	CPP	Number of collaborative papers with Indian Authors
1	A.J. Rodriquez-Moralesj.	Universidad Tecnologica de Pereira, Columbia	51.03	51.03	51.03	K. Dhama (32 papers); R.Sah (24 Ppers); R.Tiwari (17 papers); Y.S.Malik (10 papers), S.K.Patel (8 papers)(All from IVRI)
2	M. Goldust	Universitatspital Basel, Switzerland	6.86	6.86	6.86	M. Gupta (5 papers) (Treatwell Skin Center, Jammu)
3	A.A. Rabaan	John Hopkins Aramco Healthcare, USA	47.45	47.45	47.45	K. Dhama (27 papers); R.Sah (21 Ppers); R.Tiwari (12 papers); Y.S.Malik (7 papers), S.K.Patel (6 papers)(All from IVRI)
4	H. Harapan	Universitat Syiah Kuala, Indonesia	46.95	46.95	46.95	K.Dhami (22 papers)< R.Tiwari (11 papers), S.K.Patel (8 papers) (All from IVRI)
5	M. Jafferany	Central Michigan University, USA	7.36	7.36	7.36	M.Gupta (4 papers)(as above)
6	S.M.Y. Arafat	Enam Medical College and Hospital, Bangladesh	10.86	10.86	10.86	S.K.Kar (16 papers)(KGMU-Lucknow); V.Menon(7 papers) (JIPMER-Pondcherry), S.Shoib (6 papers)(AMU-Aligarh)
7	D.K.Bonilla-Aldana	Universidad Tecnologica de Pereira, Columbia	10.35	10.35	10.35	K. Dhama (20 papers); R.Sah (13 Ppers); R.Tiwari (13 papers); Y.S.Malik (7 papers), S.K.Patel 7 papers), K.Sharun (6 papers)(All from IVRI)
8	G.K. Kroumpouzos	Brown University, USA	4.32	4.32	4.32	S.Bhargava (6 papers); R.D.Gardi (5 papers)
9	P.Sookaromdee	Privatr Consultant, Thailand	1.58	1.58	1.58	V.Wiwanitkit (19 papers)
10	S.S.Lee	Hallym UNiversity-Chuncheon Sacret Heart Hospital, South Korea	28.89	28.89	28.89	M.Bhattacharya (18 papers), S.Chakraborty (18 papers)., A.R.Sharma (17 papers), G.Sharma (4 papers)

TP=Total papers; TC=Total citations; CPP=Citations per publication

Table 5: Geographical Distribution of Indian Publications on Covid-19.

S.No	Name of the City	TP	TC	%TP	CPP	S.No	Name of the City	TP	TC	CPP	%TP
1	Delhi	2237	12331	21.86	5.51	11	Bhubaneswar	243	836	3.44	2.37
2	Mumbai	747	5236	7.30	7.01	12	Jaipur	210	1059	5.04	2.05
3	Chennai	744	3594	7.27	4.83	13	Nagpur	179	597	3.34	1.75
4	Pune	659	2535	6.44	3.85	14	Ahmedabad	162	1343	8.29	1.58
5	Kolkata	618	4818	6.04	7.80	15	Bhopal	158	660	4.18	1.54
6	Chandigarh	585	3441	5.72	5.88	16	Trivandrum	148	632	4.27	1.45
7	Bangalore	541	2860	5.29	5.29	17	Dehradun	146	533	3.65	1.43
8	Hyderabad	417	1964	4.08	4.71	18	Srinagar	119	1090	9.16	1.16
9	Lucknow	383	2564	3.74	6.69	19	Patna	116	489	4.22	1.13
10	Noida	258	1143	2.52	4.43	20	Ghaziabad	102	612	6.00	1.00

TP=Total papers; TC=Total citations; CPP=Citations per publication

paper (9.82), followed by "Middle Aged" (8.58), "Adolescents" (6.84), "Adults" (6.60) and "Children" (4.77).

Subject-Wise Distribution of Research Output

On classifying India's publications on Covid-19 by Scopus classification, it was observed that Medicine contributed the largest publication share (58.02%), followed by Biochemistry, Genetics and Molecular Biology (14.34%), Pharmacology, Toxicology and Pharmaceutics (10.16%), Computer Science (8.50%), Social Sciences (8.27%), Engineering (^.66%), Immunology and Microbiology (5.93%), Environment Science (5.55%), etc. In terms of impact, Psychology registered the highest citation impact per publication (11.83) and Dentistry the least (1.27) (Table 6).

Classification by Type of Research

On classifying India's publications by type of research (eight broad categories), it was observed that "Treatment" accounts for the largest share (34.12%) in total output, followed by "Clinical Studies" (13.13%), "Epidemiology" (10.54%), "Imaging and Diagnostics"(9.64%), "Pathophysiology" (6.27%), "Use of Machine Learning" (5.57%), *et al.* Within "Treatment" category, "Drug Therapy" accounts for the largest publication share, followed by "Anti-viral Therapy" (5.61%), "Vaccine" (4.98%), etc. (Table 7)

Classification by Type of Disease in Human Body

On classifying India's publications on Covid-19 by type of disease and effect on human body, it was observed that extra-pulmonary effects on the human body constitutes the largest (16.68%) share in total

Table 6: Subject-Wise Breakup of Indian Publications on Covid-19 Research during 2020-21.

