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Global Perspective Article

## Global analysis of the COVID-19 research landscape and scientific impact



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## Key Words:

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## A B S T R A C T

**Objectives:** To consider a 1-year time window of the coronavirus disease 2019 (COVID-19) crisis to integrate qualitative and quantitative data and provide an in-depth analysis of all COVID-19 publications from geographical, epidemiological and chronological perspectives.

**Methods:** Publications on COVID-19 from December 1, 2019, to December 31, 2020 without document type limitations were extracted from the Web of Science database. Microsoft Excel 2016, GraphPad Prism 9, VOSviewer 1.6.15 and IBM SPSS 21.0 were used to analyze the global epidemiological publication landscape and its correlations, research hotspots around the world and the top 5 countries in terms of publications.

**Results:** A total of 51,317 documents were analyzed in the present study. The publication trend could be divided into an increasing output stage and an explosive output stage. There were positive correlations between monthly publications, confirmed cases and deaths. Research hotspots from the whole year, from individual quarters, and from the top 5 countries with the most publications were further identified.

**Conclusions:** The correlation analysis of publications indicated that confirmed cases and deaths were forces driving the scientific output, reflecting the growing trend to some extent. Moreover, the hotspot analysis provided valuable information for scientists, funders, policy and decision-makers to determine what areas should be their focus when faced with public health emergencies in the future.

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Coronavirus disease 2019 (COVID-19) has spread rapidly since the outbreak began in Wuhan in late 2019. As of December 2020, it had lasted 1 year, killed more than 2.2 million, sickened 1 hundred

million people and disrupted the daily lives of billions of people around the world. These numbers have continued to rise. The influence on the economy, policy and society due to COVID-19 has made it the biggest crisis since World War II.<sup>1</sup> Many words that apply to war, such as “battle,” “unseen enemy” and “wartime president,” have also been used during this pandemic. Even so, history has shown that a war or pandemic brings not only horror but also great potential to catalyze innovation and development in medicine and public health.<sup>2</sup> The institutionalized network of blood banks led by the American Red Cross and the mass production and widespread availability of penicillin were all achievements during a war or its aftermath. We do not yet know what impact COVID-19 will have on our health care, but there will be impacts.

Research on COVID-19 is an emerging and rapidly developing field, expanding almost as quickly as the spread of the virus.<sup>3</sup> To date, there have been more than fifty thousand publications on this topic,

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according to Web of Science, which gives a phenomenal average of more than 100 articles per day. Information reported by these studies might play a key role in furthering our understanding of this global pandemic.<sup>4</sup> For example, early-outbreak case reports and observational studies provide us with an evidence base for developing drugs and therapies, and subsequent clinical research, especially randomized controlled trials, have great potential to guide prevention and treatment.<sup>5</sup> However, simultaneously, having such a great volume of research historically focused on a single topic may also pose risks. It may be a case of high production at the sacrifice of high quality,<sup>6</sup> may make it difficult to use these data to guide one's own research, or it may bring us far from the ultimate aim of science (health practice and decision-making).<sup>7</sup> Given that the pandemic is ongoing, some bans remain in place, and the world is still searching for knowledge and solutions about this crisis. It is of great significance to have an overview of the existing publications, to try to identify unaddressed issues and to provide ideas and directions for future research directions from a macro perspective.

Many researchers have recognized the significant value of extracting and organizing qualitative and quantitative knowledge from large volumes of information or literature.<sup>8</sup> Thus, since the outbreak of COVID-19, various knowledge maps have been constructed by researchers covering coronavirus knowledge, environmental fields, business management fields and others.<sup>9,10</sup> However, most of the articles were published at the early stage of the outbreak. They only provided knowledge on a single topic, with a relatively small amount of literature as things stand now. As we gained increasing knowledge on the epidemiology, pathology and treatment of COVID-19<sup>11</sup> throughout 2020, the gaps and longitudinal trends in the COVID-19 literature have become topics of interest to us.

Therefore, we considered a 1-year time window of the outbreak to integrate knowledge of COVID-19, and the aim of our study was to provide an in-depth analysis of the publications on COVID-19 from geographical, epidemiological and chronological perspectives. These efforts included mapping the worldwide landscape of the epidemic situation and publications from a geographical perspective, to explore publication trends and the association of monthly publications and epidemiological indices and analyze the research hotspots throughout the year, chronologically (quarterly) and in the top 5 most productive countries.

