SARS-CoV-2 and COVID-19: a scientometric analysis of research output and international cooperation

Nadja Grammes, Dominic Millenaar, Tobias Fehlmann, Fabian Kern, Michael Böhm, Felix Mahfoud, Andreas Keller

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Abstract

Background: The coronavirus disease 2019 (COVID-19) pandemic has led to immediate and massive research efforts worldwide.

Methods: and

Results: This analysis aimed to correlate the severity of the COVID-19 outbreak with its related scientific output per region. All articles related to the COVID-19 pandemic were retrieved from Web-of-Science and analyzed utilizing the web application SciPE (Science-Performance-Evaluation), allowing large data scientometric analyses regarding global geographical distribution of scientific output. A total of 7,185 articles, including 2,898 articles, 2,275 editorial materials, 2,646 early access, 1,621 letters and 711 reviews and other contributions were extracted. The top three countries involved in COVID-19 research were the United States (US), China, and Italy. The regional number of confirmed COVID-19 cases or deaths correlated with the scientific research efforts. The US was most active in terms of collaborative efforts, sharing a significant amount of manuscripts with the United Kingdom (UK), China, and Italy. For China, the US was the frequent cooperating nation, followed by the UK.

Conclusion: The research landscape related to COVID-19 is rapidly developing and is driven by countries with a general strong research output but is also strongly affected by countries with high prevalence of COVID-19 cases. The US dominates international collaborative efforts.

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Original Manuscript

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a scientometric analysis of research output and international cooperation

Running title: Global COVID-19 research

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Abstract

Background: The global pandemic caused by the severe acute respiratory syndrome-coronarvirus-2 (SARS-CoV-2) leading to the coronavirus disease 2019 (COVID-19) has led to immediate and massive worldwide research activities. Rapid publication of research data may be desirable but also carries the risk of quality loss.

Objective: This analysis aimed to correlate the severity of the COVID-19 outbreak with its related scientific output per region.

Methods: All articles related to the COVID-19 pandemic were retrieved from Web-of-Science and analyzed utilizing the web application SciPE (Science-Performance-Evaluation), allowing large data scientometric analyses regarding global geographical distribution of scientific output.

Results: A total of 7,185 articles, including 2,898 articles, 2,275 editorial materials, 2,646 early access, 1,621 letters and 711 reviews and other contributions were extracted. The top three countries involved in COVID-19 research were the United States (US), China, and Italy. The regional number of confirmed COVID-19 cases or deaths correlated with the scientific research efforts. The US was most active in terms of collaborative efforts, sharing a significant amount of manuscripts with the United Kingdom (UK), China, and Italy. For China, the US was the frequent cooperating nation, followed by the UK.

Conclusions: The research landscape related to COVID-19 is rapidly developing and is driven by countries with a general strong research output but is also strongly affected by countries with high prevalence of COVID-19 cases. The US dominates international collaborative efforts.

Keywords

Scientometric analysis, COVID-19, SARS-CoV-2, citation analysis

List of abbreviations

AF	Africa
AS	Asia
COVID-19	Corona virus disease 2019
EU	Europe
log	logarithmic
n	number
NA	North America
OC	Oceania
SA	South America
SARS-CoV-2	severe acute respiratory syndrome-coronarvirus-2
SciPE	Science Performance Evaluation
UK	United Kingdom
US	United States
WHO	World Health Organization
WoS	Web of Science Core Collection

Introduction

The global pandemic caused by the severe acute respiratory syndrome-coronarvirus-2 (SARS-CoV-2) leading to the coronavirus disease 2019 (COVID-19) has led to immediate and massive worldwide research activities. Literature on preprint servers is increasing enormously. Prominent servers such as bioRxiv and medRxiv receive numerous new manuscripts each day and currently list 6,063 articles (July 4th, 2020). Also, the peer-reviewed literature is growing at an unprecedented speed with articles published in various leading medical and related journals[1-3]. Rapid publication of research data can be desirable but also carries the risk of quality loss. Some manuscripts were actually accepted on the day of submission, hence questioning the completion of a sufficient peer review process [4] and leading to a relatively high number of retractions even in high rank journals [5, 6].

This scientometric study aimed at providing profound insights into the current scientific SARS-CoV-2 research landscape. According to the World Health Organization (WHO), on July 4th, 2020, the United States (US) reported the highest absolute number of confirmed COVID-19 cases with 2,724,433 positive test results and 128,481 associated deaths[7]. In Europe, the United Kingdom (UK) and Italy reported the highest number of infected persons, with 284,280 and 241,184 cumulative cases, while China reported 85,287 cases[7]. The present study also aimed to correlate the severity of the COVID-19 outbreak with the COVID-19 related scientific output per region during the pandemic and to assess international collaboration.

Methods

Data search strategy

The online database Web of Science Core Collection (WoS) was searched to retrieve all analyzed data, containing the words "covid19", "covid-19", "sarscov2" or "sars-cov-2" in the title or abstract. We refrained from adding the word "corona" to our search term, as this may identify several publications unrelated to the COVID-19 pandemic. The exact search term in WoS read as follows: [TI=(covid19   OR covid-19   OR sarscov2   OR sars-cov-2)   OR AB=(covid19   OR covid-19 OR sarscov2 OR sars-cov-2)]. All articles found through this search were eligible and analyzed up until and including the date of retrieval on June 14th 2020. A second search was performed on October 25th to assess the change of the scientific landscape following the initial search. There were no exclusion criteria, in case the article was identified by the above-mentioned search term, especially no restrictions to language, article type, or region of publication. A cross-check was performed with other medical databases such as PubMed, to avoid the risk of missing articles.

Data acquisition and processing

By applying the web application **SciPE** (**Sci**ence **P**erformance **E**valuation), a dedicated web-based scientometric tool, the full set of research items was analyzed, as described elsewhere [8].

In brief, metadata of the retrieved publication data extracted from WoS were processed and visualized accordingly. WoS is the standard database for citation analyses, as it provides more details compared with other medical databases [9]. Hence, SciPE was programmed for processing WOS metadata for further analysis. For the exact analysis of institutes, all institute-specific data were compared to a normalized and comprehensive list of an online university ranking list [10]. All data were coupled to a fee-based Google API (application programming interface) key enabling the assessment of exact geo-positions of all analyzed institutes by internal processing utilizing SciPE. Consecutively, institute heatmaps were created according to these results. Information on each

country's population size was extracted from the World Factbook by the US government [11].

Assessment of collaborations between institutes and countries

For the assessment of collaborations between institutes and different countries, the affiliations of the first author were analyzed and compared with the affiliations of all other co-authors. Each institute of a country that was distinct from the first author's country was counted as one cooperation and visualized in a chord diagram. The width of each chords is proportional to the amount of existing cooperations between institutes or countries.

Ethical approval

Since this was a meta-data analysis of published work, ethics committee approval was not required.

Results

In the initial search on July 4th, a total of 7,185 articles were extracted from the WoS, including 2,592 articles, 2,091 editorial materials, 2,528 early access (likely dominated by articles and letters), 1,479 letters, 633 reviews and other contributions (*Figure 1*). Of note, some publications were attributed to various categories (*Figure 2*). For example, 1,014 publications fall in the category "article" and "early access" at the same time. Further 670 items in the category "letter" and "early access" and interestingly 15 in the categories "early access" and "correction". 58/7,185 (0.8%) of all articles were corrections or retractions of published material. In October 25th, A total of 44,944 articles were identified on WoS with the same search term. Of these, 21,218 (47,2%) were original articles, 8,727 (19,4%) editorial material, 8,389 (18,7%) letters and 4,634 (10,3%) reviews. 342 (0.8%) articles were corrections or retractions.

