COVID-19 Medical Research in Oman: A Bibliometric and Visualization Study

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Abstract

*Objective***:** Research contributions in the field of coronavirus disease 2019 (COVID-19) from individual countries needs a systematic analysis and categorization to understand the quantum and pattern and bibliometric analysis facilitates the same. This study was aimed at carrying out a bibliometric analysis based on the COVID-19 related medical research publications which included researchers from the Sultanate of Oman in the SCOPUS database.

Methods: A bibliometric method utilizing citation analysis and science mapping was applied using Scopus. VOSViewer software tool was used for constructing and visualizing bibliometric networks. The main search keywords were COVID-19 and Oman. The search was done on August 21, 2021 and included data between December 1, 2019 up to August 21, 2021.

Results: The search query returned 360 documents; however, 83 were excluded due to their irrelevance, and eventually 277 medical research documents remained for analysis. There were three research themes identified in the health-related literature: treatment of COVID-19, epidemiology and impact of COVID-19 disease, and etiology and clinical manifestations of COVID-19. A total of 4533 sources were cited in the 277 COVID-19 documents contributed by researchers from Oman. Most of the articles were published in *International Journal of Infectious Diseases*, followed by *Oman Medical Journal* and *Sultan Qaboos University Medical Journal.* The most cited references included *the Lancet*, followed by *the New England Journal of Medicine* and the *Journal of the American Medical Association.* Most of the articles

were published by researchers from Sultan Qaboos University followed by Ministry of Health, Sultanate of Oman. With regards to received citations per paper, the top ranks belonged to the Ministry of Health, followed by Sultan Qaboos University Hospital and Khoula Hospital.

Conclusions: Oman has significantly contributed to the COVID-19 medical research despite challenges associated with research and service needs during the pandemic. Most of the publications in Oman were collaborative projects. Based on the evaluated literature further research focusing on vaccines and therapeutics is warranted.

Keywords: Bibliometric analysis, COVID-19, Oman, Medical research, Publications, SARS-CoV-2, Science mapping, Visualization

Introduction

By the end of January 2020, the World Health Organization (WHO) declared that the Coronavirus disease 2019 (COVID-19)outbreak constitutes a Public Health Emergency of International Concern .[1] On 11th of March, 2020 the WHO categorised and announced COVID-19 as a pandemic.[2] Considering the urgency of this outbreak, the international community started mobilizing to significantly accelerate the development of interventions and it was expected that the global research community should maintain a high-level discussion platform.[1] The pandemic has highlighted the need for reliable information to guide clinical practice and policy.[3] Starting from the initial period of the COVID-19 outbreak, a large number of COVID-19-related articles have been published. At the same time there is a need to identify a balance between the velocity and quality of COVID-19 related research output.[4] The scientific response seen to the COVID-19 outbreak demonstrates the capabilities of modern science to react rapidly to emerging global health threats.[5]

In the Sultanate of Oman, the Ministry of Health (MOH), represented by the Directorate General of Disease Surveillance and Control, issued a statement by around 20th of January 2020 on outbreak of the new coronavirus in China and started following up the situation closely.[6] On 24th of February, the MOH registered the first two cases of novel coronavirus (COVID-

2019) in Oman.[7] Several interventions were undertaken across the various governmental and private sectors as per the directives of the Supreme Committee; the committee formed at the government level headed by the minister of interior charged with presenting solutions to weather the outbreak of the virus and limit its aftermaths. [8] Capacity building and training activities continued for health workers in private and governmental institutes.[9]

In light of the fast-progressing global pandemic, research into the various aspects related to COVID-19 in Oman gained pace. The Research Council (TRC), Oman, initiated a COVID-19 Research Program in March 2020 with the main objectives of supporting and guiding research projects to focus on conducting relevant, high quality, short-term, and applied research.[10] The areas of research included those related to clinical scope and public health, and those with non-clinical scope such as artificial intelligence, e-learning and environmental issues.

Modern science is undergoing enormous changes and transformations and is inclusive of trends and phenomena related to the use of new technologies and information.[11] Bibliometric analysis is an approach increasingly used by researchers for reviewing and representing the vastly complex and dynamic scientific literature in a tangible form that one can handle more effectively.[12] Bibliometric analysis is based on the identification of publications in their broadest sense, within a given subject area and often the focus is on a number of broad or more specialized subjects in publishing patterns.[13]

Though, much research work has been carried out on COVID-19 in Oman similar to other countries world over, the extent and pattern of the same is not available for review. Research contributions in the field of COVID-19 from the researchers in Oman needs a systematic analysis and categorization to understand the quantum and pattern of the research findings. The extent of contribution from the scientific community in Oman to the local, regional and global cause requires an analysis. Bibliometric analysis will give opportunity to

understand what have been achieved and what needs to be achieved in light of the COVID-19 pandemic. There are no published studies in this direction from Oman and this signifies the importance of the present work. The present study was aimed at carrying out a bibliometric analysis based on the COVID-19 related medical research publications which included researchers from the Sultanate of Oman listed in the SCOPUS database,.