## METHODS

### *Data source and search strategy*

The Web of Science (WOS), the best and most commonly used database for the availability and structuring of the cited references offered by its Core Collection when evaluating scientific activity,<sup>12</sup> was selected as the data retrieval source for this study. The data retrieval strategies were set as follows, based on a research group discussion: Topic Search = ("COVID-19" OR "coronavirus disease 2019" OR "2019-nCov" OR "2019 novel coronavirus" OR "SARS-CoV-2" OR "Severe acute respiratory syndrome coronavirus 2" OR "novel coronavirus disease 19" OR "novel coronavirus disease-19" OR "SARS2" OR "SARS-2" OR "COVID-2019" OR "COVID19"), time span = December 1, 2019 to December 31, 2020. The search process was completed on January 1, 2021. All types of documents were considered during this study. A total of 51,593 publications were preliminarily retrieved, and then 2 researchers independently screened all the retrieved publications by (1) title and abstract, followed by (2) the full texts. If there was still disagreement, a third author was invited. Following the screening out of irrelevant documents, 51,317 documents were identified and exported as "plain text" with "full record and cited references."

### *Data analysis*

Information about monthly publications, confirmed cases and deaths was directly gathered via WOS. Data on monthly confirmed cases and deaths were obtained from the World Health Organization. The epidemic situation and publication landscape of each country were mapped through the mapchart.net program. To evaluate the quantitative relationship between monthly publications and confirmed cases, deaths, scatter plots and Pearson correlation coefficients were performed.

VOSviewer software was used in the present analysis to generate a visualization map. Its clustering methods and similarity mapping can generate bibliometric maps of keyword co-occurrence,<sup>13</sup> which could provide us with trends and hot themes that will remain active in the COVID-19 field. To gain a clearer and more dynamic view of the research hotspots, year-round, quarterly, and country keyword co-occurrence analyses were all applied during the present study. The resulting bibliometric maps could be interpreted according to the color, circle or font size, and distance and thickness of the line. Each keyword item was represented as a circle, and different keyword item clusters were assigned with different colors. The size of the circle or font indicates the appearance frequency of a specific item, with the line distance between 2 circles indicating the strength of the connection. Additionally, the thickness of each line indicates the frequency at which each pair of items appeared together.<sup>14,15</sup>

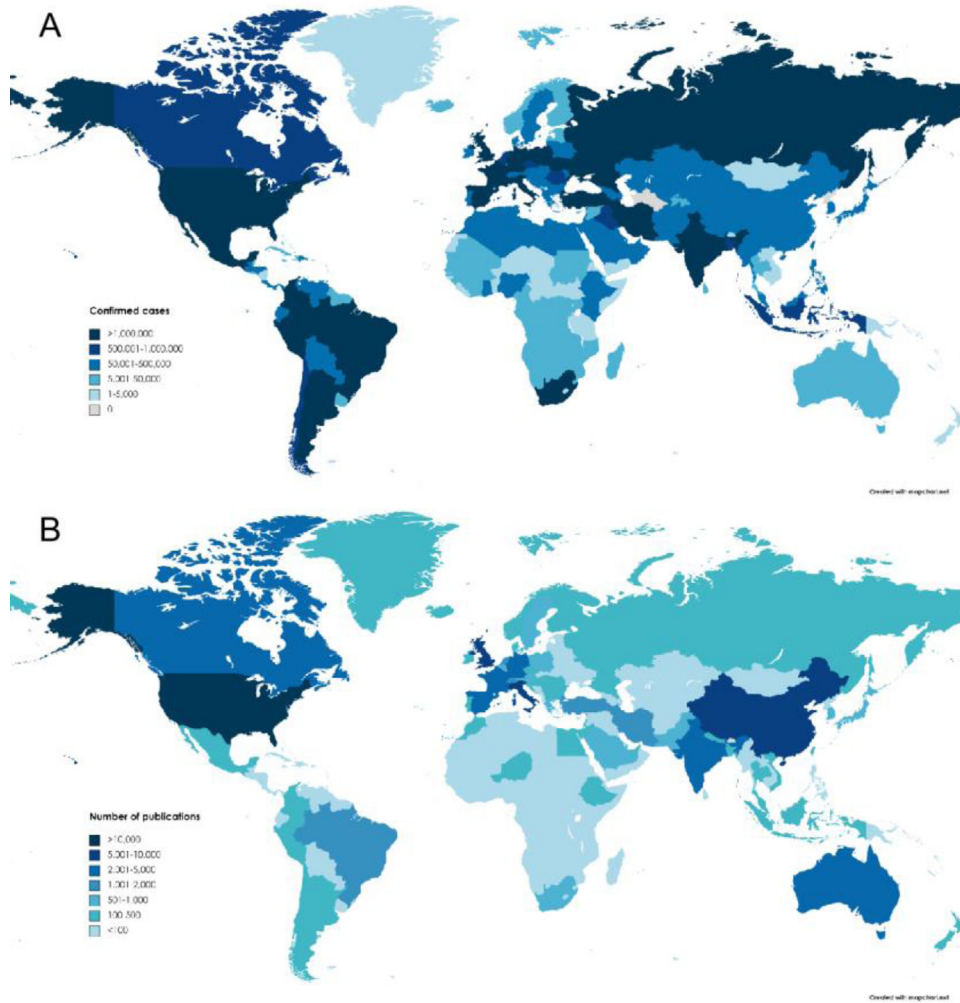
## RESULTS

A total of 51,317 articles published in 2020 were analyzed, which included 23,776 (46.33%) original research articles, 5,438 (10.59%) review articles, 8,921 (17.38%) editorials, 10,443 (20.34%) letters, and 2,739 other forms of publications, including meeting abstracts and news. These articles were written by 201,818 authors from 190 different countries or regions and 36,026 organizations and were published in 3,743 journals.

