Original Article

Top 50 cited articles on Covid-19 after the first year of the pandemic: A bibliometric analysis

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ABSTRACT

Background & aims: It has been just over a year since the Covid-19 pandemic started. The top 50 cited articles on this subject would help identify trends and focus on the research efforts.
Methods: We utilised e-utilities in PubMed to find publications on Covid-19 until the date of search on 7/2/21. The iCite website was used to find the top 50 citations of the output from the search strategy. We looked into their full text for the editorial dates, type of study, level of evidence, focus of the article and country of origin. We also counted the errata and comments on each of them.
Results: The total number of citations of all 50 articles was 123,960, the highest being 10, 754 for a single article. Huang C was the most cited first author. They were published from week 4−17, with February being the month with most citations. Lancet was the most cited journal, having published 9 of the 50 articles. Majority belonged to level 3 of the evidence ladder and were retrospective studies. Thirty percent of them had an errata published and an average of 7 comments per article.
Conclusion: The top 50 most cited articles identify the most impactful studies on Covid-19, providing a resource to educators while identifying trends to guide research and publishing efforts. There has been an explosion of publications and an unprecedented rate and number of citations within the first year for any single condition in the literature.

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1. Introduction

Covid-19 has affected humanity in a major way. An extremely dangerous virus, hitherto unknown to humanity, had to be studied and contained in order to overcome the pandemic. Research on Covid-19 had surged in the early days with an unprecedented surge in the publications on that specific topic. With vaccination drives in majorly affected countries, and the emergence of second and third waves, the interest on this topic in the scientific community has been sustained. Pubmed is the most commonly used and freely available database and most of the articles published on the Covid-19 topic in major journals were fast-tracked and made freely available for rapid dissemination of information and findings. Top 50 cited articles have been published in many areas of medicine. In fact there have been publications related to Covid-19 from an earlier period. The differences have been discussed in the discussion section of this manuscript. Due to the sheer volume of publications on this topic, there would be different outcome if two studies were done six months apart. We looked into the top 50 cited publications on this topic in the literature in the PubMed to analyse the trends and focus of research among the most cited articles.

2. Methods

A search was done on 7/2/21 with a search strategy of (COVID-19 OR SARS-CoV-2 OR "New Corona Virus" OR "coronavirus 2″ OR "new coronavirus") AND (("2020/01/01"[Date - Create]: "2021/01/

Table 1
Publications in Week number with Total Citations and citations/publication.

Week Number	Number of Publications	Total Citations	Citations/ publication
4	1	5929	**5929**
5	**8**	**24222**	3027.75
6	6	22833	3805.5
8	5	7653	1530.6
9	6	18247	3041.17
10	4	7952	1988
11	6	8582	1430.33
12	4	12950	3237.5
13	2	1799	899.5
14	3	3724	1241.33
15	2	2921	1460.5
16	1	1308	1308
17	2	3287	1643.5
Total	**50**	**121407**	**Avg: 2349.44**

Cell highlighted with green and light orange indicates the highest value and lowest value in the corresponding column in all the tables where applicable.

01"[Date - Create]))

For all publications in 2020 which gave an output of 88337.

The strategy of (COVID-19 OR SARS-CoV-2 OR "New Corona Virus" OR "coronavirus 2″ OR "new coronavirus") AND (("2021/01/01"[Date - Create]: "3000"[Date - Create])) was used for all publications from 2021 which gave an output of 11855.

When this search strategy was fed through eUtilities, we got a total of 11853 + 87793 articles. The PMIDs of all these articles were fed into the iCite website for citations and related data, from which we got 95806 articles. Some articles were left out by the iCite website and were not processed.

The output from the iCite website was fed into Excel and analysed for citation numbers and other basic outcomes. The data from the iCite website includes information on Field Citation Ratio (FCR), expected citations, number of citations, PMIDs of all articles citing every article, total number of references and DOI (Digital Object Identifier) address for each of the article obtained from the search. We analysed this preceding data and present the results. We calculated citations per week, week number the article was published in the year and percentages where appropriate.

FCR is calculated by the number of citations received by a publication divided by the average number of citations received by publications within that field in the same year. PubMed page of each of the 50 articles was scanned to see the number of comments and errata published against each of them and noted.