S.No	Name of the Subject*	TP	%TP	TC	CPP
1	Medicine	5937	58.02	34413	5.80
2	Biochemistry, Genetics and Molecular Biology	1467	14.34	9400	6.41
3	Pharmacology, Toxicology and Pharmaceutics	1040	10.16	2944	2.83
4	Computer Science	870	8.50	1696	1.95
5	Social Sciences	846	8.27	1461	1.73
6	Engineering	682	6.66	1752	2.57
7	Immunology and Microbiology	607	5.93	4671	7.70
8	Environment Science	568	5.55	4481	7.89
9	Agricultural and Biological Sciences	327	3.20	1143	3.50
10	Economics, Econometrics and Finance	291	2.84	657	2.26
11	Neuroscience	277	2.71	2371	8.56
12	Dentistry	246	2.40	313	1.27
13	Psychology	238	2.33	2815	11.83
	India's total output	10233		49168	4.80
	*There is a duplication of papers Across subjects				

TP=Total papers; TC=Total citations; CPP=Citations per publication

Table 7: Classification of India's Covid-19 Publication by Type of Research.

S.No.	Type of Research	TP	TC	CPP
1	Epidemiology	1079	7507	6.96
2	Clinical Studies	1344	16152	12.02
3	Pathophysiology	642	6569	10.23
4	Complications	542	4894	9.03
5	Risk Factors	542	5011	9.25
5	Genetics	453	4699	10.37
6	Imaging and Diagnostics	986	7735	7.84
7	Use of Machine learning	570	1396	2.45
8	Treatment	3491	55274	15.83
9	Drug Therapy	1038	9702	9.35
10	Convalescent Plasma	216	22188	102.72
11	Vaccine	510	4868	9.55
12	Steroids	306	1246	4.07
13	Antibiotic Therapy	164	2724	16.61
14	Antiviral Therapy	574	7700	13.41
15	Anticoagulant Therapy	86	405	4.71
16	Immunotherapy	104	986	9.48
17	Monoclonal Antibody	98	1246	12.71
18	Oxygen Therapy	156	2378	15.24
19	Treatment Outcome	239	1831	7.66

TP=Total papers; TC=Total citations; CPP=Citations per publication

publications, followed by mental health and psychiatry effects (14.15%) and pulmonary effects (4.80%). Within extra-pulmonary effects, diabetes and other endocrinological diseases constitute the largest publication share (3.79%), followed by Cardiovascular and related diseases (2.99%), renal diseases (2.63%), etc (Table 8)

Classification of Publications by Type of Organ

On classifying India's publications on Covid-19 by type of organ affected, it was observed that lungs are the affected the most (with 5.39% share in publications), followed by heart (2.98%), kidney (2.49%), liver (1.84%), brain (1.83%), eyes (1.58%), skin (1.09%). In terms of impact, publications related to brain registered the highest citation impact per paper (12.28), followed by pancreas (12.14), lung (8.39), heart (6.94), kidney (6.82), etc.

Significant Keywords

In all 69 significant keywords were identified which signify the current research areas in "India's Covid-19 Research Output". The frequency of occurrence of keyword varied from 18 to 8622. Among the keywords, "Covid-19" attained the maximum frequency (5899), followed by "Virus Pneumonia (5063), "Pandemic (4171), "Virology (&92), etc. (Table 9).

The frequency of their co-occurrence of the keywords in India's research on Covid-19 highlight research trends in this domain as shown in Figure 1, 2. These keywords may be divided in three colors as represented by three separate clusters in Figure 1. Figure 1, 2 were generated through VOSviewer and Biblioshny tools of co-occurrence relationship chart of top 69 keywords.

Top 30 Most Productive Organizations

1311 organizations unevenly participated in India's Covid-19 research during 2019-21: 614 organizations published 1-5 papers each, 351 organizations 6-10 papers each, 214 organizations 11-20 papers each, 73 organizations 21-50, 37 organizations 51-100 papers each and 22 organizations 107-623 papers each. The productivity of top 30 most productive Indian organizations varied from 74 to 623 publications per organization; together they contributed 43.50% (4451) share in Indian publications share and 45.62% (22431) share in in Indian citations share during 2002-19. The scientometric profile of top 8 most productive and 8 most impactful organizations is presented in Table 12.

Table 8: Classification of India's Publications on Covid-19 by Psychiatry, Pulmonary and Extra-Pulmonary Effects.

S.No	Type of Broad Disease	TP	TC	CPP	% TP
1	Mental Health and Psychiatry	1448	9665	6.67	14.15
2	Pulmonary or respiratory	491	2524	5.14	4.80
3	Extra-Pulmonary	1707	13722	8.04	16.68
4	Cardiovascular and Related Diseases	306	2128	6.95	2.99
5	Diabetes and related endocrinology Diseases	388	4225	10.89	3.79
6	Renal Diseases	269	2554	9.49	2.63
7	Gastro related	103	917	8.90	1.01
8	Eye related diseases	256	1107	4.32	2.50
9	Skin Related diseases	103	362	3.51	1.01
10	Neurological Diseases	282	2429	8.61	2.76
11	India's total	10233	49168	4.80	

TP=Total papers; TC=Total citations; CPP=Citations per publication

Table 9: Top 65 Significant Keywords Appearing in Indian Publications on Covid-19 during 2001-20.