### *Epidemic situation and publication landscape from a geographical perspective*

Figure 1A and 1B show the geographical distribution of the global publications and confirmed cases. As of December 31, 2020, countries in the Americas, Europe and part of Asia had been the most profoundly affected by COVID-19 (Fig 1A). For publications on COVID-19, countries in North America, Europe and part of Asia contributed the most (Fig 1B). To obtain a clearer view, Table 1 shows the epidemiological index and citation information for the top 20 most productive countries. Overall, the USA was the most productive country, with 14,747 publications, and China was the country with the highest total number of citations and average citations. The top 5 countries, the USA, China, Italy, the UK and India, contributed nearly 70% of the report. Eight of the top 20 countries with the most publications were in Europe, 8 in Asia, 2 in North America and 1 each in South America and Oceania. Ten of the top 20 countries with the most publications had the largest number of confirmed cases. Among the top 5 countries, only China's number of confirmed cases was not in the top 20.

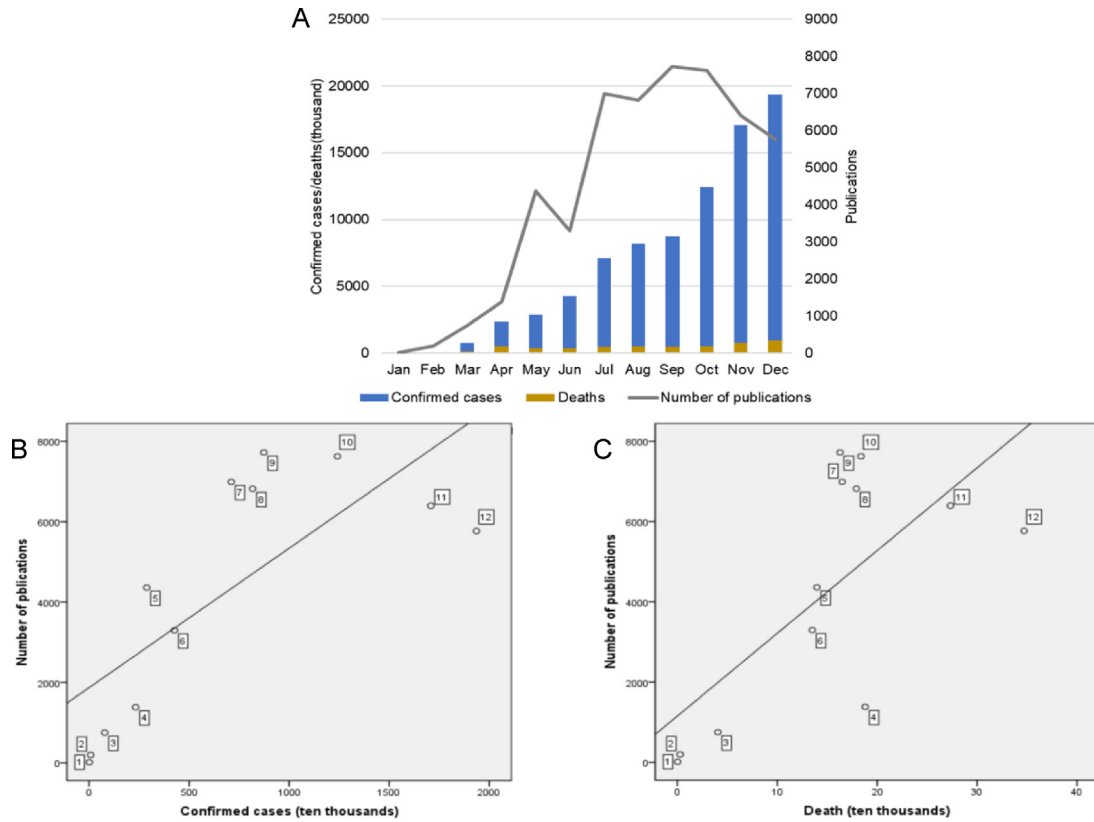
As shown in Figure 2A, an overall upward trend was detected in the monthly confirmed cases and deaths. Although the number of publications fluctuated during some months, the overall trend could be divided into 2 stages: an increasing output stage (the first 6 months of the year) and an explosive output stage (the latter half of the year). May and June could be seen as turning months. What can also be clearly seen is the opposite trend between the monthly publications and confirmed cases or deaths since October. Figure 2B and Figure 2C further show a positive correlation between monthly



**Fig 1.** (A) Global epidemic distribution map as of December 31, 2020. (B) Geographical distribution of publications on COVID-19 in 2020. The map was created with the mapchart.net program.

