

*Original Research*

## **Analyzing the Impacts of COVID-19 Vaccine Research Outputs: An Altmetric Approach**

### **Masoomeh Latifi**

Ph.D., Knowledge and Information Science,  
Scientometric Unit, Hormozgan University of  
Medical Sciences, Bandar Abbas, Iran.

[mercede\\_latifi@yahoo.com](mailto:mercede_latifi@yahoo.com)

ORCID iD: <https://orcid.org/0000-0002-7197-254X>

### **Forough Rahimi**

Assistant Prof. Knowledge and Information Science,  
Information Management Research Unit, Islamic World  
Science and Technology Monitoring and Citation  
Institute (ISC), Shiraz, Iran.

[frahami@isc.ac](mailto:frahami@isc.ac)

ORCID iD: <https://orcid.org/0000-0003-1701-2975>

### **Nader Alishan Karami**

Assistant Prof. Library and Information Sciences, Department of Health Information Technology, Faculty of  
Para-Medicine, Hormozgan University of Medical Sciences. Bandar Abbas, Iran.

Corresponding Author: [nalishan@gmail.com](mailto:nalishan@gmail.com)

ORCID iD: <https://orcid.org/0000-0003-3865-1469>

Received: 26 November 2023

Accepted: 05 May 2024

### **Abstract**

This study aimed to investigate the attention given to scientific outputs about COVID-19 vaccines worldwide on social media. It utilized scientometrics and altmetrics indicators. A dataset with 12,364 works indexed in the WOS database from 2020 to 2022 was analyzed. Altmetric Scores (AS) and Altmetrics were extracted from Altmetric Explorer. Data analysis was performed using Access, Excel, and SPSS software. The retrieved articles garnered attention on 13 social media platforms. The highest amount of social attention, accounting for 97% of the total, was related to X (Twitter) and Mendeley. The highest AS (43,765) was for an open-access article entitled "Covid-19: Researcher blows the whistle on data integrity issues in Pfizer's vaccine trial: Video 1" in the BMJ cited in 14 social media. The most productive countries in COVID-19 vaccine research were the USA, England, and China, while Harvard University, the University of London, and the University of California emerged as the most active research institutes. The findings confirmed a significant, moderate, and positive correlation between the AS and most Altmetrics with the number of citations. Additionally, a positive, substantial, and moderate correlation was observed between citations, the AS of highly-cited papers, and the AS of hot documents. Considering the positive impact of social media on increasing the chance of receiving more citations for articles and improving the impact range of articles from academic users to social users, the activities of researchers in social media are effective in increasing the visibility of scientific works.

**Keywords:** COVID-19 Vaccine, Research Outputs, Altmetrics, Altmetrics Score, Social Media.

### Introduction

Following the global spread of the new coronavirus in Wuhan, China, in September 2019, extensive international and national endeavors were undertaken to create a vaccine against this virus (Cui, Wang & Wei, 2021). Large pharmaceutical companies such as Pfizer, Janssen Biotech, AstraZeneca, Sinovac, Moderna, Biotech, Bharat, Finlay, and China National Biotech Group, along with renowned research centers and institutes like Oxford University and Gamaleya Research Institute, demonstrated more excellent promptness and success compared to their competitors in developing and producing the Covid-19 vaccine. (Fathizadeh et al., 2021). This led to the publication of a remarkable number of scientific works addressing the various aspects of the vaccine, including classification, structure, effectiveness, side effects, post-vaccination clinical symptoms, the public attitude towards accepting and hesitating to receive the vaccine, and so on (Costanzo, De Giglio, & Roviello, 2022; Cronin & Sugimoto, 2014; Pawlowski et al., 2021).

Researchers in the COVID-19 vaccine field have always recognized the importance of disseminating the findings of their work; however, recently, the need to proactively plan and drive the impact of those findings in the broader society has become a necessity. Therefore, the communication and implementation of research findings to inform policy and practice have always been challenging and are often described as a gap (Jain, Schwarz & Lorgelly, 2021). Social media is potentially a novel way of enabling research teams to both communicate about research as studies progress and disseminate findings (Schnitzler, Davies, Ross & Harris, 2016).

### Literature Review

#### Social media and research impact

With the birth of the social web, web resources such as social media have been utilized as complementary tools for evaluating research output. These media may offer a broader scope of scientific influence due to their increasing popularity (Priem, Piwowar & Hemminger, 2012). User interactions in social media can provide valuable data for evaluation (Wouters, Zahedi & Costas, 2019). This feature leads to the creation of new indicators to evaluate the impact of articles (both published and unpublished). Finally, this led to the birth of Altmetrics (Huang, Wang & Wu, 2018). Altmetrics is a measure of non-traditional attention and engagement that the article has received. It is an alternative to relying solely on citations to quantify the reach and impact of published research (Haustein, Peters, Bar-Ilan, Priem, Shema & Terliesner, 2014; Piwowar, 2013). Also, to create an Altmetric Score for the paper, many non-traditional sources are monitored and searched for links and references to the published research (Critchfield & Dixon, 2022). This data is presented in an easily digestible format that enables us to see who is commenting on our research and where these mentions are taking place (Sener & Polat, 2022). The findings of any medical research may be used at the patient's bedside or in the educational content. It may be collected by the news or used as evidence to support policy-making medical guidelines, etc. It is also interesting that the results of many studies showed the predictive power of the Altmetrics Score in counting future received citations (Critchfield & Dixon, 2022; Llewellyn & Nehl, 2022; Maddi & Sapinho, 2022).

Unlike traditional citation-based criteria, Altmetrics can measure the scientific impact within the diverse landscape of the social web. It is a novel approach that offers exceptional tools for evaluating and tracking the impact of articles on the social web. These tools enable the monitoring and evaluation of the implicit effect of scientific productions using Altmetric

indicators such as views, downloads, bookmarks, saves, likes, clicks, subscriptions, the number and quality of comments received, and the number of followers. These evaluations are based on data from the social web (Moed & Halevi, 2015; Thelwall & Kousha, 2014; Thelwall & Kousha, 2015).