S.No	Name of the Keyword	Frequency	S.No	Name of the Keyword	Frequency	S.No	Name of the Keyword	Frequency
1	Covid-19	8823	25	Anxiety	288	50	Virus Genome	145
2	Human	5899	26	Adult Respiratory Distress Syndrome	284	51	Diagnosis	136
3	Virus Pneumonia	5063	27	Cytokine Storm	280	52	Ritonavir	118
4	Pandemic	4171	28	Pneumonia	275	53	Corticosteroid	116
5	Betacoronovirus	1552	29	Depression	251	54	Immunomodulation	105
6	Non-Human	1220	30	Hypertension	248	55	Antiviral Therapy	99
7	Virology	792	31	Computer-Assisted Tomography	244	56	Vaccine	92
8	Hydroxychloroquine	603	32	Machine Learning	237	57	Drug Targeting	85
9	Quarantine	572	33	Anti-Viral Activity	233	58	Antibiotic Agents	81
10	Lockdown	517	34	Chemistry	232	59	Ivermectin	78
11	Antivirus Agents	471	35	Lopinavir Plus Ritonavir	230	60	Gene Expression	74
12	Angiotensin Converting Enzyme 2	466	36	Deep Learning	229	61	Gener Mutation	60
13	Comorbidity	420	37	Vaccination	229	62	Anticoagulant Agents	51
14	Social Distancing	417	38	Throax Radiography	226	63	Antibiotic Therapy	33
15	Remdesivir	404	39	Social Media	225	64	Anticoagulants	24
16	Immunology	390	40	Drug Repositioning	220	65	Antocoagulant Therapy	24
17	Mental Health	382	41	Azithromycine	228	66	Thrombosis	24
18	Anti-Viral Agents	348	42	Coronovirus Spike Glycoprotein	211	67	Lung Embolism	23
19	Molecular Docking	335	43	Tocilizumab	199	68	Venus Thromboembolism	22
20	Dyspnea	332	44	Aerosol	199	69	Blood Clotting Disorder	18
21	Chloroquine	331	45	Favipiravir	185			
22	Genetics	330	46	Morbidity	185			
23	Diabetes Mellitus	325	47	Virus RNA	185			
23	Psychology	317	48	Artificial Intelligence	183			
24	Hand Washing	301	49	Drug Safety	182			

Figure 1: Mapping of Keyword Co-occurrence.

Figure 2: Word Cloud Keyword Co-occurrence.

- Eight organizations registered their publication output above the group average (148.4) of all organizations : AIIMS-New Delhi (623 papers), PGIMER-Chandigarh (468 papers), Datta Meghe Institute of Medical Sciences (204 papers), Dr D.Y.Patil Vidyapeeth, Pune (186 papers), MAHE-Manipal (182 papers), Saveetha Institute of Medical and Technical Sciences and Saveetha Dental College and Hospital (161 papers each), AIIMS-Jodhpur(150 papers);

- Thirteen organizations registered their citation per paper and relative citation index above the group average (5.04 and 1.05) of all organizations: IVRI-Bareilly (21.32 and 4.44), IIT-New Delhi (12.37 and 2.58), Jamia Millia Islamia, Delhi (12.27 and 2.56), Indraprastha Apollo Hospitals (11.72 and 2.44), KGMU-Lucknow (10.29 and 2.14), TMH – Mumbai (8.21 and 1.71), NIMHANS-Bangalore (7.78 and 1.62), CMC - Vellore (7.21 and 1.5), Homi Bhabha National Institute, Mumbai (6.67 and 1.39), PGIMER – Chandigarh (6.35 and 1.32), SGPGIMS- Lucknow (5.53and 1.15), MAHE-Manipal (5.21 and 1.09) and University of Delhi (5.08 and 1.06).

Collaboration linkages among top 30 organizations

All 30 organizations have one to one collaborative linkages, as observed from Table 13. Their total collaborative linkages varied from 1-318 links. The top five organizations with largest collaborative linkages (318, 222, 158, 158 and 156) with 1-24 other organizations each were depicted by AIIMS-New Delhi, PGIMER-Chandigarh, Saveetha Institute of Medical and Technical Sciences, Saveetha Dental College and Hospital and Datta Meghe Institute of Medical Sciences. Among organization-to-organization collaborative linkages, Saveetha Institute of Medical and Technical Sciences - Saveetha Dental College and Hospital registered the highest number of collaborative linkages (158), followed by TMH-Mumbai - Homi Bhabha National Institute, Mumbai (86), AIIMS-New Delhi – PGIMER – Chandigarh

(78 linkages), AIIMS – New Delhi – SGPGIMS - Lucknow (34), AIIMS – New Delhi - VMMC and Safdarjang Hospital, New Delhi (22 linkages), Dr Ram Manohar Lohia Hospital, New Delhi - Indraprastha Apollo Hospitals (20 linkages), etc. (Table 13)

Figure 3 shows the collaboration network map of top 30 organizations based on their number of publications and collaborations between them developed using VOSviewer software. All these organizations are divided in 5 clusters.

Top 30 Most Productive Authors

3413 authors unevenly participated in India's Covid-19 research during 2019-21: 2761 authors published 1-5 papers each, 428 authors 6-10 papers each, 1177 authors 11-20 papers each, 43 authors 21-50 papers each and 4 authors 51-182 papers each. The research productivity of top 30 most productive authors varied from 23 to 182 publications per author. Together they contributed 11.57% (1184) share in Indian publications and 32.14% (15804) share in Indian citations share during 2019-21. The detailed Scientometric profile of top 8 most productive and 8 most impactful authors is presented in Table 14.