The top three authors were medical journalists not affiliated with research/academic institutes, publishing news updates. These articles were listed with 44, 37, and 28 items. The fourth most present author (with 25 senior authorship positions) mostly published "letters to the editor" commenting on various medical research fields.

International collaboration in COVID-19 research

The analyses of collaborative SARS-CoV-2 and COVID-19 literature revealed a significant amount of joint publications (*Figure 3A*). The cooperation landscape for the leading countries US, UK, China and Italy are highlighted in thumbnail graphics (*Figure 3B*). For China, the US was the most common cooperation partner, followed by the UK. Italy also shared several manuscripts with the US and the UK. Here, China played a far less significant role while neighboring European countries such as France, Germany and Switzerland were frequently found in collaborative research manuscripts. Similarly, researchers from other European countries such as Spain are often co-authoring publications from Italy. The international publication behavior did not significantly change between July and October: the US, the UK, China, and Italy remained the lead nations in terms of number of publications. The extent of international collaboration has been stable (*Multimedia Appendix 5-9*). With respect to universities and institutes, the Chinese University of Hong Kong played a leading role (*Figure 4*) sharing research manuscripts with many different other institutes, both in China and foreign countries. Likewise, the Wuhan University and the Massachusetts College of Pharmacy and Health Sciences shared several national and international publications. Of note, frequently only one or two manuscripts between the respective universities were found.

Research topics

The majority of research items were published in the topic "General & Internal; Medicine" (*Figure 5*) followed by "Environmental & Occupational Health; Public", "Nuclear Medicine & Medical

Imaging; Radiology", "Infectious Diseases", "Surgery", "Otorhinolaryngology; Surgery" and

"Dermatology", respectively. Only at position 8 the topic "Virology" can be found.

Regional differences in COVID-19 research

With 1,806 research items, the United States (US) were the leading country in terms of COVID-19

related publications. Next was China (n=1,306) followed by Italy (n=856) and the UK (n=817).

Spain and France, likewise seriously affected European countries, are listed on position 9 and 11,

respectively. Focusing on first or last authorship, the patterns look very similar and the ranking of the

top countries remained unchanged. In terms of continents, Europe, North America and Asia

published a similar number of research items (*Figure 6*). According to publications in relation to

confirmed COVID-19 cases or related deaths and total population size, the US were leading with the

highest number of both COVID-19 cases as well as related publications. In Europe, Italy was one of

the leading countries. On the other hand, china had a lower number of cases compared with those in

the US with fewer deaths, though the population count was higher (*Figure 7*). *Multimedia*

Appendices 1-4 visualize institute heatmaps for four highly affected countries, analyzing their

research output separated by the number of research institutes. In Italy, Milano and Bergamo

accounted for the highest number of COVID-19 related publications (131 publications), followed by

Rome (81 publications) and Padua (78 publications), as indicated by the numbers in the heatmap in

Multimedia Appendix 1. Another highly represented region was Naples. In China, Wuhan was

leading followed by Beijing, Shanghai and Hongkong/Shenzhen (*Multimedia Appendix 2*). In the

US, the east coast (Boston, New York and Philadelphia) and California (Los Angeles and the San

Francisco Bay area) had the highest output (*Multimedia Appendix 3*). Here, generally strong

research areas that were additionally hit by COVID-19 in a substantial manner contributed to the

research output. Likewise, Detroit and Chicago were highly represented in the publication statistics.

In France, Paris had strongest research output while other French regions had no relevant manuscript

numbers published to date (***Multimedia Appendix 4***). The leading 10 institutes were Wuhan University of Technology (Wuhan, China), Università degli Studi di Milano (Milano, Italy), MCPHS University (Boston, US), The Chinese University of Hong Kong (Hong Kong, China), Fudan University (Shanghai, China), Columbia University in the City of New York (New York, US), National University of Singapore (Singapore), Singapore Management University (Singapore), University of Oxford (Oxford, UK) and Ankara University (Ankara, Turkey).

Discussion

This scientometric analysis provides profound insights into the publication landscape of SARS-CoV-2/COVID-19 research during the first months after being declared as a pandemic. Both, countries severely affected by the pandemic such as Italy and those with generally high research output such as the US contributed significantly to the literature base. There were several retractions of published articles, indicating questionable peer-review processes and flawed data integrity. International collaborations are extensive, especially in countries with high numbers of COVID-19 cases, with an obvious underrepresentation of cooperations between China and Italy.

Considering the most active authors of COVID-19 related articles, some specifics have to be mentioned. The publications by the three most active authors were not original research articles, but consisted mainly of letters. Interestingly, these journalistic articles providing news updates were indexed in WoS, PubMed and other scientific databases along with other research work. As these articles play an important role in the visualization of the scientific landscape on COVID-19, these articles were included in our analysis for a comprehensive picture. A recent study on corona virus-related research in general revealed that medical journals have speed up their publication and production process during the pandemic. Indeed, the turnover time was reduced by 49% from submission to acceptance, which was mainly driven by a decrease in the peer-review time [12]. One may speculate that this fastened review process was related to publication pressure by researchers submitting the article, but also by the journals aiming for articles with high citation likelihood, which could enhance the relative importance of a journal within its field [4]. In line, a relatively large proportion of retractions and corrections of COVID-19 related articles was identified herein, adding up to 0.8% of all published research work and was also found in high impact journals [13, 14]. A recent study on corona virus research of the last decade found a large proportion of open access articles. From 2001-2020, 59.2% of all research articles on corona virus research were provided free

of charge. This number significantly increased in 2020 to 91.4%, mostly related to research on SARS-CoV-2/COVID-19 [15]. This high percentage of open access to scientific information and open data is crucial to facilitate better and faster research towards a vaccine and inform public health measures essential to contain the spread of the virus.

Interestingly, most articles were published in the topic "General & Internal; Medicine" as opposed to the topic "Virology", ranking at position 8. This may be driven by the overall higher aggregate impact factor (IF) in the category "General & Internal; Medicine" (aggregate IF 4.386) compared with "Virology" (aggregate IF 3.731) [16], making the first mentioned journal category in general more attractive for article submissions.

Among the countries involved in COVID-19 related research, Italy plays an exceptional role. Given the population and the general research output of Italy, it is disproportionately represented. Mapping the number of COVID-19 cases or COVID-19 associated deaths to the countries, it becomes clear that Italy, as one of the most severely hit countries in Europe, also showed largest scientific output. It is worth mentioning that the regions which suffered most from the pandemic (such as Milano, Bergamo, Bologna, and Padua) had an exceptional research output. In other countries, such as France, the majority of publications originated in the capital, whereas highly affected regions by the pandemic in peripheral areas were underrepresented.

Our analysis revealed a wide global collaboration network between several publishing countries. Here, the US were dominating, sharing a significant amount of manuscripts with the UK, China, and Italy. Collaborations in medical research have been shown in other medical fields before [17]. These cooperations are often found between neighboring countries but also – as in the present case – between countries collaborating in similar research areas. It becomes obvious however, that China

and Italy being both highly affected as well as productive in terms of research efforts, lack cooperations. This analysis focused on the first wave of the COVID-19 pandemic, however in a recent second analysis, the scientific landscape in this area including international collaborations remained similar.