### **Social media and COVID-19 vaccine**

It is not the first time that people discussed vaccine issues. Those vaccine discussions were used to identify attitude of people regarding measles, mumps, and rubella combination (MMR), tetanus, diphtheria, pertussis (Tdap), and human papillomavirus (HPV) vaccines (Liang et al., 2018), analyze vaccine images (Cuesta-Cambra, Martínez-Martínez & Niño-González, 2019), understanding the vaccine debate of Russian trolls (Yan, Barbati, Duncan, Warner & Rains, 2023), vaccine hesitancy, and sentiment analysis of HPV-related tweets (Zhang, Fan, Peng, Rao & Cong, 2020). Given that people increasingly refer to the internet and social media networks to seek information, emerging research in the literature has recently placed particular emphasis on investigating the association between social media usage and attitudes toward public health interventions, specifically COVID-19 vaccinations (Cascini et al., 2022). Not only citizens but also government officials have utilized social media to regularly share policies and news related to COVID-19 vaccines (Troiano & Nardi, 2021). A growing research trend argues that social media will play an essential role in public health (Moorhead, Hazlett, Harrison, Carroll, Irwin & Hoving, 2013; Herrera-Peco Jiménez-Gómez, Peña Deudero, Benitez De Gracia & Ruiz-Núñez, 2021). The first component of public health surveillance is monitoring, identifying, and evaluating health issues, and social media offers a largely untapped opportunity for the first component. In public health surveillance, social media can help provide real-time and relatively cheap communication (Cascini et al., 2022). Traditional citation-based criteria obtain small-scale data. To understand research impact, we need a way to look beyond the citation (Moed & Halevi, 2015; Thelwall & Kousha, 2015). Social media can provide a great opportunity to understand the research impact of COVID-19 vaccines (Hou et al., 2021).

Since 2020, some studies have utilized social media data to understand different issues related to the COVID-19 vaccine, such as exploring public opinion regarding the vaccine (Troiano & Nardi, 2021), vaccination in November 2020 (Sanders et al., 2021), Spanish pro-vaccine campaign between 14 and 28 December 2020 (Núñez, 2021), anti-vaccination on 23 August 2020 (Germani & Biller-Andorno, 2021). While the studies above offer valuable insights regarding COVID-19 vaccine issues, they have several limitations. First, they have not studied the research impact after the production and public vaccination kicked off in November 2020. Second, no study compares the kind of social media based on the research impact. The current study proposes an approach using Altmetrics methods to collect and analyze a large amount of data on the aforementioned gaps and provide a broader perspective on the research impact of the COVID-19 vaccine. This paper identifies the impact of the research and its temporal trends and discovers significant topics.

This paper addresses the following research questions:

1. What has been the trend of the scientific outputs of the world's researchers regarding the COVID-19 vaccine during the years 2020-2022?

2. In which social media have the scientific outputs of the world's researchers regarding the COVID-19 vaccine been the most present, and which articles have received the highest Altmetric Score?

3. Which organizations and countries have the most significant number of research outputs in the scientific production of world researchers regarding the COVID-19 vaccine?

4. Which organizations and countries have the most funds in the scientific output of world researchers regarding the COVID-19 vaccine?

5. Is there a relationship between the Altmetric Score of the world researchers' articles regarding the COVID-19 vaccine and their received citations?

6. Is there a relationship between the Altmetric Score of the world researchers' articles regarding the COVID-19 vaccine and their hot articles?

7. Is there a relationship between the Altmetric Score of the world researchers' articles regarding the COVID-19 vaccine and their highly cited articles?

This endeavor offers the following contributions: First, the proposed data analysis framework is a flexible approach that can be applied to other health issues. Second, we compare social media based on their research impact. Third, we identify the top social media and top papers in the COVID-19 vaccine field.

## Materials and Methods

### Study design

The present research was carried out using scientometrics and altmetrics. One of Altmetrics' goals is to help disseminate research using social network facilities. To identify how much and what type of attention a research output has received, [Altmetric.com](https://www.altmetric.com) follows all conversations and comments about online research outputs wherever they occur. This ultimately led to the creation of the Altmetric Attention Score (AAS) (Liu & Adie, 2013). The AAS is an automatically calculated, weighted count of all the attention a research output has received. The weight assigned to each source, including blogs, political documents, patents, X (Twitter), peer review, Weibo, Facebook, Wikipedia, Google Plus, LinkedIn, Reddit, Pinterest, F1000, Q&A, Video, Silabi, and Mendeley, varies from 0.25 to 8<sup>1</sup>. The score assigned to each research output was displayed as an Altmetric donut; Donut colors indicate where the article has been cited. Its purpose is to provide an index of the attention given to that research output. Altmetric Score reflects the quantity (more attention, higher score) and quality (weighting of indexes) of the received attention to each work by using some kind of normalization (Costas, Zahedi, & Wouters, 2015).

### Search strategy and collecting data

The present research examined the Web of Science (WoS) indexed articles addressing COVID-19 vaccines from January 2020 to October 2022 via extracting Altmetric information from the Altmetric Explorer platform in October 2022. To determine the actual impact of scientific works addressing the COVID-19 vaccine, the researchers collected the number of citations received per article and the amount of attention directed to them via the social media audience.

---

<sup>1</sup> <https://www.altmetric.com/blog/numbers-behind-numbers-the-altmetric-attention-score-and-sources-explained/>

Altmetric and scientometric studies are considered applied research. To ensure the comprehensiveness of the retrieved documents on COVID-19 vaccines, the authors used all the keywords from the Medical Subject Headings (MeSH) to search the WoS database. The search strategy targeted all the MeSH terms denoting the "COVID-19 vaccine" in the titles of the articles from January 2020 to October 2022.

((((((((((TI=(COVID-19 Vaccines)) OR TI=(Corona Vaccines)) OR TI=(SARS Coronavirus 2 Vaccines)) OR TI=(COVID19 Virus Vaccines)) OR TI=(COVID19 Virus Vaccine)) OR TI=(SARS-CoV-2 Vaccines)) OR TI=(SARS-CoV-2 Vaccine)) OR TI=(SARS2 Vaccines)) OR TI=(Coronavirus Disease 2019 Vaccines)) OR TI=(2019 Novel Coronavirus Vaccines)) OR TI=(2019 nCoV Vaccines) and 2020 or 2021 or 2022 (Publication Years)

Using Altmetric Explorer's advanced search page, we searched without any restrictions for the DOIs of all 12,364 articles retrieved from WoS. Out of these, 73% (9,058 records) were found and available in Altmetric Explorer.

