Pro-Metrics

Covid-19 research in Bangladesh: A scientometric analysis during 2020-23

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ABSTRACT

Objective. We examined the bibliometric characteristics of 3616 Bangladesh's publications on Covid-19 during 2020-2023. For this purpose, we used quantitative and qualitative bibliometric indicators.

Design/Methodology/Approach. Bangladesh publications on Covid-19 during 2020-2023 were retrieved using the Scopus database. From each record, we retrieved data on the title, author, organizations, journal, publication type and source, country, collaboration, funding, topic and keywords. They were exported to MS-Excell for bibliometric analysis, and VOSviewer software was used for analyzing keyword co-occurrence networks.

Results/Discussion. The Bangladesh-related Covid-19 papers in the Scopus database constitute 3616 papers, which hold 50th global rank with 0.75% share in global output and registered 14.63 average citations per article (CPP). The 732 (21.52%) out of 3616 Bangladesh papers attracted external funding support, and 2493 (72.28%) have participated in international collaboration. The U.K., USA, India and Saudi Arabia contributed the most to Bangladesh's international collaborative papers. The University of Dhaka, Jahangirnagar University, North South University and Daffodil International University were the most productive organizations. In contrast, CHINTA Research, Khulna University of Engineering & Technology, Jahangirnagar University and Jashore University of Science & Technology registered the highest impact. The most preferred communication channels were *PLOS One, Heliyon, Frontiers in Public Health* and *Annals of Medicine & Surgery*. The *Asian Journal of Psychiatry, IEEE Access, Science of the Total Environment* and *BMJ Global Health* registered the highest citations. Clinical studies were the most frequent category, followed by epidemiology, risk factors and diagnosis. In contrast, adults and the middle-aged formed the largest population age groups, followed by aged, children and adolescents.

Conclusions. The bibliometric analysis of Covid-19 research has evolved global interest, including in Bangladesh. For the first time, the present study throws light on the current status and publication trends of research and development efforts in Bangladesh.

Keywords: Covid-19; Bangladesh; publications; scientometrics; bibliometrics.

INTRODUCTION

COVID-19, a new coronavirus disease, was for the first time identified by China in December 2019. This disease showed the most rapid global spread (Wang, 2020; Chu, 2020). Because of this fast spread, Covid-19 was declared a global pandemic by WHO on March 11, 2020 (WHO, 11 March 2020). Covid-19 predominantly infects the airways, causing asymptomatic and mild respiratory infections to severe acute respiratory distress syndrome. The disease results in organ failure in some individuals and eventually leads to death. The outbreak of the Covid-19 pandemic poses a huge challenge to global public health and profoundly impacts countries' economic and social operations (Nicola et al., 2020). It has caused 764,474,387 infections worldwide, and 6,915,286 people have been killed as of April 26, 2023 (WHO Coronavirus (COVID-19) Dashboard, 26 April 2023).

The first confirmed Covid-19 case and first death because of this disease in Bangladesh were reported on March 8 and 18, 2020, respectively (BRAC, December 2020). Since then, Covid-19 affection has increased exponentially in Bangladesh's population. As of April 26, 2023, 2,038,174 confirmed cases of Covid-19, with 29,446 deaths, were reported to WHO in Bangladesh(WHO. Bangladesh, 26 April 2023). Global research on many aspects of Covid-19, such as virology and immunology, disease transmission and clinical processes, disease diagnosis and management, experimental therapy, and vaccine development, has been carried out since the outbreak (Wiersinga et al., 2019; Oberfeld et al., 2020; Hu et al., 2021). Several studies in the past used bibliometric methods for objective evaluation of scientific research, leading to identifying the research hotspots, development trends, and the key research institutions, authors and journals of relevant research activities (Durieux et al., 2010). The usefulness of bibliometric analysis and visualization techniques in the performance of emerging diseases literature using bibliometric methods has been reported by several previous studies (Gupta & Bala, 2011) along with evaluating the global Covid-19-related publications (Gupta et al., 2021; Fan et al., 2020), by many scholars.

There has been a notable increase in Covid-19-related publications from Bangladesh since its origin; however, a few bibliometric studies were carried out in South Asia, India, Nepal and Sri Lanka (Guptaet al., 2021; Koser, 2022; Gupta, 2021; Shah et al., 2020; Ullah, 2023; Raut et al., 2021; Krishanthy, 2021). Till today, there does not exist any bibliometric study on Bangladesh's Covid-19 research output. Because of the exponential growth of Covid-19 publications in Bangladesh, the present qualitative and qualitative analysis is expected to examine the current status of Bangladesh research with the following specific objectives:

- to study the literature characteristics by document, source and language types; to study the overall growth and citation impact;
- to study the extent of international collaboration and funding support available;
- to indicate the leading organizations and authors involved in research;
- to highlight the leading channels of communication and;
- and to indicate the characteristics of high-cited papers.