Limitations

It is important to mention some limitations of our scientometric study. We rely on input from WoS that is of course dependent from the input query. Efforts were made to include as many specific publications as possible and at the same time avoid false positives, along with performing cross-checks with other medical databases to ensure a comprehensive data analysis. This scientometric analysis is of quantitative but not of qualitative nature. One measure to assess the research quality would be to analyze citations but given the comparably short time in which thousands of manuscripts have been published, a reasonable analysis should be expected sometime in the future. If citation numbers grow, this will allow further analyses such as the promising modeling of productivity, total impact and how successful an author has been so far as proposed in a recent study [18]. Regarding the number of COVID-19 cases and related deaths, we relied on published data from official authorities. However, this depends on both the integrity of these self-selected numbers as well as the extent of diagnostic testing in each country. Herein, we focused on COVID-19 associated death rates, as other variables such as number of cases and hospitalizations provide only rough estimates according to the case fatality rate [19].

Conclusion

The publication landscape of SARS-CoV-2/COVID-19 is rapidly developing making it challenging to identify high quality research which substantially adds to the current knowledge. Almost 1% of the considered literature are corrections or retractions of other articles challenging the quality and integrity of the fastened review process. The high number of publications is driven by countries with a general strong research output, but also countries heavily affected by the pandemic such as Italy. In terms of international cooperation, the US are most active while China is less represented. Most obvious is an underrepresentation of joint publications between China and Italy, despite both being strongly affected by the COVID-19 pandemic with a high research output at the same time.

Funding

Conflict of interest

NG and DM made substantial contributions to the conception of the work, analyzed and interpreted the data for the work. Both drafted the manuscript.

TF and FK made substantial contributions to the acquisition of the data and revised the manuscript critically for important intellectual content.

MB gave substantial contribution to the concept of the work and revised the manuscript critically for important intellectual content.

FM and AK made substantial contributions the conception and design of the work as well as the interpretation of the data. Both revised the manuscript critically for important intellectual content.

All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

As this was no study on humans or animals, no ethical approval was required.

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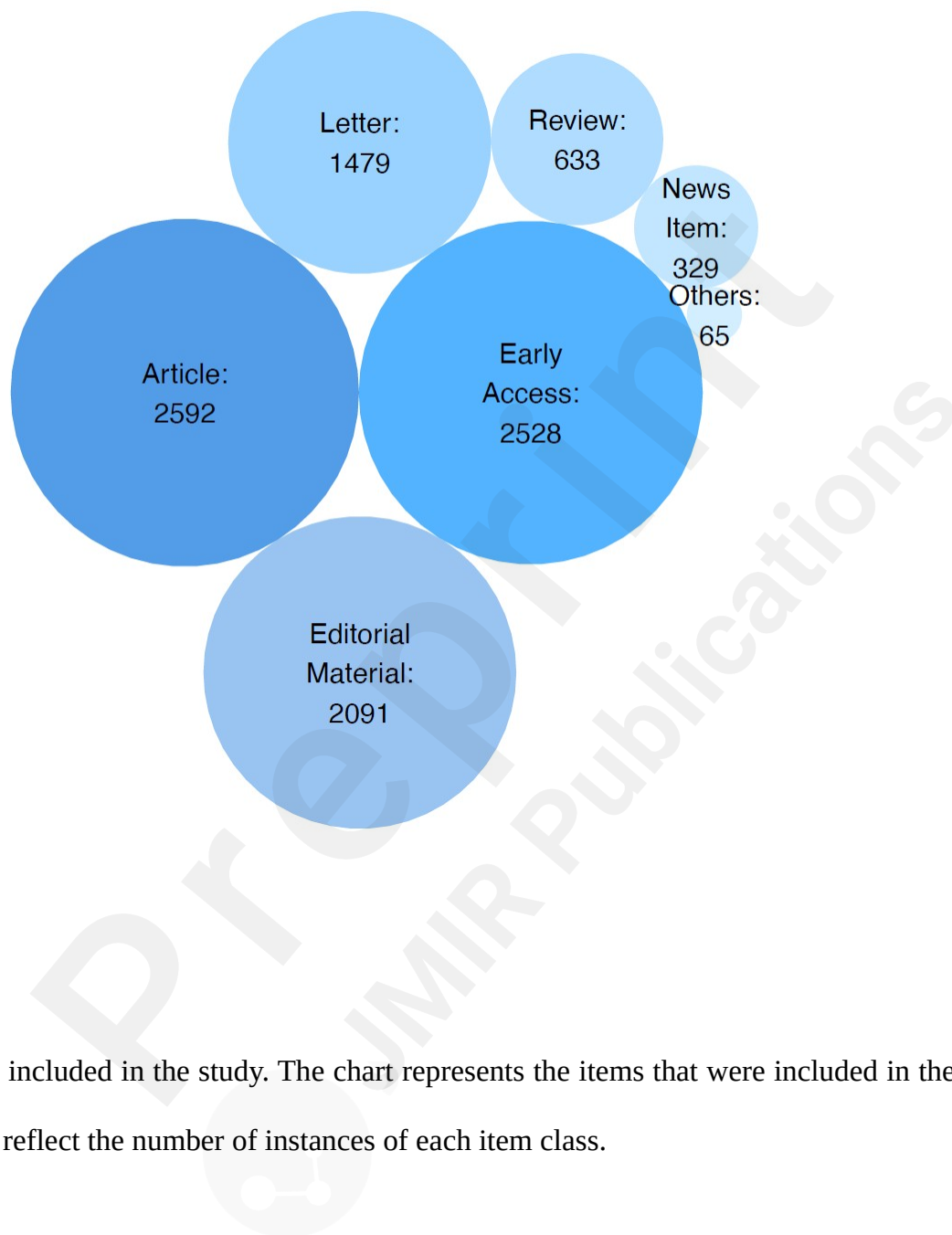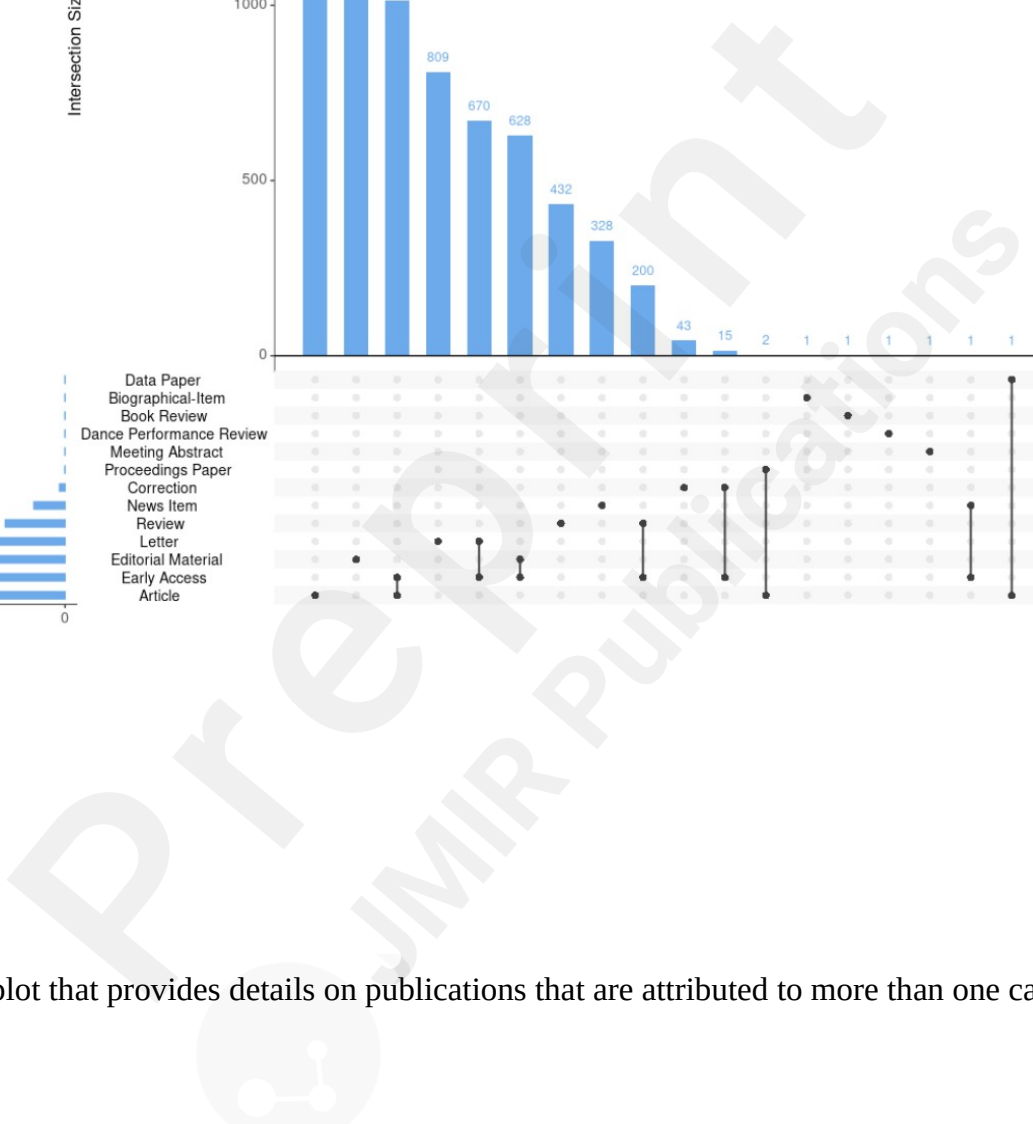
Figures