The top 50 cited articles were selected from this output and full texts collected and analysed for the purpose of this paper. We looked into the following information from the full text of each manuscript: create date in PubMed, type of study, level of evidence, focus of the paper, month published, country it was published from, week of the year it was published.

We also looked into the following times (in days) of each article as given in their full text where applicable; (i) time from submission to accepting to publish, (ii) from acceptance to publication and (iii) from submission to publication. Any errata or comments on the articles on PubMed were also noted down. We collected the data and analysed it in an Excel database.

3. Results

The total number of citations of the top 50 papers was 123,960. The top 50 cited publications were published between the weeks 4–17 of last year. Week five saw the most number of publications (8 in number) and most citations for publications, but publications from week four (6 publications) had the most citations per publication (Table 1). February was the month with most publications of the top 50 cited and had the maximum total citations as well as citations per week among the four months these articles were published (Table 2). Most publications were done in the month of February (19 in number) with a sum of citations of 53,204 for that

Table 2
Publications according to the month of the year.

Month	Publications	Citations/week	Total Citations
January	7	71.89	27037
February	19	54.45	53204
March	18	41.03	34753
April	6	35.06	8966

month. However, the citations per publication was maximum for the month of January at 3862 per citation.

Most studies published were of level 3 evidence in the evidence pyramid with 27 (40%) in number. Studies of level 3 had the most citations per publication at 2930.35. Twelve of the thirteen retrospective analyses belonged to this category with a citation sum of 38,418. Since citations are a function of duration since publication, we looked at the sum of citations per publication per week (CPW). A level 2 study [1] had the highest at 200.223 followed by a level 3 study [2] with 151.02 CPW.

Cohort study was the commonest type of study with a citation sum of 51,574. Of them, 12 were of evidence level 3, and four of these belonged to evidence level 4. Nine of the articles were correspondence to the editor, making it the second commonest type of study.
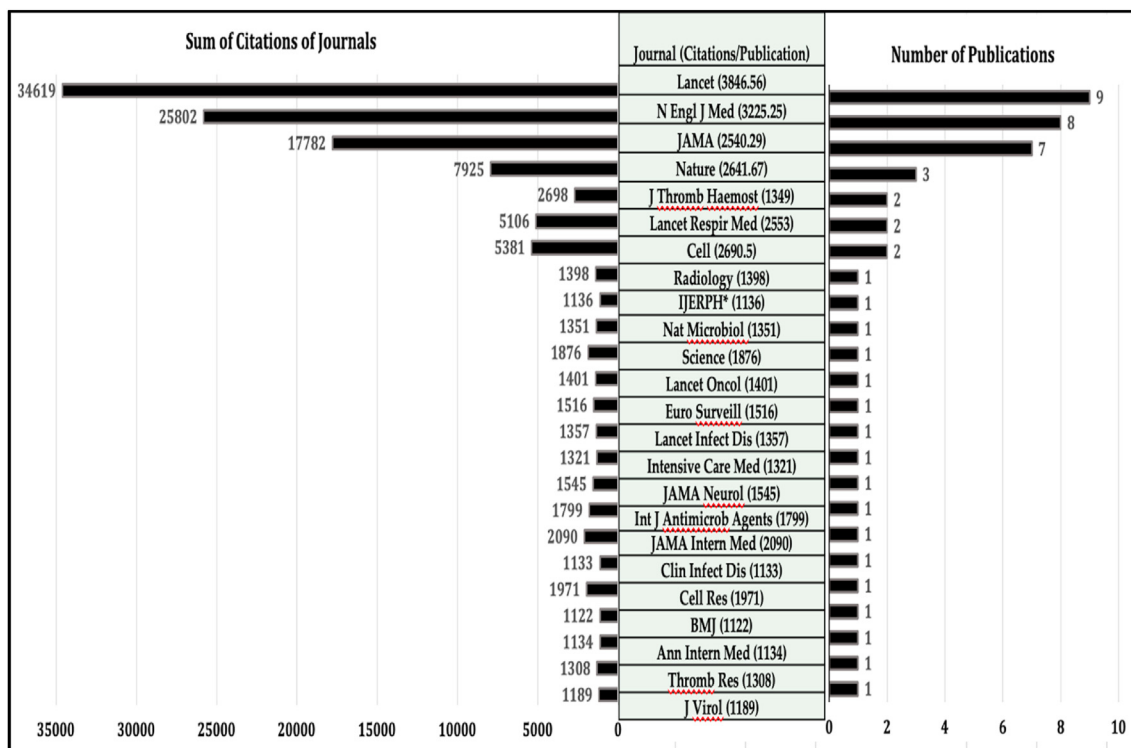
Lancet was the most cited journal publishing on this topic (Chart 1.) Table 3 gives the numbers published by each journal

with their impact factors.

