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Massive covidization of research citations and the citation elite

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Massive scientific productivity accompanied the COVID-19 pandemic. We evaluated the citation impact of COVID-19 publications relative to all scientific work published in 2020 to 2021 and assessed the impact on scientist citation profiles. Using Scopus data until August 1, 2021, COVID-19 items accounted for 4% of papers published, 20% of citations received to papers published in 2020 to 2021, and >30% of citations received in 36 of the 174 disciplines of science (up to 79.3% in general and internal medicine). Across science, 98 of the 100 most-cited papers published in 2020 to 2021 were related to COVID-19; 110 scientists received ≥10,000 citations for COVID-19 work, but none received ≥10,000 citations for non–COVID-19 work published in 2020 to 2021. For many scientists, citations to their COVID-19 work already accounted for more than half of their total career citation count. Overall, these data show a strong covidization of research citations across science, with major impact on shaping the citation elite.

COVID-19 | citations | bibliometrics

Significance

The COVID-19 pandemic saw a massive mobilization of the scientific workforce. We evaluated the citation impact of COVID-19 publications relative to all scientific work published in 2020 to 2021, finding that 20% of citations received to papers published in 2020 to 2021 were to COVID-19–related papers. Across science, 98 of the 100 most-cited papers published in 2020 to 2021 were related to COVID-19. A large number of scientists received large numbers of citations to their COVID-19 work, often exceeding the citations they had received to all their work during their entire career. We document a strong covidization of research citations across science. This may have major repercussions for research priorities and the evolution of research on COVID-19 and beyond.

The COVID-19 pandemic resulted in a massive mobilization of researchers across science to address a new major challenge (1). It is estimated that ∼4% of the scientific literature published in 2020 to 2021 was related to COVID-19 (2): over 720,000 different scientists published over 210,000 relevant publications based on items indexed in Scopus as of August 1, 2021 (2). COVID-19–related published items exceeded 440,000 by the end of 2021 according to the WHO database (https://search.bvsalud.org/global-literature-on-novel-coronavirus-2019-ncov/; last accessed December 25, 2021).

This shift of the research enterprise and massive production of COVID-19–related publications ("covidization") may have had implications for citations to recent scientific work. In most scientific disciplines, most papers get few, if any, citations in the first year, and citations appear gradually, spread over many years, with citation half-lives that typically exceed 5 y for most scientific fields and may exceed 10 y for some fields (3–5). The half-life of the citation pattern for COVID-19 work is still unknown, given the short-term follow-up for the COVID-19 published papers. However, the hundreds of thousands of COVID-19 publications likely have drawn citations largely from other very recently published COVID-19 work. Conversely, for non–COVID-19 work, citations from very recent papers (<1 to 2 y old) are expected to have been a minority. Therefore, it is likely that a large share of citations to very recent work in 2020 and 2021 reflect citations to COVID-19 papers. The extent and distribution of such a COVID-19–enriched pattern of recent citations is worth studying for their implications in understanding the evolving cultural norms. Citations of more recent papers may represent reliance on less vetted, more tentative knowledge. Reliance on less-mature knowledge may be more susceptible to reversal, and a number of high-profile retractions have unnerved the scientific world in the COVID-19 era (6).

Moreover, the massive COVID-19 literature and its citations may have had a major impact on the careers of many scientists. The possibility of receiving a large number of citations could be highly appealing to researchers whose careers are influenced by reputation and citation metrics. If covidization of research heralds a new approach to receiving citations, it may change the incentives of scientists motivated by the lure of such scientific rewards. This, in turn, may shift the work of young scientists away from more "gradualist" fields toward COVID-19. The appeal of working on COVID-19, in other words, may extend beyond its health challenges, skewing an important alignment between the burden of disease and interest by scientists.

Here, we compare scientists' acquisition of citations for COVID-19 and similarly recent non–COVID-19 work, characterize the profiles of scientists that had extraordinary boosts to their citation profiles, and assess whether COVID-19 citations correlated with overall career impact, or whether they had an independent impact in generating a new citation elite. We addressed these questions using comprehensive data from Scopus (7) from 2020 to 2021.

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Results

Citations to Work Published in 2020 to 2021 and Share of Citations to COVID-19 Work. From January 1, 2020 until August 1, 2021, a total of 5,728,015 items were published and indexed in Scopus (7), including 210,183 (4%) items related to COVID-19. The number of total citations that they received until August 1, 2021 was 9,174,336, of which 1,832,477 citations (20%) were to the published items related to COVID-19. Therefore, even though COVID-19 items were a minority, they accounted for a five-times larger share of the citations received to very recently published items.

Table 1 shows the 36 scientific disciplines (of a total of 174 fields across all science) where more than 30% of citations received in 2020 to 2021 to work published in these 2 y were to COVID-19 work. For three scientific fields, more than two-thirds of the citations received in 2020 to 2021 were for COVID-19–related work: General and Internal Medicine 79.3%, Virology 76.7%, and Emergency and Critical Care Medicine 66.8%. Stated differently, less than one-third of citations in these fields during 2020 to 2021 referenced non–COVID-19 literature, including literature from all other diseases.

