

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

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ABSTRACT

Objectives: To study the quantum and pattern of the COVID-19-related medical research publications that had contributions from researchers in Oman, using bibliometric analysis. **Methods:** Data on the COVID-19-related medical research publications with contributions from authors in Oman were sourced from the Scopus database. The main search keywords were 'COVID-19' and 'Oman'. The search included data from 1 December 2019 till 21 August 2021. A bibliometric method utilizing citation analysis and science mapping was applied to the selected data. VOSviewer software was used for constructing and visualizing various bibliometric networks. **Results:** The search query returned 360 documents which included those by authors from Oman. After excluding 83 of these due to irrelevance, 277 documents were finally selected for analysis. Three macro research themes emerged: treatment of COVID-19 cases, epidemiology and impact of COVID-19, and etiology and clinical manifestations of COVID-19. A total of 4533 sources were cited in the selected 277 documents. Most articles were published in the *International Journal of Infectious Diseases (IJID)*, 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*. The largest number of papers were authored by researchers from Sultan Qaboos University followed by the Oman Ministry of Health. Regarding the number of citations received per paper, the top rank went to the Ministry of Health, followed by Sultan Qaboos University Hospital and Khoula Hospital. **Conclusions:** Oman has significantly contributed to the COVID-19-related medical knowledge despite the challenges of conducting research amidst the increased workload during the pandemic. Most publications in Oman were collaborative projects. Based on the evaluated literature, further research focusing on vaccines and therapeutics is warranted.

When the World Health Organization (WHO) announced the COVID-19 as a global pandemic on 11 March 2020, the international community was unprepared for the enormity of the challenge and struggled to mobilize interventions.^{1,2} The pathogen SARS-CoV-2 being new to human immune system and its natural defenses often made the illness worse. Hospitals began to be overburdened with seriously ill patients, many of whom the standard management strategies were found ineffective. The pandemic exposed the inadequacies in the worldwide sharing of professional information and guidance for clinical practice

and policies.³ Realizing this, nations and research fraternities began to cooperate on an unprecedented scale and transparency, showing humanity's capacity and willingness to unite against a common enemy.⁴ New databases accessible to research scientists were made available free of cost which led to new hypotheses and experimental interventions. Many journals fast tracked and sometimes omitted, the peer review processes. This led to the rapid accumulation of research data. Inevitably, some of these were of questionable quality and utility. Added to this was the problem of plenty which gave rise to a new challenge—how to balance the velocity and quality of COVID-19-related research output.⁵

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In Oman, the trend was similar. The Directorate General of Disease Surveillance and Control under the Ministry of Health (MOH) went on alert well before the first two COVID-19 cases in Oman were registered on February 24, 2020.^{6,7} In March 2020, the Research Council (TRC) of Oman initiated a COVID-19 research program with the main objectives of supporting and guiding projects that conducted relevant, high quality, short-term, and applied research.⁸ Several interventions were undertaken across the various governmental and private sectors as per the directives of the Supreme Committee, headed by the minister of interior, charged with presenting solutions to weather the outbreak.⁹ Capacity building and health workers' training for the pandemic were initiated in private and governmental institutes.¹⁰

The extent and nature of COVID-19-related contributions from Oman to local, regional, and global scientific knowledge, both theoretical and practical, have not yet been systematically analyzed. The current study sought to address that lack. We also sought to present our results in an easy-to-understand format for busy clinicians and policymakers. 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 We opted for bibliometric analysis to present (both in tabular and pictorial formats) what has been achieved so far and what needs to be achieved by Oman's researchers on the pandemic.

Bibliometric analysis is being increasingly used worldwide in many scientific disciplines to review and represent the vastly complex and dynamic scientific literature in tangible forms comprehensible to both specialists and non-specialists.¹² Bibliometric analysis starts by identifying and categorizing publications within a given subject area in their broadest sense, and from there to move towards the specific and organize them in easily identifiable forms.¹³ This is the first study in Oman that uses bibliometric analysis to study publications related to COVID-19.