A total of 24 journals published the 50 most cited articles on Covid-19. Half of these journals (12 in number) had an impact factor of >20 Table 3. There were a total of 15 papers (30%) which published errata on PubMed. Of these, 12 articles were published in journals with an impact factor of 20 or higher.

China was the country with the most publications (31) and citations (92276) Chart 2.

Table 4 shows the Level of evidence with names of journals in each level of evidence that published on this topic. It is evident that the higher level of evidence studies were from the highest impact factor journals. The number of citations was also higher for these journals and they top each category of evidence. Standard abbreviations for the journals were used in the table. Level 3 had the highest number of citations and but citations per publication was highest for level 2 studies at 3709 followed by level 3 studies at 2930. Level 5 studies included opinions and Letters to the editors.

Sum of Citations of Journals / Journal (Citations/Publication) / **Number of Publications**

Sum of Citations	Journal (Citations/Publication)	Number of Publications
34619	Lancet (3846.56)	9
25802	N Engl J Med (3225.25)	8
17782	JAMA (2540.29)	7
7925	Nature (2641.67)	3
2698	J Thromb Haemost (1349)	2
5106	Lancet Respir Med (2553)	2
5381	Cell (2690.5)	2
1398	Radiology (1398)	1
1136	IJERPH* (1136)	1
1351	Nat Microbiol (1351)	1
1876	Science (1876)	1
1401	Lancet Oncol (1401)	1
1516	Euro Surveill (1516)	1
1357	Lancet Infect Dis (1357)	1
1321	Intensive Care Med (1321)	1
1545	JAMA Neurol (1545)	1
1799	Int J Antimicrob Agents (1799)	1
2090	JAMA Intern Med (2090)	1
1133	Clin Infect Dis (1133)	1
1971	Cell Res (1971)	1
1122	BMJ (1122)	1
1134	Ann Intern Med (1134)	1
1308	Thromb Res (1308)	1
1189	J Virol (1189)	1

* Int J Environ Res Public Health

Chart 1. Journals publishing with number of publications on the right and total citations on the left. Citations/publication of each journal were given in brackets.

Table 3
Journals publishing top 50 cited articles on Covid-19.

Journal^	No. of Publications	Latest Impact Factor	No. of Errors	No. of Comments	Submission to Acceptance (Days)	Acceptance to Publication (Days)	Submission to Publication (Days)
Ann Intern Med	1	21.317		1			
BMJ	1	30.223	1	2	23	9	32
Cell	2	38.637	1	6	13	10.5	23.5
Cell Res	1	20.507		4	3	7	10
Clin Infect Dis	1	9.117					
Euro Surveill	1	6.4	1		1	1	2
Int J Antimicrob Agents	1	4.621		14			
Int J Environ Res Public Health	1	2.849		4	18	3	21
Intensive Care Med	1	17.679	1	2		8	
J Thromb Haemost	2	4.662		24	4.5	2.5	7
J Virol	1	4.501			6	1	7

JAMA	7	45.54	2	32	10.93	6.42	16.33
JAMA Intern Med	1	18.7	1	5		8	
JAMA Neurol	1	13.608		11		15	
Lancet	9	60.392	3	49			
Lancet Infect Dis	1	24.446	1	4			
Lancet Oncol	1	33.752		27			
Lancet Respir Med	2	25.094	2	7			
N Engl J Med	8	74.699		61			
Nat Microbiol	1	15.54			14	12	26
Nature	3	42.778	2	30	17.67	6.33	24
Radiology	1	7.931		5	4	1	5
Science	1	41.846			7	2	9
Thromb Res	1	2.869		15			
	50*	23.65#	15*	303*	10.93#	6.25#	16.33#

Totals * Averages # ^Journal names are given using standard abbreviations.

Some level 5 articles received more number of citations than some level 1 and 2 articles. Huang C was the most cited first author at 10,754 citations followed by Guan WJ Table 5.

Chart 2. Most cited Countries Publishing on Covid-19. Numbers in brackets indicate number of publications and citations per week for that country.