**Table 1**  
Top 20 countries with the most publications

Rank	Country/region	Cumulative confirmed cases	Cumulative deaths	Number of publications	Citations	Average citations
1	USA	19,346,790	335,789	14,747	148,139	10.0
2	China	96,673	4,788	7,428	220,169	29.6
3	Italy	2,083,689	73,604	5,767	53,016	9.2
4	UK	2,432,892	72,548	5,740	64,542	11.2
5	India	10,266,674	148,738	2,648	12,012	4.5
6	Spain	1,986,431	51,632	2,423	16,226	6.7
7	France	2,556,708	64,004	2,379	26,366	11.1
8	Canada	565,506	15,378	2,253	21,116	9.4
9	Germany	1,719,737	33,071	2,249	29,303	13.0
10	Australia	28,381	909	2,024	23,617	11.7
11	Brazil	7,563,551	192,681	1,634	7,432	4.5
12	Switzerland	451,123	7,243	1,175	16,183	13.8
13	Iran	1,218,753	55,095	1,157	5,795	5.0
14	Turkey	2,194,272	20,642	1,057	3,482	3.3
15	Netherlands	786,197	11,295	1,024	17,640	17.2
16	Japan	230,304	3,414	992	10,096	10.2
17	Singapore	58,569	29	864	14,172	16.4
18	Belgium	647,587	19,505	795	8,426	10.6
19	South Korea	60,723	900	764	9,050	11.8
20	Saudi Arabia	362,601	6,214	760	7,036	9.3



**Fig 2.** (A) Temporal distribution of publications on COVID-19 and growth trends in confirmed cases/deaths from COVID-19 from January to December 2020 (data from WHO). (B) Correlation between monthly publications and confirmed cases. Dots: months. Linear regression  $r^2 = 0.564, P < .01$ ; (C) Correlation between monthly publications and deaths. Dots: months. Linear regression  $r^2 = 0.484, P < .05$ .

publications and confirmed cases and deaths. The correlation is positive and significant at  $r^2 = 0.564$  and  $0.484$ , respectively.

*Hotspot analysis throughout 2020, chronologically (quarterly)*

To evaluate the changes in hotspots more clearly, we performed a keyword co-occurrence analysis in 2020, further divided the analysis of clusters into 4 quarters and presented a keyword co-occurrence map of the top 5 countries with the most publications.

In reviewing global keyword clustering in 2020, the keywords from the articles that occurred at least 50 times were included in this analysis and were clustered into 5 groups (Fig 3). Of the 47,413 keywords, 553 met the threshold. The keyword “COVID-19” (total link strength 66, 611) appeared most frequently, with 19,275 (40.65%) co-occurrences, followed by SARS-CoV-2 (7,484, 15.78%), coronavirus (6,068, 12.80%), pneumonia (2,221, 4.74%) and SARS (1,803, 3.80%). Most of the top ten keywords are synonyms of COVID-19. The most frequent topics in publications on COVID-19 were classified by 5 main clusters: The red cluster involved keywords related to prevention and control that include measures, key population and psychology, such as “telemedicine,” “lockdown,” “social isolation,” “quarantine”; “mental health” “psychological impact,” “depression,” “anxiety,” and “stress.” The green cluster involved keywords related to clinical research that include characteristics, detection and diagnosis, such as “mortality,” “diagnosis,” “prognosis,” “pneumonia,” “cancer,” “outcome,” “clinical characteristics,” “thrombosis,” “surgery,” and “pregnancy.” The yellow cluster involved keywords related to virology and immunology, such as “infection,” “ACE2,” “expression,” “receptor,” “activation,” “cells,” “cytokine storm,” and “inflammation.” The blue cluster involved keywords related to treatment that

include drug and vaccine development, such as “hydroxychloroquine,” “chloroquine,” “antibody,” “efficacy,” “spike protein,” “inhibitors,” and “vaccine.” The purple cluster involved keywords related to epidemiology that include environment and virus transmission, such as “influenza,” “virus,” “transmission,” “exposure,” “temperature,” and “pollution.” The following figure shows the theme analysis and quarterly changes in the 5 clusters.

We also performed a horizontal comparison of keyword clustering during 4 quarters. In the first quarter, the top 3 clusters represented the research areas of drug development, clinical research, and epidemiology. Compared to the first quarter, the keyword cluster from the second quarter represented more about clinical characteristics, clinical treatment, and public and mental health. The third and fourth co-occurrence maps were consistent with the overall map for 2020 (Fig 4). The first quarter was characterized by scarcity and unsystematic scientific production compared with the other quarters. In the keywords co-occurrence for the 4 quarters, there were academic efforts from epidemiological research to the improvement of disease warning and prevention and control strategies, pathological research to clinical diagnosis and treatment of patients with coronavirus infection, structural biology research to the development of antiviral inhibitors, and viral immunology research to coronavirus vaccine preparation.