Methods

The basic principle of bibliometric analysis is the citation network and the two main bibliometric methods are citation analysis for research performance assessment and science mapping.[14] Science mapping is a spatial representation of how disciplines, fields, specialties, and individual papers or authors are related to one another as shown by their physical proximity and relative locations.[15] Bibliometric maps developed through science mapping helps to describe how specific disciplines, scientific domains, or research fields are conceptually, intellectually, and socially structured. Different techniques and software tools are used to carry out science mapping analysis. [16] VOSViewer is a commonly used software tool for constructing and visualizing bibliometric networks. These networks may include journals, researchers, or individual publications, and they can be constructed based on citation, bibliographic coupling, co-citation, or co-authorship relations.[17]

The methods section is structured in five parts as follows, the bibliometric techniques applied, database used, search strategies employed, inclusion and exclusion criteria during screening ,and statistical analysis.

Bibliometric indicators and visualization techniques

Using citation analysis, this bibliometric analysis focused on the publications on COVID-19 authored by World, Middle-Eastern and researchers from Oman. The publications were analyzed based on their types and languages, highly-productive journals, authors and research institutes, and highly-cited sources. Visualization was made by co-authorship, co-occurrence and co-citation analyses. Collaboration map of researchers from Oman with those in the World, the map of highly-frequent keywords in the publications, the map of highly-frequent terms used in document titles and abstracts, and the map of cited sources in researchers from Oman's publications on COVID-19 were depicted. In line with the aim of the study, the analysis focused on medical research related to COVID-19.

Database

We used Scopus® (Elsevier BV Company, USA), a known indexing and abstracting database.[18] Scopus is more comprehensive database and easier to be used in bibliometric analysis of biomedical fields compared to any other tool as it shows all authors' affiliations and is considered the World's largest database for abstract and citation information.[19,20]Researchers in medical fields regularly use the database in various bibliometric studies.

Search strategy and keywords

The main search keywords were COVID-19 and Oman. For making a comprehensive search, *MeSH (Medical Subject Headings)* was used for retrieving possible synonyms. As National Library of Medicine (NLM) controlled vocabulary thesaurus, *MeSH* is used for indexing papers in medical fields. After retrieving all COVID-19 synonyms, the following search query was conducted for extracting needed data via Scopus:

(TITLE-ABS-KEY ("COVID-19") OR TITLE-ABS-KEY ("COVID-19 Virus Disease") OR TITLE-ABS-KEY ("COVID 19 Virus Disease") OR TITLE-ABS-KEY ("COVID-19 Virus Diseases") OR TITLE-ABS-KEY ("Disease, COVID-19 Virus") OR TITLE-ABS-KEY ("Virus Disease, COVID-19") OR TITLE-ABS-KEY ("COVID-19 Virus Infection") OR TITLE-ABS-KEY ("COVID 19 Virus

Infection") OR TITLE-ABS-KEY ("COVID-19 Virus Infections") OR TITLE-ABS-KEY ("Infection, COVID-19 Virus") OR TITLE-ABS-KEY ("Virus Infection, COVID-19") OR TITLE-ABS-KEY ("2019-nCoV Infection") OR TITLE-ABS-KEY ("2019 nCoV Infection") OR TITLE-ABS-KEY ("2019-nCoV Infections") OR TITLE-ABS-KEY ("Infection, 2019-nCoV") OR TITLE-ABS-KEY ("Coronavirus Disease-19") OR TITLE-ABS-KEY ("Coronavirus Disease 19") OR TITLE-ABS-KEY ("2019 Novel Coronavirus Disease") OR TITLE-ABS-KEY ("2019 Novel Coronavirus Infection") OR TITLE-ABS-KEY ("2019-nCoV Disease") OR TITLE-ABS-KEY ("2019 nCoV Disease") OR TITLE-ABS-KEY ("2019-nCoV Diseases") OR TITLE-ABS-KEY ("Disease, 2019-nCoV") OR TITLE-ABS-KEY ("COVID19") OR TITLE-ABS-KEY ("Coronavirus Disease 2019") OR TITLE-ABS-KEY ("Disease 2019, Coronavirus") OR TITLE-ABS-KEY ("SARS Coronavirus 2 Infection") OR TITLE-ABS-KEY ("SARS-CoV-2 Infection") OR TITLE-ABS-KEY ("Infection, SARS-CoV-2") OR TITLE-ABS-KEY ("SARS CoV 2 Infection") OR TITLE-ABS-KEY (sars-cov-2 AND infections) OR TITLE-ABS-KEY ("COVID-19 Pandemic") OR TITLE-ABS-KEY ("COVID 19 Pandemic") OR TITLE-ABS-KEY ("COVID-19 Pandemics") OR TITLE-ABS-KEY ("Pandemic, COVID-19") OR TITLE-ABS-KEY ("COVID-19")) AND PUBYEAR > 2018)

After retrieving worldwide COVID-19 publications, the search was limited to the Middle-Eastern countries and Oman. For preventing possible bias of daily update of Scopus, the search was done in one day, i.e. on August 21, 2021. All related publications were retrieved from the database in the time span of December 1, 2019 - and August 21, 2021. No language limitation was done.

