Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Review

Contribution of Saudi Arabia to regional and global publications on COVID-19–related research: A bibliometric and visualization analysis

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ABSTRACT

Background: At the global level and in Saudi Arabia, COVID-19 remains a major public health problem. The COVID-19 pandemic contributed substantially to a surge in publications on the novel coronavirus responsible for this pandemic. This research is intended to assess the increasing contribution of Saudi Arabia to the global research on COVID-19.

Methods: A bibliometric analysis of all Saudi-affiliated publications on COVID-19 documented between December 2019 and October 2021 was conducted in October 2021 using the Web of Science advanced search builder.

Results: A total of 175,615 global publications on COVID-19 were retrieved in the search. Among these, 9118 (5.2%) publications were from Arab nations. Among the Arab nations, Saudi Arabia (n = 3615) had the highest number of COVID-19 publications, followed by Egypt (n = 2053) and the United Arab Emirates (n = 1057), respectively. Globally, Saudi Arabia ranked 15th among the countries with the highest publication productivity, and the rank was 11th after standardization based on the population size and the gross domestic product. International collaborations were mainly with the researchers from Egypt, followed by the United States, India, Pakistan, and the United Kingdom. King Saud University was the most productive among all institutes in terms of COVID-19-related publications at both local and regional levels.

Conclusion: Saudi Arabia is the leading Arabian nation and one of the top fifteen nations worldwide in terms of COVID-19 research output. Further efforts are warranted from the researchers based in Saudi Arabia in the direction of increasing the quality and the number of publications at the global level. This can be achieved by timely response, proper planning, understating the global research progress, and enhancing the knowledge exchange and collaboration with the other local and international institutes.

Contents

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1. Introduction

A novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was responsible for the coronavirus disease of 2019 (COVID-19), which was officially declared a pandemic by the World Health Organization on March 11, 2020 [1,2]. At that time, no specific treatment or preventive vaccine was available for this disease, and using personal protective equipment and minimizing human contact were the only ways to decelerate the spread of the pathogenic virus [3]. In the early stages of the pandemic, several million people were killed by this novel coronavirus, which placed a substantial economic burden on the world [4,5].

The COVID-19 pandemic contributed substantially to a surge in the number of publications on the novel coronavirus responsible for this pandemic. In order to fill the knowledge gaps in the global research on this virus, several researchers and various public health authorities across the world contributed continually to update the epidemiological data and information on this virus and the associated disease [6–10]. As of October 16, 2021, a total of 187,562 published articles on COVID-19 were available on PubMed [11].

The usefulness of bibliometric analysis and visualization techniques in the evaluation of the research output for any emerging disease outbreaks has been reported by several previous studies [12–16]. Therefore, several bibliometric studies were conducted worldwide to evaluate the COVID-19-related publications [17–20].

Since the beginning of the pandemic, there has been a notable increase in the COVID-19-related publications from Saudi Arabia; however, a few bibliometric studies were released from the Middle East and Gulf countries [21–23]. Because of the rapid increase in the number of publications released from Saudi Arabia on COVID-19, the bibliometric analysis is expected to change with time.

In this context, the main objective of the present study are:

1. To expand the bibliometric analysis on COVID-19-related research released from Saudi Arabia using different bibliometric software.
2. To ascertain the global ranking of Saudi Arabia in the field of COVID-19-related research according to the population size and the gross domestic product.
3. To assess the collaborative patterns between different countries and institutions on COVID-19 related research released from Saudi Arabia.
4. To examine the relationships based on a three-factor analysis (countries, keywords, and organizations).
5. To explore the most cited author keywords with the strongest citation bursts.

2. Material and methods

2.1. Study setting and design

There are several famous indexing and abstracting databases. These include multidisciplinary databases such as Scopus and Web of Science (WoS) and other subject-specific databases like MEDLINE and PubMed. Out of these databases, Scopus and WoS were the most frequently used databases worldwide. WoS is considered the most authentic and trusted database, as is it guided by the inventor of the world's first citation index [24]. Therefore, WoS was selected as the database for the present study. Data published between December 2019 and October 2021 were retrieved from WoS. The search was conducted in October 2021, and all COVID-19-related publications released until October 14, 2021 were included in the analysis. The details of the search strategy used in the current study are attached to (Supplementary File 1)

2.2. Data analysis and visualization

The primary output data retrieved from the search and the selected articles were the publication output, journal, authorship, document type, affiliation, and citations. The retrieved data were exported to Microsoft Excel 2013 for Windows (Microsoft Corp., Redmond, WA, United States of America, USA). The data analysis was performed using MS Excel and various bibliometric and visualization software, including VOSviewer software version 1.6.16 (http://www.vosviewer.com), Biblioshiny (RStudio), and CiteSpace version 6.1.R1. The VOSviewer software enables creating and interactively visualizing bibliometric networks. The visualization maps were constructed for the co-authorship country and the co-occurrence author keywords. The maps and clusters were generated by merging the selected document types, such as the document type or the countries related to each other in a certain manner, which generated output in the form of clusters distinguished by different colors. Using this viewer, the total link strength (TLS) was calculated, which indicated the total strength of the links of an item with the other items. We also used Biblioshiny software, a part of R-studio tools, to perform bibliometric analysis and mapping. It summarizes the data from different bibliometric aspects, including authors, sources, keywords, and collaboration networks. CiteSpace software (version 6.1.R1) was used to visualize the most cited authors' keywords with the strongest citation bursts

Further accuracy of the obtained results was ensured in the present study by adjusting the publication output according to the population size and the gross domestic product (GDP) of 2019 using the following adjustment index (AI) formula [26–28]: AI = [The total number of papers for the country/GDP per capita of the country] × 1000; here, GDP per capita was calculated by dividing the country's GDP by its population. The impact factor (IF) of the journal was obtained from the 2020 list of journals in the Incites Journal Citation Reports by Clarivate Analytics.