- Five authors registered their publications output above the group average of 39.47: V. Wiwanitkit (Dr D.Y. Patil University, Pune) (182 papers), K. Dhama (IVRI-Bareilly)(107 papers), R. Tiwari (IVRI-Bareilly)(56 papers), B. Joob (Dr D.Y.Patil University, Pune) (51 papers) and R. Vaishya (Indraprastha Hospitals) (48 papers);

- Thirteen authors registered their citation per paper and relative citation index above the group average (13.35 and 2.78) of all authors: R. Sah (IVRI-Bareilly)(42.89 and 8.93), A. Misra (Diabetes Foundation of India)(41.93 and 8.74), Y.S. Malik (IVRI-Bareilly) (31.80 and 6.63), A. Haleem (Jamia Millia Islamia, Delh)(23.44 and 4.88), R. Tiwari (IVRI-Bareilly)(23.43 and 4.88), M. Javaid (Jamia Milia Islamia, Delhi)(22.97 and 4.79), K. Dhama (IVRI-

Table 12: Top 8 Most Productive and Most Impactful Organizations in Indian Covid-19 Research during 2001-20.

S.No	Name of the Organization	TP	TC	CPP	HI	ICP	ICP (%)	RCI
	Top 8 Most Productive Organizations							
1	All India Institute of Medical Sciences (AIIMS), New Delhi	623	2223	3.57	22	93	14.93	0.74
2	Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh	468	2970	6.35	26	67	14.32	1.32
3	Datta Meghe Institute of Medical Sciences	204	173	0.85	7	5	2.45	0.18
4	Dr D.Y. Patil Vidyapeeth, Pune	186	476	2.56	13	14	7.53	0.53
5	Manipal Academy of Higher Education (MAHE), Manipal	182	949	5.21	14	75	41.21	1.09
6	Saveetha Institute of Medical and Technical Sciences	161	48	0.30	3	18	11.18	0.06
7	Saveetha Dental College and Hospital	161	73	0.45	3	15	9.32	0.09
8	All India Institute of Medical Sciences (AIIMS), Jodhpur	150	413	2.75	11	22	14.67	0.57
	Top 8 Most Impactful Organizations							
1	Indian Veterinary Research Institute	117	2494	21.32	22	84	71.79	4.44
2	Indian Institute of Technology (IIT), New Delhi	75	928	12.37	13	19	25.33	2.58
3	Jamia Millia Islamia, Delhi	113	1386	12.27	15	33	29.20	2.56
4	Indraprastha Apollo Hospitals	86	1008	11.72	17	46	53.49	2.44
5	King George"s Medical University (KGMU), Lucknow	112	1152	10.29	16	27	24.11	2.14
6	Tata Memorial Hospital (TMH), Mumbai	119	977	8.21	8	29	24.37	1.71
7	National Institute of Mental Health and Allied Sciences (NIMHANS), Bangalore	143	1113	7.78	18	25	17.48	1.62
8	Christian Medical College (CMC), Vellore	97	699	7.21	11	27	27.84	1.50

TP=Total papers; TC=Total citations; CPP=Citations per publication; ICP=International collaborative papers; RCI=Relative citation index

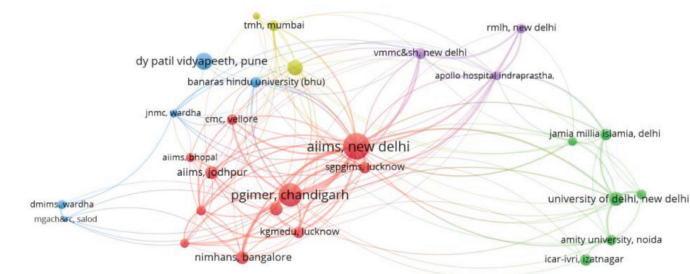**Table 13: Collaborative linkages among top 30 organizations.**