Bibliometric analysis helps evaluate the pattern and quality of scientific publications by generating citation networks using citation analysis.¹⁴ It also enables science mapping, a spatial representation of how disciplines, fields, specialties, journals, papers, and authors are interrelated.¹⁵ Bibliometric

maps developed through science mapping can visually describe how specific disciplines, scientific domains, research fields, etc. are conceptually, intellectually, and socially structured. Different techniques and software tools are used to conduct 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

METHODS

To collect raw data on research documents on COVID-19 worldwide, we used Scopus® (Elsevier BV, USA), considered the world's largest database of peer-reviewed scientific publications. The fact that Scopus indexes citations, abstracts, and author affiliations makes this database a reasonably comprehensive resource for researchers in medical bibliometrics.^{18–20}

For making the Scopus search comprehensive, we retrieved possible COVID-19-related synonyms from Medical Subject Headings (MeSH).²¹ MeSH is a vocabulary thesaurus controlled by the National Library of Medicine, and is used for indexing papers in medical fields. After retrieving all COVID-19 synonyms, the following search query was issued to Scopus:

TITLE-ABS-KEYs were 'COVID-19'/ 'COVID-19 Virus Disease'/ 'COVID 19 Virus Disease'/ 'COVID-19 Virus Diseases'/ 'Disease, COVID-19 Virus'/ 'Virus Disease, COVID-19'/ 'COVID-19 Virus Infection'/ 'COVID 19 Virus Infection'/ 'COVID-19 Virus Infections'/ 'Infection, COVID-19 Virus'/ 'Virus Infection, COVID-19'/ '2019-nCoV Infection'/ '2019 nCoV Infection'/ '2019-nCoV Infections'/ 'Infection, 2019-nCoV'/ 'Coronavirus Disease-19'/ 'Coronavirus Disease 19'/ '2019 Novel Coronavirus Disease'/ '2019 Novel Coronavirus Infection'/ '2019-nCoV Disease'/ '2019 nCoV Disease'/ '2019-nCoV Diseases'/ 'Disease, 2019-nCoV'/ 'COVID19'/ 'Coronavirus Disease 2019'/ 'Disease 2019, Coronavirus'/ 'SARS Coronavirus 2 Infection'/ 'SARS-CoV-2 Infection'/ 'Infection, SARS-CoV-2'/ 'SARS CoV 2 Infection'/ 'sars-cov-2 AND infections'/ 'COVID-19

Pandemic’/‘COVID 19 Pandemic’/‘COVID-19 Pandemics’/‘Pandemic, COVID-19’/‘COVID-19’, and PUBYEAR > 2018.

For preventing possible bias due to the daily update of Scopus, the search was conducted on a single day, i.e., on 21 August 2021.

We filtered the retrieved data further by applying the following inclusion criteria: (a) all COVID-19-related medical publications and non-medical research publications which are related to clinical/medical or public health-related aspects of COVID-19 in any language from any part of the world that were published from 1 December 2019 to 21 August 2021; and (b) educational research publications during the COVID-19 pandemic including those related to educational technologies, provided these dealt with psychological and other health related aspects of students and teachers due to COVID-19-related disruptions. Publications that did not fulfill the above criteria were excluded from the study.

Within the selected publications worldwide, a further search was conducted to select all medical research publications related to COVID-19 which included at least one author from Oman. One of the authors manually reviewed the resultant documents (titles and in a few cases the abstracts as well) and excluded those not meeting the inclusion criteria from the study. Statistical Package for the Social Sciences SPSS Inc. Released 2008. SPSS Statistics for Windows, Version 17.0. Chicago: SPSS Inc.) was used for statistical description and analysis.

We subjected the selected publications on COVID-19 to bibliometric analysis using citation analysis. The publications were analyzed based on their types, languages, highly-productive journals, authors and research institutes, and highly-cited sources.

VOSviewer software version 1.6.13 for Windows was used to generate visualizations including scientific maps and networks, reflecting the interactions between co-authorship, co-occurrence, and co-citation analyses. We generated a 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.