3. Results

3.1. Regional and global research output on COVID-19

A total of 175,615 research articles published on COVID-19 between December 2019 and October 2021 were retrieved from the

Table 1
Top ten productive institutions of Saudi Arabia in terms of COVID-19-related publications.

Ranking	Institution	No. of publications	% of 3,615
1st	*King Saud University*	708	19.58%
2nd	*King Abdulaziz University*	549	15.18%
3rd	*King Saud Bin Abdulaziz University for Health Sciences*	311	8.60%
4th	*Umm Al Qura University*	214	5.92%
5th	*Imam Abdulrahman Bin Faisal University*	210	5.81%
6th	*Taif University*	202	5.59%
7th	*King Khalid University*	167	4.62%
8th	*Taibah University*	161	4.45%
9th	*Ministry of Health*	154	4.26%
10th	*King Faisal Specialist Hospital Research Center*	152	4.21%

WoS English database when searched without stating the name of any country. Among these publications, 9118 (5.2 % of the total global COVID-19-related research output) articles were from the authors affiliated with the Arab nations, 3615 (2.1 % of the total global COVID-19-related research output) articles were from the authors affiliated from Saudi Arabia, and 1256 (0.7 % of the total global COVID-19-related research output) were from the authors affiliated exclusively from Saudi Arabia.

Among the total 3615 COVID-19-related research articles published by the authors affiliated from Saudi Arabia, there were 2754 (76.2 %) original journal articles, 570 (15.8 %) review articles, 147 (4.1 %) letters, and 373 (10.31 %) other categories of articles, such as editorials or early access articles.

3.2. Most productive institutes

Table 1 lists the top ten institutions in Saudi Arabia that produced the largest number of publications on COVID-19. Among these institutions, the top ranking one was the King Saud University with the highest number of publications (n = 708, 19.6%), followed by the King Abdulaziz University (n = 549, 15.2%) and King Saud bin Abdulaziz for Health Sciences (n = 311, 8.6%), respectively. The annual number of published articles on COVID-19 from Saudi Arabia was 1259 in 2020, which increased to 2,337 in 2021.

The top three institutions that produced the largest number of publications on COVID-19 by the authors affiliated exclusively from Saudi Arabia were the King Saud University (n = 256, 20.38 %), King Abdulaziz University (n = 197, 15.68 %), and King Saud bin Abdulaziz for Health Sciences (n = 151, 12.02 %).

3.3. Contribution of Saudi Arabia to Arab and non-Arab nations on COVID-19–related research

In the global research output of 175,615 publications on COVID-19, 9118 (5.2 %) publications were from the Arab nations. Fig. 1 presents the top 10 Arab countries that produced the largest number of publications, citations, and TLS on COVID-19. The majority of the Arabian research output on COVID-19 was from Saudi Arabia, which accounted for 3615 publications (39.7 %). Egypt, with its 2053 research articles (22.5 %), ranked second among the Arab nations in terms of producing the largest number of publications on COVID-19, followed by the United Arab Emirates with its 1057 (11.6 %) research articles. The most productive universities in the Arab world were King Saud University with 708 publications (7.75 %), King Abdulaziz University with 547 publications (5.99 %), and Cairo University with 444 publications (4.87 %). Further details regarding the top 10 most active research centers in the Arab nations are provided in Table 2.

Table 3 lists the top 15 countries arranged according to the number of publications produced and the AI-generated GDP per capita. Globally, Saudi Arabia ranked 11th based on the AI evaluation and 15th based on the production of COVID-19-related publications.

3.4. Authors' productivity and highly cited articles

Table 4 lists the top 10 most cited articles on COVID-19 published by the authors affiliated from Saudi Arabia, with the citation counts ranging from 290 to 1231 [29–38]. The data revealed that the articles published by Hui et al. [29], Alhazzani et al. [30], and Rodriguez-Morales et al. [31] had the highest number of total citations [(n = 1231), (n = 1079), and (n = 634), respectively].

Table 5 demonstrates the percentage of authors' contributions and the number of documents on COVID-19 related research. The table shows total contributions by 23815 authors with an average of less than 1 % (0.29) papers per author. It reveals that 63.4 % (n = 15100) of the authors have contributed to only one publication, whereas 36.6 % (n = 8715) have published at least two documents. The percentage of authors participating in more than two articles is less than 20 %. Moreover, out of the 23815 authors retrieved from WoS, only one author produced approximately 66 documents and 13 authors above 30 documents.

Fig. 2 shows the distribution of Lotka's law of the distribution of authors' productivity. Using the Lotka function of Bibliometrix R, the analysis calculated the beta coefficient at 2.3. The results indicated that the distribution of scholarly production varied significantly, with a few authors have made a significant contribution to the topic. In contrast, a majority of the authors have published a single article.

3.5. Authors' keyword analysis

The VOSviewer visualization software was employed to generate a visualization network regarding the co-occurrence of the author keywords. When the minimum number of occurrences of a keyword was set to 5, only 427 keywords among the total of 7586 keywords searched were processed. The top three author keywords were “COVID-19” (occurrences = 2014, TLS = 4438), “SARS-CoV-2” (occurrences = 605, TLS = 1575), and “Saudi Arabia” (occurrences = 307, TLS = 892). The co-occurrence of the author keywords is presented in Fig. 3.

3.6. Authors' keywords with the strongest citation bursts

A citation burst is an indicator of a burst event of a particular reference keyword, which can last for months and even years. It provides evidence that a particular publication is associated with a surge of citations [25]. In other words, it means that the publication has attracted an extraordinary degree of attention in a specified time.