METHODS

From the Scopus international database, Covid-19-related publications indexed from Bangladesh were downloaded. For the search strategy, we employed the terms: 'Covid-19' and 'Bangladesh' in "TITLE-ABS-KEY" and "Affiliation Country" tags. The time coverage was from December 2019 to February 2023. The full records and cited references of all publications from Scopus were downloaded in a CVS file. The search yielded 3616 records. The authors downloaded for each record the following bibliometric elements: title, keywords, journal, publication year, citation, author, institution, country, and reference, for further analysis. The 3616 downloaded records were finally imported into Microsoft Excel 2010 and VOSviewer software, which aims to identify the most prolific contributors (e.g., prolific authors, institutions, and countries) and study the collaborative linkages among leading actors involved.

RESULTS

All 481461 global publications have been published on Covid-19 since its origin in December 2019. The USA took the lead by contributing the largest number of publications (n=115539), to be followed by the U.K. (n=47073), China (n=43260), India (n=35279), Italy (33290), Germany (20663), Canada (20,016), Spain (19,160), Australia (n=10,018), and France (n=14,892). India took the lead by contributing the largest number of publications (n=135279) in South Asia, followed by Pakistan (n=6305), Bangladesh (n=3617), Nepal (n=1108), and Sri Lanka (n=729).

The 498 publications were published in 2020, which increased to 1414 in 2021, 1402 in 2022 and declined to 302 in 2023 due to less coverage of three months this year. These 3616 publications received 52898 citations, averaging 14.63 citations per paper (CPP). Of the 3616 publications, 2744 (75.88%) appeared as articles, 515 (14.24%) as conference papers, 505 (13.96%) as reviews, 261 (7.22%) as letters, 120 (2.41%) as book chapters, 87 (2.40%) as notes, 47 (1.30%) as editorials, 13 (0.36%) as erratum, 7 (0.19%) as data paper and 5 (0.14%) as books and short surveys. By citations registered, 34.82% (1259) of publications received no citations. Among the remaining 2357 cited publications, there was an uneven distribution: 1380, 599 and 166 (38.16%, 16.56%, 4.59% and 2.90%) publications were in citation range 1-10, 11-30, 31-50 and 51-99, in contrast to only 86 (2.38%) publications were in citation range 101 to 1361.

Only 16.79% (607) of 3616 Bangladesh publications could attract external funding support and registered 13093 citations, averaging 16.79 CPP. The significant global funding support was: the Bill & Melinda Gates Foundation (n=47), followed by the National Institute of Health, USA (n=36), National Research Foundation of Korea (n=25), King Saud University (n=23), National Natural Science Foundation of China (n=23), Japanese Society for the Promotion of Science (n=20), National Institute of Allergy & Infectious Diseases, USA and U.K. Research & Innovations (n=17 each), Ministry of Science & Technology, Bangladesh (n=16), and University Grant Commission, Bangladesh (n=12).

Of the 3616 publications, 2290 (66.33%) were international collaborative publications (ICPs), which received 41027 citations, averaging 17.91 CPP. Among the 2290 ICPs, the maximum contribution (636) came from the USA, followed by India (n=535), Australia (n=525), U.K. (n=499), Malaysia (n=399), China (n=284), Pakistan (n=271), Saudi Arabia (n=263), Canada (n=238), Japan (n=220), and Indonesia (n=138). Of the 3616 publications, 566 and 228 were focused on adults and middle-aged (n=228), followed by aged (n=186) and children and adolescents (n=152 and 148). By medical classification, Epidemiology and Clinical studies accounted for the most publications (590 and 421) among 3616 Bangladesh Covid-19 papers, followed by risk factors (n=199), diagnosis (n=145), genetics (n=138), pathophysiology (n=72) and complications (n=69)

Subject-wise distribution

The highest share of publications (45.13% and 18.94%) of publications were in the subject categories: Medicine and Computer Science. These two subjects were followed by Social Science, Engineering, Biochemistry, Genetics & Molecular Biology, and Immunology & Microbiology (from 10.26% to 13.61%), Environment Science, Pharmacology, Toxicology & Pharmaceutics, Psychology, Energy and Neurosciences (from 2.07% to 7.88%). Regarding citation impact per paper, Psychology is at the top of Table 1 with 22.63 CP and Computer Science the least (8.20).

Most productive and impactful organizations

Individually the top 25 organizations contributed 58 to 456 publications. They together contributed 3641 papers and 53251 citations, accounting for more than 100% share each in Bangladesh's total publications and citations. Among the top 25 organizations, only nine organizations registered more than the average productivity (145.64) of all top organizations: the University of Dhaka (n=456), Jahangirnagar University (n=341), North South University (n=247), Daffodil International University (n=243), BRAC University (n=228), International Centre for Diarrheal Disease Bangladesh (n=205), University of Chittagong and Rajshahi University (n= 163 each) and Mawlana

No.	Subject Name	TP	TC	CPP	%TP
1	Medicine	1632	25886	15.86	45.13
2	Computer Science	685	5618	8.20	18.94
3	Social Sciences	492	4885	9.93	13.61
4	Engineering	473	4734	10.01	13.08
5	Biochemistry, Genetics & Molecular Biology	384	6603	17.20	10.62
6	Immunology & Microbiology	371	6836	18.43	10.26
7	Environment Science	285	5173	18.15	7.88
8	Pharmacology, Toxicology & Pharmaceutics	208	3061	14.72	5.75
9	Psychology	148	3349	22.63	4.09
10	Energy	118	1624	13.76	3.26
11	Neurosciences	75	1888	25.17	2.07
	Bangladesh total	3616	52898	14.63	100.00

TP: Total publications; TC: Total citations; CPP: Citations per paper

Table 1. Distribution of Publications on "Covid-19 in Bangladesh" by Scopus-defined subject areas.