Fig. 1. Items included in the study. The chart represents the items that were included in the analysis.
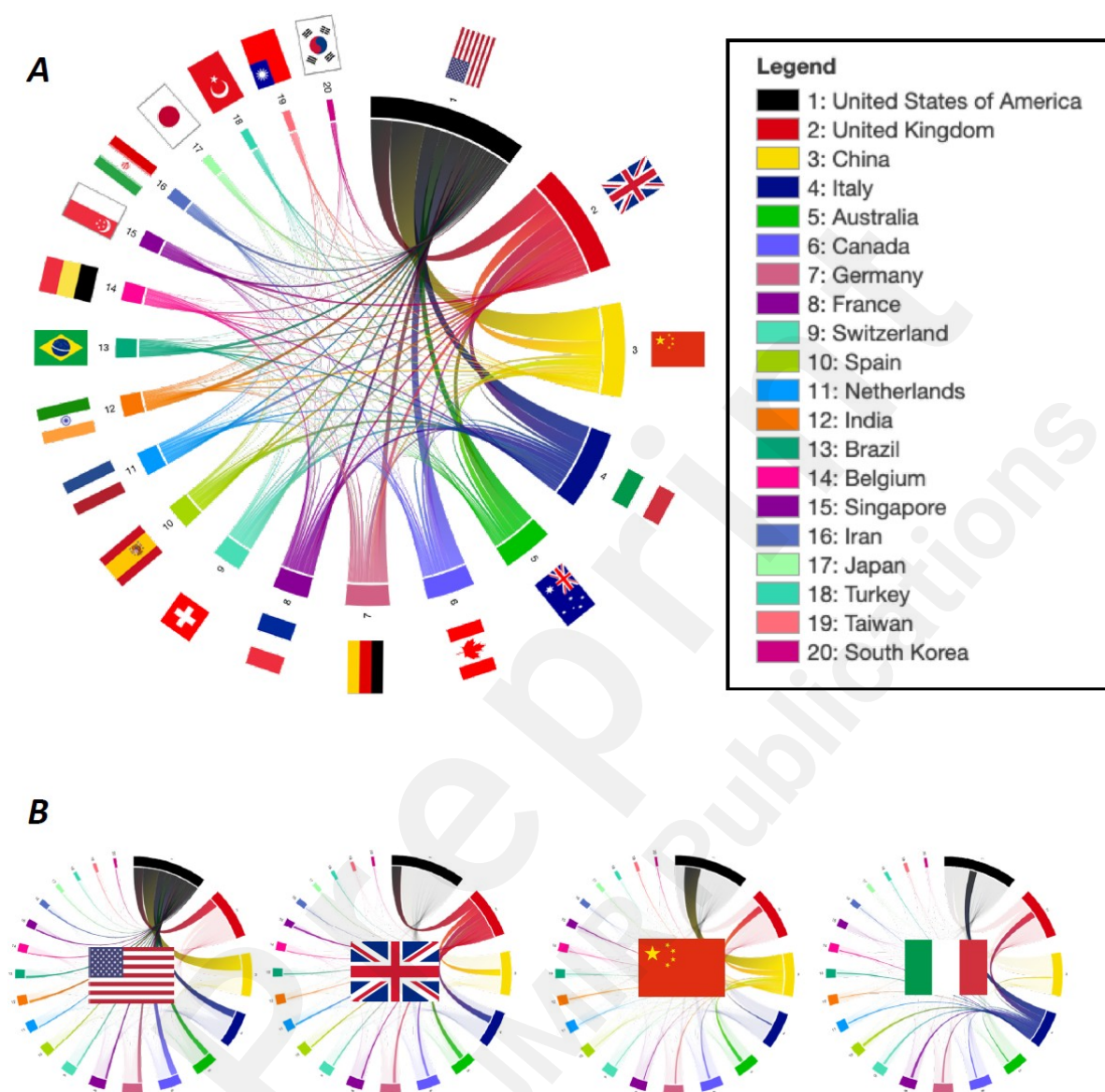
Bubble sizes reflect the number of instances of each item class.

Fig. 2. UpSet plot that provides details on publications that are attributed to more than one category.