Fig. 4 demonstrates the top twenty highly cited keywords regarding COVID-19 research released from Saudi Arabia. This figure has been generated through (CiteSpace 6.1.R1 software). Because the COVID-19 emerged in late 2019, we calculated the citation bursts over one year (between October 2020 and October 2021) using a time slice of 1 month. The blue color presents the overall period of a citation, and the red color presents the extraordinary degree of citation in a particular period. The top three keywords with the strongest citation bursts are ‘transmission’ (strength = 6.92), ‘pneumonia’ (strength = 6.56), and “covid-19 pandemic” (strength = 5.53). It is noted that the keyword 'transmission' has the longest citation burst period (October 2020- February 2021).

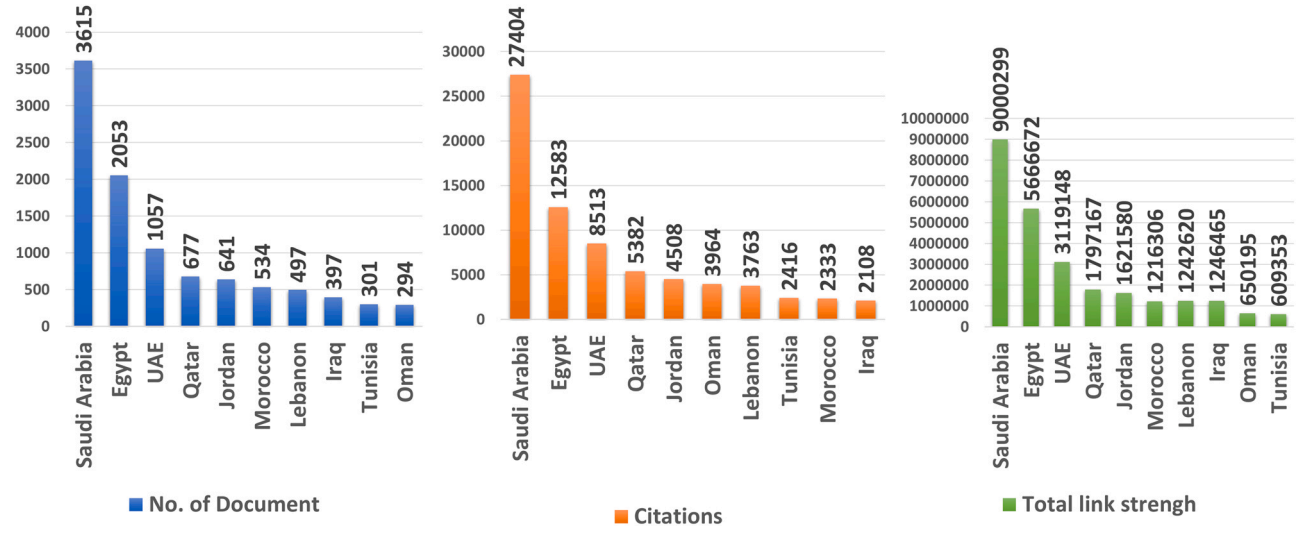

Fig. 1. The total number of COVID-19 publications, citations, and total link strength (TLS) from the Arab nations.

Table 2
The top ten productive institutions in Arab countries in terms of production of COVID-19-related publications.

Ranking	Institution	Country	No. of publications	% of 3,615
1st	*King Saud university*	Saudi Arabia	707	7.75%
2nd	*King Abdulaziz university*	Saudi Arabia	547	5.99%
3rd	*Cairo University*	Egypt	444	4.86%
4th	*King Saud Bin Abdulaziz University For Health Sciences*	Saudi Arabia	311	3.41%
5th	*Hamad Medical Corporation*	Qatar	269	2.95%
6th	*University of London*	UAE	249	2.73%
7th	*Qatar University*	Qatar	245	2.68%
8th	*American University of Beirut*	Lebanon	243	2.66%
9th	*Ain Shams University*	Egypt	233	2.55%
10th	*Alexandria University*	Egypt	217	2.38%

Table 3
Rankings and contributions of different nations of the world in the field of COVID-19-related research.

Ranking	Country	No. of publications	Population by million	GDP by billion P (current US$)*	AI**	AI rank
1st	USA	51,229	330	20,936	808	3rd
2nd	China	19,676	1,439	14,722	1,929	2nd
3rd	England	18,027	67	2,707	450	8th
4th	Italy	15,766	60	1,886	501	7th
5th	India	12,759	1,380	2,622	6,715	1st
6th	Canada	8,223	38	1,643	190	10th
7th	Austria	7,646	9	428	161	13th
8th	Germany	7512	83	3,806	164	12th
9th	Spain	6941	46	1,281	250	9th
10th	France	6337	65	2,603	158	14th
11th	Brazil	5416	214	1,444	803	4th
12th	Turkey	4976	84	720	578	6th
13th	Iran	4389	84	491	757	5th
14th	Japan	3800	126	5,064	95	15th
15th	Saudi Arabia	3615	35	700	181	11th

*GDP = Gross domestic product.** AI = Adjustment index [AI = (Total number of publications for the country/GDP per capita of the country) × 1000; here, GDP per capita was calculated by dividing the country's GDP by its population].

3.7. Three-factor analyses of major aspects of the data (Countries, keywords, and organizations)

Fig. 5 presents the three-factor analysis of the relationship among authors' affiliated organizations (left), keywords (middle), and countries (right). It shows that six organizations (King Saud University, King Abdulaziz University, Imam Abdulrahman Bin Faisal University, King Saud Bin Abdulaziz University for Health Sciences, King Khalid University, and Umm Al Qura University published COVID-19 literature mostly using five main keywords (COVID-19, sars-cov-19, pandemic, Saudi Arabia and coronavirus,). These organizations and keywords have a strong relationship with six countries (Saudi Arabia, USA, Egypt, India, United Kingdom and Pakistan).

3.8. Most influential research journals

The ten most influential peer-reviewed journals of Saudi publications on COVID-19 accounted for approximately 16.38% of the total journals publishing scientific research in this research area. Among these, the top five most influential journals were the International Journal of Environmental Research and Public Health

Table 4
The top 10 most highly cited articles by researchers from Saudi Arabia in the field of COVID-19.