Across all disciplines, 98 of the 100 most-cited publications published in 2020 to 2021 were COVID-19 related. Similarly, 97 of the 100 most-cited publications published in 2020 were COVID-19 related. The proportion declined to 76 of the 100 most-cited among publications published in 2021.

As shown in Fig. 1, the proportion of papers receiving very high numbers of citations by August 1 of the next calendar year increased only slightly between 2017 and 2019. However, papers published in 2020 had a major shift, with much larger proportions of papers receiving very high numbers of citations. The shift was entirely attributable to COVID-19–related publications. Of the 3,183,277 publications in 2020, the 96,351 COVID-19–related publications received 8.4-fold more citations than the non–COVID-19 publications. The fold difference was 20.9-fold for General and Internal Medicine; that is, on average a COVID-19–related paper received more than 20 times the number of citations received by a non–COVID-19 paper. The average citations per paper were higher for COVID-19 papers than for non–COVID-19 papers for 128 of the 129 scientific disciplines that published more than 50 COVID-19–related papers in 2020 (with the exception of Computational Theory and Mathematics) (*SI Appendix*, Table S1).

Table 1. Scientific disciplines where COVID-19 work received >30% of the citations given to papers published in 2020 to 2021 (until August 1, 2021)

Scientific discipline	Published items	COVID-19 items (%)	Citations received	Citations to COVID-19 items (%)
General and internal medicine	125,491	21,099 (17)	495,196	392,681 (79)
Virology	20,076	4,240 (21)	112,723	86,407 (77)
Emergency and critical care medicine	17,921	3,155 (18)	41,399	27,654 (67)
Tropical medicine	13,241	1,886 (14)	35,529	23,254 (66)
Epidemiology	6,906	1,642 (24)	20,099	12,828 (64)
General clinical medicine	11,684	1,593 (14)	20,604	13,059 (63)
Microbiology	84,347	10,623 (13)	326,174	203,465 (62)
Respiratory system	29,206	3,521 (12)	73,569	42,997 (58)
Pediatrics	30,127	3,013 (10)	42,647	24,455 (57)
Otorhinolaryngology	18,684	1,626 (9)	22,046	12,500 (57)
Psychiatry	42,893	4,847 (11)	97,234	52,158 (54)
Allergy	7,474	742 (10)	21,473	10,343 (48)
Immunology	56,436	5,181 (9)	208,502	96,864 (47)
Environmental and occupational health	4,619	620 (13)	5,067	2,317 (46)
Nuclear medicine and medical imaging	47,979	2,758 (6)	87,276	39,580 (45)
Public health	46,141	6,190 (13)	63,333	27,337 (43)
Cardiovascular system and hematology	87,112	6,786 (8)	182,546	78,478 (43)
Dermatology and venereal diseases	29,796	2,199 (7)	34,284	14,461 (42)
Anesthesiology	21,658	2,433 (11)	32,644	13,577 (42)
Geriatrics	10,825	1,139 (11)	20,734	8,205 (40)
Arthritis and rheumatology	22,188	1,595 (7)	35,697	13,790 (39)
Medical informatics	14,592	1,915 (13)	28,145	10,768 (38)
Surgery	51,521	3,459 (7)	58,520	21,731 (37)
Pathology	9,479	482 (5)	16,313	5,924 (36)
Gastroenterology and hepatology	38,427	2,810 (7)	81,915	29,014 (35)
Obstetrics and reproductive medicine	37,973	2,270 (6)	45,199	16,002 (35)
Applied ethics	7,735	1,027 (13)	7,863	2,772 (35)
Urology and nephrology	31,929	1,898 (6)	41,758	14,512 (35)
Nursing	48,218	3,992 (8)	28,855	9,891 (34)
Clinical psychology	10,797	709 (7)	16,865	5,769 (34)
Endocrinology and metabolism	36,541	2,356 (6)	87,770	29,581 (34)
Sport, leisure, and Tourism	9,808	882 (9)	19,323	6,315 (33)
Toxicology	39,493	3,163 (8)	78,274	25,359 (32)
Substance abuse	10,825	751 (7)	16,141	5,182 (32)
Biophysics	8,558	594 (7)	20,885	6,606 (32)
Gender studies	3,473	215 (6)	2,159	654 (30)