### Data analysis

The data obtained were stored in MS Excel files. To merge the data, we compared the DOIs of the retrieved articles from WoS and Altmetric using MS Access. The data were then analyzed using descriptive and analytical tests, including correlation tests in SPSS.

### Results

The results showed that out of 12,364 documents retrieved in WoS, the number of articles addressing COVID-19 vaccines in 2021 increased nearly sixfold compared to 2020. It reached 5,838 articles, a significant rise from the 937 articles in the previous year. (Figure 1).

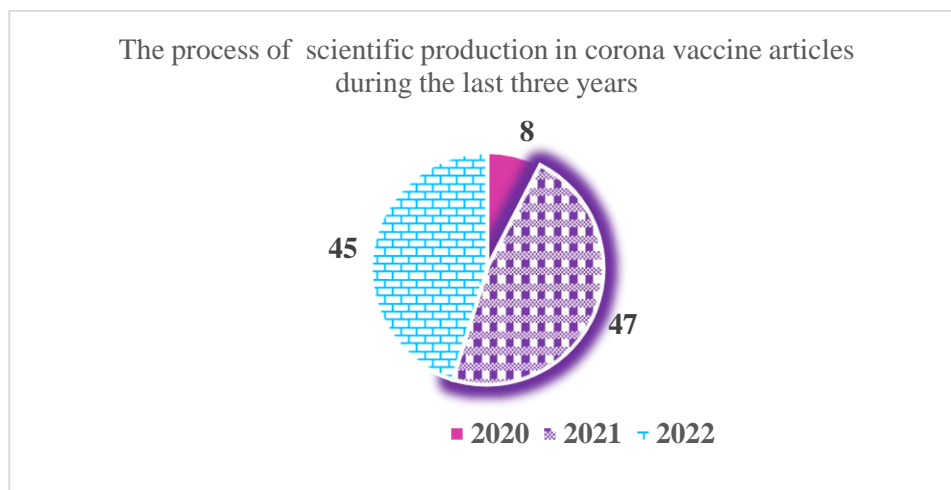


Figure 1: Frequency of Covid-19 Vaccine-Related Articles (2020-2022)

In the publication of COVID-19 vaccine-related research, there were works from 3,520 universities, 8,480 institutes and research centers. By publishing more than 120 articles on the COVID-19 vaccines, 26 universities and institutes accounted for 37% of the scientific works. Harvard University, the University of London, and the University of California were ranked first to third. (Table 1)

Table 1

### Analyzing the Impacts of COVID-19 Vaccine ...

#### *The Most Productive Countries Worldwide in the Field of Publishing Articles Related to COVID-19 Vaccines*

Row	Name of university or institution	Frequency	Percentage
1	USA	3858	31.2
2	England	1087	8.7
3	China	1021	8.2
4	Italy	956	7.7
5	India	744	6
6	Canada	514	4
7	Germany	510	4
8	France	461	3.7
9	Spain	434	3.5
10	Australia	414	3.3
11	Israel	323	2.6
12	Saudi Arabia	311	2.5
13	Turkey	306	2.4
14	Japan	294	2.3
15	Swiss	257	2
16	Brazil	253	2
17	Iran	241	1.9
18	Netherlands	214	1.7
19	South Korea	200	1.6

Searching the Altmetric Explorer using DOI revealed that out of 12,364 documents indexed in WoS, the users cited 9,058 articles (73%) on social media. Most of the articles retrieved in Altmetrics were open-access (Table 2).

*Table 2*

#### *Frequency of Covid-19 Vaccine-Related Articles Retrieved in Altmetrics*

Articles addressing Covid-19 vaccine (2020-2022)	Frequency	Percentage
Indexed in Web of Science	12364	100
Retrieved from Altmetrics	9058	73
open access	8400	93

From all the research studies retrieved in the Altmetric platform, 39% of the articles had an Altmetric Score between 0 and 5; Meanwhile, 98% of them showed an Altmetric Score of greater than one, and only 2% showed a score of zero, and 13% of the articles had an Altmetric Score of 200 or more (Table 3).

Table 3  
Frequency Distribution Based on Altmetric Score

Group	Group Altmetrics Score	frequency	Relative frequency	The cumulative frequency
1	0	181	2	2
2	1-5	3883	37	39
3	6-10	1047	12	51
4	11-19	993	11	62
5	20-24	1161	13	75
6	50-99	627	7	82
7	100-199	492	5	87
	200 and more	1174	13	100
Total		9058	100	

The results showed that the studied articles were reflected in 13 social media. Studies related to COVID-19 vaccines were reflected on X (Twitter) a total of 2,841,525 times, and then, in the next rank, they were read 688,066 times by Mendeley readers. The highest amount of social attention, accounting for 97% of the total, was related to X (Twitter) and Mendeley. Following that, news media, blogs, and Facebook occupied third to fifth positions regarding the highest amount of social attention. Due to the big difference between X (Twitter) and Mendeley data and the other Altmetrics, their statistics are not shown in the figure (Figure 2).