Inclusion/exclusion criteria during screening

Inclusion criteria:

1. Medical research publications related to COVID-19 which included at least one researcher from Oman

2. Published between December 1st 2019-August 21 st 2021.

Exclusion criteria:

1. Non-medical documents which are not related to clinical/medical or public health related aspects of COVID-19

2. Publications related to education and use of technologies in education during the pandemic without indication of its impact on psychological/medical well-being of students/teachers (education in general and medical education).

Inclusion/exclusion of the COVID-19 documents authored by researchers from Oman was evaluated by one author (Jimmy Jose). Based on the review of the titles and in few cases, the abstracts as well, the authors concluded that it is ideal to exclude 83 of the publications due to the reasons mentioned under exclusion criteria; non-medical documents or - ones related to education and use of technologies in education during the pandemic

Statistical analysis

We used the Statistical Package for the Social Sciences (SPSS) 17.0 for Windows (SPSS Inc., Chicago, IL, USA) for statistical description and analysis. VOSViewer software (version 1.6.13 for Microsoft Windows System) was used for visualization and depicting scientific maps and networks.

Results

Highly-productive World's countries in COVID-19 research publication

As Table 1 shows, out of the total 199,217 COVID-19 publications worldwide, the USA ranked first, publishing 50,680 (25.44%) of all publications, followed by the United Kingdom with 20,958 publications (10.52%) and thirdly China with 19,051 publications (9.56%), respectively. Three middle Eastern countries were among the top 20 publishing countries,

including Iran , Turkey and Saudi Arabia. . With 360 publications, Oman ranked 70th in the world.

Table 1. Top 20 countries publishing on COVID-19.

Rank	Country	Publications	% of total
1	United States	50,680	25.44
2	United Kingdom	20,958	10.52
3	China	19,051	9.56
4	Italy	16,020	8.04
5	India	13,958	7.01
6	Germany	8,482	4.26
7	Spain	8,416	4.22
8	Canada	8,347	4.19
9	Australia	7,364	3.70
10	France	7,091	3.56
11	Brazil	6,148	3.09
12	Iran	4,642	2.33
13	Turkey	4,372	2.19
14	Switzerland	3,793	1.90
15	Netherlands	3,655	1.83
16	Japan	3,536	1.77
17	Saudi Arabia	3,334	1.67
18	South Korea	2,726	1.37
19	Russian Federation	2,714	1.36
20	Indonesia	2,666	1.34

Contribution of Middle-Eastern countries in COVID-19 research publications

Table 2 outlines the contribution of all 17 Middle-Eastern countries in COVID-19 publications. Out of 21,310 documents, 57.95% were published by the top-ranked countries, including Iran (4,642; 21.78%), Turkey (4,372; 20.52%) and Saudi Arabia (3,334; 15.65%), respectively. The other 14 countries (including Egypt, Israel, United Arab Emirates, Jordan, Qatar, Iraq, Lebanon, Oman, Cyprus, Kuwait, Bahrain, Palestine, Yemen, and Syrian Arab Republic) contributed in publishing 42.05% of total publications in the field. Oman ranked 11th in the region.

Table 2. Middle-Eastern countries' contribution to COVID-19 research publications.

No.	Country	Publications	% of total	Rank
1	Iran	4642	21.78	1
2	Turkey	4372	20.52	2
3	Saudi Arabia	3334	15.65	3
4	Egypt	2060	9.67	4
5	Israel	1813	8.51	5
6	United Arab Emirates	1138	5.34	6
7	Jordan	730	3.43	7
8	Qatar	636	2.98	8
9	Iraq	553	2.60	9
10	Lebanon	511	2.40	10
11	Oman	360	1.69	11
12	Cyprus	357	1.68	12
13	Kuwait	296	1.39	13
14	Bahrain	201	.94	14
15	Palestine	135	.63	15
16	Yemen	107	.50	16
17	Syrian Arab Republic	65	.31	17
	Total	21310	100	

Research publications on COVID-19 from Oman

Researchers from Oman published 360 documents on COVID-19 and as noted in the methods section, 83 documents were excluded due to their irrelevance and 277 related documents remained. A total of 2,451 citations were recorded by these 277 documents, with the mean rate of citations per paper (CPP) amounted to 8.84. The h-index of these documents was 22. The majority of the documents were original articles (169; 61.01%), followed by reviews (41; 14.80%) and letters (38; 13.71%).. The majority of the documents (274; 98.91%) were in English. One each document was in Arabic, French and Spanish.

Journals publishing research articles from Oman on COVID-19

Table 3 shows top 10 journals publishing at least four documents authored by researchers from Oman on COVID-19. In total, 85 documents (30.68%) were published in these journals.

Approximately, 7.94% (n = 22) of COVID-19 documents were published in *International Journal of Infectious Diseases*, followed by *Oman Medical Journal* (5.78%), and *Sultan Qaboos University Medical Journal* as well as *Journal of the College of Physicians and Surgeons Pakistan* (2.89%). Among these 10 journals, 5 journals were in the Q2 Cite Score Quartile.

Table 3. Top journals publishing researchers from Oman's documents on COVID-19.