Bhashani Science & Technology University (n=156) and Shahjalal University of Science & Technology (n=139). The eleven organizations received citations per paper (CPP) and Relative Citation Index (RCI) above the average value (14.63 and 1.00) of top all top organizations: CHINTA Research (41.47 and 2.83), Khulna University of Engineering & Technology (25.02 and 1.71), Jahangirnagar University (23.23 and 1.59), Jashore University of Science & Technology (21.78 and 1.49), BGC Trust University (19.78 and 1.35), Banglabandhu Sheikh Mujib Medical University (17.45 and 1.19), University of Chittagong (16.88 and 1.15), International Centre for Diarrheal Disease Bangladesh (16.5 and 1.13), Shahjalal University of Science & Technology (16.16 and 1.1) and Bangladesh Agricultural University(15.89 and 1.09) (Table 2).

Individually, the top 25 organizations registered 17 to 346 collaborative linkages measured by total link strength (TLS). The largest number was depicted by the University of Dhaka (346), followed by Jahangirnagar University (253 linkages), BRAC University (171 linkages), North South University (155 linkages), Daffodil International University (147 linkages), and Jashore University of Science & Technology (123 linkages). The one-to-one collaborative linkages among the top 25 organizations varied from 1 to 57. The largest number of collaborative linkages (57) was depicted by the institutional pair "Jahangirnagar University and CHINTA Research", followed by "University of Dhaka and BRAC University" (38 linkages), "University of Dhaka and Jashore University of Science & Technology" (36 linkages), Jahangirnagar University and BRAC University"(33 linkages) , "University of Dhaka and North South University" (32 linkages), "University of Dhaka and Jahangirnagar University" and "University of Dhaka and Daffodil International University" and "University of Dhaka and University of Chittagong" (25 linkages each), "University of Dhaka and BGC Trust University" (22 linkages), "University of Dhaka and International Centre for Diarrheal Disease Bangladesh" (20 linkages), Jahangirnagar University and Daffodil International University" and "University of Dhaka and Noakhali Science & Technology University"(19 linkages each), "BRAC University and Shahjalal University of Science & Technology"(18 linkages), and Jahangirnagar University and North South University" (17 linkages).

Most productive and impactful authors

Individually, the top 25 authors published 19 to 87 publications. They collectively contributed 846 papers and 17339 citations, accounting for 23.40% and 32.78% share in Bangladesh publications and citations. Among the top 25 authors, six authors contributed more their average productivity (33.84): (i) T.B. Emran (n=87), M.M. Hasan (n=80), M.A. Mamun(n=62), M.R. Islam (n=55), M.Y. Essar (n=46) and M.S. Islam (n=38); and (ii) Twelve authors registered citation impact by citations per paper (CPP) and Relative Citation Index (RCI) more than their average value (20.50 and 1.40): M.T.

No.	Name of the organization	TP	TC	CPP	RCI	TLS
1	University of Dhaka	456	6395	14.02	0.96	346
2	Jahangirnagar University	341	7922	23.23	1.59	253
3	North South University	247	2767	11.20	0.77	155
4	Daffodil International University	243	1656	6.81	0.47	147
5	BRAC University	228	2454	10.76	0.74	171
6	International Centre for Diarrheal Disease Bangladesh	205	3382	16.50	1.13	106
7	University of Chittagong	163	2752	16.88	1.15	104
8	Rajshahi University	163	1878	11.52	0.79	72
9	Mawlana Bhashani Science & Technology University	156	1576	10.10	0.69	77
10	Shahjalal University of Science & Technology	139	2246	16.16	1.10	108
11	Bangladesh University of Engineering & Technology	134	2031	15.16	1.04	49
12	Khulna University	132	1749	13.25	0.91	71
13	Noakhali Science & Technology University	120	1253	10.44	0.71	102
14	Jashore University of Science & Technology	98	2134	21.78	1.49	123
15	Khulna University of Engineering & Technology	89	2227	25.02	1.71	26
16	Banglabandhu Sheikh Mujib Medical University	84	1466	17.45	1.19	45
17	Bangladesh Agricultural University	81	1287	15.89	1.09	23
18	Dhaka Medical College	81	778	9.60	0.66	89
19	BGC Trust University	80	1582	19.78	1.35	75
20	University of Asia Pacific	76	1114	14.66	1.00	54
21	Jagannath University	71	514	7.24	0.49	73
22	Independent University	66	636	9.64	0.66	47
23	CHINTA Research	66	2737	41.47	2.83	81
24	Bangladesh University of Professionals	64	509	7.95	0.54	51
25	American International University Bangladesh	58	206	3.55	0.24	17
	Total of 25 organizations	3641	53251	14.63	1.00	
	Bangladesh total publications	3616	52898	14.63	1.00	
	TP: Total publications; TC: Total citations; CPP: Citations per paper; RCI: Relative citation index; TLS=Total link strength					

Table 2. Publication profile of top 25 organizations.