Ranking	Title	Authors	Year	Source	Cited by
1st	The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health-The latest 2019 novel coronavirus outbreak in Wuhan, China	Hui et al. [29]	2020	The International Journal of Infectious Diseases	1231
2nd	Surviving Sepsis Campaign: guidelines on the management of critically ill adults with Coronavirus Disease 2019 (COVID-19)	Alhazzani et al. [30]	2020	Intensive Care Medicine	1079
3rd	Clinical, laboratory and imaging features of COVID-19: A systematic review and meta-analysis	Rodriguez-Morales et al. [31]	2020	Travel Medicine and Infectious Disease	634
4th	COVID-19: towards controlling of a pandemic	Bedford et al. [32]	2020	The Lancet	558
5th	Intensive care management of coronavirus disease 2019 (COVID-19): challenges and recommendations	Phua et al. [33]	2020	The Lancet Respiratory Medicine	553
6th	Inborn errors of type I IFN immunity in patients with life-threatening COVID-19	Zhang et al. [34]	2020	Science	454
7th	WHO Scientific and Technical Advisory Group for Infectious Hazards. COVID-19: what is next for public health?	Heymann et al. [35]	2020	The Lancet	407
8th	Structural basis of SARS-CoV-2 $3CL^{pro}$ and anti-COVID-19 drug discovery from medicinal plants	Tahir Ul Qamar et al. [36]	2020	Journal of Pharmaceutical Analysis	341
9th	Anti-HCV, nucleotide inhibitors, repurposing against COVID-19	Elfiky et al. [37]	2020	Life Sciences	323
10th	Systematic Comparison of Two Animal-to-Human Transmitted Human Coronaviruses: SARS-CoV-2 and SARS-CoV	Xu et al. [38]	2020	*Viruses*	290

Table 5
Lotka's law coefficient estimation: Distribution of COVID-19 research production.

Documents written	N. of authors	Proportion of authors
1	15100	0.634
2	3993	0.168
3	2815	0.118
4	1029	0.043
5	375	0.016
6	186	0.008
7	83	0.003
8	60	0.003
9	32	0.001
10	30	0.001
11	24	0.001
12	17	0.001
13	12	0.001
14	8	0
15	11	0
16	6	0
17	2	0
18	3	0
19	2	0
20	2	0
21	2	0
22	4	0
24	1	0
25	1	0
26	1	0
27	2	0
28	1	0
30	2	0
31	2	0
32	1	0
36	2	0
37	1	0
40	1	0
45	1	0
48	1	0
56	1	0
66	1	0

(2.71%, IF = 3.39), Journal of Pharmaceutical Research International (2.27%, IF= 0.67), Journal of Infection and Public Health (2.16%, IF=3.718), Cureus (1.96%, IF = 1.15), and CMC Computers Materials Continua (1.46%, IF = 3.77), which produced 98, 82, 78, 71 and 53 publications, respectively. (Fig. 6)

3.9. Institutional collaboration network

Fig. 7 maps the collaboration network on COVID-19 literature between different organizations. The results suggest collaboration among organizations in conducting research. To measure collaboration, this study considered 40 nodes with maximum labels at 50; furthermore, it used the Walktrap cluster algorithm to generate a chart.

A strong collaboration is exhibited between King Saud University, King Abdulaziz University, King Saud Bin Abdulaziz University for Health Sciences, Imam Abdulrahman Bin Faisal University, King Khaled University, Umm Al Qura University, and Taif University. A strong partnership is also noted between the universities and their affiliated hospitals, such as Alfaisal University and King Faisal Specialist Hospital and Research center. In contrast, King Saud Bin Abdulaziz University for Health Sciences displayed moderate collaboration with the University of Oxford and the University of Toronto.

3.10. Regional and international collaboration in COVID-19 literature

Fig. 8 presents the country collaboration map between Saudi Arabia and other countries on COVID-19 literature. There are 52 entries of collaborations between Saudi Arabia and other countries worldwide, with a maximum of 594 to one collaboration. Saudi

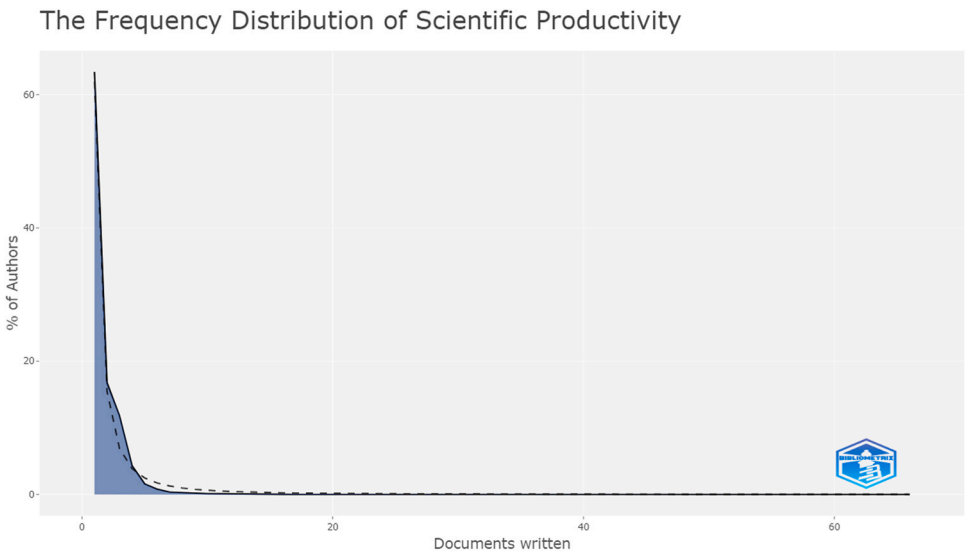

Fig. 2. Lotka's law coefficient estimation.