No	Journal title	Documents (N=277)		Impact factor	CiteScore	h-index	CiteScore Quartile
		n	%				
1	International Journal of Infectious Diseases	22	7.94	3.623	7.00	89	Q1
2	Oman Medical Journal	16	5.78	N/A	1.90	31	Q2
3	Sultan Qaboos University Medical Journal	8	2.89	N/A	1.40	27	Q2
4	Journal of the College of Physicians and Surgeons Pakistan	8	2.89	N/A	N/A	N/A	N/A
5	Diabetes and Metabolic Syndrome Clinical Research and Reviews	7	2.53	N/A	4.90	40	Q2
6	International Journal of Nutrition Pharmacology Neurological Diseases	6	2.17	N/A	0.90	6	Q3
7	Journal of Paediatrics and Child Health	5	1.81	1.954	2.29	76	Q2
8	Vox Sanguinis	5	1.81	2.144	3.70	83	Q2
9	Disaster Medicine and Public Health Preparedness	4	1.44	1.385	2.29	41	Q3
10	Journal of Infection and Public Health	4	1.44	3.718	4.90	35	Q1

Researchers' from Oman's Most Highly-cited Documents on COVID-19

Out of 277 documents authored by researchers from Oman on COVID-19, 155 documents (55.95%) received at least one citation. Table 4 shows the bibliographic information of top ten highly-cited ones (5 original articles, 4 reviews and 1 letter). The first-ranked highly cited document entitled as "COVID-19, SARS and MERS: are they closely related?" was authored by Petrosillo N.et al.

Table 4. Top highly-cited documents published by researches from Oman on COVID-19.

Rank	Authors	Document title	Pub. year	Source title	Volume (Issue)	Pages	Cited by	Document Type
1	Petrosillo N.et al	COVID-19, SARS and MERS: are they closely related?	2020	Clinical Microbiology and Infection	26 (6)	729-734	413	Review
2	Petersen E. et al.	Comparing SARS-CoV-2 with SARS-CoV and influenza pandemics	2020	The Lancet Infectious Diseases	20 (9)	e238-e244	319	Review
3	Parma V. et al	More than smell - COVID-19 is associated with severe impairment of smell, taste, and chemesthesis	2020	Chemical Senses	45 (7)	609-622	110	Original Article
4	Labrague L.J. et al.	COVID-19 anxiety among front-line nurses: Predictive role of organisational support, personal resilience and social support	2020	Journal of Nursing Management	28 (7)	1653-1661	104	Original Article
5	Reiner Ž. et al.	Statins and the Covid-19 main protease: In silico evidence on direct interaction	2020	Archives of Medical Science	16 (2)	490-496	102	Original Article
6	Albarello F. et al.	2019-novel Coronavirus severe adult respiratory distress syndrome in two cases in Italy: An uncommon radiological presentation	2020	,"International Journal of Infectious Diseases"	93	192-197	95	Original Article
7	Atkinson B. et al.	SARS-CoV-2 shedding and infectivity	2020	The Lancet	395(10233)	1339-1340	71	Letter
8	Zahedipour F. et al.	Potential effects of curcumin in the treatment of COVID-19 infection,	2020	Phytotherapy Research	34 (11)	2911-2920	60	Review
9	Saleh J.	Mitochondria and microbiota dysfunction in COVID-19 pathogenesis	2020	,"Mitochondrion"	54	1--7	59	Review
10	Labrague L.J et al.	Fear of COVID-19, psychological distress, work satisfaction and turnover intention among frontline nurses	2021	Journal of Nursing Management	29 (3)	395-403	48	Original Article

Top highly-productive research institutions in Oman on COVID-19

Table 5 shows top 7 Omani research institutes with publishing at least ten COVID-19 articles. Ranking based on the number of published documents reveals that the first to third ranks in publishing on COVID-19 belonged to Sultan Qaboos University (92: 33.21%), Ministry of Health Oman (66; 23.82%) and Sultan Qaboos University Hospital (52; 18.77%). However, when ranked by mean rates of received (CPPindicator, the top ranks belonged to the Ministry of Health Oman (18.09), followed by Sultan Qaboos University Hospital (7.96) and Khoula Hospital (7.1).

Table 5. Top highly-productive Omani institutions contributing to COVID-19.

Rank	Institution	Documents (N = 277)	%	Total citations	Citations per paper (Rank)	h-index
1	Sultan Qaboos University	92	33.21	645	7.01 (4)	15
2	Ministry of Health Oman	66	23.82	1194	18.09 (1)	14
3	Sultan Qaboos University Hospital	52	18.77	414	7.96 (2)	9
4	Royal Hospital	41	14.80	223	5.44 (6)	8
5	University of Nizwa	14	5.05	31	2.21 (7)	3
6	Oman Medical Specialty Board	12	4.33	66	5.50 (5)	-
7	Khoula Hospital	10	3.61	71	7.10 (3)	3

Top productive researchers from Oman on COVID-19

As Table 6 depicts, the most active authors from Oman in COVID-19 publications were Khamis, F. with 20 documents, AL-Zakwani, I. with 11 documents and 3 other authors each with 10 documents. When CPP was considered, Labrage L.J. ranked first (16.08), followed by Pandak, N. (14.85), and Al-Zakwani, I. (12.09). Five most active authors were affiliated to the Sultan Qaboos University.