*Hotspot analysis in the top 5 productive countries*

In the keyword clustering analysis on the top 5 most productive countries, the total number of keywords in each country was different, but by adjusting the minimum co-occurrence number, the number of items presented in each country was similar. Compared with

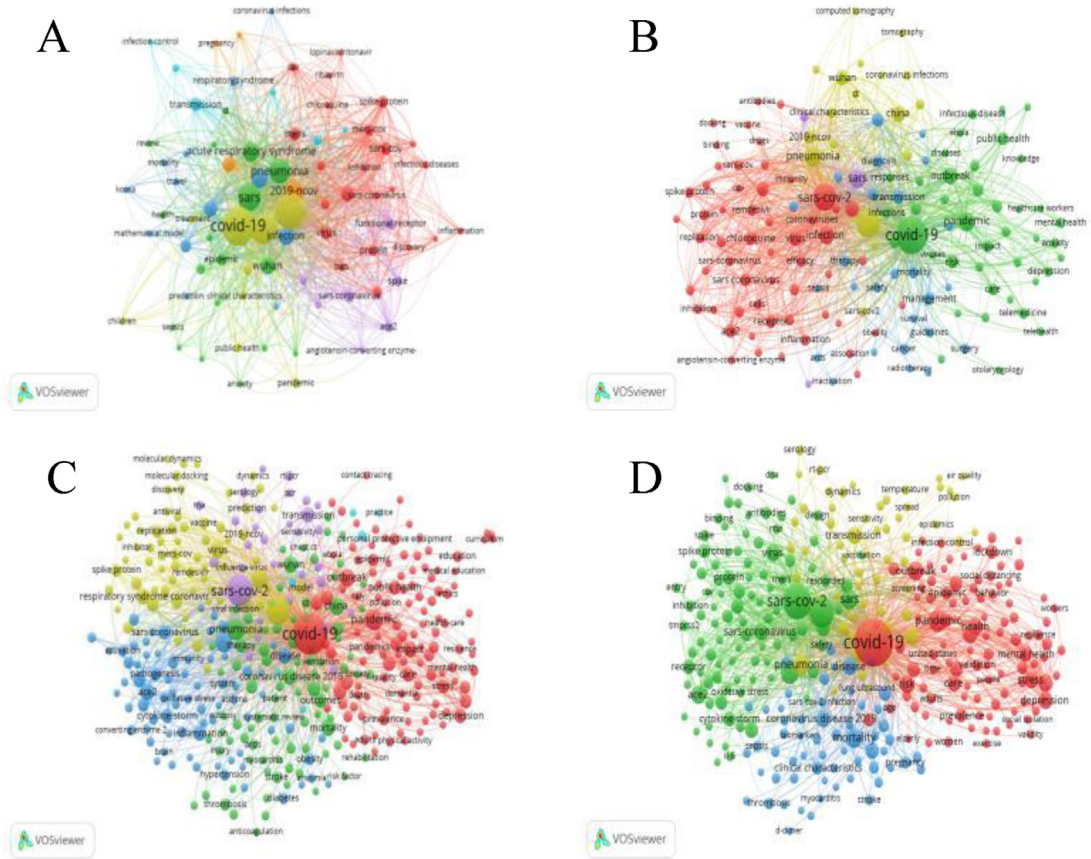


Fig 3. Co-occurrence map of keywords in 2020.