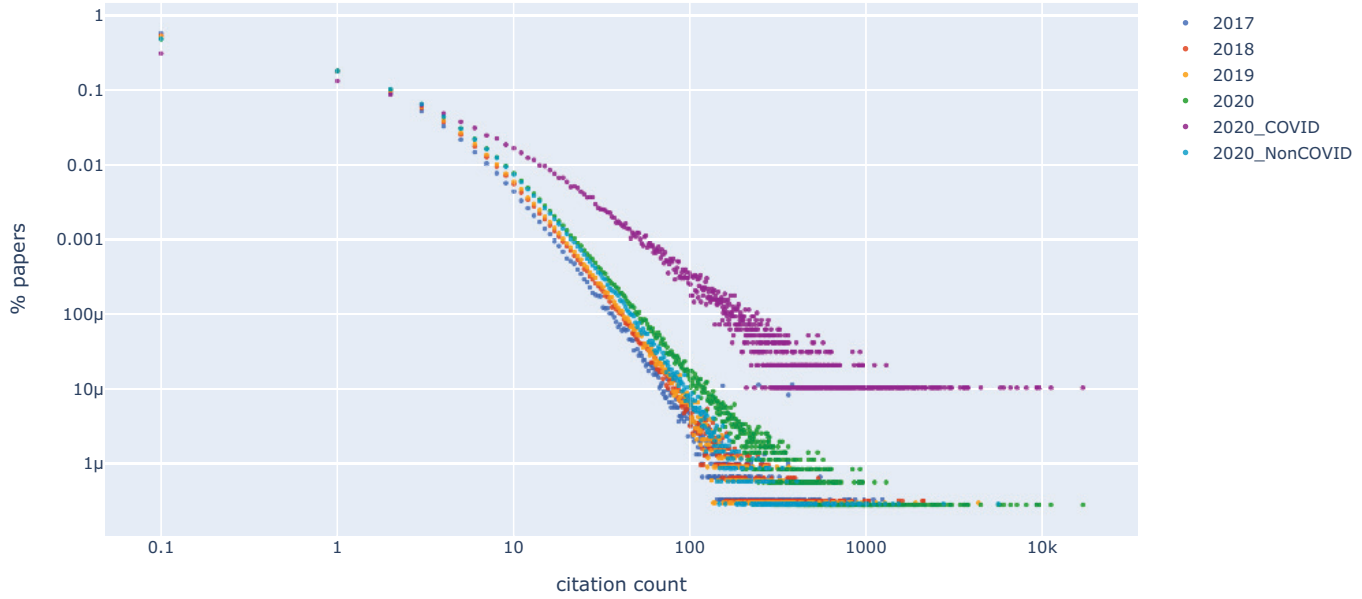

Fig. 1. Distribution of the publications with different numbers of citations until August 1 of the next calendar year for publications published in 2017, 2018, 2019, and 2020. For publications published in 2020, separate data are shown for COVID-19 publications and non–COVID-19 publications.

Scientists with High Numbers of Citations to Their 2020 to 2021 Published Work. A total of 84,757 scientists had received ≥100 citations to their work published in 2020 to 2021 by August 1, 2021 (among a total of 4,183,909 Scopus IDs that had published at least one paper in that time period and five or more papers in their entire career). Among these 84,757 scientists, 35,358 had received ≥300 citations, 5,773 had received ≥1,000 citations, 240 had received ≥5,000 citations, and 110 had received ≥10,000 citations for such very recent work.

Of the 84,757 scientists with ≥100 citations to very recent work, 53% had published at least some COVID-19 papers and of the 5,773 scientists with ≥1,000 citations to very recent work, 65% had published some COVID-19 work. Table 2 shows the number of scientists who had received high numbers of citations to very recent work overall, COVID-19–related work, and non–COVID-19 work. As shown, the number of authors who received ≥100 citations to very recent work was almost double for non–COVID-19 work than for COVID-19 work, but the difference was eliminated at the ≥1,000 citations threshold. Greater than or equal to 5,000 citations were received only for COVID-19 work, with the exceptions of six scientists (three authors of an annual cancer statistics reference and three authors of cardiology guidelines). At the ≥10,000 citation threshold, all 110 scientists conducted COVID-19 work; only 15 of these scientists had also received ≥100 citations for their very recent non–COVID-19 work.

Almost all of the scientists who had received >10,000 citations to their very recent work were from China, because the eight most-cited papers of 2020 to 2021 were all papers from China published in the early days of the pandemic and describing clinical characteristics and preliminary epidemiological features of COVID-19.

Boosting of Career Citation Impact by Citations to COVID-19 Work. Among the 84,757 scientists with ≥100 citations to their very recent work (published in 2020 to 2021), for $n = 11{,}767$ scientists the citations to their COVID-19 work already accounted for more than half of their total career citation count. Correspondingly, for $n = 5{,}071$ of the 84,757 scientists the citations to their non–COVID-19 work published in 2020 to 2021 already accounted for more than half of their total career citation count.