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

Rank	Country	Publications	% of total
1	USA	50680	25.4
2	UK	20958	10.5
3	China	19051	9.6
4	Italy	16020	8.0
5	India	13958	7.0
6	Germany	8482	4.3
7	Spain	8416	4.2
8	Canada	8347	4.2
9	Australia	7364	3.7
10	France	7091	3.6
11	Brazil	6148	3.1
12	Iran	4642	2.3
13	Turkey	4372	2.2
14	Switzerland	3793	1.9
15	Netherlands	3655	1.8
16	Japan	3536	1.8
17	Saudi Arabia	3334	1.7
18	South Korea	2726	1.4
19	Russian Federation	2714	1.4
20	Indonesia	2666	1.3

RESULTS

As Table 1 shows, out of the total 199 217 COVID-19 publications worldwide, USA accounted for a quarter, with 50 680 (25.4%) publications. Three Middle Eastern countries—Iran, Turkey, and Saudi Arabia—were among the top 20. With 360 publications (before manual check), Oman ranked 70th in the world.

Table 2 outlines the contribution of all the 17 Middle-Eastern countries in COVID-19 publications. Out of 21 310 documents, Iran led with 4642 (21.8%) publications, followed by Turkey (n = 4372; 20.5%), and Saudi Arabia (n = 3334; 15.6%). The other 14 countries (Egypt, Israel, United Arab Emirates, Jordan, Qatar, Iraq, Lebanon, Oman, Cyprus, Kuwait, Bahrain, Palestine, Yemen, and Syrian Arab Republic) contributed 42.1% from the total publications. Oman ranked 11th in the region.

Researchers from Oman published 360 documents on COVID-19 of which 83 were excluded due to their irrelevance and 277 related documents remained. A total of 2451 citations were recorded by these 277 documents, with the mean rate of citations per paper (CPP) amounting to 8.84. The h-index of these documents was 22. The majority

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

Rank	Country	Publications	Percentage
1	Iran	4642	21.8
2	Turkey	4372	20.5
3	Saudi Arabia	3334	15.6
4	Egypt	2060	9.7
5	Israel	1813	8.5
6	UAE	1138	5.3
7	Jordan	730	3.4
8	Qatar	636	3.0
9	Iraq	553	2.6
10	Lebanon	511	2.4
11	Oman	360	1.7
12	Cyprus	357	1.7
13	Kuwait	296	1.4
14	Bahrain	201	0.9
15	Palestine	135	0.6
16	Yemen	107	0.5
17	Syria	65	0.3
Total		21 310	100

of the documents were original articles (169/277; 61.0%), followed by reviews (41/277; 14.8%), and letters (38/277; 13.7%). Nearly all documents were in English (274/277; 98.9%), except for one each in Arabic, French, and Spanish.

Table 3 lists the journals that published at least four documents authored by researchers from Oman.

Table 3: Journals with the highest numbers of COVID-19 publications authored by researchers in Oman.

No	Journal title	Documents (N = 277)		Impact factor ²²	Cite Score (a) ²³	h-index (b) ²⁴	CiteScore Quartile ^{24,25}
		n	%				
1	<i>International Journal of Infectious Diseases</i>	22	7.9	3.623	7.00	89	Q1
2	<i>Oman Medical Journal</i>	16	5.8	N/A	1.90	31	Q2
3	<i>Sultan Qaboos University Medical Journal</i>	8	2.9	N/A	1.40	27	Q2
4	<i>Journal of the College of Physicians and Surgeons Pakistan</i>	8	2.9	N/A	N/A	N/A	N/A
5	<i>Diabetes and Metabolic Syndrome: Clinical Research and Reviews</i>	7	2.5	N/A	4.90	40	Q2
6	<i>International Journal of Nutrition, Pharmacology, Neurological Diseases</i>	6	2.2	N/A	0.90	6	Q3
7	<i>Journal of Paediatrics and Child Health</i>	5	1.8	1.954	2.29	76	Q2
8	<i>Vox Sanguinis</i>	5	1.8	2.144	3.70	83	Q2
9	<i>Disaster Medicine and Public Health Preparedness</i>	4	1.4	1.385	2.29	41	Q3
10	<i>Journal of Infection and Public Health</i>	4	1.4	3.718	4.90	35	Q1

^aCiteScore is a simple and robust way of measuring the citation impact of peer-reviewed research in serial titles such as journals.

