Dissemination of research during the first year of the coronavirus disease 2019 pandemic

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The rapid and effective dissemination of research during the coronavirus disease 2019 (COVID-19) pandemic is critical if healthcare providers and public health officials are to remain aware of new developments. Several organizations have collected relevant COVID-19 articles to facilitate data sharing, including the World Health Organization and the National Institutes of Health (NIH). Yet, in this time of remarkable research productivity and social media influence, how peer-reviewed research disseminates to the global community remains poorly understood.

In order to ascertain how published research disseminated during the COVID-19 pandemic, we examined the world’s peer-reviewed literature on COVID-19 through the application of alternative metrics (altmetrics) based on social media engagement and evaluative bibliometrics using citation rates. We utilized altmetrics and citation rates to analyze COVID-19 articles indexed in the NIH’s iSearch COVID-19 portfolio and the Altmetric Explorer (study flow chart, figure 1). The iSearch COVID-19 Portfolio contains peer-reviewed COVID-19 articles from PubMed and preprints from several sources. We restricted our analysis to articles and used this dataset to ascertain citation rates. These data were merged by articles’ unique PubMed identification numbers with altmetrics from the Altmetric Explorer, where we ascertained articles’ Almetric Attention Scores (AAS; composite score of social interest that includes mentions in newsfeeds, Twitter, Facebook, and Google, among other sources).

We analyzed COVID-19 articles in the ISI Web of Science (WoS) Core Collection to evaluate article characteristics, including study type, authorship, and funding sources. We queried the ISI WoS Core Collection using the search terms “coronavirus disease 2019”, “COVID-19”, “severe acute respiratory syndrome coronavirus 2”, “SARS-CoV-2”, and “novel coronavirus”. The ISI WoS query was limited to publications from January 2020 to February 2021 (with no language or article type restrictions). Although there are several search engines that can be used for bibliometric analysis, including Scopus, Medline, and Google Scholar, we selected the ISI WoS Core Collection because this database was classically used by Eugene Garfield, the developer of the impact factor metric, to identify “citation classics”.

Research data were downloaded from iSearch and merged with Altmetric Explorer on February 26, 2021. The results of the ISI WoS query were also downloaded on February 26, 2021. This analysis was based on a total of 87,643 articles in iSearch that were merged with data from the Altmetric Explorer (75,960 (86.7%) published in 2020 and 11,682 (13.3%) published in 2021) and

Figure 1 Study flow chart. WoS, ISI Web of Science.
90,609 articles in the ISI WoS query (82,008 (90.5%) published in 2020 and 8601 (9.5%) in 2021).

COVID-19 articles were published rapidly during the first months of the pandemic, peaking in April 2020, and then plateauing at persistently high rates (figure 2A). Trends in citation rates and AAS mirrored each other during the study period (figure 2B). There were 48 articles in iSearch with unique PubMed identification numbers that were retracted or were retraction notices, corresponding to 34 (0.04%) articles (geometric mean citation rate (95% CI) 7.7 (3.5 to 16.5) and arithmetic mean (SD) 30.3 (80.3) and geometric mean AAS (95% CI) 26.9 (8.5 to 84.9) and arithmetic mean AAS (SD) 1243.3 (3784.0)). Some of these articles received

![Figure 2](image-url)

**Figure 2** Monthly distribution of citation rates and altmetrics for articles indexed in the National Institutes of Health's iSearch Coronavirus Disease 2019 Portfolio, January 2020 to February 2021. (A) Distribution of citation rates by month of publication. (B) Distribution of monthly article publication, mean citation rates, and mean Altmetric Attention Scores (AAS).