Impact on the Citation Elite. Using a composite citation indicator for ranking the citation impact of scientists, among the top-300 ranked scientists for their COVID-19 work, 117 were among the top-100,000 ranked science-wide for their entire career impact as of August 1, 2021, and 54 were among the top-20,000 ranked science-wide for their career impact. Fig. 2 shows the trajectory for the ranking of these 54 scientists across science according to the composite indicator, considering the citations received in a single year. As shown, in 2019 versus 2017, improvements in ranking were as common as worsening ranking: 13 of 54 scientists improved their ranking by a third or more and 10 of 54 worsened their ranking by as much. Conversely, in the 2020 versus 2019 comparison, 47 of 54 scientists improved their ranking by a third or more, while no scientists worsened their ranking by this margin. Six scientists improved their ranking more than sixfold. These six scientists worked largely independently, and the extremely highly cited papers on

Table 2. Number of scientists who received high numbers of citations to COVID-19 work and to non–COVID-19 work published in 2020 to 2021 (data from Scopus until August 1, 2021)

No. citations	All published work in 2020 to 2021	COVID-19 work in 2020 to 2021	Non–COVID-19 work in 2020 to 2021
≥100 citations	84,757	30,307	54,891
≥1,000 citations	5,773	2,923	2,558
≥5,000 citations	240	229	6
≥10,000 citations	110	110	0

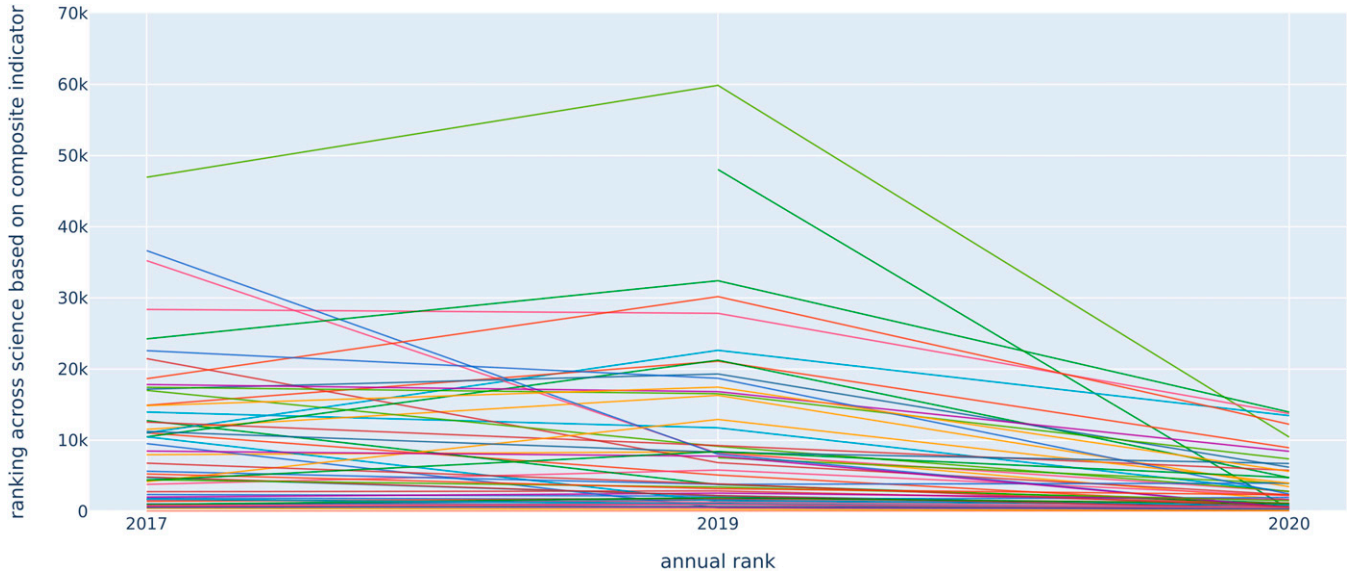

Fig. 2. Trajectory of annual ranking (based on composite citation indicator) for 54 scientists who were among the top-300 for the citation impact of their COVID-19 publications and among these top-20,000 for the cumulative citation impact of their work by August 1, 2021.

COVID-19 that they authored were typically different, except for one paper that introduced the RT-PCR for diagnosis and where two of them were among the authors. Three of them were virologists and made major contributions in identifying the virus and its receptors and developing testing. One was a respiratory medicine specialist who coauthored early papers on COVID-19 clinical features. Another one was a clinician who published a highly cited single-authored viewpoint on African Americans and COVID-19. The sixth scientist was an immunologist who wrote a highly cited single-authored early review. The most impressive improvement was for a long-time coronavirus virologist who went from rank 48,045 in 2019 to rank 362 in 2020, a 133-fold improvement.