Sikder (42.25 and 2.89), M.A. Mamun (42.06 and 2.88), O. Ahmed (38.16 and 2.61), S. Hossain (31.41 and 2.15), M.M. Rahman (30.57 and 2.09), H. Harapan (29.68 and 2.03), M.A. Hossain (28.65 and 1.96), I. Ullah (27.09 and 1.85), R. Kabir (26.33 and 1.80), S.M.Y Arafat (25.45 and 1.74), M.S. Islam (24.37 and 1.67) and S. Islam (23.76 and 1.62) (Table 3).

The individual total link strength (TLS) or collaborative linkages of the top 25 authors ranges from 0 to 70, with M.M. Hasan depicting the largest collaborative linkages (70). He is followed by M.Y. Essar (65 linkages) and M. Rahman (41 linkages). However, the author-to-author collaborative linkages varied from 1 to 38. The author pair "M.M. Hasan and M.Y. Essar" made the largest collaborative linkages (32), followed by "M.Y. Essar and A. Ahmad" (26 linkages), "M.M. Hasan and S. Ahmad" (25 linkages), "M.R. Islam and M.J. Hussain" (18 linkages), "T. Shirin and F.Qadri"(16 linkages), "T.B. Emran and H.Harapan"(14 linkages),), "T.B. Emran and M.J. Hussain"(11 linkages), and "S.M.Y Arafat and R. Kabir" (10 linkages).

Most productive and impactful journals

The 3172 (87.72%) of 3616 total Bangladesh papers were published in journals. The rest were published as 276 (7.63%) in conference proceedings, 119 (7.63%) in book series, 47 (3.29%) as books and 2 (0.05%) in a trade journal. Individually, the top 25 journals' contributions varied from 18 to 112 papers. These 25 journals together contributed 835 papers, constituting 26.32% share in all journal papers of Bangladesh. The top 6 most productive journals were *PLOS One* (n=112), *Heliyon* (n=100), *Frontiers in Public Health* (n=64), *Annals of Medicine & Surgery* (n=40), *Journal of Medical Virology* (n=39), *International Journal of Environmental Research & Public Health* (n=37). The top 6

No.	Name of the author	Affiliation of the author	TP	TC	CPP	RCI	TLS
1	T. B. Emran	BGC Trust University	87	1780	20.46	1.40	35
2	M. M. Hasan	Mawlana Bhashani Science & Technology University	80	706	8.83	0.60	70
3	M. A. Mamun	CHINTA Research	62	2608	42.06	2.88	16
4	M. R. Islam	University of Asia Pacific	55	1013	18.42	1.26	28
5	M. Y. Essar	Mawlana Bhashani Science & Technology University	46	434	9.43	0.64	65
6	M. S. Islam	Jahangimagar University	38	926	24.37	1.67	22
7	I. Ullah	Ministry of Health & Family Welfare, Dhaka	33	894	27.09	1.85	24
8	O. Ahmed	University of Chittagong	32	1221	38.16	2.61	0
9	T. Shirin	ICDDR-Bangladesh	30	148	4.93	0.34	26
10	S. M. Y Arafat	Enam Medical College & Hospital	29	738	25.45	1.74	10
11	M. J. Hossain	State University of Bangladesh	29	342	11.79	0.81	31
12	S. Ahmad	Mawlana Bhashani Science & Technology University	26	264	10.15	0.69	42
13	M. T. Sikder	Jahangimagar University	28	1183	42.25	2.89	31
14	Y. Araf	Shahjalal University of Science & Technology	27	547	20.26	1.38	3
15	S. Hossain	Jahangimagar University	27	848	31.41	2.15	12
16	R. Kabir	Anglia Ruskin University	24	632	26.33	1.80	12
17	M. D. H. Hawlader	North South University	23	139	6.04	0.41	6
18	F. Qadri	ICDDR-Bangladesh	23	91	3.96	0.27	28
19	M. M. Rahman	Jahangimagar University	23	703	30.57	2.09	3
20	M. Z. Rahman	ICDDR-Bangladesh	23	112	4.87	0.33	34
21	M. Rahman	ICDDR-Bangladesh	22	199	9.05	0.62	41
22	S. Islam	Jahangimagar University	21	499	23.76	1.62	3
23	M. A.Hossain	University of Dhaka	20	573	28.65	1.96	11
24	N. Adnan	Jahangimagar University	19	175	9.21	0.63	9
25	H. Harapan	Universitas Syiah Kuala	19	564	29.68	2.03	18
		Total of 25 organizations	846	17339	20.50	1.40	580
		Bangladesh total publications	3616	52898	14.63	1.00	
		Share of top 25 organizations in Bangladesh total publications	23.40	32.78			