S.No	Name of the Organization	Collaborative linkages with other organizations	TCL(NOC)
1	All India Institute of Medical Sciences (AIIMS), New Delhi	2(78), 3(2), 5(8), 8(7), 9(11), 10(12), 11(34), 12(19), 13(5), 14(12), 16(5), 17(15), 18(22), 19(9), 20(15), 1(1), 22(1), 23(13), 24(9), 25(9), 26(7), 27(11), 29(10), 30(4)	318 (24)
2	Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh	1(78), 3(2), 5(4), 8(7), 10(17), 11(18), 12(19), 13(3), 17(8), 18(12), 20(17), 21(3), 23(1), 24(6), 25(5), 26(8), 27(10), 30(4)	222(18)
3	Datta Meghe Institute of Medical Sciences	1(2), 2(2), 4(1), 8(2), 21(78), 28(71)	156 (6
4	Dr D.Y.Patil Vidyapeeth, Pune	3(1)	1(1)
5	Manipal Academy of Higher Education (MAHE), Manipal	1(8), 2(4), 14(11), 19(11), 21(1), 22(2), 27(1), 29(1), 30(1)	40(9)
6	Saveetha Institute of Medical and Technical Sciences	7(158)	158(1)
7	Saveetha Dental College and Hospital	6(158)	158(1)
8	All India Institute of Medical Sciences (AIIMS), Jodhpur	2(7), 2(7), 3(2), 10(2), 11(5), 12(2), 17(5), 24(4), 27(4), 30(2)	40(10)
9	University of Delhi	1(11), 11(2), 12(3), 13(11), 12(3), 16(7), 22(18), 29(4), 30(1)	60(9)
10	National Institute of Mental Health and Allied Sciences (NUMHANS), Bangalore	1(12), 2(17), 3(2), 8(2), 12(4), 17(4), 24(4), 27(2), 30(4)	51(9)
11	Sanjay Gandhi Postgraduate Institute of Medical Sciences (SGPGIMS), Lucknow	1(34), 2(18), 8(5), 9(2), 12(5), 13(2), 14(3), 15(2), 17(10), 18(5), 20(8), 21(3), 22(1), 23(1), 24(4), 25(10), 26(5), 27(3), 30(1)	122 (19)
12	All India Institute of Medical Sciences (AIIMS), Rishikesh	1(19), 2(19), 8(2), 9(3), 10(4), 11(5), 17(3), 24(1), 27(4),	60(9)
13	Amity University, Noida	1(5), 2(3), 11(2), 15(4), 26(5)	19(5)
14	Tata Memorial Hospital (TMH), Mumbai	1(12), 5(11), 11(3), 19(86), 20(3)	115(5)
15	Indian Veterinary Research Institute	11(2), 13(4), 17(4), 26(6)	16(4)
16	Jamia Millia Islamia, Delhi	1(5), 9(7), 18(1), 22(2), 25(15), 29(3)	33(6)
17	King George"s Medical University (KGMU), Lucknow	1(15), 2(8), 11(10), 15(4), 24(10), 27(2),	49(6)
18	VMMC and Safdarjang Hospital, New Delhi	1(22), 2(12), 11(5), 21(2), 24(1), 25(12), 29(1), 30(1)	56(8)
19	Homo Bhabha National Institute, Mumbai	1(9), 5(11), 14(86)	106(3)
20	Christian Medical College (CMC), Vellore	1(15), 11(2), 14(3), 21(2), 24(4), 26(3), 30(1)	30(7)
21	Jawaharlal Nehru Medical College, Wardha	2(3), 3(78), 5(1), 11(3), 18(2), 20(2), 25(3), 26(2)	94(8)
22	Jawaharlal Nehru University (JNU), New Delhi	1(1), 5(2) , 9(18), , 11(1), 16(2), 24(4), 30(1)	29(7)
23	Dr Ram Manohar LOhia Hospital, New Delhi	1(13), 2(1), 11(1), 18(15), 25(20)	50(5)
24	Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER), Pondicherry	1(9), 2(6), 8(4), 10(4), 11(4), 12(1), 17(10), 18(1), 20(4), 26(1), 27(10), 30(1)	55(12)
25	Indraprastha Apollo Hospitals	1(9), 2(5), 11(10), 16(15), 18(12), 21(3), 23(20), 26(3)	77(8)
26	Banaras Hindu University, Varanasi	1(7), 2(8), 11(5), 13(5), 15(6), 20(3), 21(2), 24(1), 25(3)	40(9)
27	All India Institute of Medical Sciences (AIIMS), Bhubaneswar	1(11), 2(10), 5(1), 8(4), 10(2), 11(3), 12(4), 17(2), 24(10)	47(9)
28	Mahatma Gandhi Ayurveda College and Hospital Center (MGACH and RC)	3(71)	71(1)
29	Indian Institute of Technology (IIT), New Delhi	1(10), 5(1), 9(4), 16(3), 18(1)	19(5)
30	All India Institute of Medical Science (AIIMS), Bhopal	1(4), 2(4), 5(1), 8(2), 9(1), 10(4), 11(1), 18(1), 20(1), 22(1), 24(1)	21(11)

*TCL=Total Collaborative Linkages; NOC=Number Of Countries

Figure 3: Collaboration Network Map of Top 30 Organizations.

Bareilly)(22.44 and 4.67), K. Sharun (IVRI-Bareilly)(20.06 and 4.18), P.Sarma (PGIMER-Chandigarh)(18.63 and 3.88), S.K.Patel (IVRI-Bareilly)(16.42 and 3.42), R. Vaishya (Indraprastha Hospitals) (16.33 and 3.4), R. Pal (PGIMER-Chandigarh)(15.36 and 3.20), D. Banerjee (NIMHANS-Bangalore)(15.19 and 3.17) and B. Medhi (PGIMER-Chandigarh)(14.94 and 3.11).

Collaborative linkages among top 30 authors

Among top 30 authors, except 5 authors, all other 25 authors have one to one collaborative linkages with each other as observed in Table 15. The top five authors with largest collaborative linkages (326, 100, 81, 76 and 72) with 2-10 other authors each were depicted by K. Dhama, Y.S. Malik, R. Sah, S.K. Patel and V. Wiwannitkit. Among author-to-author collaborative linkages, K. Dhama – R. Tiwari together have registered

Table 14: Top 8 Most Productive and Most Impactful Authors in Covid-19 Research in India during 2020-21.

S.No	Name of the Author	Affiliation of the Author	TP	TC	CPP	HI	ICP	ICP (%)	RCI
		Top 8 Most Productive Authors							
1	V. Wiwanitkit	Dr D.Y.Patil University, Pune	182	448	2.46	12	142	78.02	0.51
2	K. Dhama	IVRI-Bareilly	107	2401	22.44	20	82	76.64	4.67
3	R. Tiwari	IVRI-Bareilly	56	1312	23.43	17	46	82.14	4.88
4	B. Joob	Dr D.Y.Patil University, Pune	51	223	4.37	8	47	92.16	0.91
5	R. Vaishya	Indraprastha Hospitals	48	784	16.33	15	23	47.92	3.40
6	S. Grover	PGIMER-Chandigarh	37	239	6.46	9	2	5.41	1.35
7	K. Sharun	IVRI-Bareilly	36	722	20.06	12	21	58.33	4.18
8	S. Bhatnagar	AIIMS-New Delhi	35	49	1.40	4	3	8.57	0.29
		Top 8 Most Impactful Authors							
1	R. Sah	IVRI-Bareilly	35	1501	42.89	14	34	97.14	8.93
2	A. Misra	Diabetes Foundation of India	29	1216	41.93	16	5	17.24	8.74
3	Y.S. Malik	IVRI-Bareilly	35	1113	31.80	13	26	74.29	6.63
4	A.Haleem	Jamia Millia Islamia, Delhi	32	750	23.44	13	2	6.25	4.88
5	R. Tiwari	IVRI-Bareilly	56	1312	23.43	17	46	82.14	4.88
6	M. Javaid	Jamia Milia Islamia, Delhi	34	781	22.97	14	2	5.88	4.79
7	K. Dhama	IVRI-Bareilly	107	2401	22.44	20	82	76.64	4.67
8	K. Sharun	IVRI-Bareilly	36	722	20.06	12	21	58.33	4.18