Table 6 shows the speciality-wise distribution of publications, citations and citations per week. Not surprisingly, Pulmonology was the speciality that topped the list. In fact, the first four entries in the table are expected to be high as major work on this topic was done in those fields. These were followed by molecular sciences and internal medicine.

The studies were analysed and categorised according to the focus of the study to give a comprehensive idea about the research trends, as shown in Table 7. Majority of the papers describe the clinical data, which included the timeline of the disease, demographics of the patients, risk factor analysis, clinical features, blood and radiological investigations, treatment protocols used, prognostic factors, predictors of mortality, psychological impact and the outcomes.

One article was a consensus of the Coronaviridae Study Group (CSG) of the International Committee on Taxonomy of Viruses to name the virus as 2019-nCoV and individual isolates as SARS-CoV-2. 4 studies detailed the diagnostic aspect of the disease. These included proving a diagnostic workflow of the disease, identification of the nCov-19 in body fluids and assessment of viral loads, analysing sensitivity and specificity of the RT-PCR and CT scans in the diagnosis. Twelve studies described the epidemiological characteristics of COVID-19. These studies described the aetiology and
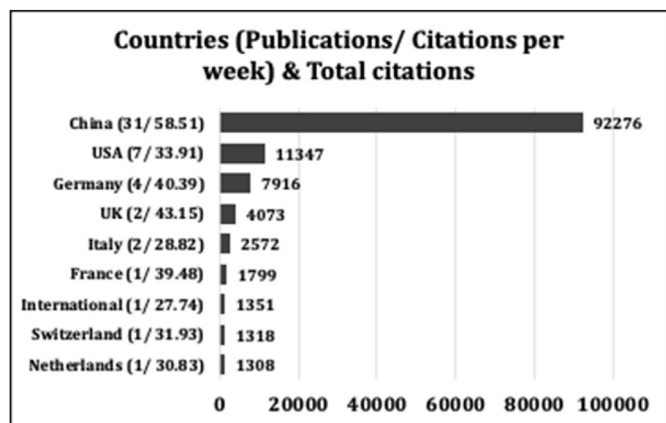
Table 4
Level of Evidence with journals in each level along with the numbers and citations of publications.

Level of Evidence & Journal	Total Citations	Number of Articles	Citations per article
1	**1767**	**1**	**1767**
N Engl J Med	1767	1	1767
2	**14836**	**4**	**3709**
Ann Intern Med	1134	1	1134
Euro Surveill	1516	1	1516
JAMA	1432	1	1432
Lancet	10754	1	10754
3	**58607**	**20**	**2930.35**
BMJ	1122	1	1122
Cell	5381	2	2690.5
Clin Infect Dis	1133	1	1133
J Thromb Haemost	2698	2	1349
J Virol	1189	1	1189
JAMA	7619	2	3809.5
JAMA Intern Med	2090	1	2090
JAMA Neurol	1545	1	1545
Lancet	14657	3	4885.67
Lancet Respir Med	2748	1	2748
N Engl J Med	11253	2	5626.5
Nature	4466	1	4466
Radiology	1398	1	1398
Thromb Res	1308	1	1308
4	**37418**	**18**	**2078.78**
Int J Antimicrob Agents	1799	1	1799
Int J Environ Res Public Health	1136	1	1136
JAMA	8731	4	2182.75
Lancet	5337	3	1779
Lancet Oncol	1401	1	1401
Lancet Respir Med	2358	1	2358
N Engl J Med	9970	3	3323.33
Nat Microbiol	1351	1	1351
Nature	3459	2	1729.5
Science	1876	1	1876
5	**11332**	**7**	**1618.86**
Cell Res	1971	1	1971
Intensive Care Med	1321	1	1321
Lancet	3871	2	1935.5
Lancet Infect Dis	1357	1	1357
N Engl J Med	2812	2	1406

Table 5
Top 10 authors on Covid-19.

First Author	Total Citations
Huang C	**10754**
Guan WJ	7421
Zhou F	6513
Wang D	6243
Zhu N	5929
Chen N	5264
Zhou P	4466
Wu Z	4322
Li Q	3832
Hoffmann M	3724

source of origin, modes of transmission, incubation period, timeline of the outbreak, epidemiologic curve and doubling time, stability of nCov19 in aerosols and other surfaces, tracking of the disease and geographical distribution of the outbreak. Some of the epidemiological studies focussed on the clinical data as well. The epidemiological data is very beneficial for the authorities to draft public

Table 6
Publications and citations according to speciality.