TP: Total publications; TC: Total citations; CPP: Citations per paper; RCI: Relative citation index; TLS=Total link strength

Table 3. Publication profile of top 25 most productive authors.

journals in terms of citation per paper were the *Asian Journal of Psychiatry* (74.0), *IEEE Access* (53.44), *Science of the Total Environment* (36.78), *BMJ Global Health* (31.79), *Informatics in Medicine Unlocked* (29.55) and *Journal of Medical Virology* (29.51) (Table 4).

Keyword co-occurrence analysis

The keywords indicate the prevalent concepts in the subject. They, independently or in combination with other keywords, indicate important concepts, and their co-occurrence helps us understand essential research areas. Among 3616 Bangladesh publications, 1207 authors' keywords appeared, with the frequency of occurrences varying from 1 to 2990. We have identified 41 most important keywords from these author keywords, with the frequency of occurrences ranging from 71 to 2990 listed in Table 5. The leading keywords by their frequency of co-occurrence were Covid-19 (n=2990), Vaccination (n=250), COVID-19 Vaccine (n=214), Mental Health (n=197), Depression (n=189), Anxiety (n=186), Deep Learning (n=174), Prevention & Control (n=169), Machine Learning (n=164), Virus Transmission (n=149) and Psychology (n=143).

From these, a selection was made based on keywords with at least 70 occurrences, resulting in 41 selected keywords with a total link strength of 9292 and 671 links. The co-occurrence network of the 41 selected significant keywords and their co-occurrence was visualized and clustered as depicted in Figure 2 to discover the theme cluster indicated in various colors.

| No.	Name of the journal	TP	TC	CPP	% TP
1	PLOS One	112	2115	18.88	3.53
2	Heliyon	100	1490	14.90	3.15
3	Frontiers in Public Health	64	1115	17.42	2.02
4	Annals of Medicine & Surgery	40	109	2.73	1.26
5	Journal of Medical Virology	39	1151	29.51	1.23
6	International Journal of Environmental Research & Public Health	37	534	14.43	1.17
7	Sustainability Switzerland	34	413	12.15	1.07
8	Environmental Science & Pollution Research	30	464	15.47	0.95
9	Frontiers in Psychiatry	29	283	9.76	0.91
10	Informatics in Medicine Unlocked	29	857	29.55	0.91
11	BMJ Open	28	206	7.36	0.88
12	Scientific Reports	26	374	14.38	0.82
13	Asia Pacific Journal of Public Health	25	183	7.32	0.79
14	Vaccines	25	520	20.80	0.79
15	Bangladesh Journal of Medical Science	24	114	4.75	0.76
16	Health Science Reports	24	101	4.21	0.76
17	Computers in Biology & Medicine	23	546	23.74	0.73
18	Science of the Total Environment	23	846	36.78	0.73
19	Journal of Molecular Structure & Dynamics	21	580	27.62	0.66
20	Journal of Medicine Bangladesh	10	10	1.00	0.32
21	Journal of Global Health	19	150	7.89	0.60
22	BMJ Global Health	19	604	31.79	0.60
23	International Journal of Health Planning & Management	18	201	11.17	0.57
24	IEEE Access	18	962	53.44	0.57
25	Asian Journal of Psychiatry	18	1332	74.00	0.57
	Total of 25 top journals	835	15260	18.28	26.32
	Bangladesh total papers in journals	3172			
	Share of top 25 journals in Bangladesh total journal papers	26.32			
	TP: Total publications; TC: Total citations; CPP: Citations per paper				

Table 4. Publication profile of top 25 most productive journals.

The keywords' co-occurrence network consisted of 671 links and 9292 total link strengths, showing the main topics within this research field. According to the cluster results in VOSviewer, as reflected in Figure 1, five clusters that vary in size and are represented by various colors were identified. The selected clusters and their associated keywords are as follows:

- Cluster 1 (Red, 12 keywords) includes Angiotensin Converting Enzyme 2, antiviral agents, antivirus agents, coronavirus spike glycoprotein, drug therapy, immune response, molecular docking, molecular docking simulation, molecular dynamics, Remdesivir, virology, and virus replication. These keywords reflect the extensive research on the virology and pharmacology of Covid-19. The high frequency of molecular docking and dynamics highlights the computational methods used in drug discovery and development. The antiviral and antivirus agents keywords indicate the potential of these drugs in treating Covid-19.

- Cluster 2 (Green, 11 keywords) includes anxiety, depression, fear, lockdown, mental health, psychology, quarantine, social distancing, social media, virus pneumonia, and virus transmission, indicating the impact of the Covid-19 pandemic on mental health and social behavior. The larger frequency of anxiety, depression, and mental health keywords underscores the need for mental health support for individuals and communities affected by the pandemic. The keywords related to social distancing and quarantine indicate the importance of public health measures in controlling the spread of Covid-19.