TP=Total papers; TC=Total citations; CPP=Citations per publication; ICP=International collaborative papers; RCI=Relative citation index

Table 15: Collaborative linkages among top 30 authors.

S.No	Name of the Author	Affiliation of the Author	Collaborative linkages with other authors	TCL(NOC)
1	V. Wiwanitkit	Dr D.Y.Patil University, Pune	4(49), 24(23)	72(2)
2	K. Dhama	IVRI-Bareilly	3(56), 7(34), 10(33), 12(33), 28(23)	326 (10)
3	R. Tiwari	IVRI-Bareilly	2(56), 7(28), 10(24), 12(19), 28(20)	
4	B. Joob	Dr D.Y.Patil University, Pune	1(49)	49(1)
5	R. Vaishya	Indraprastha Hospitals	9(4), 13(15), 15(13)	32(3)
6	S. Grover	PGIMER-Chandigarh	17(30), 18(30),	60(2)
7	K. Sharun	IVRI-Bareilly	2(34), 3(28), 10(13), 12(6), 28(8)	89 (5)
8	S. Bhatnagar	AIIMS-New Delhi	Nil	Nil
9	I. Ish	VMMC and Safdarjang Hospital, New Delhi	5(4), 14(25)	29(2)
10	Y.S. Malik	IVRI-Bareilly	2(35), 3(24), 7(13), 12(13), 28(15)	100 (5)
11	S. Misra	AIIMS-Jodhpur		
12	R. Sah	IVRI-Bareilly	2(33), 3(19), 7(6), 10(13), 28(10)	81 (5)
13	M. Javaid	Jamia Milia Islamia, Delhi	5(15), 15(30)	45(2)
14	N. Gupta	VMMC and Safdarjang Hospital, New Delhi	9(25)	25(1)
15	A.Haleem	Jamia Millia Islamia, Delhi	5(13), 13(30)	43(2)
16	B. Medhi	PGIMER-Chandigarh	29(24)	24(1)
17	A. Mehra	PGIMER-Chandigarh	6(30), 18(29)	59(2)
18	S. Sahoo	PGIMER-Chandigarh	6(30), 17(29)	59(2)
19	A. Misra	Diabetes Foundation of India	Nil	Nil
20	R. Pal	PGIMER-Chandigarh	Nil	Nil
21	D. Banerjee	NIMHANS-Bangalore	Nil	Nil
22	A. Agrawal	AIIMS-Bhopal	Nil	Nil
23	L. Gupta	SGPGIMS-Lucknow	30(15)	15(1)
24	R. Mungmunpuntipantip	Dr D.Y.Patil University, Pune	1(23)	23(1)
25	P.Abraham	ICMR-New Delhi	26(4), 27(8)	12(2)
26	B.Bhargava	ICMR-New Delhi	25(4), 27(6)	10(2)
27	N.Gupta	ICMR-New Delhi	25(8), 26(6)	14(2)
28	S.K.Patel	IVRI-Bareilly	2(23), 3(20), 7(8), 10(15), 12(10)	76(5)
29	P.Sarma	PGIMER-Chandigarh	16(24)	24(1)
30	V.Agarwal	SGPIMS-Lucknow	23(15)	15(1)

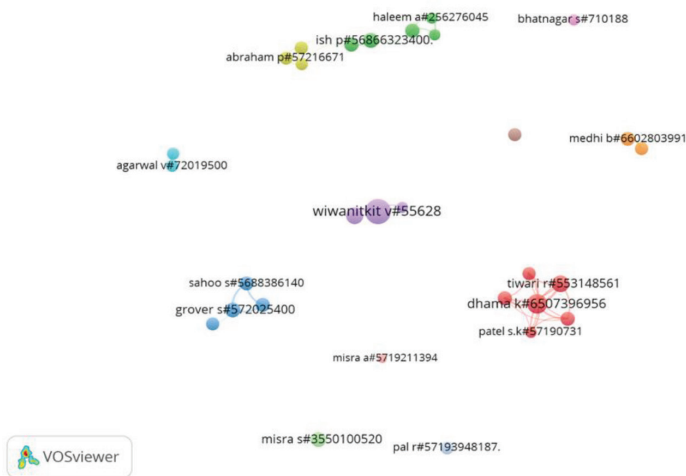*TCL=Total Collaborative Linkages; NOC=Number Of Countries

Figure 4: Co-authorship network of Top 30 Authors.

highest number of collaborative linkages (56 each), followed by V. Wiwanitkit – B. Joob (49 linkages), K. Dhama – K. Sharun (34 linkages), K. Dhama – Y.S. Malik (33 linkages), M. Javaid – H. Haleem (30 linkages), S. Grover – A. Mehra and A. Mehra – S. Sahoo (29 linkages each), R. Tiwari – K. Sharun (28 linkages), N. Gupta – I. Ish (25 linkages), R. Tiwari – Y.S. Malik (24 linkages), B. Medhi – K. Sarma (23 linkages), etc. (Table 15)

A collaborative networks visualization chart of top 20 most authors is presented in Figure 4. The thickness of the box is proportional to its number of collaborative publications. The bigger the box size and its font size, the more the number of collaborative publications. The chart suggests there has been active collaboration amongst the most productive authors among their own organizations.