Among the top-100 ranked scientists according to the composite citation indicator for their work published in 2018 to 2019, 48 had not been among the top-1,000 ranked for their work published in 2016 to 2017. Among the top-100 ranked scientists according to the composite citation indicator for their work published in 2020 to 2021, 70 had not been among the top-1,000 ranked for their work published in 2018 to 2019. Among the top-100 ranked scientists across science in 2018 to 2019, only 36 focused on Health Sciences subfields and only 14 of the 36 had risen to such extremely high ranks even though they did not belong to the top-1,000 ranked in 2016 to 2017. Conversely, among the top-100 ranked scientists across science in 2020 to 2021, 70 focused on Health Sciences subfields and most (57 of 70) had risen to such extremely high ranks even though they did not belong to the top-1,000 ranked in 2018 to 2019. Twelve of the 70 were editors or journal staff who published profusely in their journals, mostly on COVID-19. These 12 authors were all highly qualified in editor roles and/or journalism, but none of them were COVID-19 specialists themselves, with their own research agenda on COVID-19 investigation and, more generally, none were active, practicing researchers.

Correlation between Metrics of Impact: Career Impact and 2020 to 2021 Work. Across the 84,757 scientists, the performance for the recent work in 2020 to 2021 correlated strongly with the respective performance during their entire career, for the number of papers ($r = 0.69$, $\rho = 0.79$), the ranking according to the composite citation indicator ($r = 0.55$, $\rho = 0.56$), the h-index ($r = 0.56$, $\rho = 0.59$), and the hm-index ($r = 0.59$, $\rho = 0.76$), but not for the number of citations ($r = 0.16$, $\rho = 0.31$). The number of citations to recent non–COVID-19 work correlated strongly with the number of citations for the entire career ($r = 0.46$, $\rho = 0.54$), but the number of citations to very recent COVID-19 work did not correlate with the number of citations to the entire career ($r = -0.03$, $\rho = -0.29$).

The lack of correlation between performance metrics on COVID-19 work and performance for the entire career was seen also for all other metrics besides citations. Fig. 3 shows the strong relationship between the hm-index for entire career and the hm-index for very recent work overall, but weak relationship between the hm-index for entire career and the hm-index for COVID-19 work.

Discussion

The present analysis shows a massive covidization of research citations during 2020 to 2021. A large share of the citations to papers published in 2020 to 2021 has gone to COVID-19–related items. This pattern is seen across many scientific disciplines, with the highest rates in General and Internal Medicine, where >79% of the citations to recent work are to COVID-19 papers. COVID-19 papers published in 2020 received on average more than 8-fold the number of citations than non–COVID-19 papers and the difference exceeded 20-fold in General and Internal Medicine. Almost all of the top-100 most-cited reports published in 2020 across all science (not just biomedicine) were related to COVID-19, and the same applied to three quarters of the most-cited publications published in 2021. Many scientists received in a limited time high numbers of citations to their COVID-19 work and already have higher citations counts for COVID-19 alone than for all other scientific topics combined. Many authors who are highly cited for their COVID-19 work have had limited citation impact before the pandemic. COVID-19 is generating a new citation elite. During 2020 to 2021, the top-100 most-cited scientists included mostly authors who rose sharply from much lower