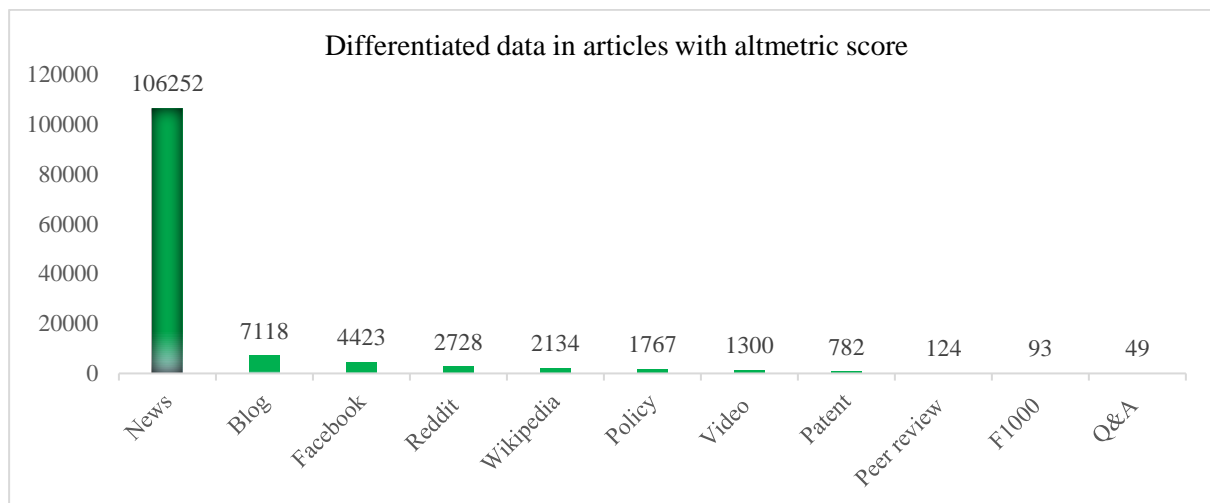


Figure 2: The Number of Social Attention to Covid-19 Vaccine Articles

The social attention received from different social media was from a minimum of 1 to a maximum of 148,512 from X (Table 4). The most influential article, based on the Altmetric Attention Score (AAS), was an open article entitled "Covid-19: Researcher blows the whistle on data integrity issues in Pfizer’s vaccine trial: Video 1" published in the British Medical Journal. It obtained an AAS of 43,765 and received 14 scientific citations (Table 4).

This article has been tweeted by users in 204 countries worldwide, with the most reflection

in the US, England, and France. News media from 29 countries, including the US, France, and Canada, provided the most extensive coverage of this article.

Table 4

*The Most Effective Article Related to Covid-19 Vaccines Based on Altmetric Score*

Indicator	International article bibliography	value
Altmetric Score	Thacker, P. D. (2021). Covid-19: Researcher blows the whistle on data integrity issues in Pfizer's vaccine trial. <i>BMJ</i> , 375.	43765
Citation in Web of Science		14
news media		195
weblog		17
X (Twitter)		148512
Facebook		26
Mendeley readers		160
Google Plus		0
Policy documents		0
Wikipedia		7
Reddit		120
F1000		1

Table 5 shows that the highest reflection on an article and its influence in society was seen on X (Twitter), Mendeley, and news media Altmetrics. The lowest number of citations belonged to Q&A and F1000. The article on the safety and efficacy of COVID-19 vaccines received the highest number of reflections on six social media sites: news media, blogs, Facebook, Wikipedia, video, and Mendeley. The article has been reflected in news agencies in 66 countries, and the most news coverage was in the US, Australia, and England. These articles focused mainly on the effectiveness of COVID-19 vaccines on different groups, such as pregnant women and children, as well as the mortality rate etc. (Table 5).

Despite its novelty, the recent article on the immunogenicity of mRNA vaccines for COVID-19 in pregnant and breastfeeding women has been noted and cited in 39 World Health Organization health documents.

Table 5

*Titles of Articles with the Highest Amount of Reflection in Each Social Media*

Article title	Journal title	Social media	The highest amount of reflection in the media	Altmetric Score
Safety and Efficacy of the BNT162b2 mRNA Covid-19 Vaccine through 6 Months Polack, F. P., Thomas, S. J., Kitchin, N., Absalon, J., Gurtman, A., Lockhart, S., ... & Gruber, W. C. (2020). Safety and efficacy of the BNT162b2 mRNA Covid-19 vaccine. <i>New England journal of medicine</i> .	New England journal of medicine	News media	2494	29885
		weblog	151	
		Facebook	79	
		Wikipedia	58	
		video	73	
		Mendelian	9155	
Characterization of the receptor-binding domain (RBD) of 2019 novel	Cellular &	Patent license	47	407

Article title	Journal title	Social media	The highest amount of reflection in the media	Altmetric Score
coronavirus: implication for development of RBD protein as a viral attachment inhibitor and vaccine Tai, W., He, L., Zhang, X., Pu, J., Voronin, D., Jiang, S., ... & Du, L. (2020). Characterization of the receptor-binding domain (RBD) of 2019 novel coronavirus: implication for development of RBD protein as a viral attachment inhibitor and vaccine. <i>Cellular &amp; molecular immunology</i> , 17(6), 613-620.	molecular immunology			
Covid-19: Researcher blows the whistle on data integrity issues in Pfizer's vaccine trial: Video 1 Thacker, P. D. (2021). Covid-19: Researcher blows the whistle on data integrity issues in Pfizer's vaccine trial. <i>BMJ</i> , 375.	BMJ	X (Twitter)	148512	43765
		Reddit	120	
Coronavirus disease 2019 (COVID-19) vaccines: A concise review Samaranayake, L. P., Seneviratne, C. J., & Fakhrudin, K. S. (2021). Coronavirus disease 2019 (COVID-19) vaccines: A concise review. <i>Oral diseases</i> .	Oral diseases	peer review	8	4
SARS-CoV-2 vaccines in development Krammer, F. (2020). SARS-CoV-2 vaccines in development. <i>Nature</i> , 586(7830), 516-527.	Nature		4	4824
Impact and effectiveness of mRNA BNT162b2 vaccine against SARS-CoV-2 infections and COVID-19 cases, hospitalizations, and deaths following a nationwide vaccination campaign in Israel: an observational study using national surveillance data Haas, E. J., Angulo, F. J., McLaughlin, J. M., Anis, E., Singer, S. R., Khan, F., ... & Alroy-Preis, S. (2021). Impact and effectiveness of mRNA BNT162b2 vaccine against SARS-CoV-2 infections and COVID-19 cases, hospitalizations, and deaths following a nationwide vaccination campaign in Israel: an observational study using national surveillance data. <i>The Lancet</i> , 397(10287), 1819-1829.	The Lancet	F1000	2	9438

## Analyzing the Impacts of COVID-19 Vaccine ...

Article title	Journal title	Social media	The highest amount of reflection in the media	Altmetric Score
Immunogenicity of COVID-19 mRNA Vaccines in Pregnant and Lactating Women Ai-ris, Y. C., McMahan, K., Yu, J., Tostanoski, L. H., Aguayo, R., Ansel, J., ... & Barouch, D. H. (2021). Immunogenicity of COVID-19 mRNA vaccines in pregnant and lactating women. <i>Jama</i> , 325(23), 2370-2380.	JAMA	Question and Answer	39	1580

The findings showed that there was a significant, moderate, and positive correlation between the Altmetric Score and most Altmetrics with the number of citations. Additionally, a strong and significant positive correlation was observed between the number of citations and the number of studies in Mendeley. There was also a positive, important, and moderate correlation between citation and Altmetric Score and citation and Altmetrics of news, X (Twitter), blog, and political documents. However, other Altmetrics showed a weak and low correlation with citation. Finally, no correlation between peer review and citation was observed (Table 6).