Speciality	Publications	Citations	Citations/ week
Pulmonology	8	**37051**	**91.57**
Virology and Infectious disease	**10**	26321	51.29
Infectious disease	6	13892	46.3
Critical care	4	11688	58.52
Molecular Sciences	6	11115	38.58
Internal Medicine	4	6902	35.32
Laboratory Analysis	4	5456	29.96
Neurology	3	3814	27.91
Public Health	1	2009	38.22
Psychology	1	1556	31.76
Oncology	1	1401	27.7
Radiology	1	1398	28.29
Civil and Systems Engineering	1	1357	27.14

Table 7
Publications according to the focus of the study.

Focus of the study	Number	Citations
Clinical data	17	51995
Consensus	1	1351
Diagnostic	4	5932
Epidemiological	12	32892
Pathological findings	3	4809
Structural analysis	6	14921
Therapeutic	7	12060

health policies such as quarantine guidelines. Three studies focussed on providing various aspects of pathological findings. Two of them were post-mortem analyses detailing the histopathology of various organs, whereas the other study described the immune pathways and their dysregulation. Six studies carried out a detailed structural analysis of the virus. They provide insights into full-length genome sequencing, cell receptors, pathogenic mechanisms at the cellular level, phylogenetic origin and, antibody testing. This information identifies potential targets for developing diagnostic tests, vaccines, and anti-viral drugs, accelerating the countermeasure development. The remaining seven studies concentrated on therapeutic interventions. Various anti-viral agents were tested and compared to determine their applicability and efficacy. Three of them focussed on the coagulation profile abnormalities and stressed the importance of using anticoagulants in the treatment as the thrombotic phenomenon is associated with a worse prognosis.

Table 8
Publications grouped as clinical/non clinical and Basic sciences, each category classified according to the level of evidence.

Type of Study (Level of Evidence)	Total Citations	Number of articles	Citations per article
Clinical	**87752**	**30**	**2925.07**
1	1767	1	1767
2	13320	3	4440
3	52037	17	3061
4	20628	9	2292
Non Clinical	**26246**	**15**	**1749.73**
4	14914	8	1864.25
5	11332	7	1618.86
Basic Science	**9962**	**5**	**1992.4**
2	1516	1	1516
3	6570	3	2190
4	1876	1	1876

Table 8 groups publications into clinical studies involving patients (clinical trials, case Series, Case Reports, RCTs), non-clinical publications (e.g. Correspondence letters, Reviews) and Basic Science studies (Lab studies, Non-human experimental research). Each of these categories have been classified according to the level of evidence in the table. Majority (60%) were clinical studies and the highest citations per article was seen for a clinical study at 2925.

4. Discussion

As of Feb 9, 2021, the top 50 cited papers were cited 123,960 times on PubMed. There was a study looking into the top 50 cited papers on this subject [3]. But this was done in May 2020 which was very early during the pandemic. We feel now that sufficient time has passed since onset of the pandemic, (just over a year since the pandemic started), it is an appropriate time for a relook into this topic, especially with reference to citation numbers. ElHawary et al. [3] reported 63,849 citations for the top 50 cited articles which is about half of what we found about nine months after they studied. They searched Web of science (WOS), Google Scholar and Scopus for their top 50 citations. Pubmed search was not done in their study. They reported that over half of the publications were done in just three journals. Retrospective case series and correspondence/viewpoints formed the bulk of publications at 42% and 26% respectively.

In another study by Yuetian Yu [4], done in May 2020, scanning WOS database, 3626 publications were identified on this topic. Martinez-Perez et al. [5] found 14,335 publications between January and July 2020 with 42,374 citations from WOS. Senel et al. [6] reviewed literature on publications on coronavirus from 1980 to 2019 and found only 13,833 publications with a peak publication year of 2016 having 837 publications. This study may be considered as the baseline level of interest on coronavirus before the current pandemic. We found a total of 99,646 articles before we filtered the top 50 cited articles. Our study looked into some publication metrics of the articles which the previous publications did not include. These included, apart from general bibliometric data, like citations, journal and author data, clinically relevant data like focus of the paper, type of study, level of evidence of the study, speciality, month and week of publication, and country from which it was published. Most studies looked into WOS since citations are readily given in that database whereas for PubMed, it requires to use a different portal to get citation numbers which is not common knowledge.