### Table 1

| Publication date | PMID | First author | Article title | Journal | Total citations | AAS |
|------------------|------|--------------|---------------|---------|----------------|-----|
| 2020-01-28       | 31 986 264 | Huang, Chaolin | Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China | Lancet | 11,403 | 14,215 |
| 2020-02-29       | 32 109 013 | Guan, Wei-Jie | Clinical characteristics of coronavirus disease 2019 in China | NEJM | 7893 | 10,360 |
| 2020-03-15       | 32 171 076 | Zhou, Fei | Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study | Lancet | 6942 | 13,466 |
| 2020-02-08       | 32 031 570 | Wang, Dawei | Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China | JAMA | 6586 | 6413 |
| 2020-01-25       | 31 978 945 | Zhu, Na | A novel coronavirus from patients with pneumonia in China, 2019 | NEJM | 6271 | 5648 |
| 2020-02-03       | 32 007 143 | Chen, Nanshan | Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study | Lancet | 5534 | 4422 |
| 2020-02-06       | 32 015 507 | Zhou, Peng | A pneumonia outbreak associated with a new coronavirus of probable bat origin | Nature | 4765 | 6132 |
| 2020-02-25       | 32 091 533 | Wu, Zunyu | Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72,314 cases from the Chinese Center for Disease Control and Prevention | JAMA | 4582 | 11,466 |
| 2020-01-30       | 31 995 857 | Li, Qun | Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia | NEJM | 4027 | 7042 |
| 2020-03-07       | 32 142 651 | Hoffmann, Markus | SARS-CoV-2 cell entry depends on ACE2 and TMPRSS2 and is blocked by a clinically proven protease inhibitor | Cell | 3998 | 4383 |
| 2020-04-15       | 32 284 675 | Andersen, Kristian | The proximal origin of SARS-CoV-2 | Nature Med | 1021 | 35,223 |
| 2020-11-19       | 33 205 991 | Bundgaard, Henning | Effectiveness of adding a mask recommendation to other public health measures to prevent SARS-CoV-2 infection in Danish mask wearers: a randomized controlled trial | Ann Intern Med | 12 | 28,937 |
| 2021-02-06       | 33 545 094 | Logunov, Denis | Safety and efficacy of an rAd26 and rAd5 vector-based heterologous prime-boost COVID-19 vaccine: an interim analysis of a randomized controlled phase three trial in Russia | Lancet | 0 | 27,639 |
| 2020-03-18       | 32 182 409 | van Doremalen, Noelle | Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1 | NEJM | 2273 | 26,117 |
| 2020-06-05       | 32 497 010 | Chu, Derek | Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis | Lancet | 481 | 23,966 |
| 2020-06-13       | 32 527 856 | Zhang, Renyi | Identifying airborne transmission as the dominant route for the spread of COVID-19 | PNAS USA | 135 | 21,657 |
| 2020-11-22       | 33 219 229 | Cao, Shiyi | Post-lockdown SARS-CoV-2 nucleic acid screening in nearly ten million residents of Wuhan, China | Nature Comm | 3 | 20,849 |
| 2020-05-07       | 32 371 934 | Leung, Nancy | Respiratory virus shedding in exhaled breath and efficacy of face masks. | Nature Med | 394 | 20,847 |
| 2020-04-01       | 32 292 127 | Koster, Stephen | Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period. | Science | 604 | 19,609 |

Retracted articles were not included in the top 10 lists.

AAS, Altmetric Attention Score; Ann Intern Med, Annals of Internal Medicine; JAMA, Journal of the American Medical Association; Nature Comm, Nature Communications; Nature Med, Nature Medicine; NEJM, New England Journal of Medicine; PNAS, Proceedings of the National Academy of Sciences of the United States of America.
substantial social media attention. For example, among the top 10 articles with highest AAS, one of the articles was retracted and another article was the official retraction notice from the journal that published that article. The top 10 articles with the highest citation rates and highest AAS, after excluding retracted articles, are described in Table 1.

The ISI WoS query revealed the most common document types were “articles” (47,717; 52.7%); “editorials” (14,491; 16.0%), and “letters” (14,073; 15.5%). The most frequent WoS categories were “Medicine, General & Internal” (11,111; 12.2%), “Public, Environmental & Occupational Health” (7281; 8.0%), and “Infectious Disease” (4790; 5.2%). Over half of all articles originated from four countries: the US (25,312; 27.9%), China (10,535; 11.6%), Italy (8899; 9.8%), and England (8759; 9.7%). The top funding agencies were the NIH, the National Natural Science Foundation of China, and the European Commission.

In this study of the world’s peer-reviewed COVID-19 literature in the first year of the pandemic, we observed a dramatic explosion of research output. With rapid publication of approximately 90,000 peer-reviewed articles that addressed all facets of COVID-19, the global community has been inundated with data. Notably, nearly 60% of the world’s research output originated from four countries that were hit first and hardest by COVID-19. Three countries are geographically distinct from the origination site of the virus, highlighting the global impact of the disease.

We observed that mean citation rates and AAS mirrored each other. Although there is debate about whether altmetrics correlate with citation rates, this study suggests these metrics have correlated during the pandemic.

While citation rates and altmetrics reflect influence, they do not provide insight into research quality. The explosion of COVID-19 publications has raised legitimate concerns about research quality11 as well as misconduct.12 Many journals, particularly top-tier journals, prioritized submissions of COVID-19-related articles, potentially at the expense of other topics, and expedited their peer review and publication. The rush to publish on the part of investigators and journals may have encouraged suboptimal research designs and methods as well as suboptimal peer review. Retracted articles perhaps reflect the most egregious examples of how the push to publish during the pandemic promoted poor-quality research. While the proportion of retracted articles in this study was small, these articles received substantial social media attention as well as high citation rates. This study underscores the need for a novel metric that prioritizes research quality rather than quantity.

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