Table 6

*Correlation Between Citations and Altmetrics in Articles on Covid-19 Vaccines*

	Citations	Pearson Correlation	Sig. (2-tailed)	Number
1	Mendeley	**0.831	0/000	9058
2	AAS	**0.471	0/000	9058
3	News	**0.445	0/000	9058
4	X (Twitter)	**0.411	0/000	9058
5	Blogs	**0.385	0/000	9058
6	Policy	**0.300	0/000	9058
7	Facebook	**0.298	0/000	9058
8	Wikipedia	**0.273	0/000	9058
9	Video	**0.273	0/000	9058
10	Patent	**0.225	0/000	9058
11	F1000	**0.121	0/000	9058
12	Q&A	**0.104	0/000	9058
13	Peer review	**0.012	0/000	9058

\*\*Correlation is significant at the 0.01 level (2-tailed)

Out of all the articles on COVID-19 vaccines retrieved in the WoS, 810 articles received a high number of citations, of which 775 titles were retrieved from the Altmetric Explorer platform. Approximately 50% of highly cited articles were related to America, while 28% were from England and China. Harvard University ranked first among universities globally, with 10% of the highly cited articles on COVID-19 vaccines published by researchers affiliated with the institution. Investigations regarding the correlation between the citation and Altmetric Score of highly cited articles revealed a positive, significant, and moderate correlation between them

(Table 7)

Table 7

*Correlation Between Citations and Altmetric Score in Highly Cited Articles on Covid-19 Vaccine*

Correlations			
Citation Highly	AAS Highly		
.506**	1.000	Correlation Coefficient	
.000	.	Sig. (2-tailed)	AAS Highly
775	775	N	
1.000	.506**	Correlation Coefficient	Spearman's rho
.	.000	Sig. (2-tailed)	Citation Highly
775	775	N	

\*\*. Correlation is significant at the 0.01 level (2-tailed)

Out of all the COVID-19 vaccine-related articles retrieved from the WoS Database, 169 articles were considered hot, of which 163 titles were found on the Altmetric Explorer platform, and none had an Altmetric Score of zero. This was even though the Altmetric Score of 5 highly cited articles was zero. Nearly 60% of the hot articles were associated with the US, while 38% were linked to England and Israel. Harvard University is the leading university globally, with 18% of the hot articles on Covid-19 vaccines. Evaluation of the correlation between hot articles and Altmetric Score showed a positive, significant, and moderate correlation between citation and Altmetric Score of these articles (Table 8).

Table 8

*Correlation Between Citations and Altmetric Score in Hot Covid-19 Vaccine Articles*

Correlations			AASHot	CiationHot
Spearman's rho	AAS Hot	Correlation Coefficient	1.000	.631**
		Sig. (2-tailed)	.	.000
		N	163	163
Spearman's rho	CiationHot	Correlation Coefficient	.631**	1.000
		Sig. (2-tailed)	.000	.
		N	163	163

\*\*. Correlation is significant at the 0.01 level (2-tailed).

### Discussion

The present study analyzed the citations and Altmetric score of scientific publications focusing on COVID-19 vaccines worldwide. Following the global outbreak of the COVID-19 virus, many pharmaceutical companies competed to develop vaccines to combat the spread of the disease. Consequently, this topic attracted the attention of many researchers worldwide between 2020-2022. This article is the first work reporting the Altmetric results of scientific articles addressing COVID-19 vaccines during this period. The research focused specifically on the WoS database to investigate the impact of these articles on social networks.

The findings showed that in 2021, the number of articles related to COVID-19 vaccines

increased almost six times compared to 2020, and it is at the top of the scientific productions related to COVID-19 vaccines. The articles in this field have been one of the hot topics during recent years and have received a lot of attention from the scientific community and the general public. Similar research analyzing the performance of Covid-19 has also demonstrated the same finding (Batooli & Sayyah, 2022; Shehata, El Dakar & Salem, 2021). The results showed that each of the 19 countries (Table 1) has published at least 200 articles. In other words, almost 100% of the articles were published in these countries. The most productive ones included the United States of America, England, and China.

Meanwhile, 26 universities and institutes published over 120 articles on COVID-19 vaccines, contributing to 37% of the scientific production. The top bodies included Harvard, London, and California universities. The results confirm that the United States and England, which were the first producers of the COVID-19 vaccine and the largest pharmaceutical companies, along with research centers and institutes, have successfully produced and disseminated scientific content.

Regarding the social attention to the articles by social networks, the findings showed that the highest number of attention - considering 97% of all attention - was related to X (Twitter) and Mendeley. The third to fifth places belonged to news media, blogs, and Facebook. Many studies also found that the large number of X (Twitter) and Mendeley users increased the chances of users paying attention to the articles and reflecting them on these networks (Klar, Krupnikov, Ryan, Searles & Shmargad, 2020; Jeng & Jiang, 2015). Moreover, X (Twitter) is a public social network that increases the chances of reading and sharing information about articles (Fang & Costas, 2020; Golchin, Isfandyari-Moghaddam, Mirhosseini, Famil Rohani & Zarei, 2022; Shehata et al., 2021). It enables users to share and receive information instantly, offering valuable insights into current trends and discussions. This makes it a robust networking platform with significant engagement in disseminating research findings. Shehata et al. (2021) emphasized that researchers in medical fields tend to share their scientific results through X (Twitter) and Mendeley due to the short half-life of products in this field. Other findings have also shown that some researchers appropriately share their articles on X (Twitter) to distribute information (Sousa, Alves, Donato, & Sargento-Freitas, 2022). As Mendeley allows users to easily organize and manage their research references, it is a valuable tool for academics and researchers. It enables users to collaborate with colleagues and peers on research projects, facilitating communication and sharing of resources, discover new research, and share their work.