Table 6. Top productive researchers from Oman authoring on COVID-19

Author's name	No. of Published articles	Total citations (R)	Citations per paper (rank)	h-index (R)	Affiliation	Scopus Author Identifier
Khamis, F.	20	207 (1)	10.35 (4)	8 (1)	Royal Hospital, Muscat, Oman	55218145400
Al-Zakwani, I.	11	133 (3)	12.09 (3)	5 (2)	Sultan Qaboos University, College of Medicine and Health Sciences, Muscat, Oman	55903793100
Al Salmi, I.	10	79 (5)	7.9 (5)	3 (4)	Royal Hospital, Muscat, Oman	23395966600
Al-Abri, S.	10	17 (8)	1.7 (8)	2 (5)	Ministry of Health Oman, Muscat, Oman	14827719600
Labrague, L.J.	10	168 (2)	16.8 (1)	4 (3)	Sultan Qaboos University, Muscat, Oman	55582670400
Al Awaidy, S.T.	9	62 (6)	6.88 (6)	2 (5)	Ministry of Health Oman, Muscat, Oman	6508132710
Al Yazidi, L.S.	8	8 (9)	1 (9)	2 (5)	Sultan Qaboos University Hospital, Muscat, Oman	56012835000
Al-Riyami, A.Z.	8	51 (7)	6.37 (7)	4 (3)	Sultan Qaboos University Hospital, Muscat, Oman	37025510100
Sheikh, S.	8	1 (10)	.12 (10)	1 (6)	Sultan Qaboos University Hospital, Muscat, Oman	8948045600
Pandak, N.	7	104 (4)	14.85 (2)	4 (3)	Royal Hospital, Muscat, Oman	6506008185

Co-authorship network of Omani authors collaborating with foreign authors in publishing on COVID-19

In total, authors from Oman collaborated with authors from 112 countries in authoring 277 COVID-19 documents. Authors from 18 countries co-authored with authors from Oman in authoring at least 10 COVID-19 documents. Therefore, the number 10 was considered as the threshold for depicting co-authorship network of collaborating countries. The circles/node

sizes in the map depict the number of co-authored documents and the lines among nodes depict the co-authorship number. The thicker the line between two nodes is, the more the collaboration between the two countries. As Figure 1 depicts, researchers from Oman mostly collaborated with the USA researchers with co-authoring 45 documents, followed by UK researchers with 42 and Indian researchers with 41 co-authored documents.
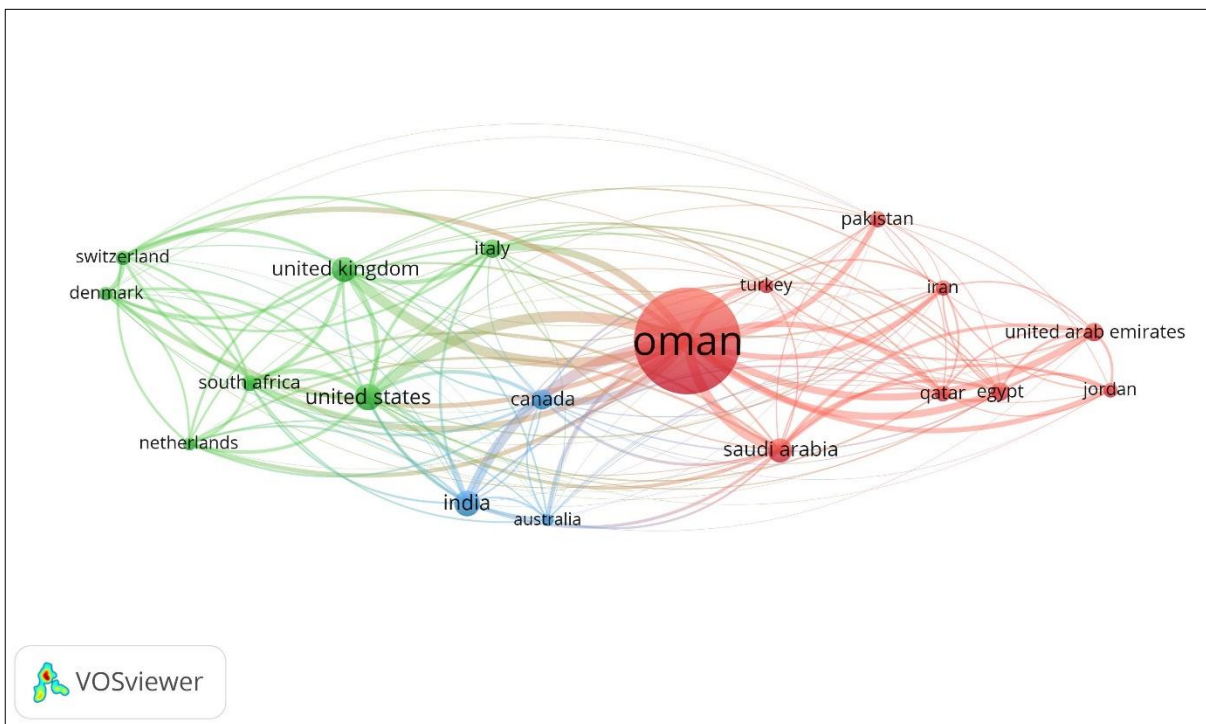
Figure 1. Co-authorship network of countries collaborating with Oman in research on COVID-19