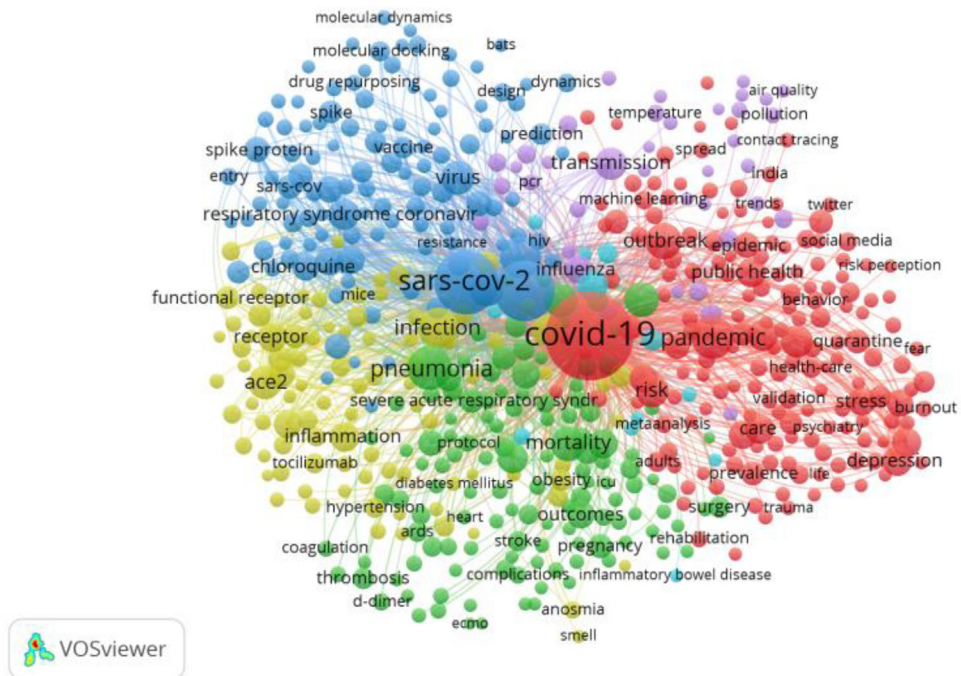
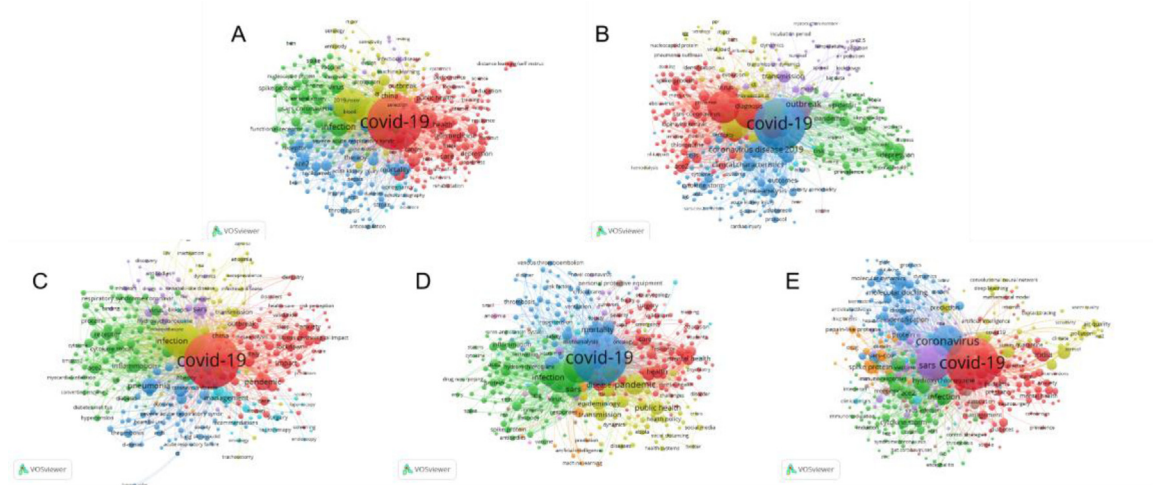


Fig 4. (A) Co-occurrence map of keywords for the first quarter. (B) Co-occurrence map of keywords for the second quarter. (C) Co-occurrence map of keywords for the third quarter. (D) Co-occurrence map of keywords for the fourth quarter.



**Fig 5.** Keyword co-occurrence map of the top 5 countries for publications. (A) Keyword co-occurrence map of the USA. (B) Keyword co-occurrence map of China. (C) Keyword co-occurrence map of Italy. (D) Keyword co-occurrence map of the UK. (E) Keyword co-occurrence map of India.

the global keyword co-occurrence map, each country showed comprehensive research on COVID-19, including epidemiology, virology, immunology, detection, diagnosis, treatment, clinical research, disease prevention and control, psychology and others. However, the research domains of high-frequency keywords were different (Fig 5). As shown in Figure 5, “telemedicine” was reflected in all top 5 countries, but the occurrences of “telemedicine” and “telehealth” in the USA, the UK and Italy were more advanced, especially in the USA (Table 2). Table 2 shows the top 20 high-frequency keywords in the top 5 countries with the most publications, excluding synonyms of COVID-19 and keywords with no special meaning such as outbreak and respective countries. Moreover, from the keyword cluster map of the USA, researchers paid more attention to education research (keywords “education,” “medical education,” “curriculum,” “distance learning,” and “internet/web-based learning”). In the keyword cluster analysis for China, “meta-analysis,” the article type, appeared more frequently than it did for other countries. In synthesizing the cluster map, 2 of the high-frequency words, “big data” and “traditional Chinese medicine,” appeared only in the Chinese keyword cluster. In the keyword clustering for the UK, there were more keywords related to

mental health than in other countries, such as “mental health,” “depression,” “anxiety,” “stress,” “psychological impact,” “psychiatry,” “psychological distress,” “burnout,” and “suicide.” The keyword clustering for drug development was more prominent in the keyword co-occurrence map of India. “Molecular docking” has become a research hotspot in India with a high occurrence.