Social media such as Research Gate, Academia, Linked In, Mendeley, Google Scholar, X (Twitter), Blogs, etc. provide academics with one of the most direct routes for sharing research work (Pulido, Redondo-Sama, Sordé-Martí & Flecha, 2018). News outlets and blogs can help increase the visibility of research findings by reporting on relevant studies and discoveries and bringing attention to significant scientific findings. This increased visibility can lead to greater awareness and understanding of the research among the general public, policymakers, and other stakeholders.

The relatively complete Altmetric coverage of all types of media, such as news media, scientific and non-scientific blogs, and political documents caused the statistics of the citations on the social networks to articles through news media, blogs, and political documents to be close to reality and higher acceptability (Holmberg & Park, 2018). Of course, the effect of the type of scientific or non-scientific social network on the visibility and citation of scientific

articles should not be ignored (Pulido et al., 2018). Citing an article in the news is different from LinkedIn or Twitter.

Analyzing the Altmetric Score of the articles showed that seven articles - mainly focused on the effectiveness of COVID-19 vaccines on different groups, such as pregnant women, children, mortality rate, etc. - have attracted the maximum attention. These results show that clinical subjects in the field of COVID-19 vaccines have been of interest to physicians, researchers, and even the general public. Of course, they have had the most reflection in social networks, news media, weblogs, and Mendeley, which indicates the direct relationship between the spread of medical outputs related to COVID-19 vaccines in social networks and the increase of public awareness and social health level. Studies in the field of COVID-19 also confirmed these results (Royal et al., 2021; Yousefinaghani, Dara, Mubareka, Papadopoulos & Sharif, 2021).

Evaluation of the relationship between the Altmetric Score and Altmetrics with the greatest number of citations showed a significant, moderate, and positive correlation. This indicates a close relationship between citations in scientific journals and citations on social media to the articles on COVID-19 vaccines. Batooli and Sayyah (2022) also found a significant correlation between citations and Altmetrics. Among the Altmetrics, X (Twitter) and Mendeley were more important media than others. The findings of this study confirmed that the articles on the COVID-19 vaccination have attracted a lot of citations and attention on social networks (Batooli & Sayyah, 2022; Shehata et al., 2021).

Assessment of the correlation between hot articles and highly cited articles with Altmetric Score showed a positive, significant, and moderate correlation between citation and Altmetric Score of hot articles and citation and Altmetric Score of highly cited articles. Although this finding does not align with the results of other studies (Cho, 2021; Kousha & Thelwall, 2020), the reason might be found in the importance of the vaccine debate for the general public. This topic has been and continues to be crucial in saving human lives. The international news coverage of COVID-19 vaccine research in 204 countries, the news coverage by various agencies, the reflection of findings in political documents, and the publication of content in understandable language for blog users not only increased the citations to the articles on the social networks but also resulted in more academic citation of those articles and finally being included in the list of highly cited and hot articles. The topic of Covid-19 vaccines has been one of the hot topics in the last three years. Like what we found out in the present work, Huang et al. (2018) and Cho (2021) reported a significant and direct relationship between the amount of attention paid to work in social networks and citations in different subject areas, specifically in medicine.

The results of this research showed that despite the relatively short life of articles related to COVID-19 vaccines from 2020 until the present, there has been a remarkable and rapid engagement from social networks and researchers worldwide on this topic. Many of these articles have attracted academic citations and social attention from many social media users in recent months. Notably, almost 100% of the observed articles in this field in Altmetric Explorer were open-access articles, contributing to their increased visibility. The existence of a correlation and relationship between citation indices and Altmetrics may enhance the use of Altmetrics as a stable and reliable index. As a result, it is recommended that Altmetrics be used as a complementary tool to citation indexes in research evaluation. Researchers can also use social media to "self-archive" their work. This study is one of the first scientometric studies

utilizing Altmetric tools to analyze articles related to COVID-19 vaccines. It is recommended to assess scientific outputs related to COVID-19 vaccines on other platforms and databases and compare the results with the present research.

### Acknowledgments

The authors express their sincere gratitude to the Altmetric team for their collaboration in providing access to Altmetric Explorer. This research was conducted with the financial support of Hormozgan University of Medical Sciences, the Vice Chancellor for Research and Technology. The authors declare no conflict of interest.

### Funding

This research was conducted with the financial support of the Hormozgan University of Medical Sciences Vice Chancellor for Research.

### Conflict of Interest

No potential conflict of interest was reported by the authors. Ethical considerations: This research was approved by the ethics committee of HUMS and the assigned code was IR.HUMS.REC.2023.286

### Authors' contribution

Masoomeh Latifi supervised the study in all stages and steps. Forough Rahimi performed data analysis and drafted the manuscript-Nader Alishan Karami Study design, literature and drafting the manuscript, article writing.

### References

- Batooli, Z. & Sayyah, M. (2022). Measuring social media attention of scientific research on COVID-19: An investigation on article-level metrics data of dimensions. *Journal of Educational & Psychological Research (JEPR)*, 4(2), 361, 368. Retrieved from <https://www.opastpublishers.com/open-access-articles/measuring-social-media-attention-of-scientific-research-on-covid19-an-investigation-on-articlelevel-metrics-data-of-dime.pdf>
- Cascini, F., Pantovic, A., Al-Ajlouni, Y. A., Failla, G., Puleo, V., Melnyk, A., Lontano, A. & Ricciardi, W. (2022). Social media and attitudes towards a COVID-19 vaccination: A systematic review of the literature. *EClinicalMedicine*, 48, 101454. <https://doi.org/10.1016/j.eclinm.2022.101454>
- Cho, J. (2021). Altmetrics of highly cited research papers in social science. *Serials Review*, 47(1), 17-27. <https://doi.org/10.1080/00987913.2021.1882652>
- Costanzo, M., De Giglio, M. A. & Roviello, G. N. (2022). Anti-coronavirus vaccines: past investigations on SARS-CoV-1 and MERS-CoV, the approved vaccines from BioNTech/Pfizer, Moderna, Oxford/AstraZeneca and others under Development Against SARSCoV-2 Infection. *Current Medicinal Chemistry*, 29(1), 4-18. <https://doi.org/10.2174/0929867328666210521164809>
- Costas, R., Zahedi, Z. & Wouters, P. (2015). Do “altmetrics” correlate with citations? Extensive comparison of altmetric indicators with citations from a multidisciplinary perspective. *Journal of the Association for Information Science and Technology*, 66(10), 2003-2019. <https://doi.org/10.1002/asi.23309>