Fig. 3A. Research collaborations identified by joint publications. Each edge corresponds to a joint publication between the connected countries. **Fig 3B**. The same diagram as in **Fig. 3A** highlighted for the leading countries USA, UK, China and Italy.
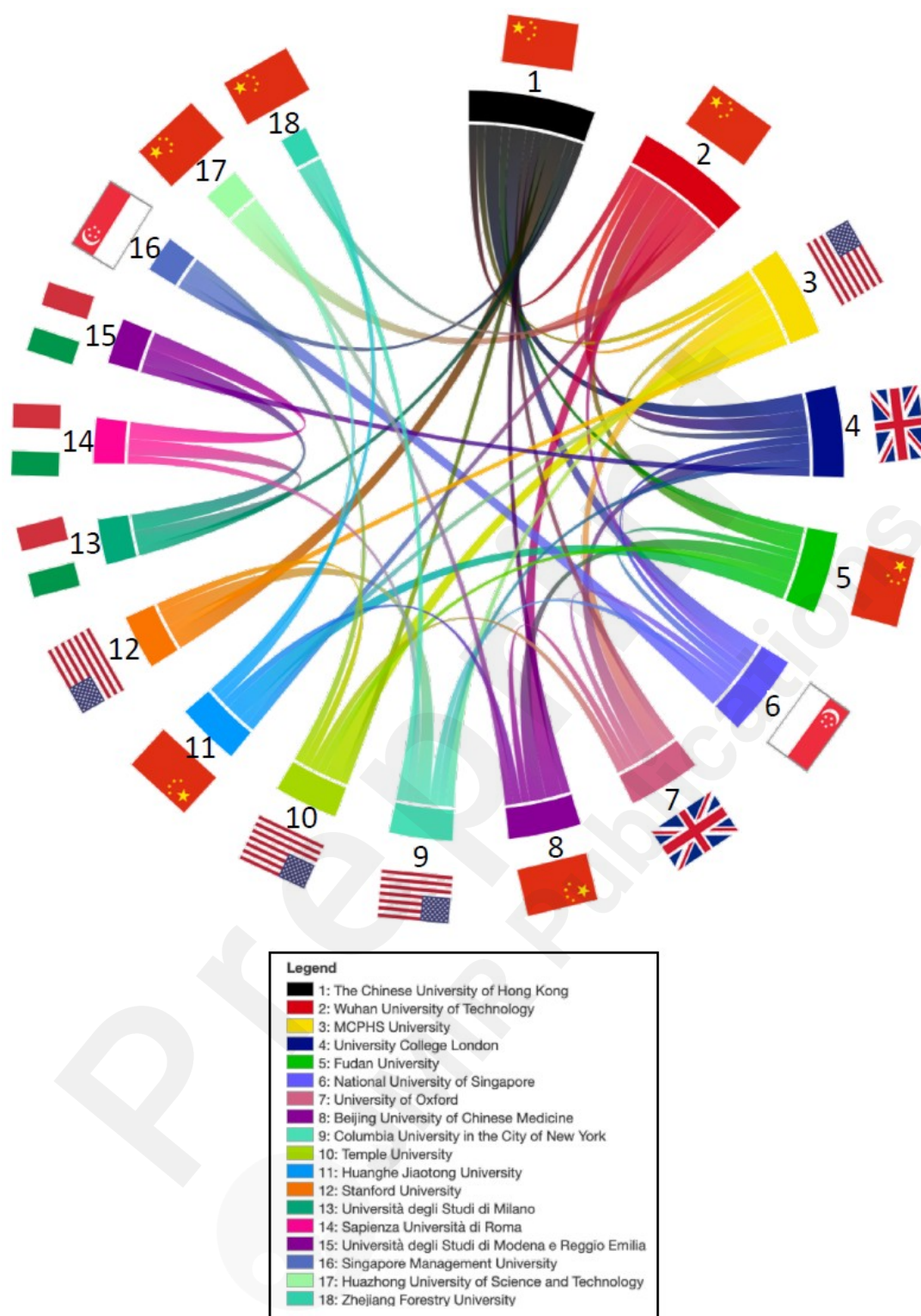
Fig. 4. The collaborative analysis applied to institutes. Each edge now connects two institutes that share a publication. The flags in