^bThe h-index expresses the journal's number of articles (h) that have received at least h citations.

These ten journals accounted for 85/277 (30.7%) documents with authors from Oman. Among these 10 journals, 5 journals were in the Q2 Cite Score Quartile.

Out of the 277 documents authored by researchers from Oman on COVID-19, 155 (56.0%) received at least one citation. Table 4 shows the bibliographic information of the top 10 highly-cited publications (five original articles, four reviews, and one letter).

Table 5 shows the top seven Omani research institutions that contributed at least 10 COVID-19 articles. Based on the number of published documents, the first three ranks belonged to Sultan Qaboos University (SQU) (92/277; 33.2%), Ministry of Health (66/277; 23.8%), and Sultan Qaboos University Hospital (SQUH) (52/277; 18.8%). However, when ranked by CPP indicator, the top rank went to the Ministry of Health (18.09), followed by SQUH (7.96), and Khoula Hospital (7.1).

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 three other authors each with 10 documents. When CPP was considered, Labrage LJ ranked first (16.08), followed by Pandak N (14.9), and AL-Zakwani I (12.1). The five most active authors were affiliated to SQU.

In total, authors from Oman collaborated with authors from 112 countries in authoring 277

Table 4: Highly-cited COVID-19-related documents authored by researchers from Oman.

Rank	Authors	Document title	Pub. Year	Source title	Volume (Issue)	Pages	No. of citations	Document type
1	Petrosillo et al	COVID-19, SARS and MERS: are they closely related?	2020	Clinical Microbiology and Infection	26 (6)	729–734	413	Review
2	Petersen 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 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 et al	COVID-19 anxiety among front-line nurses: Predictive role of organizational support, personal resilience and social support	2020	Journal of Nursing Management	28 (7)	1653–1661	104	Original Article
5	Reiner 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	Albarelo 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 et al	SARS-CoV-2 shedding and infectivity	2020	The Lancet	395 (10233)	1339–1340	71	Letter
8	Zahedipour 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 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

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

Rank	Institution	Documents (N = 277)	%	Total citations	Citations per paper (Rank)	h-index
1	Sultan Qaboos University	92	33.2	645	7.01 (4)	15
2	Ministry of Health, Oman	66	23.8	1,194	18.09 (1)	14
3	Sultan Qaboos University Hospital	52	18.8	414	7.96 (2)	9
4	Royal Hospital	41	14.8	223	5.44 (6)	8
5	University of Nizwa	14	5.1	31	2.21 (7)	3
6	Oman Medical Specialty Board	12	4.3	66	5.50 (5)	-
7	Khoul Hospital	10	3.6	71	7.10 (3)	3

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. As Figure 1 depicts, researchers from

Oman mostly collaborated with the researchers from the USA with co-authoring 45 documents, followed by UK researchers with 42, and Indian researchers with 41 co-authored documents.

Co-occurrence analysis focuses on analyzing counts of co-occurring entities within a collection

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)	10.4 (4)	8 (1)	Royal Hospital, Muscat, Oman	55218145400
Al-Zakwani I	11	133 (3)	12.1 (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, Muscat, Oman	14827719600
Labrague LJ	10	168 (2)	16.8 (1)	4 (3)	Sultan Qaboos University, Muscat, Oman	55582670400
Al Awaidy ST	9	62 (6)	6.9 (6)	2 (5)	Ministry of Health, Muscat, Oman	6508132710
Al Yazidi LS	8	8 (9)	1.0 (9)	2 (5)	Sultan Qaboos University Hospital, Muscat, Oman	56012835000
Al-Riyami AZ	8	51 (7)	6.4 (7)	4 (3)	Sultan Qaboos University Hospital, Muscat, Oman	37025510100
Sheikh S	8	1 (10)	0.1 (10)	1 (6)	Sultan Qaboos University Hospital, Muscat, Oman	8948045600
Pandak N	7	104 (4)	14.9 (2)	4 (3)	Royal Hospital, Muscat, Oman	6506008185