No.	Keyword	Occ.	TLS	Cluster	No.	Keyword	Occ.	TLS	Cluster
1	Covid-19	2990	3573	Yellow	22	Prediction	98	303	Yellow
2	Vaccination	250	793	Lavender	23	Immune Response	93	329	Red
3	COVID-19 Vaccine	214	463	Lavender	24	Diabetes Mellitus	91	366	Blue
4	Mental Health	197	577	Green	25	Social Distancing	89	276	Green
5	Depression	189	606	Green	26	Hospitalization	88	317	Blue
6	Anxiety	186	605	Green	27	Hypertension	88	393	Blue
7	Deep Learning	174	294	Yellow	28	Quarantine	87	277	Green
8	Prevention & Control	169	618	Lavender	29	Forecasting	87	154	Yellow
9	Machine Learning	164	284	Yellow	30	Molecular Dynamics	81	329	Red
10	Virus Transmission	149	466	Green	31	Headache	79	308	Blue
11	Psychology	143	503	Green	32	Angiotensin Converting Enzyme 2	79	338	Red
12	Virus Pneumonia	143	345	Green	33	Coronavirus Spike Glycoprotein	79	325	Red
13	Lockdown	138	324	Green	34	Molecular Docking Stimulation	75	372	Red
14	Virology	137	430	Red	35	Fear	74	222	Green
15	Social Media	129	333	Green	36	Remdesivir	73	320	Red
16	Molecular Docking	128	463	Red	37	Dyspnea	72	326	Blue
17	Vaccines	122	281	Lavender	38	Drug Therapy	72	340	Red
18	Comorbidity	121	444	Blue	39	Risk Assessment	71	207	Blue
19	Convolutional Neural Networks	115	164	Yellow	40	Antiviral Agents	71	354	Red
20	Antivirus Agents	99	454	Red	41	Virus Replication	71	299	Red
21	Coughing	98	409	Blue					

Table 5. Most occurred author keywords in Bangladesh covid-19 publications.
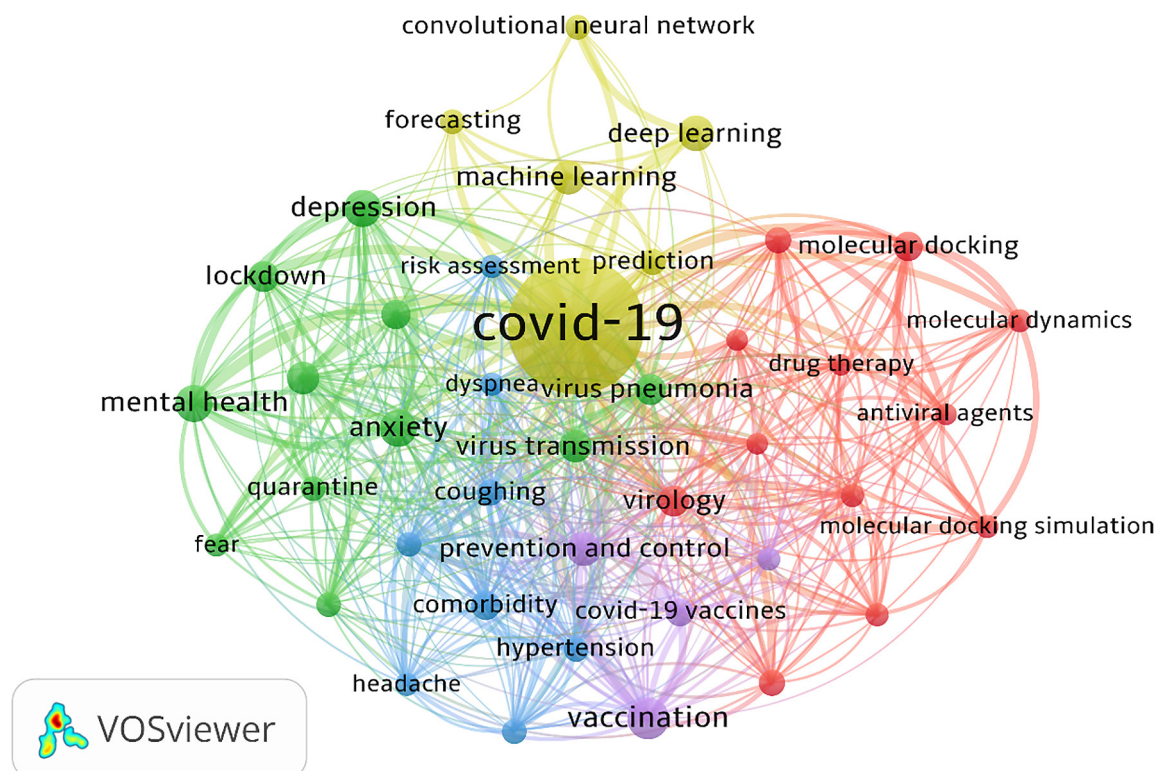
Figure 1. Top 41 selected keywords co-occurrence visualization network map.