- Critchfield, T. S. & Dixon, D. R. (2022). A scientist-practitioner's guide to tracking personal dissemination impact: Using the altmetric attention score and bookmarklet.
- Cronin, B. & Sugimoto, C. R. (2014). *Beyond bibliometrics: Harnessing multidimensional indicators of scholarly impact*. MIT press.
- Cuesta-Cambra, U., Martínez-Martínez, L. & Niño-González, J. I. (2019). An analysis of pro-vaccine and anti-vaccine information on social networks and the internet: Visual and emotional patterns. *Profesional de la Información*, 28(2), e280217. <https://doi.org/10.3145/epi.2019.mar.17>
- Cui, X., Wang, P. & Wei, Z. (2021). Emergency use of COVID-19 vaccines is recommended by the World Health Organization (WHO) as of June 2021. *Drug Discoveries & Therapeutics*, 15(4), 222-224. <https://doi.org/10.5582/ddt.2021.01064>
- Fang, Z. & Costas, R. (2020). Tracking the Twitter attention around the research efforts on the COVID-19 pandemic. <https://doi.org/10.48550/arXiv.2006.05783>
- Fathizadeh, H., Afshar, S., Masoudi, M. R., Gholizadeh, P., Asgharzadeh, M., Ganbarov, K. & Kafil, H. S. (2021). SARS-CoV-2 (Covid-19) vaccines structure, mechanisms and effectiveness: A review. *International Journal of Biological Macromolecules*, 188, 740-750. <https://doi.org/10.1016/j.ijbiomac.2021.08.076>
- Germani, F. & Biller-Andorno, N. (2021). The anti-vaccination infodemic on social media: A behavioral analysis. *PLoS ONE*, 16(3), e0247642. <https://doi.org/10.1371/journal.pone.0247642>
- Golchin, M., Isfandyari-Moghaddam, A., Mirhosseini, Z., Famil Rohani, S. A. A. & Zarei, A. (2022). Investigating the presence of articles in Iranian journals indexed by Scopus via social media during 2010-2018. *Scientometrics Research Journal*, 8(15), 35-48. <https://doi.org/10.22070/rsci.2020.5716.1418> [in Persian]
- Haustein, S., Peters, I., Bar-Ilan, J., Priem, J., Shema, H. & Terliesner, J. (2014). Coverage and adoption of altmetrics sources in the bibliometric community. *Scientometrics*, 101(2), 1145-1163. <https://doi.org/10.1007/s11192-013-1221-3>
- Herrera-Peco, I., Jiménez-Gómez, B., Peña Deudero, J. J., Benitez De Gracia, E., & Ruiz-Núñez, C. (2021). Healthcare professionals' role in social media public health campaigns: Analysis of Spanish pro-vaccination campaign on Twitter. *Healthcare* 9(6),662. <https://doi.org/10.3390/healthcare9060662>
- Holmberg, K. & Park, H. W. (2018). An altmetric investigation of the online visibility of South Korea-based scientific journals. *Scientometrics*, 117(1), 603-613. <https://doi.org/10.1007/s11192-018-2874-8>
- Hou, Z., Tong, Y., Du, F., Lu, L., Zhao, S., Yu, K., Piatek, S. J., Larson, H. J. & Lin, L. (2021). Assessing COVID-19 vaccine hesitancy, Confidence, and public engagement: A global social listening study. *Journal of Medical Internet Research*, 23(6), e27632. <https://doi.org/10.2196/27632>
- Huang, W., Wang, P. & Wu, Q. (2018). A correlation comparison between Altmetric Attention Scores and citations for six PLOS journals. *PLoS ONE*, 13(4), e0194962. <https://doi.org/10.1371/journal.pone.0194962>
- Jain, V., Schwarz, L. & Lorgelly, P. (2021). A rapid review of COVID-19 vaccine prioritization in the US: alignment between federal guidance and state practice. *International Journal of Environmental Research and Public Health*, 18(7), 3483. <https://doi.org/10.3390/ijerph18073483>