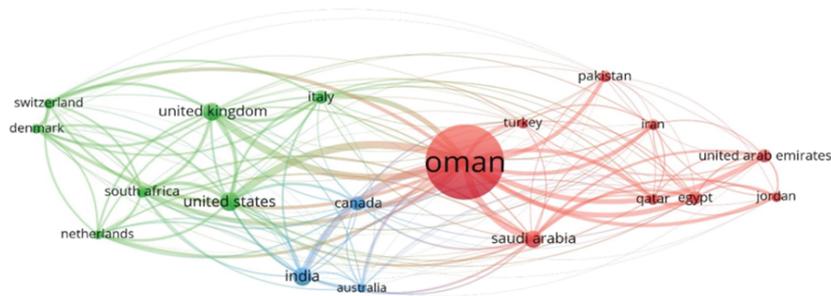
of units.²⁶ Co-occurrence analysis offers an overview of the structure of topics investigated, the relative focus, as measured by the number of occurrences, depicted as the size of nodes. Further, the different colors in the co-occurrence map indicate different general research foci.²⁷

In the documents on COVID-19 authored by researchers from Oman, 701 unique keywords were found. The keywords with the highest number of occurrences were 'human' followed by 'COVID-19', 'Coronavirus Disease 2019', and 'pandemic' [Figure 2].

Figure 3 represents the co-occurrence network of most frequent terms used by researchers from Oman's COVID-19 document titles and abstracts. It represents the terms most frequently co-occurred in

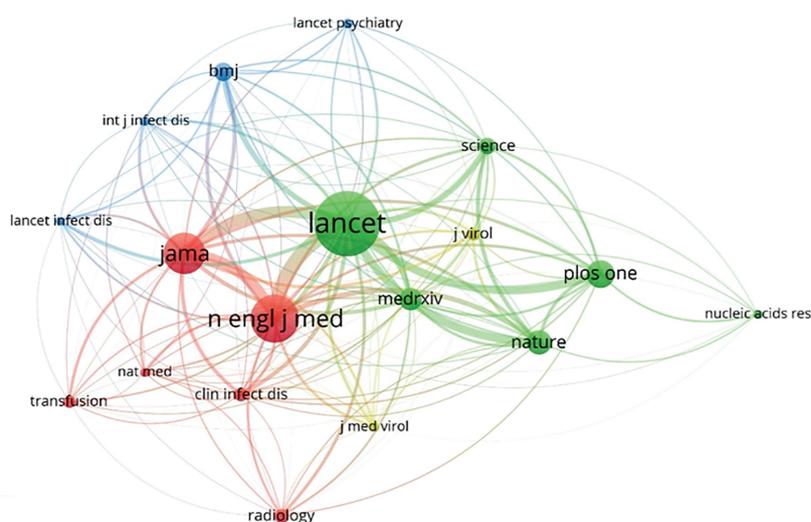
the publications which are represented as clusters. A total of 5830 terms were extracted from the titles and abstracts of 277 documents authored by researchers in Oman on COVID-19. The terms with at least 10 occurrences were included in the map.

In total, 4533 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 citations) topped the cited sources, followed by the New England Journal of Medicine (*NEJM*) (167) and the Journal of the American Medical Association (*JAMA*) (144).



Note: The size of a circle (node) depicts the number of papers from researchers collaborating with co-authors in Oman. The lines connecting the nodes depict the co-authorship number. The thicker the line between two nodes, the more the collaboration between the two countries.

Figure 1: Co-authorship network of countries collaborating with Oman in research on COVID-19.



Note: The top-cited sources are delineated into four color-coded clusters (red, green, blue, and yellow). The red cluster consists of seven cited sources and the green cluster, six. The blue and yellow clusters have four and two cited sources, respectively. The map also makes it obvious that sources within the same cluster have more co-citations. e.g., New England Journal of Medicine – Journal of the American Medical Association; Lancet – PLOS One – Nature.