**DISCUSSION**

The pandemic ravaged countries all over the world throughout 2020 and has driven a wave of work in academic circles. This study provided an in-depth analysis of all the publications on COVID-19 in 2020 from geographical, epidemiological and chronological perspectives.

As of December 31, 2020, 51,317 COVID-19-related publications had been retrieved from the WOS database. The overall trend could be divided into 2 stages (increasing output stage and explosive output stage), which were bounded by May and June. As previous studies have reported, many factors, such as the improvement of a specific topic, major legislation and the social environment, could all

**Table 2**  
Top 20 high-frequency keywords in the top 5 countries for publications

	USA	China	Italy	UK	India
1	ace2	clinical characteristics	inflammation	risk	spike protein
2	telemedicine	transmission	management	mortality	lockdown
3	mortality	mortality	risk	public health	molecular docking
4	risk	ace2	mortality	health	docking
5	care	depression	ace2	impact	ace2
6	health	risk	children	transmission	chloroquine
7	impact	anxiety	impact	epidemiology	protein
8	transmission	impact	receptor	care	transmission
9	outcomes	epidemiology	cancer	management	hydroxychloroquine
10	influenza	meta-analysis	cytokine storm	mental health	receptor
11	epidemiology	health	telemedicine	depression	identification
12	inflammation	diagnosis	stress	ace2	replication
13	telehealth	management	therapy	influenza	prediction
14	management	outcomes	diagnosis	children	impact
15	public health	cytokine storm	depression	diagnosis	management
16	receptor	influenza	transmission	outcomes	vaccine
17	depression	receptor	lockdown	telemedicine	diagnosis
18	cytokine storm	stress	care	cancer	epidemiology
19	children	inflammation	epidemiology	surgery	pathogenesis
20	expression	children	anxiety	anxiety	drug repurposing

contribute to a specific time point.<sup>16,17</sup> COVID-19, the latest epidemic, was naturally unrecognized at the beginning. With its rapid spread worldwide, it soon attracted the attention of the government and academic fields. Around March 2020, the WHO raised the global risk level for the COVID-19 outbreak to “very high,” European Centers for Disease Control raised the risk level for the novel coronavirus from “medium” to “high,” the outbreak was assessed as a pandemic, and nearly 50 countries declared states of emergency. All of these measures could have caused a significant increase in publications in May and June compared to the first several months.

Then, as knowledge of the epidemiology, virology, and immunology of the coronavirus increased, many countries loosened their regulations and policies. Japan lifted its state of emergency in many prefectures, and the 50 states in the United States opened up to varying degrees at the end of May. In particular, substantial progress has been made in vaccine research, and on May 29, 2020, the WHO launched a COVID-19 Technology Access Pool to accelerate the development of vaccines, tests, treatments and other technologies for COVID-19 through open scientific research. As signs of a postpandemic era, “lift the lockdown” and “no new cases” have gradually emerged in countries such as China.<sup>18</sup> Since then, a large number of articles on more extensive topics have exploded and remained at a relatively steady level, which is the explosive output stage.

A total of 190 countries contributed to the retrieved publications, indicating that the topic of COVID-19 has attracted worldwide attention. As expected, there was a significant correlation between monthly publications and confirmed cases and deaths. This study indicated a positive correlation between these factors. However, the global output began to decline in October, while the growth rate of confirmed cases continued to rise at an uncontrollable rate. Therefore, although the high incidence and deaths are important factors that affect scientific output, it seemed that there are other latent factors. During the first few months of the outbreak, since China was initially the most affected by COVID-19, Chinese institutions maintained the highest number of publications in the world and played an important role in the response to the pandemic.<sup>19</sup> Throughout 2020, the USA, China, Italy, the UK and India published the largest number of papers, with the scientific research team of the USA as the main force. The USA, the UK, and other European countries appear on the list of the most active in terms of publications in most bibliometric studies.<sup>20</sup> Comparatively, some continents, such as South America and Africa, have had limited research compared with North America, Asia, and Europe. In the same way, in many developing countries, especially in Africa, the lower number of publications can be explained by the lower number of confirmed cases and mortality.<sup>21</sup> However, Russia showed a completely different trend; although there were a large number of COVID-19 cases, the share of Russian researchers in COVID-19 publications was low. It is worth noting that the number of confirmed cases and deaths in Singapore, which is in the top 20 list with the most publications, is very low compared with other countries. The above special cases further validated that confirmed cases and deaths were not the only factors affecting country publication. Therefore, there are many other social and economic factors that may affect the number of publications, which require more research in the future.<sup>22</sup> As time passes, the threat of this crisis decreases, as will funding and other support.<sup>23</sup> Moreover, a postpandemic effect may also be the force behind their relationship since the impact of a pandemic on all aspects of human life is unprecedented, challenging, and far-reaching.