Co-occurrence network of most frequent keywords in researchers from Oman's' publications on COVID-19

In the documents on COVID-19, 701 unique keywords were used. Of them, the keywords with the highest number of occurrences were "human" followed by "COVID-19", "Coronavirus Disease 2019", and "pandemic".. Figure 2 depicts the co-occurrence map of keywords with at least 10 co-occurrences. As observed, these keywords were included in 3 main clusters. The first cluster (in red) includes keywords generally related to the treatment of COVID-19. The second cluster (in green) is related to keywords manifesting the epidemiology and impact of

the disease and the third one (in blue) is related to etiology and clinical manifestations of COVID-19.

Figure 2. Co-occurrence map of highly-frequent keywords used in Omani researchers documents on COVID-19.

Co-occurrence network of most frequent terms used in researchers from Oman's COVID-19 document titles and abstracts

Figure 3 represents the co-occurrence network of most frequent terms used in researchers from Oman's COVID-19 document titles and abstracts. It represents the terms most frequently co-occurred in the publications which is represented as clusters. A total of 5,830 terms were extracted from the titles and abstracts of 277 documents authored by researchers in Oman on COVID-19. The terms with at least 10 occurrences were included in the map. The term co-occurrence map (Figure 3) consisted of three main clusters. Some main terms in the first cluster (in red) were severe acute respiratory syndrome, coronavirus 2, virus, vaccine, treatment and drug. The cluster can be named as "diagnosis and treatment studies on COVID-19". Named as

"manifestations and outcomes of COVID-19, the second cluster (in green) included terms such as mortality, hospital and outcome. The third cluster (in blue) reflected "psychological impact of COVID-19" with terms including among others, depression, stress, anxiety and mental health.


Figure 3. Co-occurrence map of highly-frequent terms used in Omani researchers' COVID-19 document titles and abstracts

Co-citation Network of Cited Sources in Researchers' from Oman's Documents on COVID-19

In total, 4,533 sources were cited in the references section of 277 COVID-19 documents contributed by researchers in Oman. For identifying core sources and their visualization, co-citation analysis was used. Only 18 cited sources were cited at least 30 times and are included in the co-citation map. As Figure 4 shows, *the Lancet* (266) ranked first as the cited source in these documents, followed by *the New England Journal of Medicine (NEJM)* (167) and *Journal of the American Medical Association (JAMA)* (144). The top-cited sources were included in four clusters. The first cluster in red consisted of 7 sources; the second one in green

had 6 sources. The third cluster in blue and the fourth cluster in yellow had 4 and 2 cited

sources, respectively. It is notable that cited sources in the same cluster are more co-cited.
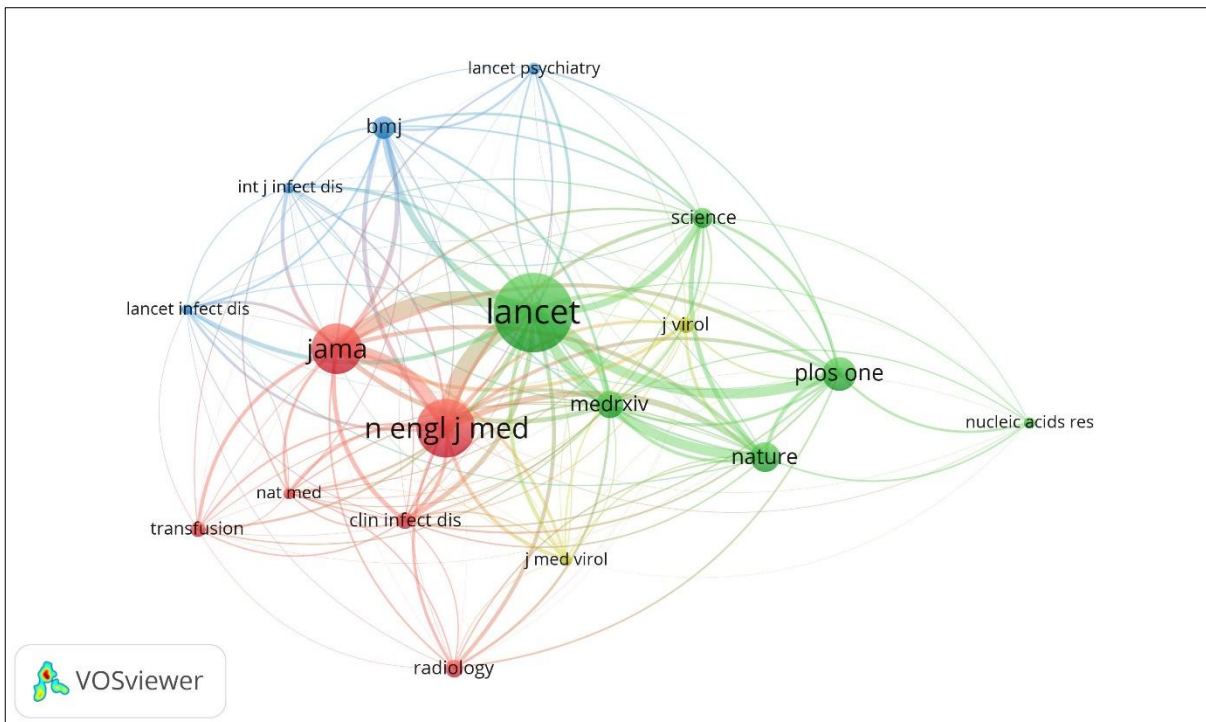
Figure 4. Co-citation map of cited sources in researchers from Oman's documents on COVID-19.