- Cluster 3 (Blue, 8 keywords) includes comorbidity, coughing, diabetes mellitus, dyspnea, headache, hospitalization, hypertension, and risk assessment. These keywords primarily pertain to the clinical features and risk factors associated with Covid-19. Comorbidity, diabetes mellitus, and hypertension are significant risk factors for severe Covid-19 outcomes, while coughing, dyspnea, and headache are common symptoms. The high frequency of hospitalization and risk assessment highlights the importance of timely and appropriate healthcare delivery and monitoring.
- Cluster 4 (Yellow, 6 keywords) includes Convolutional Neural Networks, Covid-19, Deep Learning, Forecasting, Machine Learning, and Prediction. These keywords reflect the increasing use of artificial intelligence and machine learning techniques in Covid-19 research, which underscores the potential of these methods in analyzing large datasets and making predictions about the course of the pandemic.
- Cluster 5 (Lavender, 4 keywords) includes the Covid-19 vaccine, prevention & control, vaccination, and vaccines. These keywords reflect the ongoing efforts to develop and implement vaccines against Covid-19. The focus on prevention & control highlights the need for a multi-faceted approach to managing the pandemic, including vaccination, public health measures, and healthcare delivery.

High-cited papers

Only 86 (4.32%) out of 3616 publications on Covid-19 by Bangladesh received 101 to 11361 citations. They collectively registered 20815 citations, averaging 147.66 per paper (CPP). The 86 HCPs were in the following citation range: 48 papers (101-198 citations), 22 papers (201-297 citations), 11 papers (319-421 citations), 3 papers (628-838 citations) and 2 papers (1194-1361 citations). Among the 86 HCPs, 62 were articles, 18 reviews and 6 letters. Of the 86 HCPs, 58 were published in 2020, 23 in 2021 and 5 in 2022. Only 20 (23.25%) out of 86 HCPS received research support from external funding agencies. The 20 funded papers registered 7064 citations, averaging 82.14 CPP. The major funding agencies supporting research in this area include the National Institute of Health (5 papers), National Institute of Allergy & Infectious Diseases, USA and National Center for Advancing Translational Sciences, USA (4 papers each), European Commission, and National Health & Medical Research Council (3 papers).

The 69 (80.23%) out of 86 HCPs involve international collaboration. The 69 ICPs together registered 17791 citations, averaging 206.87. The USA contributed the most (30 papers) among 86 HCPs, followed by U.K. (23 papers), Australia (20 papers), China and Pakistan (14 papers each), Canada and India (13 papers each), Sweden (11 papers), Japan (10 papers), Brazil and Malaysia (9 papers each), Saudi Arabia (8 papers), Indonesia (5 papers), Nepal and South Korea (4 papers each), Nigeria and Sri Lanka (3 papers each). By participating population age groups, "Adults" and "Middle Aged" contributed the most papers (n=26 and n=18) among 86 HCPs, followed by "Aged" and "Adolescents" & "Children" (n=12 and n=7). Among the type of studies in 86 HCPs, "Clinical Studies" and "Epidemiology" account for the largest number of studies (n=20 and n=18), followed by "Genetics" (n=18), "Risk Factors"(n=12), "Diagnosis"(n=4), "Pathophysiology"(n=3), and "Complications" (n=2). Medicine contributed the most significant number (49 papers) of papers by Scopus subject categories, followed by Immunology & Microbiology (9 papers), Biochemistry, Genetics & Molecular Biology, Environmental Science (9 papers), Engineering and Psychology (8 papers each), Social Sciences, (7 papers), Computer Science (5 papers), Energy and Neurosciences (3 papers each), and Pharmacology, Toxicology & Pharmaceutics (2 papers).

The Jahanginagar University contributed the most papers (16 papers) among 76 participating organizations in 86 HCPs, followed by the University of Dhaka (10 papers), CHINTA Research and International Centre for Diarrhoel Disease Research Bangladesh (9 papers), Jashore University (7 papers), BRAC University and Khulana University of Engineering & Technology (5 papers each), North-South University and Shahjalal University of Science & Technology (4 papers), University of Chittagong and Bangladesh University of Engineering & Technology (3 papers each), Daffodil International University, Rajshahi University, Khulna University,

Banglabandhu Sheikh Mujib Medical University, Bangladesh Agricultural University, and Dhaka Medical College and Independent University (2 papers each). The M.A. Mamun contributed the most significant number of papers (8) among 216 participating authors in 86 HCP, followed by S. Hossain and M.T. Sikder (4 papers each), I. Ullah (3 papers), M.S. Islam, O. Ahmed and M.M. Rahman (2 papers), etc.