Arabia's cooperation is on top with Egypt with 594 collaborations, followed by the USA with 562 collaborations, India with 489 collaborations, Pakistan with 376 collaborations, and the United Kingdom (UK) with 339 collaborations.

The VOSviewer visualization software was employed to generate a visualization network of cooperation between Saudi Arabia and other Arab and non-Arab nations in regard to COVID-19 related publications (Fig. 9). The publications co-authored by researchers from several nations were excluded, with the maximum number of countries per publication set to 25 and the minimum number of publications per country set to 5. Among 126 nations, only 91 nations fulfilled the above criteria. The countries that emerged as the center of cooperation with the most substantial collaboration with Saudi Arabia were Egypt [documents = 594, TLS = 1205], the USA [documents = 562, TLS= 2321], and India [documents = 489, TLS = 1782].

4. Discussion

Bibliometric analysis is one of the most frequently used tools for analyzing and networking the research output on a specific topic at a particular time. Recent advances in health informatics and scientometrics software and websites have enabled analyzing the influence of publications based on citation reports, networking techniques, and other quantitative bibliometrics parameters [39,40]. The Saudi Digital Library (SDL), which was launched in 2010, has been a substantial step that has allowed the students and faculty members in Saudi Arabia to access over 200 million pieces of scientific material [41]. This would lead to a substantial increase in the use of bibliometric studies to explore the productivity of publications per field in the setting of advanced search builders in the search engines, such as WoS, PubMed, Scopus, and Google Scholar, among others.

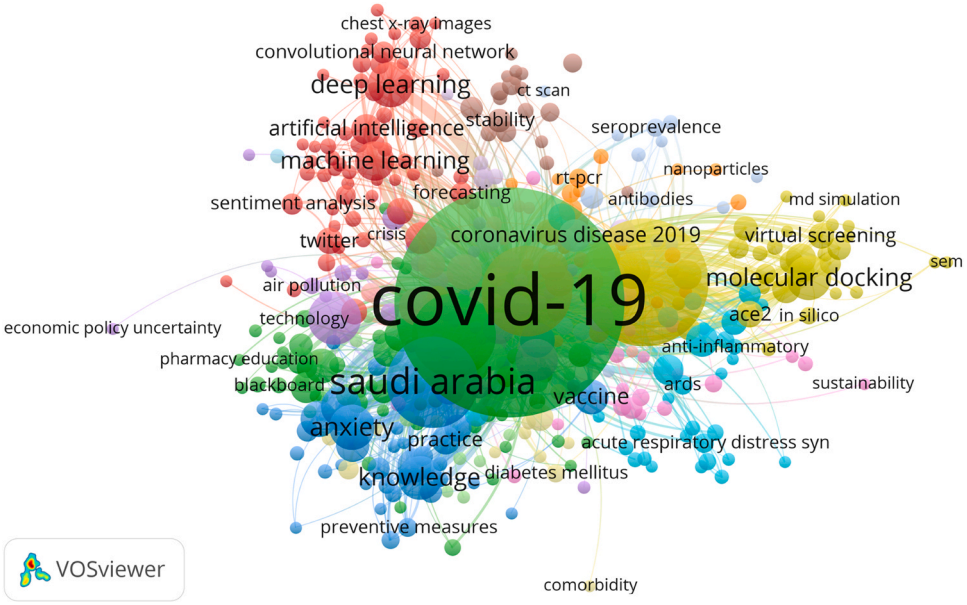

Fig. 3. The visualization network map of the co-occurrence of author keywords. Fifteen clusters were formed, which were weighted based on the occurrences. Cluster 1 (59 words) is indicated in red, Cluster 2 (58 words) in green, Cluster 3 (47 words) in blue, Cluster 4 (38 words) in yellow, Cluster 5 (32 words) in purple, Cluster 6 (31 words) in light-blue, Cluster 7 (25 words) in orange, Cluster 8 (23 words) in brown, Cluster 9 (23 words) in pink, Cluster 10 (22 words) in light-pink, Cluster 11 (19 words) in light-green, Cluster 12 (18 words) in light-blue, Cluster 13 (17 words) in golden, Cluster 14 (14 words) in light-purple, and Cluster 15 (1 word) in Cyan.

Top 20 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2020-OCT - 2021-OCT
transmission	2020-OCT	6.92	**2020-OCT**	2021-FEB	
sar	2020-OCT	4.3	**2020-OCT**	2020-NOV	
coronavirus	2020-OCT	3.46	**2020-OCT**	2020-OCT	
pneumonia	2020-OCT	6.56	**2020-NOV**	2020-DEC	
stability analysis	2020-OCT	3.32	**2020-DEC**	2021-FEB	
psychological impact	2020-OCT	3.04	**2020-DEC**	2021-JAN	
covid-19 pandemic	2020-OCT	5.53	**2021-MAR**	2021-APR	
drug discovery	2020-OCT	2.98	**2021-MAR**	2021-MAY	
spread	2020-OCT	3.79	**2021-APR**	2021-JUN	
antiviral activity	2020-OCT	3.39	**2021-APR**	2021-MAY	
prevention	2020-OCT	3.08	**2021-APR**	2021-APR	
main protease	2020-OCT	3.25	**2021-MAY**	2021-JUN	
activation	2020-OCT	3.14	**2021-MAY**	2021-JUN	
neural network	2020-OCT	3	**2021-MAY**	2021-JUN	
performance	2020-OCT	2.96	**2021-MAY**	2021-JUN	
disorder	2020-OCT	3.32	**2021-JUN**	2021-OCT	
clinical characteristics	2020-OCT	4.36	**2021-JUN**	2021-AUG	
physical activity	2020-OCT	3	**2021-JUN**	2021-OCT	
acceptance	2020-OCT	3.93	**2021-AUG**	2021-OCT	
risk factor	2020-OCT	3.12	**2021-AUG**	2021-OCT	

Fig. 4. Top 20 keywords with the strongest citation burst.