Discussion

COVID-19 pandemic has triggered a major threat to the global society and humanity. The rapid spread and the substantial morbidity and mortality[21] demanded an urgent need for pertinent research in all aspects related to the disease. This led to the emergence and publication of a diverse array of research whether descriptive, diagnostic, therapeutic or preventive. The open access policy and fast-tracked editorial process that have been adopted by many journals has contributed to the rapid dissemination of COVID-19 data and research in a short period of time.[22] Controlling COVID-19 pandemic require countries to sustain COVID-19 research by not only producing data but also ensuring implementation into effective polices. A rapid increase in research activities related to COVID-19 over such a short period of time compared

to other diseases or infections is noticed.[22-27] Representing the data from the analysis in the current study, the top COVID-19 related research has been produced from United states, United Kingdom and China representing 25.44%, 10.53% and 9.46% of the global output, respectively. These countries also had the largest number of affected populations, resources including research grants, biological materials and the skilled researchers. United States and United Kingdom was found to have superior collaborative publication output based on the combined publications.[28]

Among the countries in the Middle East; the most COVID-19 related research contribution comes from Iran, Turkey and Saudi Arabia, representing 57.95% of all the publications from the region. This finding is also in line with another study that have assessed the quantity of all COVID-19 research from the region.[29] This is probably attributed to the increased capacity for research in these countries, in terms of affected cases and the number of research institutions.[30,31] Increasing productivity has also been associated with increased funding and gross domestic product (GDP) of the country[32,33], availability of qualified researchers, public health expenditure, as well as allocation of resources for research and development (R&D)[34]. However, this productivity is uneven across the region and the least number of COVID-19 related publications originated from Syria, Yemen, Palestine; probably an indication of the ongoing conflict in these countries, low number of researchers and low GDP per capita.

Countries with higher research output appear to allocate approximately 2.5% of their GDP to R&D.[35] Countries in the region should collaborate to strengthen regional research capacity building by supporting researchers and investing in research. The culture of research would also improve if national-level policies include more local funding grants and doctoral and postdoctoral programs.

In this study we mainly evaluated the quantity and qualityof COVID-19 research productivity in Oman over a period of 20 months by using bibliometric methods including citation analysis and science mapping. Overall, health research productivity in Oman has gone through a steady increase during the study period, though remains low in comparison to other countries in the region. Among the 277 COVID-19 publications selected for evaluation, the top cited published articles from Oman were original articles (61.01%) followed by reviews (14.8%) and letters (13.71%). Similarly, globally, the highest number of studies (n=1515) were surveys, followed by reviews (systematic review, scoping review, or meta-analyses), cohort studies, meta-analysis, randomized controlled trials (RCTs), case studies, scoping reviews and case control studies.[36]

In times of pandemic and while facing deadly diseases, the type of research that is necessary and more important remains controversial.[4,26,38] In the new modern era of medicine, scientists and researchers are more inclined towards conducting RCTs, a process that is lengthy and publishing of its results may require long time. Thus, case-series and observational studies, though regarded of lower quality research, might be a valuable tool for faster dissemination of information and helps in developing management guidelines and treatment algorithms that are highly needed by clinicians. In a comprehensive meta-research by Raynaud et al. comprising of 10,516 COVID-19-related medical articles published since the start of the pandemic, the authors observed that peer-reviewed original articles accounted for only 10% of all COVID-19 research. Moreover, most of the publications were without original data and tended to be in the form of research letters, which often lacks methodological information for quality assessment. These authors concluded that there is an urgent demand to achieve a balance between the "velocity and quality of research, and to cautiously consider medical information and clinical applicability in a pressing, pandemic context".[4]

Several bibliometric analyses have been conducted to investigate COVID-19 research activity from different countries.[21,24,26-28,35] Bibliometrics analyses used in the current study assess quantitative citations of the articles published by researchers in Oman. A network representing the citations of different documents was produced. VOSViewer software was used for constructing and visualizing bibliometric networks. The highly cited authors were Petrosillo N with 413 citations, followed by Petersen E with 319. The majority of the highly cited research was on understanding the SARS-CoV-2 virus in comparison with other corona viruses such as SARS and MERS-COV. In addition, the highly cited COVID-19-related research was in the form of original research article.