the middle represent the countries where the institutes are located.
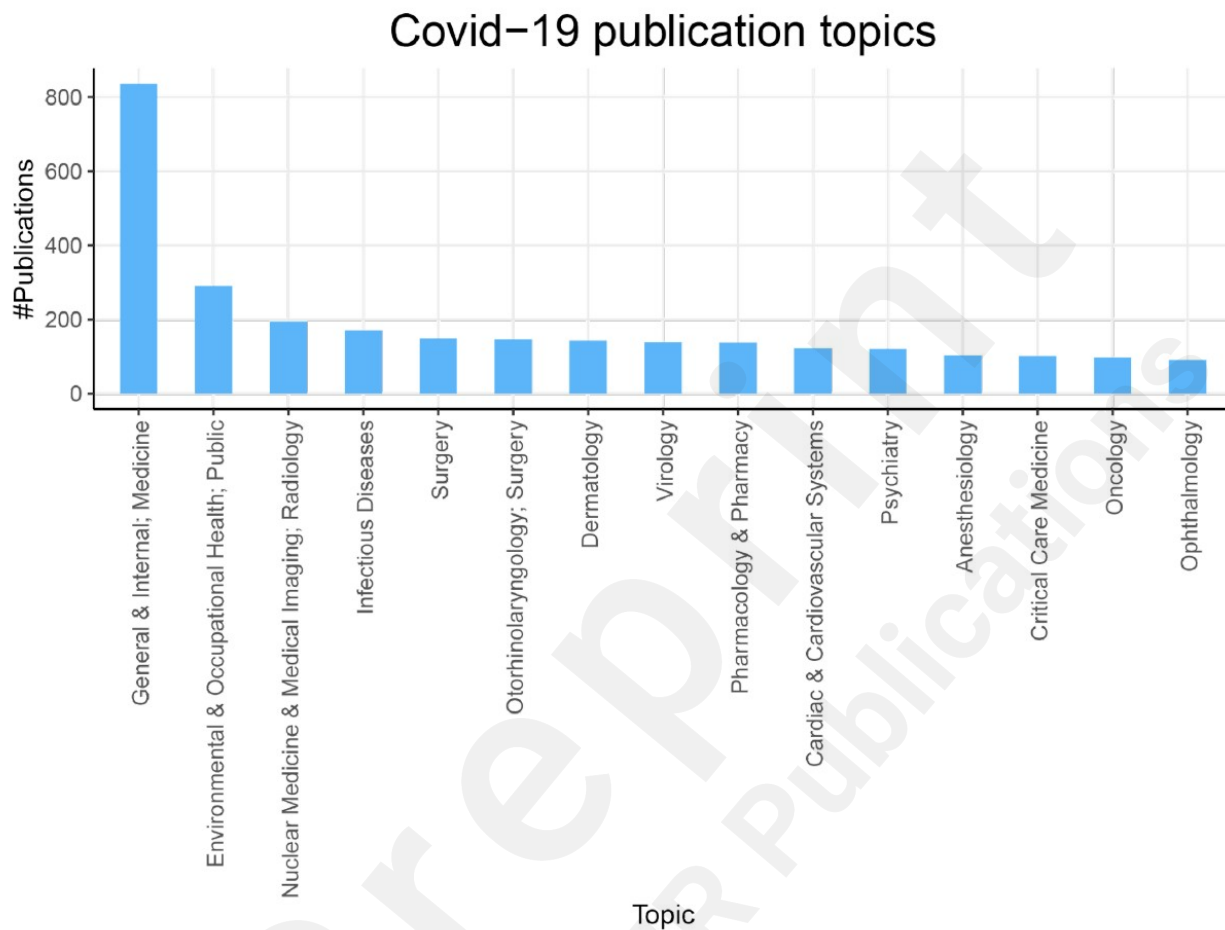
Fig. 5. Research categories of publications matched to the respective topics. Items are sorted in decreasing order.
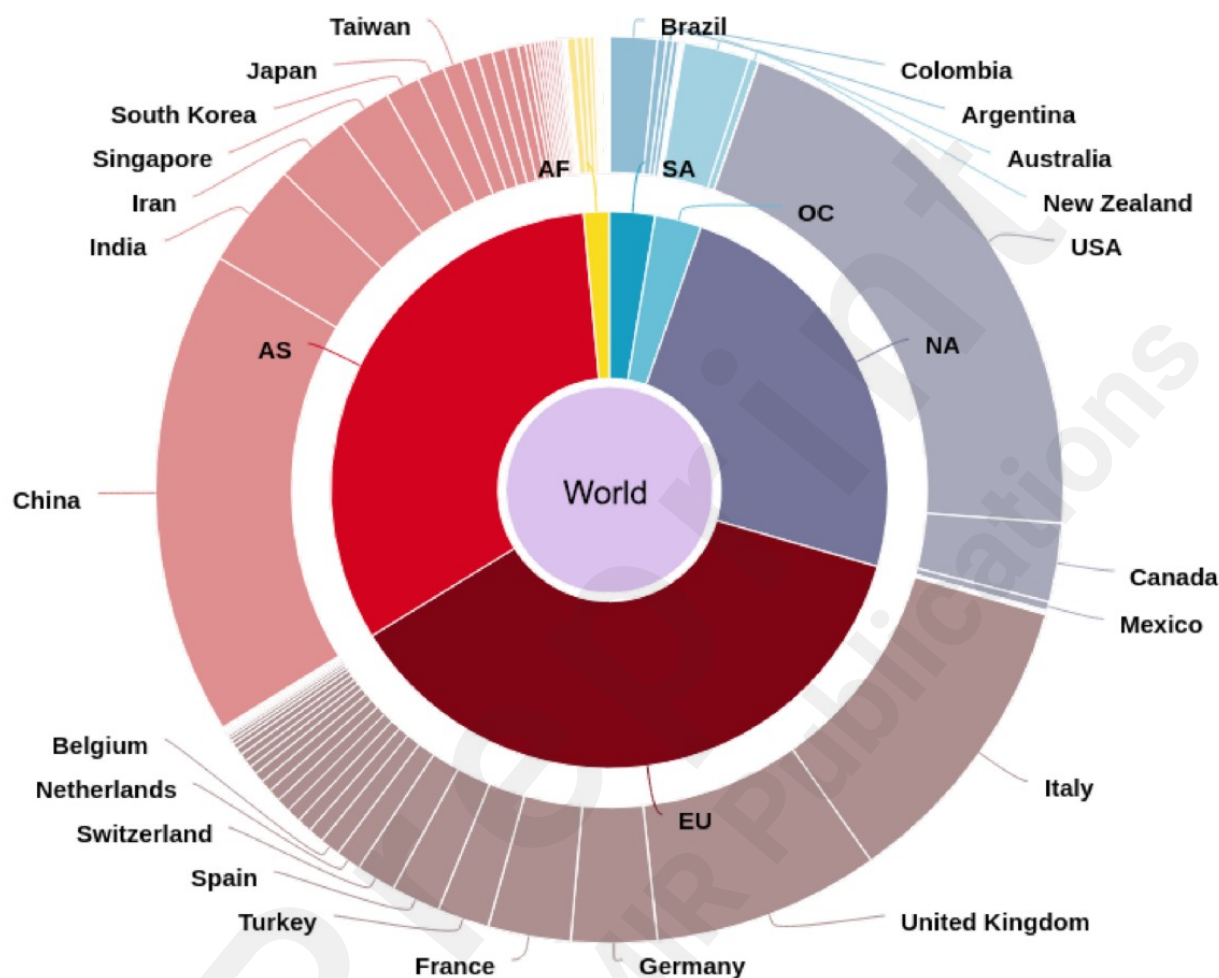
Fig. 6. Country coverage of publications. The donut chart represents the continents (AS Asia; EU Europe; NA North America; SA South America; OC Oceania; AF Africa) and