Figure 4: Co-citation map of cited sources in researchers from Oman's documents on COVID-19.

DISCUSSION

The COVID-19 pandemic's rapid spread, the often self-harming host immune response to the novel pathogen, and the failure of known treatments to reduce the morbidities of this respiratory disease, initially lead to high morbidity and mortality.²⁸ This triggered the formation of worldwide collaborative research and transparent sharing of information. The fast-tracking of the editorial processes and adoption of open access policy by prestigious journals contributed to rapid dissemination of COVID-19 data and research, a commendable first in the history of medical research.^{29–34} It soon became apparent that controlling the COVID-19 pandemic required countries to not only produce clinical and research data but also organize them so that the vital information was clearly transmitted to busy clinicians for effective patient care, and to policymakers for evolving practical action plans. The current study shows that the bulk of COVID-19-related research has emerged from the USA, UK, and China representing 25.4%, 10.5%, and 9.5% of the global output, respectively. Another study also reported that the USA and UK have superior collaborative publication output based on the combined publications.³⁵ It is to be noted that these countries were in a position for high output, with their ample financial and material resources, and a

broad infrastructure including many universities and dedicated medical research institutions. Indeed, at the international level, a significant dominance of universities and research institutions in COVID-19 research output has been observed.^{36,37}

In the Middle East, the bulk of COVID-19-related research (58.0%) emanated from three countries, Iran, Turkey, and Saudi Arabia. This finding is supported by another study that found a similar trend in COVID-19 research publications from the region.³⁸ There is a higher capacity for research in these larger countries with higher gross domestic product (GDP), with larger populations, more COVID-19 cases, and higher allocations and facilities for medical research.^{36,39–42} The same reasons (in reverse) explain the fewer publications from Syria, Yemen, and Palestine. Yet, the fact that the researchers of these economically constrained and conflict-weary nations were able to produce as many as 307 papers on COVID-19 is to be acknowledged.

Higher research output tends to occur in countries that have invested a greater share of their GDP in research and development.⁴³ Each country and region may have its own special research needs due to ethnic and genetic characteristics, climate, culture, and tradition, etc. Thus, countries in the Middle East need to increase their spending on internal medical research, in addition to establishing

collaboration and sharing of health research to enrich the regional research by supporting researchers, and investing in research throughout the region. 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 focused on Oman and evaluated the quantity and quality of COVID-19 research productivity in this country over the COVID-19 affected 20 months. We used bibliometric methods including citation analysis and science mapping. Overall, health research productivity in Oman shows a steady increase during the study period, though it remains low compared to other countries in the region. However, proportionate to population, Oman's research output is at par with the rest of the Middle East.⁴⁴ Among the 277 COVID-19 publications from Oman selected for evaluation, the top-cited were original articles (61.0%) followed by reviews (14.8%), and letters (13.7%). 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, case studies, scoping reviews, and case-control studies.⁴⁵

In times of a pandemic and while facing deadly diseases, the type of research that should be prioritized can be controversial.^{5,33,46} In the modern era of medicine, scientists and researchers prefer conducting randomized controlled trials which may take months before useful results emerge. Thus, case-series and observational studies, though regarded of lower research quality, might be preferable for faster dissemination of information and may help in developing management guidelines and treatment algorithms that are highly needed by clinicians. A comprehensive meta-research of 10 516 COVID-19-related medical articles by Raynaud et al⁵ found that only 10% were peer-reviewed original research. Most publications were without original data, tended to be in the form of research letters, and lacked methodological information for quality assessment. Such suboptimal quality led these authors stress the need to balance the "velocity and quality of research, and to cautiously consider medical information and clinical applicability in a pressing, pandemic context".⁵

Several bibliometric analyses have been conducted to investigate COVID-19 research activity in

different countries.^{28,31,33-35,43} Bibliometrics analyses used in the current study assess the 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 with 413 citations, followed by Petersen with 319. The majority of the highly cited research focused on comparing the SARS-CoV-2 virus with other corona-viruses such as SARS and MERS-CoV. In addition, the highly cited publications were original research articles.