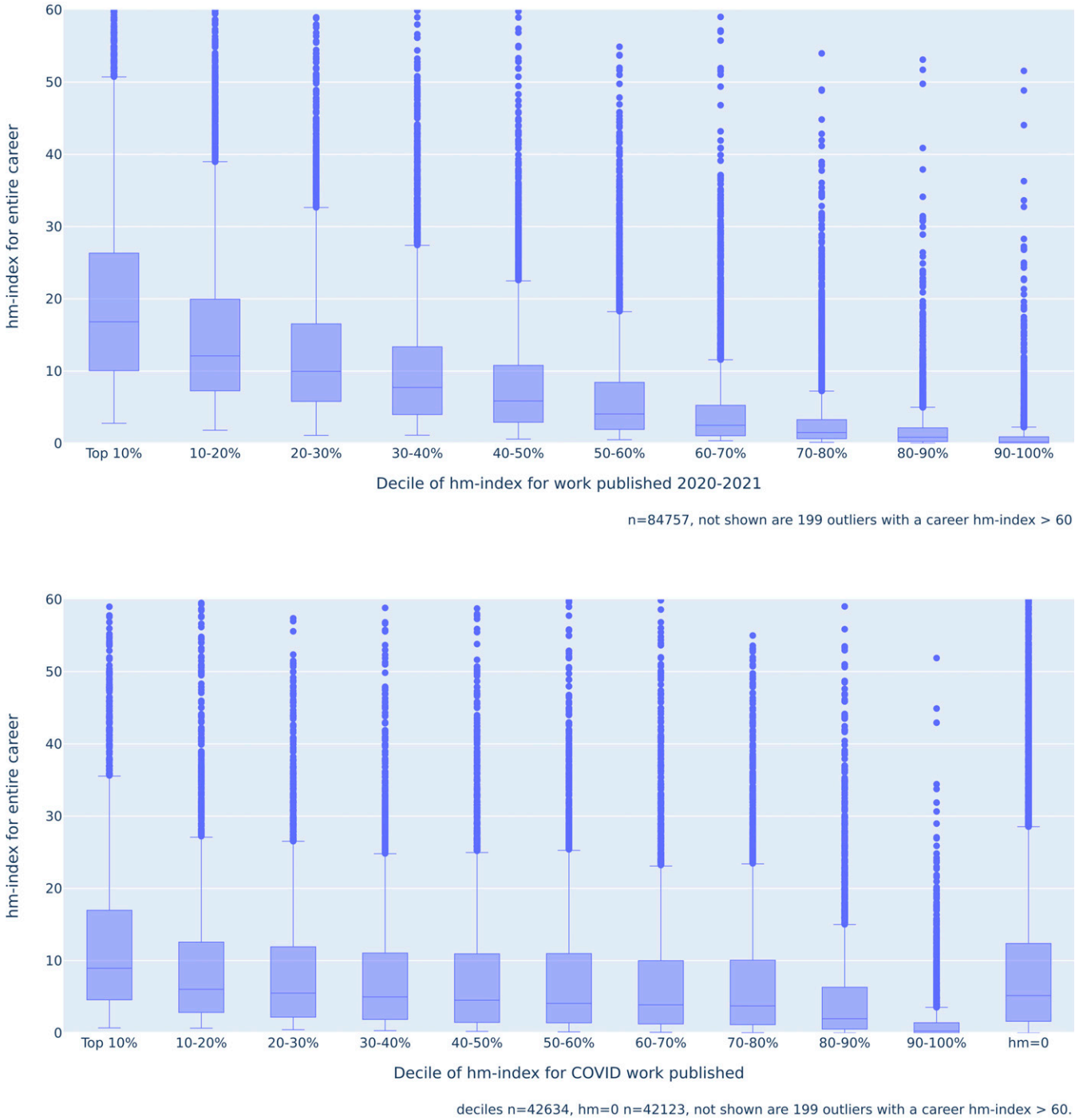

Fig. 3. Correlation between coauthorship-adjusted hm-index for work published in 2020 to 2021 and coauthorship-adjusted hm-index for entire career (*Upper*) and lack of correlation between coauthorship-adjusted hm-index for COVID-19 work published in 2020 to 2021 and coauthorship-adjusted hm-index for entire career (*Lower*).

ranks in 2018 to 2019. In Health Sciences, the top citation elite was comprised in its vast majority by such new sharply rising scientists.

COVID-19 attracted the efforts of both established scientists with strong prior publication and citation record and of new entrants to the scientific literature and young investigators. It is unknown whether these scientists will continue to be heavily involved in COVID-19–related research and whether the vast influence and dominance of COVID-19 on research citations will continue in subsequent years. Perhaps as the pandemic dissipates, the large share of citations to recent work for COVID-19 papers may also dissipate in parallel. The appearance of far more non–COVID-19 related publications among the list of the most-cited papers in 2021 as opposed to the respective list of 2020 is an early indication of such a decline. However, even among the 2021 cohort, still three-quarters of the most-cited publications were COVID-19–related. With COVID-19 papers attracting on average 8 times more citations than other papers in the short-term (up to 20 times more in General and Internal Medicine) and with a given that journals and editors are anxious to boost their impact factors, the attraction for publishing COVID-19 work must have been very strong.

Citation impact may not necessarily mean high quality or validity of the cited work. Many empirical evaluations of quality aspects of different segments of the COVID-19 scientific literature have consistently shown low quality (8–17). To our knowledge, there is no large-scale assessment of the correlation between quality scores (with all the difficulty of obtaining such scores) and citation impact of COVID-19 work specifically. However, other investigators have found that COVID-19 papers published in the most influential journals have weaker designs than non–COVID-19 papers in the same venues (14). Moreover, several extremely cited COVID-19 papers reflect topics that are debated or even refuted, such as editorials about the origin of the new coronavirus and early reports claiming effectiveness for interventions, such as hydroxychloroquine, that were not subsequently validated for major outcomes (e.g., mortality). High rates of nonreplication and refutation for many of the most highly cited papers have also been presented in the pre–COVID-19 scientific literature (18, 19). Beyond COVID-19, there is debate in the literature in other fields on the extent to which citations are influenced by quality (20–23) and the relative contribution of rigor and relevance is attracting citations (24–26).

There are several limitations to our work. First, the classification into COVID-19 versus non–COVID-19 work may not be perfect. However, it is unlikely that the existence of a border zone of difficult-to-classify papers and of papers misclassified by our search algorithm would change the big picture of the results. Second, some scientists may have their publications split into two or more Scopus ID files and some Scopus ID files may include papers by more than one author. Nevertheless, Scopus data have high precision and recall (98.1% and 94.4%, respectively) (2), therefore this is unlikely to be a source of major error. Third, we could not evaluate whether the massive advent of the COVID-19 literature and of its citation footprint affected (negatively) the non–COVID-19 literature and its citations. This is very difficult to evaluate since there are dynamic changes in the volume of the Scopus-indexed literature over time, irrespective of COVID-19. Some of these changes are genuine (e.g., due to emergence of some new hot research areas) and others are artifacts of indexing (e.g., more journals are indexed in Scopus over time).