Because of the exponential increase in the number of publications related to COVID-19, the current study was conducted to enhance clarity and update the data related to the contribution of Saudi Arabia to this field. In comparison with the previous studies, the current study specifically added more information to ascertain the dominant global ranking of Saudi Arabia in COVID-19 related

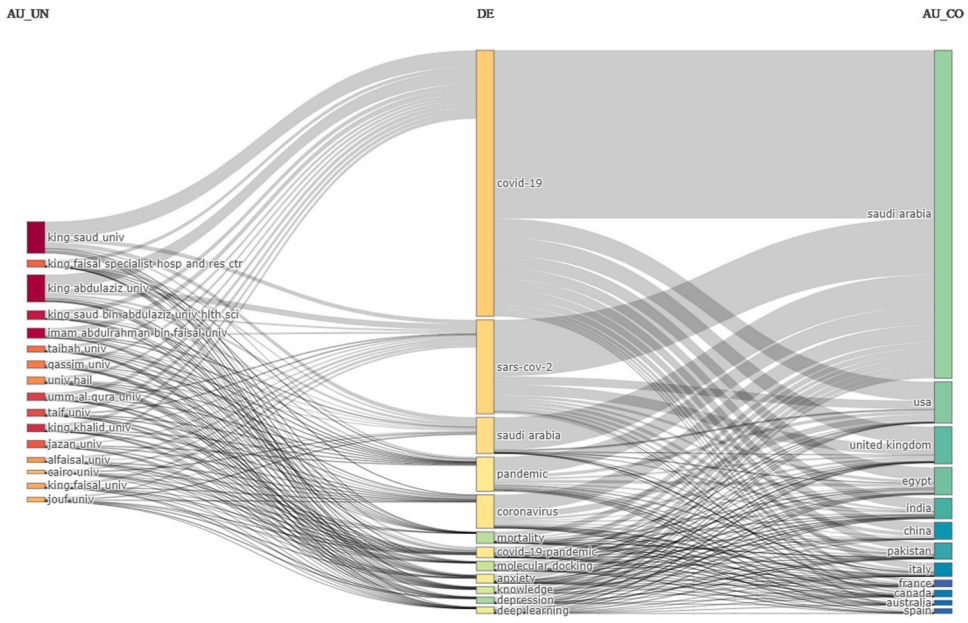

Fig. 5. Three-factor analysis of the relationship among authors' affiliated organizations (left), keywords (middle), and countries (right).

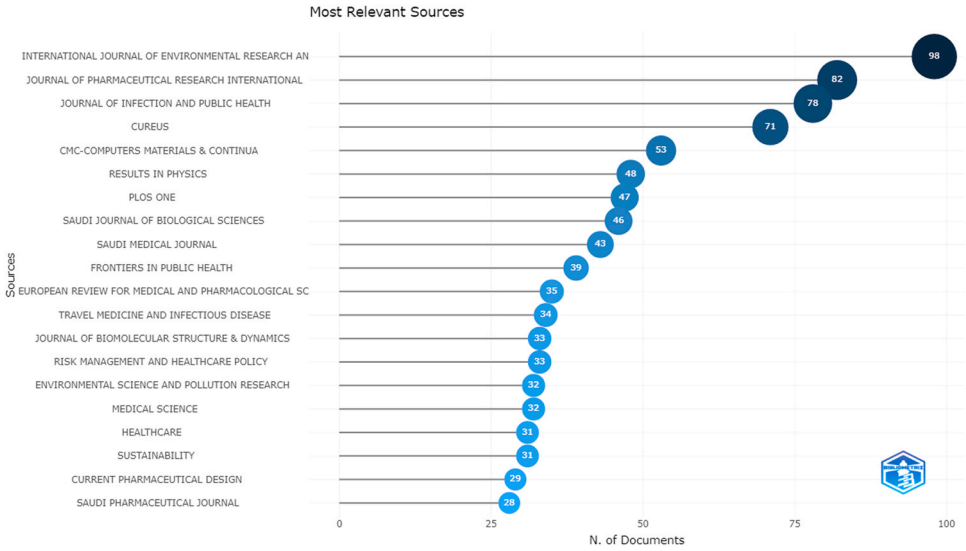

Fig. 6. The top 20 most influential journals of Saudi publications on COVID-19.

research. Moreover, additional bibliometric analyses using various software were used to assess the collaborative patterns, the three-factor analysis (countries, keywords, and organizations), and to explore the most cited author keywords with the strongest citation bursts [21–23].

Since the beginning of the COVID-19 pandemic, the number of COVID-19-related publications originating from Saudi Arabia has increased remarkably. While the number of publications arising from the Arab world remains quite low relative to the global production of publications, the major bulk of these publications has originated from Saudi Arabia, which is listed among the top 15 countries of the world in terms of the number of COVID-19-related publications produced. Moreover, Saudi Arabia is the leading Arabian nation and ranks first among the Arab nations in terms of the production of COVID-19-related publications. Regarding the global output of COVID-19 literature, Al-Duwaish et al. reported that Saudi Arabia was ranked 19th and Zyoud et al. reported the rank improved to 17th; however, our analysis showed that Saudi Arabia ranked 15th based on the production and 11th based on the AI evaluation [22,23]. Not surprisingly, with robust support for research in Saudi Arabia, the rank is expected to improve with time.

It is also essential to highlight that three of the Saudi universities emerged among the top 10 active Arabian institutions producing COVID-19-related publications. King Saud University ranked first among the Arabian academic institutions that were the most active in producing COVID-19-related articles, followed by King Abdulaziz University. King Saud Bin Abdulaziz University for Health Sciences ranked fourth after the Cairo university in terms of the number of publications on COVID-19. This trend was similar to that reported in previous bibliometric studies in other fields [23,42,43]. King Saud University was established in 1957 by King Saud bin Abdulaziz. At that time, it was named Riyadh University and was later renamed King Saud University in 1982. The university has received immense research support at all levels, with a dedicated budget maintained to support its research labs and centers.