Since most of the top cited studies we found were from the early stages of the Pandemic, one could expect that retrospective analysis is the type of study that would be the most commonly done as information was still needed to define various aspects of the disease. It could also be expected that lower level evidence studies in the evidence ladder would be done at this stage as higher level studies need greater understanding about the disease before they can be planned. Citations for studies done later take time to increase and catch up.

In a previous publication [7], we found 6831 total publications in the first 3 months of the pandemic and 1638 in the last week of the study alone from PubMed. This outbreak of Coronavirus has triggered an interest in publications and research that has never been seen on this subject. The publication numbers on Covid-19 have dwarfed those from any other subject during the pandemic. Irmak et al. [8] did the only study looking into the top 50 cited articles on PubMed in May 2020. They studied citations and co-citations and mapped them using R statistical software and Gephi softwares. Our study is different from theirs. We wanted to look into the top cited papers and analyse metric data as stated above.

Since the Pandemic originated in China, preliminary studies from china were the most cited studies and hence this country topped the citation numbers among countries at 92,276 which is 74.4% of the total number of citations of all the 50 publications[4]. Thirty one of the fifty publications originated from China. The maximum number of these top-cited articles belong to the speciality of Pulmonology. It is not surprising, as the COVID-19 disease is primarily a respiratory disease.

It has been reported in a study that more than 50% of the publications looked into had cited two high profile articles published in high impact factor journals even after the articles were retracted from publication [9]. A mechanism may need to be put in place to identify and prevent retracted articles from being cited in future studies. This may perhaps be included in the reference manager as a feature and/or included in scanning of manuscripts while submitting in the editorial manager of a journal.

We looked at the PubMed page of each article for the number of comments and errata Table 3. Fifteen publications (30%) had at least one erratum published and of these, two articles had two errata on them. We are not aware of the average number errata published on PubMed, but 30% in the top 50 cited quality articles appears high. One study reported 19% studies containing errata among 127 studied [10]. They classified them into trivial, minor and major. Since errata are usually published after a time lag, for a fast evolving pandemic like the Covid-19, studies with major errata which could potentially change the conclusion of the study should be minimized so that further studies do not use any wrong conclusions. Their occurrence could be due to fast tracking of the articles on Covid-19 by most journals which reduces the reviewing times and also the deluge of submissions for publication [7,11,12].

We looked at the times related to publishing these articles (Table 3). Not all journals give this data. From the data that was available, most journals appear to have fast tracked the publication process with an average time for submission to accepting at 10.9

days, acceptance to publication at 6.2 days and from submission to publication at just over two weeks (16.3 days).

The total number of comments published were 303 in all 50 publications with an average of 7.97 for each. Thirty eight of the top 50 cited had at least one comment published in PubMed. It indicates the level of interest the pandemic has evoked in the academic circles. It could also be due to free full text availability which encourages more researchers to be involved in the discussions.

All the articles in this study were published as open access and were freely available. Covid-19 publications in most major journals have been fast tracked and published open access for faster dissemination of knowledge and control of the pandemic. This could be one reason why the citation numbers have been so high. Shekhani et al. found open access provided a low magnitude but a significant correlation to high citation rate for manuscripts [13]. The most cited publication in the top 50, with a citation count of 10,754 in our study was by Huang C et al. [1].

5. Limitations

Limitations of our study include the fact that this study looked into a single database, namely PubMed. This has not been done in any of the previous studies. Most studies on citations looked into WOS. Although the citation number may be different from database to database, we believe the overall trends may be similar. But we do not have data to support this point. We could not compare with other studies to prove this because they were done at a different point of time.

6. Conclusions

There has been an explosion of publications on this topic and an unprecedented rate of citations within the first year for any condition in the literature. Chinese authors published on COVID-19 maximally, and Pulmonology was the medical speciality on which the articles were written and maximally by the Chinese authors. Majority of the publications focussed on the clinical data of the condition. The high-impact journals published these top-cited articles. The results identify impactful articles on Covid-19, providing a resource to educators while identifying trends that may be used to guide research and publishing efforts.

Declaration of competing interest

There is no conflict of interest to disclose for any of the authors.

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