- Jeng, W., He, D. & Jiang, J. (2015). User participation in an academic, social networking service: A Mendeley survey of open group users. *Journal of the Association for Information Science and Technology*, 66(5), 890-904. <https://doi.org/10.1002/asi.23225>
- Klar, S., Krupnikov, Y., Ryan, J. B., Searles, K. & Shmargad, Y. (2020). Using social media to promote academic research: Identifying the benefits of Twitter for sharing academic work. *PLoS ONE*, 15(4), e0229446. <https://doi.org/10.1371/journal.pone.0229446>
- Kousha, K. & Thelwall, M. (2020). COVID-19 publications: Database coverage, citations, readers, tweets, news, Facebook walls, Reddit posts. *Quantitative Science Studies*, 1(3), 1068-1091. [https://doi.org/10.1162/qss\\_a\\_00066](https://doi.org/10.1162/qss_a_00066)
- Liang, J. L., Tiwari, T., Moro, P., Messonnier, N. E., Reingold, A., Sawyer, M. & Clark, T. A. (2018). Preventing pertussis, tetanus, and diphtheria with vaccines in the United States: Recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recommendations and Reports*, 67(2), 1-44. <https://doi.org/10.15585/mmwr.rr6702a1>
- Liu, J. & Adie, E. (2013). Five challenges in altmetrics: A toolmaker's perspective. *Bulletin of the American Society for Information Science and Technology*, 39(4), 31-34. <https://doi.org/10.1002/bult.2013.1720390410>
- Llewellyn, N. M. & Nehl, E. J. (2022). Predicting citation impact from altmetric attention in clinical and translational research: Do big splashes lead to ripple effects? *Clinical and Translational Science*, 15(6), 1387-1392. <https://doi.org/10.1111/cts.13251>
- Maddi, A. & Sapinho, D. (2022). Article processing charges, altmetrics, and citation impact: Is there an economic rationale? *Scientometrics*, 127(12), 7351-7368. <https://doi.org/10.1007/s11192-022-04284-y>
- Moed, H. F. & Halevi, G. (2015). Multidimensional assessment of scholarly research impact. *Journal of the Association for Information Science and Technology*, 66(10), 1988-2002. <https://doi.org/10.1002/asi.23314>
- Moorhead, S. A., Hazlett, D. E., Harrison, L., Carroll, J. K., Irwin, A. & Hoving, C. (2013). A new dimension of health care: Systematic review of the uses, benefits, and limitations of social media for health communication. *Journal of Medical Internet Research*, 15(4), e1933. <https://doi.org/10.2196/jmir.1933>
- Pawlowski, C., Lenahan, P., Puranik, A., Agarwal, V., Venkatakrishnan, A. J., Niesen, M. J. M., O'Horo, J. C., Virk, A., Swift, M. D., Badley, A. D., Halamka, J. & Soundararajan, V. (2021). FDA-authorized mRNA COVID-19 vaccines are effective per real-world evidence synthesized across a multi-state health system. *Med (New York, N.Y.)*, 2(8), 979-992.e8. <https://doi.org/10.1016/j.medj.2021.06.007>
- Piwowar, H. (2013). Introduction altmetrics: What, why, and where? *Bulletin of the American Society for Information Science and Technology*, 39(4), 8-9. <https://doi.org/10.1002/bult.2013.1720390404>
- Priem, J., Piwowar, H. A. & Hemminger, B. M. (2012). Altmetrics in the wild: Using social media to explore scholarly impact. *arXiv preprint arXiv:1203.4745*. [doi.org/10.48550/arXiv.1203.4745](https://doi.org/10.48550/arXiv.1203.4745)
- Pulido, C. M., Redondo-Sama, G., Sordé-Martí, T. & Flecha, R. (2018). Social impact in social media: A new method to evaluate the social impact of research. *PLoS ONE*, 13(8), e0203117. <https://doi.org/10.1371/journal.pone.0203117>

- Royal, A., Ahmad, S., Qureshi, A., Chaudhary, V., Jindal, T., Kumar, V. & Mehta, K. (2021). An altmetric analysis of online news on India's first indigenous COVID-19 vaccine. *Journal of Education and Health Promotion*, 10,348. [https://doi.org/10.4103/jehp.jehp\\_1603\\_20](https://doi.org/10.4103/jehp.jehp_1603_20)
- Sanders, J. G., Spruijt, P., van Dijk, M., Elberse, J., Lambooij, M. S., Kroese, F. M. & de Bruin, M. (2021). Understanding a national increase in COVID-19 vaccination intention, the Netherlands, November 2020-March 2021. *Euro Surveillace: Bulletin Europeen sur les Maladies Transmissibles = European Communicable Disease Bulletin*, 26(36), 2100792. <https://doi.org/10.2807/1560-7917.ES.2021.26.36.2100792>
- Schnitzler, K., Davies, N., Ross, F. & Harris, R. (2016). Using Twitter™ to drive research impact: A discussion of strategies, opportunities, and challenges. *International Journal of Nursing Studies*, 59, 15-26. <https://doi.org/10.1016/j.ijnurstu.2016.02.004>
- Sener, H. & Polat, O. A. (2022). Altmetric analysis of the most-cited 100 articles on the retina published between 2010 and 2020. *Retina*, 42(2), 283-289. <https://doi.org/10.1097/IAE.0000000000003318>
- Shehata, A., El Dakar, M., & Salem, N. (2021, December). Top COVID-19 100 vaccine papers: An altmetric study. In *2021 22nd International Arab Conference on Information Technology (ACIT)* (pp. 1-13). IEEE.
- Sousa, J. A., Alves, I. A., Donato, H. & Sargento-Freitas, J. (2023). The Twitter factor: How does Twitter impact #Stroke journals and citation rates? *International Journal of Stroke: Official Journal of the International Stroke Society*, 18(5), 586–589. <https://doi.org/10.1177/17474930221136704>
- Troiano, G. & Nardi, A. (2021). Vaccine hesitancy in the era of COVID-19. *Public Health*, 194, 245-251. <https://doi.org/10.1016/j.puhe.2021.02.025>
- Thelwall, M. & Kousha, K. (2014). Academia.edu: Social network or academic network? *Journal of the Association for Information Science and Technology*, 65(4), 721-731. <https://doi.org/10.1002/asi.23038>
- Thelwall, M. & Kousha, K. (2015). Web indicators for research evaluation. Part 1: Citations and links to academic articles from the Web. *Profesional de la Información*, 24(5), 587-606. <https://doi.org/10.3145/epi.2015.sep.08>
- Wouters, P., Zahedi, Z. & Costas, R. (2019). Social media metrics for new research evaluation. In *Springer Handbook of Science and Technology Indicators* (pp. 687-713). Cham: Springer International Publishing.
- Yan, K., Barbati, J. L., Duncan, K. L., Warner, E. L. & Rains, S. A. (2023). Russian troll vaccine misinformation dissemination on Twitter: The role of political partisanship. *Health Communication*, 38(8), 1591-1600. <https://doi.org/10.1080/10410236.2021.2021692>
- Yousefinaghani, S., Dara, R., Mubareka, S., Papadopoulos, A. & Sharif, S. (2021). An analysis of COVID-19 vaccine sentiments and opinions on Twitter. *International Journal of Infectious Diseases*, 108, 256-262. <https://doi.org/10.1016/j.ijid.2021.05.059>
- Zhang, L., Fan, H., Peng, C., Rao, G. & Cong, Q. (2020). Sentiment analysis methods for HPV vaccine-related tweets based on transfer learning. *Healthcare*, 8(3), 307. <https://doi.org/10.3390/healthcare8030307>