Medium of Research Communication

Of the total Indian output in research on Covid-19 research, 94.99% (9669) appeared in journals, 3.63% (371) in conference proceedings, 1.79% (183) in book series, 0.07% (7) in books and 0.03% (3) as trade journal during 2001-20. Of the 845 journals which reported 9669 articles, 434 published 1-5 papers each, 212 published 6-10 papers each, 110 published 11-20 papers each, 63 published 21-50 papers each, 13 published 51-100 papers each and 8 published 101-270 papers each. The top 30 most productive journals contributed 39 to 270 papers and together accounted for 27.06% share of total Indian journal output on Covid-19 research output.

The top 10 most productive journals were *International Journal of Research in Pharmaceutical Sciences* (270 papers), *Indian Journal of Ophthalmology* (210 papers), *Diabetes and Metabolic Syndromes. Clinical Research and Reviews* (168 papers), *European Journal of Molecular and Clinical Medicine* (138 papers), *Journal of Biomedical Structure and Dynamics* (137 papers), *Asian Journal of Psychiatry* (136 papers), *International Journal of Current Research and Reviews* (135 papers), *Indian Journal of Medical Research* (117 papers), *Indian Pediatrics* (93 papers0 and Economic and Political Weekly (89 papers)

The top 10 most impactful journals in terms of citations per paper were *Science of the Total Environment* (43.98), *Asian Journal of Psychiatry* (19.19), *Diabetes and Metallic Syndromes. Clinical Research and Reviews* (18.84), *Chaos Solitons and Fractals* (18.69), *Journal of Biomedical Structure and Dynamics* (16.44), *Indian Journal of Pediatrics* (15.94), *Journal of Medical Virology* (13.44), *Indian Journal of Medical Research* (6.87), *PLOS One* (6.78) and *Indian Journal of Anaesthesia* (5.49).

High-Cited Papers

Of the total 10233 Indian publications on Covid-19, 78 papers (0.76% share) registered 100 or more citations per paper. These 78 papers together received a total of 17090 citations, averaging 219.10 citations per paper. The distribution of 78 highly cited papers is high-cited 54 papers registered citations in the range 101-200, 10 papers in citation range 201-300, 6 papers in citation range 301-400, 3 papers in citation range 401-500, 2 papers in citation range 501-600, 2 papers in citation range 801-900 and one paper received highest 908 citations. Among the 78 highly cited papers, 45 are articles, 20 review papers, 6 letters, 3 each as notes and editorial and 1 conference paper.

Out of 78 high-cited papers only 5 papers have single authors each and the rest involve multi-authors. Of the 73 collaborative papers, 29 papers are national collaborative and 41 as international collaborative. For these 41 internationally collaborated high-cited Indian publications 74 foreign countries have participated with the USA contributing the highest number of papers (19), followed by U.K. (15 papers), China (20 papers), Brazil, Japan and South Korea (8 papers each), Spain (7 papers), Australia, Canada, France, Italy and Netherlands (6 papers each), South Africa (5 papers), Bangladesh, Germany, Thailand and Switzerland (4 papers each), 8 countries (3 each), 11 countries (2 each) and 19 countries with 1 each.

A total 2274 authors from more than 1500 organizations participated in these 78 high cited papers. PGIMER-Chandigarh participated in 6 out of 78 India's high-cited papers, followed by IVRI-Bareilly and Jamia Millia Islamia (5 papers each), College of Veterinary Science, Mathura and GD Hospital and Diabetes Institute, Kolkata (4 papers each), Fortis CDOC Hospital for Diabetes and Allied Sciences, Delhi, National Diabetes, Obesity and Chlorostol Foundation and Diabetes Foundation (India), New Delhi (3 papers), IIT-New Delhi, Indraprastha Apollo Hospital, King Georg's Medical University, Lucknow, Medanta, Gurgaon, NIHMANS-Bangalore and Tata Memorial Hospital, Mumbai (2 papers each), etc.

K. Dhama of IVRI-Bareilly contributed the largest number of papers (6) to India's high cited papers, followed by R. Tiwari and Y.S. Malik (IVRI-Bareilly)(4 papers each), A. Misra (Diabetes Foundation (india), New Delhi and A.K. Singh (GD Hospital and Diabetes Institute, Kolkata (3 papers each), R. Vaishya (Indraprastha Hospitals), R. Sah and K. Sharun (IVRI), M. Javaid and A. Haleem (Jamia Millia Islamia), B. Medhi and P. Sarma (PGIMER), D. Banerjee (NIHMANS) (2 papers each), A Ghosh and R. Gupta (Fortis CDPC Hospital, New Delhi (2 papers each), etc.

Of the 78 India's high-cited papers on Covid-19, 77 were published in 40 journals, with 10 papers in *Diabetes and Metabolic Syndrome. Clinical Research and Review*, 9 papers in Journal of Biomedical Structure and Dynamics, 7 papers in *Science of the Total Environment*, 5 papers each in *Asian Journal of Psychiatry* and *The BMJ*, 3 papers in the *Journal of Medical Virology* and *The Lancet* and 2 papers each in *Brain, Behavior and Immunity, IEEE Access, Science* and *Virus Research* and 1 paper each in 29 other journals.