The *PLOS One* journal contributed the largest number of papers (5) among 63 participating journals in 86 HCPs, followed by *Heliyon, International Journal of Mental Health & Addition,* and *Journal of Affective Disorders* (3 papers), *Asian Journal of Psychiatry, BMG Global Health, Frontiers in Public Health, International Journal of Environmental Research & Public Health, Informatics in Medicine Unlocked, Journal of Medical Virology, Journal of Infection & Public Health, Lancet Global Health, Psychiatry Research, Science Immunology, Science of the Total Environment, Science and Sustainable Production & Consumption* (2 papers) and one paper each in 46 other journals.

Amongst appearing author keywords in 86 Bangladesh HCPs, the most important keywords considered by the frequency of their occurrence were Covid-19 (n=76), Virus Pneumonia (n=31), Psychology (n=19), Mental Health (n=11), Virology (n=10), Depression, Anxiety, Fear and Virus Transmission (n=9 each), Covid-19 Vaccines (n=7), Diabetes Mellitus, Mental Disease and Infection Risk (n=6 each), Vaccination, Mental Stress, Deep Learning, Prevention & Control, Disease Transmission, Infection Control, Convolutional Neural Network, and Hypertension (n=5 each), "Vaccine Hesitancy", "Stress", "Machine Learning", and "Infection Prevention".

DISCUSSION AND FINAL CONSIDERATIONS

It was observed that Bangladesh researchers contributed 0.75% share to global output on Covid-19. Regarding publication productivity, Bangladesh was ranked 49th in the global research output. Bangladesh research received 52898 citations, with a citation impact per paper (CPP) of 14.63. International collaboration was depicted by 66.33% of Bangladesh Covid-19 publications and depicted a higher 17.91 CPP than an average 16.79 CPP of all Bangladesh

publications. The USA (n=636) contributed the most among Bangladesh foreign ICPs, followed by India (n=535), Australia (n=525), U.K. (n=499), Malaysia (n=399), China (n=284), Pakistan (n=271), Saudi Arabia (n=263), Canada (n=238), Japan (n=220), Indonesia (n=138), etc. The study indicates that Bangladesh should expand its current international collaboration efforts, which may increase its research output and improve its citation impact and quality. The Bangladesh research revealed that funded research publications are cited more than non-funded ones. Funded publications received 16.79 citations per paper vis-a-vis the national average of 14.63 CPP for the total research output. There is a need to provide more external funding to Covid-19 research through national and national sources.

Institutional findings suggest that several medical institutions and particularly universities across Bangladesh are involved in the present research study, with maximum output from the University of Dhaka (n=456 Jahangirnagar University (n=341), North South University (n=247), Daffodil International University (n=243), etc. It has been witnessed that most impactful organizations (with higher citations) differ from top productive organizations. The most impactful organizations were CHINTA Research (41.47 and 2.83), Khulna University of Engineering & Technology (25.02 and 1.71), Jahangirnagar University (23.23 and 1.59) and Jashore University of Science & Technology (21.78 and 1.49).

Although several authors were involved in Bangladesh Covid-19 research, only a few authors contributed the most: T.B. Emran (n=87), M.M. Hasan (n=80), M.A. Mamun(n=62) and M.R. Islam (n=55). The most impactful authors, in contrast, were different from the most productive and included M.T. Sikder (42.25 and 2.89), M.A. Mamun (42.06 and 2.88), O. Ahmed (38.16 and 2.61) and S. Hossain (31.41 and 2.15),

The author's productivity is more unevenly distributed compared to institutional productivity. The top 25 organizations contribute more than 100% share each in Bangladesh overall output, as against 23.40% and 32.78% share by the top 25 Bangladesh authors. The Bangladesh publication productivity at the level of research organization was 145.34 per organization, and at the author level, it was 33.84 per author.

Measured by citation frequency, only a few Bangladesh papers (86, 4.32%) received at least 100+ citations per paper, were low and received 147.66 CPP. The USA contributed the most papers (30) among 86 HCPs, followed by the U.K. (23 papers), Australia (20 papers), China and Pakistan (14 papers each), Canada and India (13 papers each), Sweden (11 papers), Japan (10 papers), Brazil and Malaysia (9 papers each).

The present study examined research trends and future directions in Bangladesh Covid-19 research using various bibliometric indicators, focusing mainly on the core relevant literature. Foreign collaboration and availability of external funding was the most dominating feature of Bangladesh's Covid-19 research, leading to an exponential increase in its publications and a high citation impact of most of its publications. The study will help the research scholars and policymakers understand the present situation, make more intelligent decisions in choosing their research problem, and look for appropriate collaborative partners and funding agencies for research support.

Contribution statement

Conceptualization: B. M. Gupta and M. Kappi.

Data curation, visualization: Mallikarjun Kappi and Rajpal Walke.

Investigation, methodology, writing- original draft and project administration: B. M. Gupta and Madhu Gupta.

Writing-review and editing: B. M. Gupta.

Conflict of interest

The authors declare that there is no conflict of interest.

Statement of data consent

The data generated during the development of this study has been included in the manuscript. ●

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