By design, we opted to focus on authors with at least five full papers, conference papers, or reviews under their belt by August 21, 2021. This choice has also been adopted in previous work (2). This design probably excluded from the evaluation a substantial number of early career scientists who have not published that many papers yet, but who may have already coauthored COVID-19 work that gathered many citations. Therefore, the number of authors who more than doubled their total career citations would be probably much larger than our estimates, if these authors with few papers were to be added. However, many Scopus author ID files with few items are fragments that belong to larger profiles and considering these ID files would have added spurious noise to the analysis. Moreover, many of the author ID files with few papers may represent people who have an auxiliary role in the research process rather than being key investigators.

Allowing for these caveats, our analysis shows a massive covidization of research citations. Citations are a main coinage used for choices reflecting funding and career advancement in both academia and the wider scientific community, and are widely deemed highly desirable (27, 28). Other investigators have expressed concerns about the covidization of research (29, 30). The duration and evolution of the phenomenon are unknown, but they warrant careful monitoring. The ultrafast generation of the broad COVID-19 research community is most welcome to the extent that it serves the needs of scientific investigation and its translation to useful medical and public health interventions and policy. Conversely, if that community grows disproportionally large or it remains pervasive even when the pandemic dissipates, challenges may arise.

Evidence from evaluations of citation patterns in very large scientific fields (31) suggests that when scientific fields grow very large, the list of most-cited papers ossifies to become a canon that slows disruption and real progress. COVID-19 offers a unique example of a scientific field that grew to extremely large dimensions extremely fast. The pandemic has shown the great ability of the scientific workforce to shift attention to an acute problem. It is unknown if this versatility can also translate reversely to shifting away from COVID-19 research and citations, when COVID-19 is no longer an acute and major threat, and refocusing on different priorities, if such priorities arise.

As of this writing (April 4, 2022), of the 100 most-cited articles published in 2022, 43 are COVID-19–related. This is a substantial decline compared with the previous 2 y, but it still represents an inordinately large share across the entire scientific literature. Moreover, the WHO Global Literature on Coronavirus Disease includes 557,066 items, 117,000 more compared with just 100 d ago. In other words, this literature is still growing, even if the extreme covidization is leveling off (32). As the pool of citable papers has become very large, the vast majority of newly published papers may attract very few citations, in contrast to the early days of the pandemic. However, the availability of extensive funding and the generation of a large scientific workforce that has made a career of COVID-19 suggest that COVID-19 may continue to have a dominant presence in the scientific literature and its citations well beyond the end of the pandemic. Several citation leaders in the new citation elite may occupy prominent roles in academia, serve as role models, and possess outsized influence on science funding. As the total public funding for research is likely to change only gradually, and human productivity also has limits, it is plausible that persisting overemphasis on COVID-19 may reduce resources for other scientific work. This may have negative consequences on scientific progress, unless the imbalance in allocation is corrected promptly enough.

Materials and Methods

COVID-19 and Non–COVID-19 Work Published in 2020 to 2021. We used a copy of the Scopus database (7) extracted on August 1, 2021. We identified all publications published and indexed in 2020 and 2021 as of that date. We then separated COVID-19 publications from all publications. Similar to previous work (2), COVID-19–related publications were retrieved by searching in articles published in 2019 or later for any of the following terms in the title, abstract, or key words: 'sars-cov-2' OR 'coronavirus 2' OR 'corona virus 2' OR covid-19 OR {novel coronavirus} OR {novel corona virus} OR '2019-ncov' OR 'covid' OR 'covid19' OR 'ncovid-19' OR 'coronavirus disease 2019' OR 'corona virus disease 2019' OR 'corona-19' OR 'SARS-nCoV' OR 'ncov-2019', with further filtering through the Elsevier International Center for the Study of Research Lab infrastructure to limit to publications indexed (loaded) in Scopus in 2020 or 2021 only, and with the publication year of 2020 or later.

Citations to Work Published in 2020 to 2021. Scopus citations to all publications in 2020 to 2021, to COVID-19 publications in 2020 to 2021, and to non–COVID-19 publications in 2020 to 2021 were counted as of August 1, 2021. Preprint publications from *ArXiv*, SSRN, *BioRxiv*, *ChemRxiv*, and *medRxiv* account for 9% of COVID-19 publications (2). Citations from or to preprints are

not systematically recorded in Scopus, thus preprints are excluded from all citation analyses.

Publications in 2020 to 2021 were assigned to a discipline based on their journal of publication and according to the Science Metrix classification of science, which is a standard mapping of all science into 21 main fields and 174 subfield disciplines (33, 34). For each of the 174 subfields, we estimated the share of citations received in 2020 to 2021 by COVID-19 publications published in 2020 to 2021 against all publications in the same time frame.