SUMMARY AND CONCLUSION

The bibliometric analysis of India's literature on Covid-19 indicates that there were 10,233 indexed publications in Scopus database published from the early stage of the outbreak until 6 June 2021. Of all these publications, 52.87% were original articles, 17.5% reviews and 16.59% letters, etc. The 10, 233 India's publications received 49168 citations, averaging 4.80 citations per paper (CPP). Of the total India's publications, 11.75% (1202) publication received external funding from more than 150 agencies and 27.41% (2805) involve international collaboration with more than 150 countries. The external funded papers and papers involving

international collaboration registered 8.82 CPP and 16.35 CPP, much higher than for India's total papers. USA contributed the largest share (38.47%) in India's international collaborative papers, followed by U.K. (22.89%), China (11.55%), Saudi Arabia (11.44), Australia (11.23%), etc. Among top foreign organizations and authors collaborating with India, (I) Hainan Medical University, China tops the list with 92 collaborative papers, followed by King Saud University, Saudi Arabia (73 papers), University of New South Wales, Sydney, Australia (66 papers) and (II) A.J. Rodriquez-Moralesj, Columbia tops the list with 34 collaborative papers, followed by M. Goldust, Switzerland and A.A. Rabaan, USA (29 papers each), H. Harapan, Indonesia and M. Jafferany, USA (22 papers each), etc. Considering the geographical distribution through cities, the top five Indian cities are Delhi (21.86% share), Mumbai (7.30%), Chennai (7.27%), Pune (6.44%) and Kolkata (6.04%). Available indications using keywords indicate that "Adults" (with 9.98% publication share) received the maximum attention in Covid-19 research, followed by "Middle Aged" (5.07%), "Children" (3.65%), "Aged" (3.65%) and "Adolescents" (2.82%). The most prevalent topics of research in Covid-19 include "Treatment studies" (with 34.12% share), followed by "Clinical Studies" (13.13%), "Epidemiology" (10.54%), "Imaging and Diagnostics"(9.64%), "Pathophysiology" (6.27%), "Use of Machine Learning" (5.57%), *et al.* Within "Treatment" category, "Drug Therapy" accounts for the largest publication share, followed by "Anti-viral Therapy" (5.61%), "Vaccine" (4.98%), etc. About 1311 organizations and 3413 authors participated in India's research on Covid—19, of which the top 30 organizations and authors contributed 43.50% and 11.57% national publication share and 45.62% and 32.14% national citation share. AIIMS-New Delhi, PGIMER-Chandigarh and Datta Meghe Institute of Medical Sciences (204 papers) were the most productive organizations (with 623, 468 and 204 papers). IVRI-Bareilly (21.32 and 4.44), IIT-New Delhi (12.37 and 2.58) and Jamia Millia Islamia, Delhi (12.27 and 2.56) were the most impactful organizations. V. Wiwanitkit, K. Dhama and R. Tiwari were the most productive authors (with 182. 107 and 56 papers). R. Sah (42.89 and 8.93), A. Misra (41.93 and 8.74) and Y.S. Malik (IVRI-Bareilly) (31.80 and 6.63) were the most impactful authors. International Journal of Research in Pharmaceutical Sciences (270 papers), *Indian Journal of Ophthalmology* (210 papers) and *Diabetes and Metabolic Syndromes. Clinical Research and Reviews* (168 papers) were the most productive journals (with 270, 210 and 168 papers). *Science of the Total Environment* (43.98), *Asian Journal of Psychiatry* (19.19) and *Diabetes and Metallic Syndromes. Clinical Research and Reviews* (18.84) were the most impactful journals.

Conclude that the Covid-19 pandemic and its debilitating impact have exposed the inadequacy of the existing public health and institutional mechanisms to respond to health emergency of this scale. Its containment necessitated multi-lateral cooperation across nations and multi-sectoral involvement within countries. The Covid-19 pandemic over whelmed existing surveillance systems and exposed their adequacies. Public health system struggled to investigate breaks, trace contacts, quarantine suspects and contain outbreaks. Healthcare facilities were overstretched and saw shortages of beds, PPEs, drugs and manpower. The National Center for Disease Control (NCDC) in Delhi, which monitors communicable diseases outbreaks in the country, needs to be urgently strengthened to address these issues. It should be recasted as the repository of technical knowledge for Indian health emergency response authority (IHERA). A massive expansion and up gradation of India's healthcare facilities is an urgent priority. A robust surveillance system, early warning protocols, a vigil and health emergency response and a well-equipped healthcare-system are indispensable for creating an appropriate response to epidemics.[14]

Conclude that investments made by Indian government in Covid-19 R&D during the last 18 month has shown positive results and Indian scientists were successful in development of several products including different types of vaccines. This became possible with the active collaboration between different research organizations and collaboration between research organizations and industry with the funding mainly coming from the government. India in fact need to effectively leverage its research sector in order to develop to tackle critical development priorities and to contribute to economic productivity and competitiveness. In order to achieve its research objectives, it must address the following: (i) increase the quantity and improve the quality of tertiary education; (ii) develop criteria to determine priority research areas; (iii) establish financial and administrative mechanism to enhance the quantity and quality of research produced in priority areas, (iv) dedicate specific funding streams to support domestic, intra-regional and extra-regional collaboration and promote research partnership between academic institutions and the private sector.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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