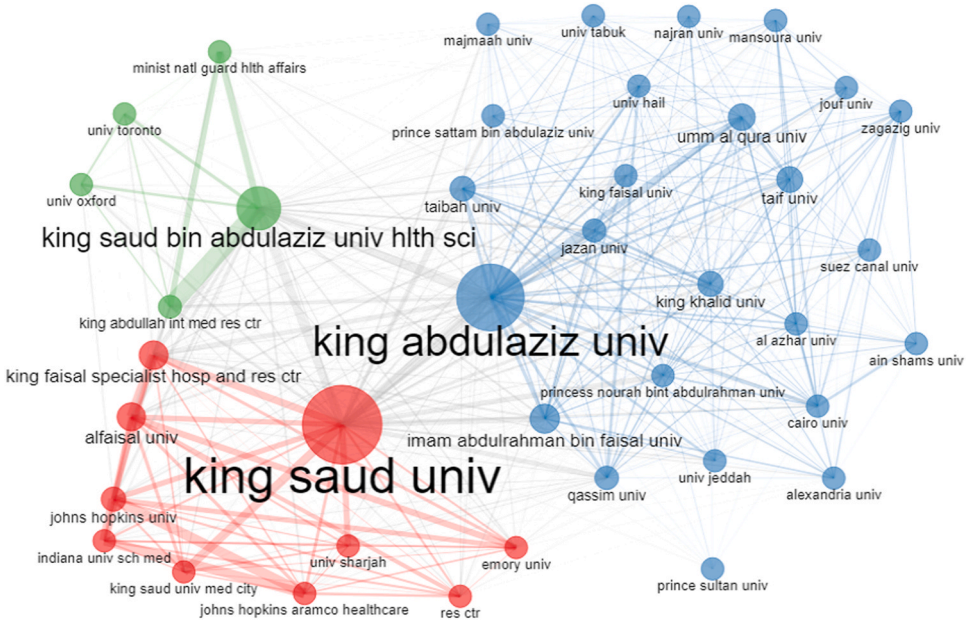

Fig. 7. Mapping of collaboration by institutions.

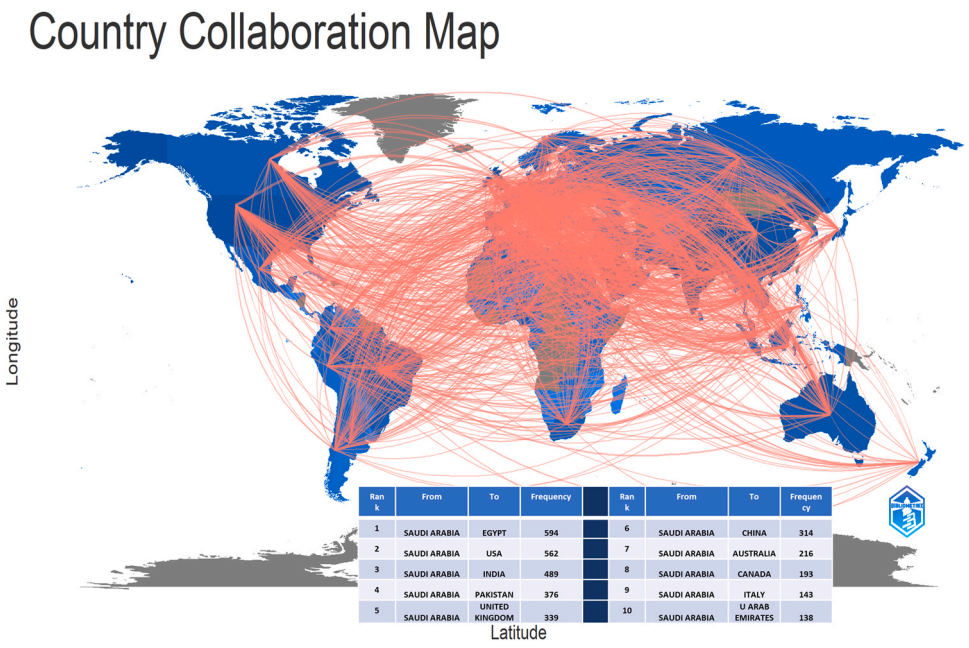

Fig. 8. Country collaboration map on COVID-19 literature around the world.

Our analysis regarding authorship and collaborative patterns shows that the distribution of scholarly production varied significantly, with a few authors have made a significant contribution to the topic. In contrast, most of the authors have published a single article. In addition, it is evident that articles published by Hui et al. [29], Alhazzani et al. [30], and Rodriguez-Morales et al. [31] received a significantly high number of total citations. These high numbers of citations reflect the valuable perspective and the significant global contribution of publications from Saudi Arabia to the research on COVID-19. This also reflects a potentially enhanced knowledge exchange between Saudi Arabia and the other world nations. A review of these papers suggested several common factors that probably have contributed to the increased number of citations. These include the timely investigation and the novelty of these studies to demonstrate first of their kind results on the novel virus. Moreover, because the knowledge on COVID-19 is rapidly evolving, these studies provided significant results and early comprehensive guidance focused on the real-world practice and expertize required to deal with the virus. It was also noted that most of these publications were published by a large collaborative number of authors from different institutions and countries, which brought more knowledge, insights, and personal networks of contacts that could positively impact the