According to the 4-quarter changes in keyword clustering, the concerns in psychiatry and environmental health increased from the second quarter, the result was similar to Zein Tawil's point of view that after May, the spread of COVID-19, clinical diagnosis and testing research mostly stagnated, and the interest in mental health research became increasingly strong.<sup>24</sup> Moreover, due to the COVID-19

lockdown, air and water pollution dropped sharply, and research on environmental topics increased.

This study demonstrated the experience and research hotspots of each country in fighting the epidemic from the keyword analysis of the top 5 countries with the most publications. The keyword “race” only appeared in the USA. In the USA, compared with the whole population, the proportion of communities of color dying from COVID-19 was much higher than that of white ones. Telemedicine reports primarily came from the USA, the UK and Italy, which could be explained by the fact that the use of telemedicine to improve patient care and population health was primarily concentrated in high-income countries.<sup>25</sup> However, in Italy, telemedicine was not included in the basic medical services provided to all citizens by the national health service, and telemedicine solutions are limited. To reduce the risk of transmission, the USA promoted and scaled telemedicine based on video consultations.<sup>26</sup> The ongoing global COVID-19 pandemic quickly destroyed the traditional operational mode in medical and educational fields,<sup>27</sup> schools across the country had to close their campuses and transitioned to distance learning, and it prompted medical colleges to incorporate telemedicine training into medical education in a timely and practical way.<sup>28</sup> Countries could expand the application of telemedicine to major public health events because the telemedicine revolution would be a vital factor in providing health care in the future.<sup>29</sup> As the epidemic was raging, countries were forced to start with drastic action, including border closures, travel bans, and social distancing. China, in particular, took severe prevention and control measures during the early stage to control the situation successfully. Traditional Chinese medicine is one of the main representative elements of China. In China, the treatment of SARS-COV-2 infection is primarily based on traditional medicine and traditional Chinese medicine.<sup>30</sup> Big data technology plays a crucial role in personal tracking, virus source tracking, surveillance and early warning, drug screening, etc.<sup>31</sup> The smart use of big data and digital technology was a key factor for China to combat this virus.<sup>32</sup> There are almost no “hospitalization” keywords in India. According to the OECD data, the lowest number of hospital beds was found in India, with 0.53 hospital beds for every 1,000 inhabitants, and 2.87 in the USA, 4.31 in China, 3.18 in Italy and 2.53 in the UK. In mid-March of 2021, India struggled with the second COVID-19 wave. Its grossly underfunded and scattered public health system poses special challenges to the country's disease control strategy.<sup>33</sup> In addition, India ran a very low number of diagnostic tests compared to other countries.<sup>34</sup> In the keyword cluster for India, there were more keywords related to drug and vaccine development. One of the most common keywords was “molecular docking.” Indian scholars have attempted to predict potential drugs for COVID-19 by using molecular docking technology and drug repurposing.<sup>35</sup> Perhaps after the second wave of the epidemic, research on clinical treatment, prevention and control in India will increase. It is also worth noting that Singapore had been succeeding extraordinarily in the prevention and control of epidemics, and Singapore's approach is worth learning from.

Limitations should also be noted when interpreting the results of the present study. Web of Science was selected as the only data source, and even though WOS was the most popular database for bibliometrics,<sup>36</sup> some articles published in journals that were not included in the database may still be excluded from this study. Moreover, during the search process, there were articles in WOS with no publication month, and some of the publication dates did not seem inconsistent with their actual publication date. In addition, this study retrospectively reviewed articles about COVID-19 from 2019–2020, but the epidemic is still ongoing, and the data and patterns will undoubtedly be updated dynamically in future studies.

However, professional help was obtained from WOS (Clarivate) through email and phone. According to the WOS rules, for articles with volume and issues, the recorded publication date in the WOS



core collection was in accordance with their form publication date instead of the accepted or Epub date. Although some articles were received and accepted in 2020, the publication date could be 2019, because they were recorded as a supplement to a journal. For journals coming out once a year or quarterly, in taking 2020 as an example, the publication date would be set to January 1, 2020, or the first month of the season. One thousand nine hundred articles only had year information, and the monthly information for 502 articles was inaccurate. To analyze the relationship between the number of published articles and the number of confirmed cases and research hotspots during different periods, a manual adjustment was performed. Moreover, considering the above cases, the number of publications on WOS could unavoidably have been increasing even at the end of 2020. However, it would be a small amount compared with those involved in the present study.

## CONCLUSIONS

This study indicated how rapidly the scientific community has flocked to the front lines in the fight against COVID-19. The correlation analysis of publications indicated that confirmed cases and deaths created a driving force for scientific output, reflecting the growing trend to some extent. However, other latent findings regarding this correlation should be further explored in the future. Moreover, the hotspot analysis provided information on how each country responded when it was in a different epidemic situation, which is valuable information for scientists, funders, and policy and decision-makers to judge what should be the focus when faced with another public health emergency in the future.

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