The three most productive Omani research institutes were SQU, MOH, and SQUH. Both SQU and SQUH have received research funds for 12 projects through TRC,⁴⁶ indicating the relationship between research funding and academic output. Despite the many new areas of research opened by this pandemic and the prompt governmental response for research through TRC, larger productivity was expected from the academic institutions in Oman. A major reason for the apparent underperformance was that the entire healthcare system in the country was overwhelmed and heavily pre-occupied with clinical care and preparedness response which were the top priorities.⁴⁷ Consequently, most researchers had less time to conduct studies and write and publish articles, particularly during the acute phases of the pandemic.⁴⁸

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. The regional thriving medical journals in Oman and its neighboring countries can be attributed to a spurt in medical research and development that began two decades ago. The presence of two peer-reviewed, internationally indexed medical journals in Oman³⁶ has been advantageous to Oman's researchers who could publish their work on the pandemic's local aspects and gain international visibility.

In this study, we have identified 10 top authors on COVID-19 along with numbers of their publications, total citations, CPP, and corresponding

h-index values to evaluate the productivity as well as the impact of their publications. Khamis F was the most prolific author, having published a total of 20 documents, followed by Al-Zakwani I with 11 articles. The authors with the highest CPP were Labrage LJ and Al-Zakwani I. Considering the impact of publication in terms of total citations and the 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 received 133 citations with an h-index of 5. In the cluster of authors, we found that the collaboration 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, mainly the USA, UK, and India. International collaboration enriches the understanding of the pathogen and the disease, the efficacy of different therapeutics and provides cross-national information on the clinical and epidemiological characteristics of COVID-19 patients of different demographics, cultures, and climates. It needs to be highlighted that many of the articles coauthored by researchers in Oman were multinational studies, which explains the large number (112) of collaborating countries.

In bibliometrics, a network graph of keyword co-occurrences reflects hot topics.²⁸ 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.⁴⁹ We identified a total of 701 keywords used by the authors in Oman. The most frequently used keywords 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, the impact of COVID-19, and epidemiology and clinical manifestations of COVID-19. Terms representing 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 4533 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 *NEJM* (167), and *JAMA* (144). Researchers and readers tend to trust these high-impact journals.⁵⁰

This study has ranked the countries in the Middle East according to their contributions to COVID-19 research. Within Oman, we have identified the top contributing authors and research institutions. The current study also 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 a few limitations. First, the representation of the institutions may not be entirely accurate as the data was obtained automatically, which might have caused rare misrepresentations of affiliation details provided by the authors while publishing. We listed a few major Omani institutions separately despite their being under the same management. For example, SQUH is part of SQU. It can also be argued that Royal Hospital and Khoula Hospital should be taken as a single institution as both are part of the Ministry of Health. Second, preprint articles were not included though they represent a good proportion of COVID-19 literature. Third, the quality of research was not assessed as we analyzed only article titles, abstracts, and author data. Finally, citation frequency is affected by multiple factors such as journal and institution's reputation. Due to an inherent limitation of the bibliographic analysis, our results do not take those variations into account, and may not be a perfect reflection of academic influence.

CONCLUSION

Two years of the COVID-19 pandemic research has generated a huge quantity of medical research, raising the urgent need to select, organize, and present important data to facilitate timely and practical clinical and administrative policies. Oman has contributed to this body of research, despite the challenges of prioritizing between research and patient services 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 and institutes in this area and explored connections and collaborations between researchers in Oman with their international counterparts. The top-cited articles from Oman were published in recognized international and local medical journals which enabled rapid dissemination of key information. Collaborative research between Omani authors and international researchers saw an increasing trend during the pandemic. Though the health research productivity in Oman has increased during the study period, it remains low in comparison to other countries in the region. It is also noticed that relatively less research attention has been given to vaccines and therapeutics, which calls for greater focus on these aspects of the COVID-19 pandemic.

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