We also examined specifically the top-100 most-cited publications published in 2020 to 2021, in 2020 alone, and in 2021 to identify how many of them were COVID-19–related. We used citation counts in Scopus as of August 1, 2021.

We also generated plots of the proportion of publications receiving different numbers of citations for papers published in 2017, 2018, 2019, and 2020 considering citations received until August 1 of the following calendar year. For 2020, we considered separately COVID-19–related and non–COVID-19 publications. For each of the scientific fields that had published at least 50 COVID-19 publications in 2020, we assessed the ratio of mean citations to COVID-19 publications over mean citations to non–COVID-19 publications. This analysis is slightly biased in favor of non–COVID-19 publications, since very few COVID-19 publications appeared in the first 2 mo of 2020 and thus non–COVID-19 publications had slightly more time available to be cited on average.

Authors with at Least 100 Citations to Their 2020 to 2021 Published Work. We identified all authors who had received by August 1, 2021 at least 100 citations to their work published in 2020 to 2021. We noted how many of them had published at least one COVID-19–related publication. We also noted how many authors had received by August 1, 2021 at least 100 citations to their COVID-19 versus non–COVID-19 work published in 2020 to 2021. Numbers of authors passing higher citation thresholds ($\geq$500, $\geq$1,000, $\geq$5,000, $\geq$10,000) for these categories were also noted. We examined the country of the authors at the highest citation levels. For all analyses of authors, similar to prior work (2), we only considered those that have published at least five papers (articles, conference papers, or reviews) in their career. This allows the exclusion of authors with limited presence in the scientific literature and of author IDs that may represent split fragments of the publication record of some more prolific authors.

Citation Metrics for the 2020 to 2021 Work and for Career-Long Impact. For each author with $\geq$100 citations to their work published in 2020 to 2021, we also recorded the number of published items in 2020 to 2021 (publications including preprints, citations to preprints are not recorded), and additional citation indices limited to the impact of the 2020 to 2021 published work, the Hirsch h-index (35), and the coauthorship adjusted Schreiber hm-index (36). Using a previously published and validated composite citation indicator (37–39; see URLs for the individual versions in ref. 39) that combines total citations, h-index, hm-index, and three indicators of citations to works as single, single/first, single/first/last author, we generated a ranking of scientists based on their 2020 to 2021 work alone. We did the same calculations and generated the respective and rankings limited to COVID-19 work published in 2020 to 2021.

For each author with $\geq$100 citations to their work published in 2020 to 2021, we also calculated the same citation metrics and overall ranking across all science as of August 1, 2021 for the work published during their entire career (39). We evaluated for how many authors their COVID-19 work accounted for at least half of the citations they had received in their entire career; and for how many authors their non–COVID-19 work published in 2020 to 2021 accounted for more than half of the citations they had received in their entire career.

We had previously generated (2) a list of the top-300 ranked scientists for their COVID-19 work based on the composite citation indicator. We investigated how many of those were also among the top-100,000 ranked science-wide for their entire career impact as of August 1, 2021 and how many were among the top-20,000 ranked science-wide for their career impact. For the scientists who were among the top-20,000 ranked science-wide for their career impact, we also noted their science-wide ranking for their annual citation impact in the single years 2017, 2019, and 2020; data were extracted from previously published, publicly available datasets that use the composite citation indicator for the ranking (38, 39). This allowed us to assess the evolution of the trajectory of the ranking of these scientists before the pandemic and during the pandemic. The annual assessments consider all the citations received in a single year to all work published in the scientist's career. Therefore, they reflect the recent attention not only to the recent work, but also to all past work.

For each of three periods 2016 to 2017, 2018 to 2019, and 2020 to 2021, we calculated the composite citation indicator for all scientists in Scopus for their work published in the respective years. We excluded books and book chapters because Scopus assigns to the latest edition of books also the citations to previous editions from past years. We evaluated how many scientists rose to the top-100 ranked according to the composite citation indicator while they were not even among the top-1,000 ranked in the previous 2-y period. We also report such major rises specifically for scientists whose Science Metrix classification of their primary and/or secondary subfield was in the 60 subfields of Health Sciences.

Finally, we calculated Pearson and Spearman correlation coefficients for the productivity and citation metrics of the scientists for their entire career as of August 1, 2021 and the respective metrics for COVID-19 work and non–COVID-19 work published in 2020 to 2021. This allowed us to evaluate whether the career impact tracked with their recent COVID-19 work, non–COVID-19 work, or both.

All calculations throughout the paper include self-citations. No statistical tests were used and no *P* values are reported, since analyses are descriptive.

Data Availability. Key data are in the main text. Specific names of individual elite top-cited researchers are available from the authors upon request. The large majority of detailed data, including author names, can be obtained from the large datasets that are available publicly via Mendeley. For the analyses of the top-100 and top-1,000 elite for 2016 to 2017, 2018 to 2019, and 2020 to 2021, detailed data are available from the authors upon request.

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