The three top highly productive Omani research institutes were Sultan Qaboos University (SQU), Ministry of Health (MOH) and Sultan Qaboos University Hospital (SQUH). Both SQU and SQUH have received research funds for 12 projects through TRC[38], indicating that academic output needs financial support. Due to the many unknowns in regard to this pandemic, and especially with the prompt governmental response through the support provided by TRC, one expected larger productivity from the academic institutions in Oman. However, the healthcare systems and experts were overwhelmed and heavily pre-occupied with the urgent health sector needs. As clinical care and preparedness response were the top priorities[39], researchers had less time to write and publish articles particularly during the acute phases of the pandemic[40]. At the international level, a significant dominance of the universities and research institutions was observed.[30,41]

The studies related to COVID-19 from Oman were published in recognized international and local medical journals such as *International Journal of Infectious Diseases, Journal of Infection and Public Health, Oman Medical Journal* and *Sultan Qaboos University Medical Journal.* These publications enabled rapid dissemination of key information between researchers and provided essential information for prompt decisions by policy makers.

Additionally, the availability of the local medical journals where researchers can publish their work can increase publication output and addresses local interests that may not be equally represented by international journals. An increased interest of R&D has spurt since 2002 in the region. The indexing of journals onto Scopus and other search engines have resulted in increased visibility of the research from the region and therefore reaching higher impact factors[30].

In this study, we presented the 10 most publishing authors along with their number of total publications (NP), total citations, citations per paper (CPP) and corresponding *h*-index values to evaluate the productivity as well as the impact of their publications. Considering the number of scientific outputs, Khamis F. was the most prolific, having published a total of 20 scientific documents, followed by Al-Zakwani I., who published 11 articles at the time this bibliometric analysis was conducted. The authors with the highest CCP were Labrage LJ and Al-Zakwani I. Considering the impact of publication in terms of total citations and *h*-index reflects the overall citations per article rate (31), Khamis F. was the top-ranked author with 207 citations and an h-index of 8, followed by Al-Zakwani I, who has received a total of 133 citations with an *h*-index value of 5. In the cluster of authors, we found that the cooperation between the various authors was close. Our data demonstrated that substantial collaborative research was undertaken between authors from Oman and international researchers from 112 countries, mostly the USA, UK and India. This collaboration enriches knowledge of the SARS-CoV-2 virus, helps in understanding the role of the different therapeutics, and provides the international community with essential information on the clinical and epidemiological characteristics of COVID-19 patients in this region. It needs to be considered that many of the published articles were multinational studies including researchers from numerous countries. This could be the reason for the very high number of collaborating countries listed as 112.

In bibliometrics, a network graph of keyword co-occurrences reflects hot topics.[21] Such analyses enable researchers to understand the local research capacity and potential gaps in the literature, and set the path and direction for future research.[42] We identified a total of 701 keywords used by the authors in Coronavirus related research in Oman. The most frequently used keywords in the publications were "Human" followed by "COVID-19", "Coronavirus Disease 2019", and "Pandemic".. Moreover, keywords that are the basis for understanding the scientific outputs and the intellectual structure of COVID-19 research reported in the present study can be organized into three primary clusters; treatment of COVID-19, impact of COVID-19, and epidemiology and clinical manifestations. Preventive measures and vaccine studies were under-represented, thus, prioritizing the research on COVID-19 public health interventions, prevention strategies and vaccination impact, is highly needed.

A total of 4,533 references were included in the 277 COVID-19 articles contributed by the researchers in Oman. Only 18 cited sources were cited at least 30 times and included in the co-citation map; *Lancet* (266) was ranked first among the cited sources in these documents, followed by *the New England Journal of Medicine* (167) and *Journal of the American Medical Association (JAMA)* (144). Researchers and readers tend to trust these journals with higher impact factors.[43]

In this study, beside recognizing the most contributing authors, research institutions, and countries, we provided several visualizations to further understand the data such as: co-authorship network of collaborating countries sources to identify the geographic intensity, co-occurrence map of highly frequent keywords and terms, and co-citation maps of cited sources in the articles produced from Oman.

This study has few limitations. The representation of the institutions may not be most appropriate as the data was obtained automatically, which might have misrepresented

affiliation details provided by the authors while publishing. It should be noted that Sultan Qaboos University Hospital could be considered along with Sultan Qaboos University. Royal Hospital and Khoula hospital are part of the Ministry of Health. Second, preprint articles were not included which represent a good proportion of COVID-19 literature. Third, the quality of research was not assessed as we only analyzed article titles, abstracts, and authors' data. Finally, due to the inherent limitation of the bibliographic analysis, citation frequency might be affected by multiple factors such as journal and institutions reputation and therefore is not a perfect reflection for academic influence.

Conclusion

The COVID-19 pandemic has highlighted the urgent need for research that translates into effective policy. Oman has contributed to this body of COVID-19 research, despite challenges associated with research and service needs during the pandemic. In this study we provided a comprehensive overview of the current state of the COVID-19 publications in Oman in order to explore gaps in the existing research topics and prioritize research needs. Furthermore, we identified the leading researchers andinstitutes, in this area ,and explored connections and collaborations between researchers in Oman with other parts of the world. Though the health research productivity in Oman has gone through a steady increase during the study period, it remains low in comparison to other countries in the region. The top cited published articles from Oman were published in recognized international and local medical journals which enable rapid dissemination of key information. Collaborative research was undertaken between Omani authors and international researchers which is a increasing general trend world over especially during the pandemic. It is noticed that further research focusing on vaccines and therapeutics is warranted in the country.

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