the countries on the continents contributing to the publication output.
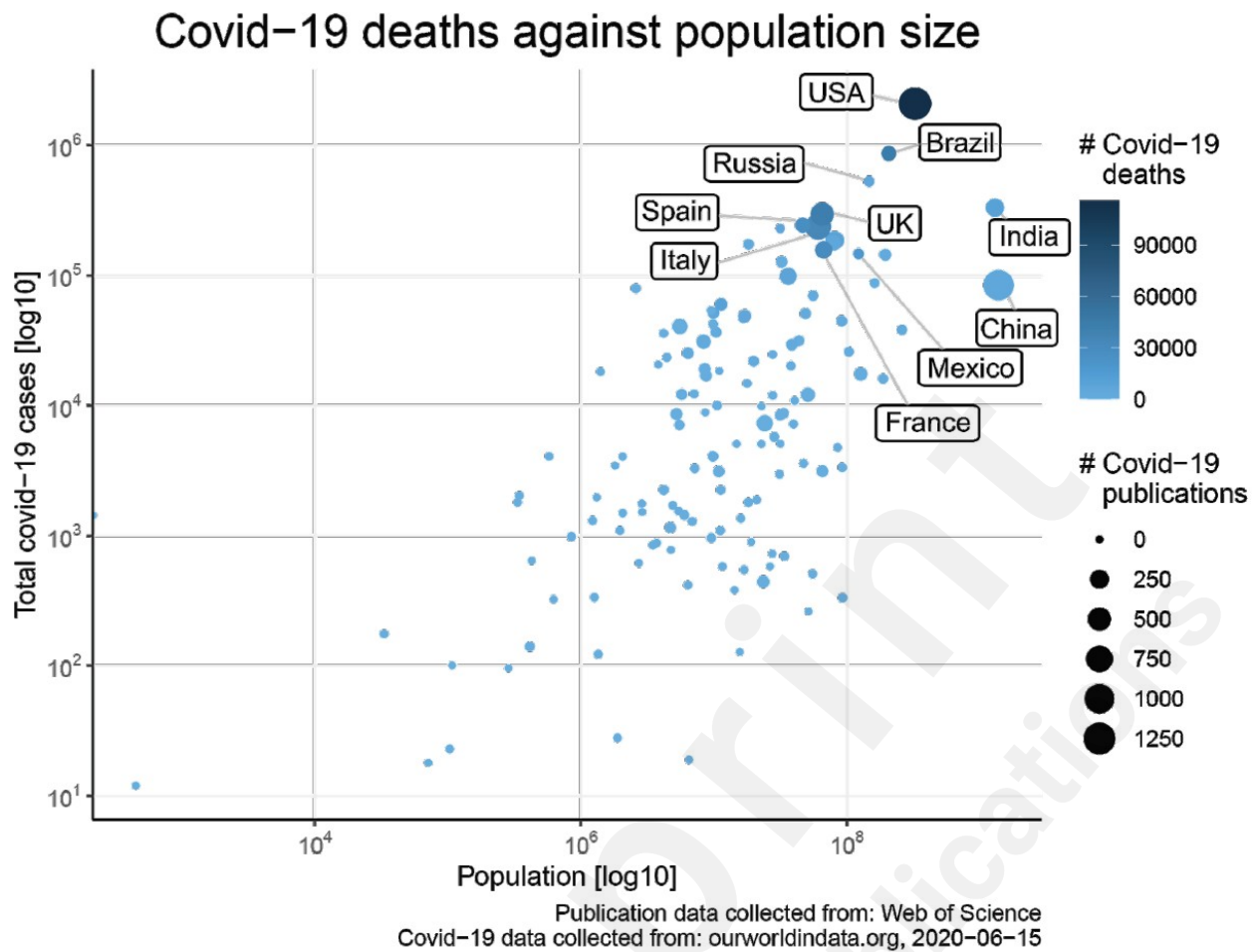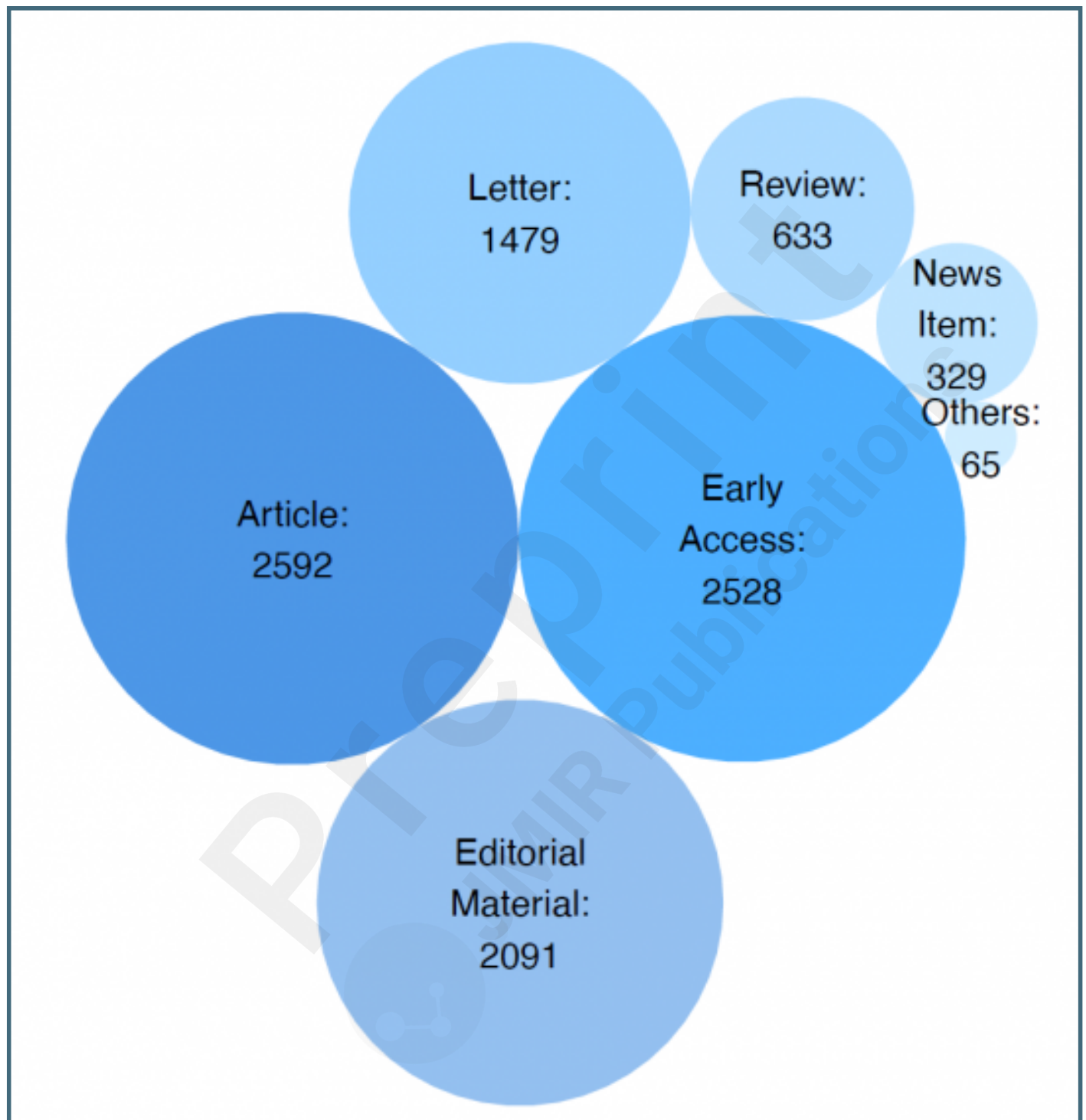
Fig. 7. Population of the countries versus the number of reported COVID-19 cases. Bubble sizes represent the number of publications; the color of the bubble represents the number of deaths. Data from ourworldindata.org.
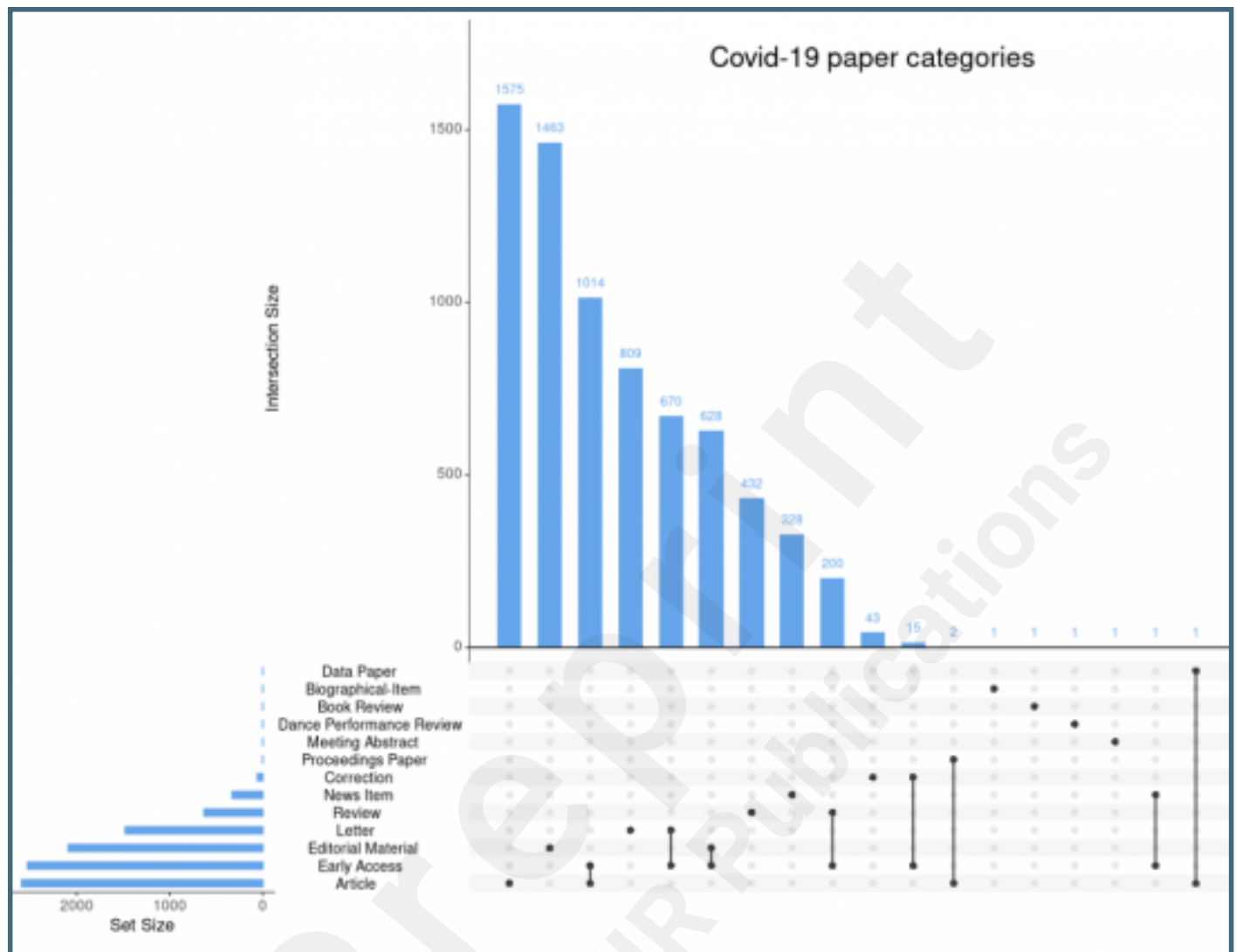
Supplementary Files