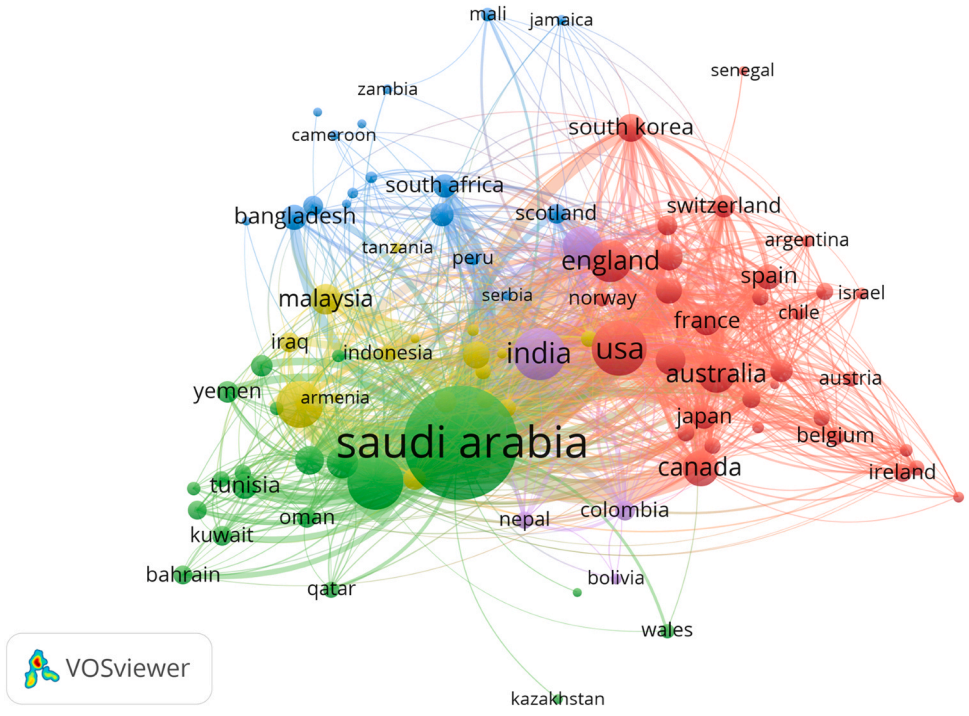

Fig. 9. The network visualization map of Saudi international research collaboration among countries, with a minimum research output of 91 documents on COVID-19-related publications from the Arab nations.

number of citations. Other potential contributing factors to the high number of citations are that most of these papers were published in high-impact journals and were freely accessed.

Another major finding of the study is that Saudi Arabia has an overwhelming research collaboration with the other Arab nations as well as with the non-Arab nations. Egypt, the USA, India, Pakistan, and the UK emerged as the leading nations with a remarkable contribution to the COVID-19 publications from Saudi Arabia, which is in agreement with the findings of Al-Duwaish et al.[22] Our analysis also demonstrates a strong collaboration between the Saudi institutions and international institutions in the aforementioned countries. Another important aspect highlighted by our study is the immediate response of Saudi researchers in reporting, communicating and collaborating during the pandemic. This denotes the importance of multidisciplinary scientists working and collaborating on COVID-19-related research.

The bibliometric analysis regarding the most productive journal publishing research on COVID-19 from Saudi Arabia discloses some interesting results. The International Journal of Environmental Research and Public Health has the most publications, closely followed by the Journal of Pharmaceutical Research International and the Journal of Infection and Public Health. Similarly, Zyoud et al.[23] found that the International Journal of Environmental Research and Public Health was the most productive journal on the topic among the Arab regions, and Qamar et al. [21] reported that the Journal of Infection and Public Health was the most prolific in publishing documents on the topic from Gulf region.

From the keyword perspective, in relation to COVID-19, SARS-CoV-2 and Saudi Arabia are the top keywords in the COVID-19 related research from Saudi Arabia. This was in agreement with the previous studies [21,22]. Moreover, the keywords transmission, pneumonia and COVID-19 pandemic received an extraordinary degree of citation during the period between October 2019 and October 2020. The three-factor analysis provides the most productive institutes such as King Saud University, King Abdulaziz University and Imam Abdulrahman bin Faisal University, focusing on the five main keywords including COVID-19, sars-cov-19, pandemic, Saudi Arabia, and coronavirus.

4.1. Limitations and future research directions

As with all research, the present study also has certain drawbacks that could have influenced the results of the bibliometric analysis. First, the nations and institutions were ranked based on the data retrieved from only one database, i.e., WoS. However, unlike the bibliometric studies on other topics, the ranking related to COVID-19 publications is expected to change continually with time because of the exponential global production of COVID-19-related publications currently. Moreover, the spellings of the names of the institutions might vary in certain instances, which could have affected the accuracy of the results in terms of the actual number of productivities recorded for these institutions.

Future research activities in this domain would have to verify the impact of economic and public health on the research outputs per country. Moreover, the future local research direction related to the COVID-19 could incorporate the Kingdom of Saudi Arabia's Vision 2030. This is because research and knowledge transfer are outlined in the vision to be critical sectors that will strengthen non-profit organizations such as universities.

5. Conclusion

The current study examined the contribution of Saudi Arabia to COVID-19 literature. Globally, Saudi Arabia ranked 15th among the countries with the highest publication productivity, and the rank was 11th after standardization based on the population size and the gross domestic product. Among the Arab nations, the most cited country is Saudi Arabia, and the most active universities are King Saud University and King Abdulaziz University. A robust collaboration was also observed between Saudi Arabia and other countries like Egypt, the USA, India, Pakistan and the UK.

Considering the immense support that the Saudi government agencies provide for research and also the skills of Saudi researchers, it is expected that Saudi Arabia could lead the Arab nations in the field of COVID-19 research. This scenario is further supported by the robust cooperative relations between Saudi Arabia and other nations of the world in the field of COVID-19 research. Moreover, a proper understanding of the global research trends and progression in addition to timely response and adequate planning, could further enhance the quality of research released from Saudi Arabia. Nonetheless, this scenario could be further improved if Saudi scientists, researchers, and institutions strive strongly to advance the nation's global research ranking to meet the expectations outlined in the Saudi Vision 2030. The findings of the present study could facilitate further support for COVID-19 research in Saudi Arabia in terms of funding, planning, and improvement of quality.

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Declarations of interest

none

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jiph.2022.05.013.

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