Figures

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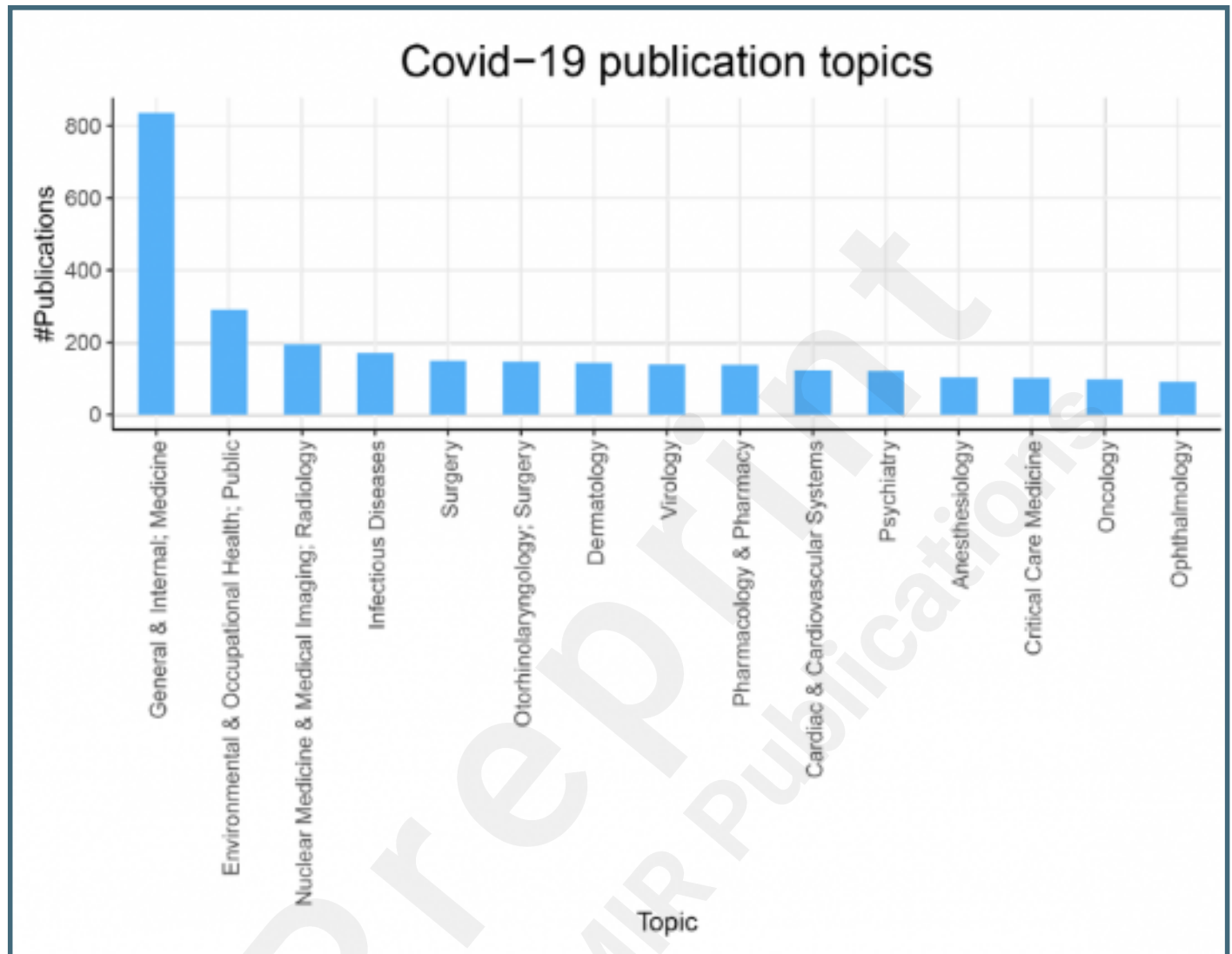

Covid-19 paper categories

Population of the countries versus the number of reported COVID-19 cases. Bubble sizes represent the number of publications; the color of the bubble represents the number of deaths. Data from ourworldindata.org.
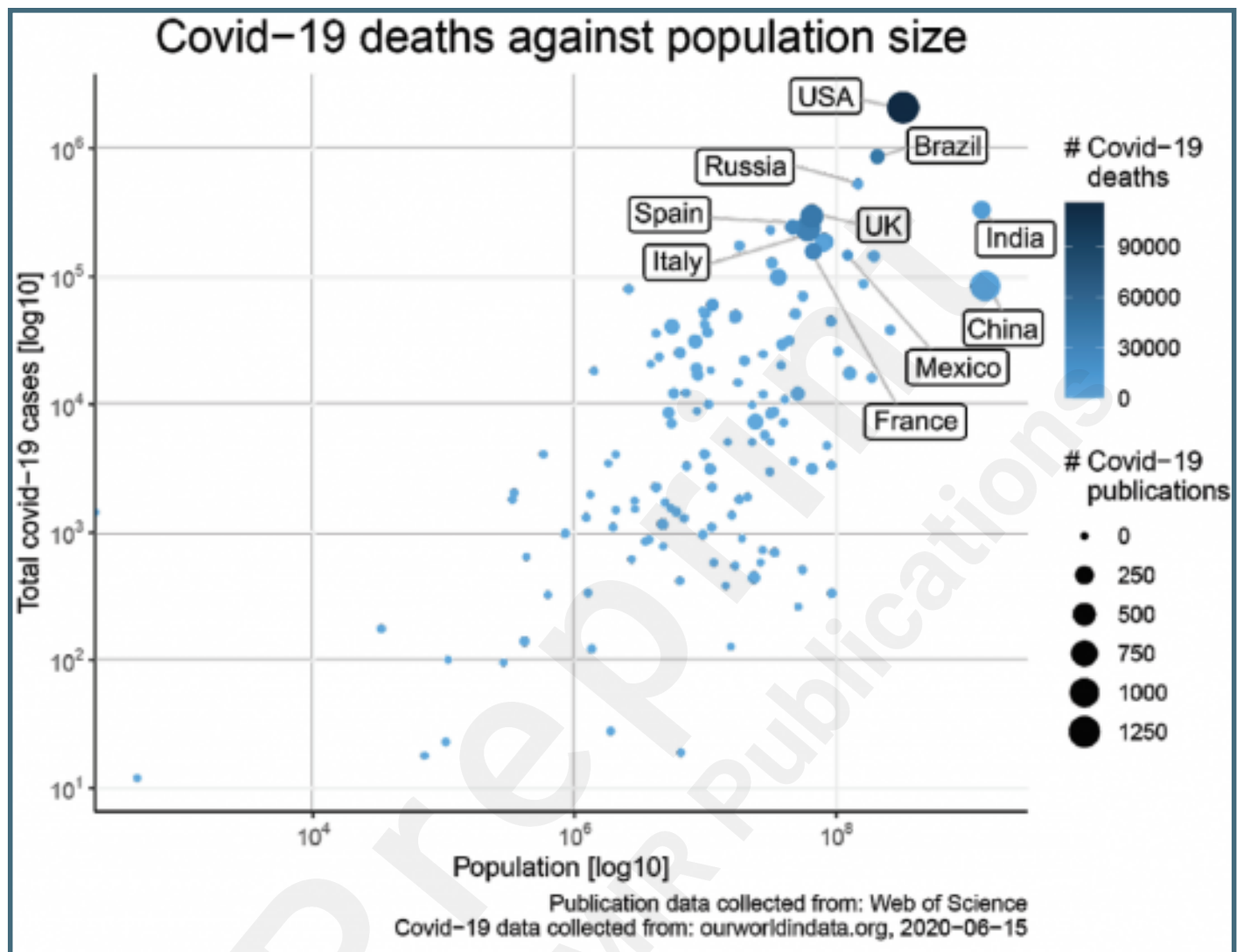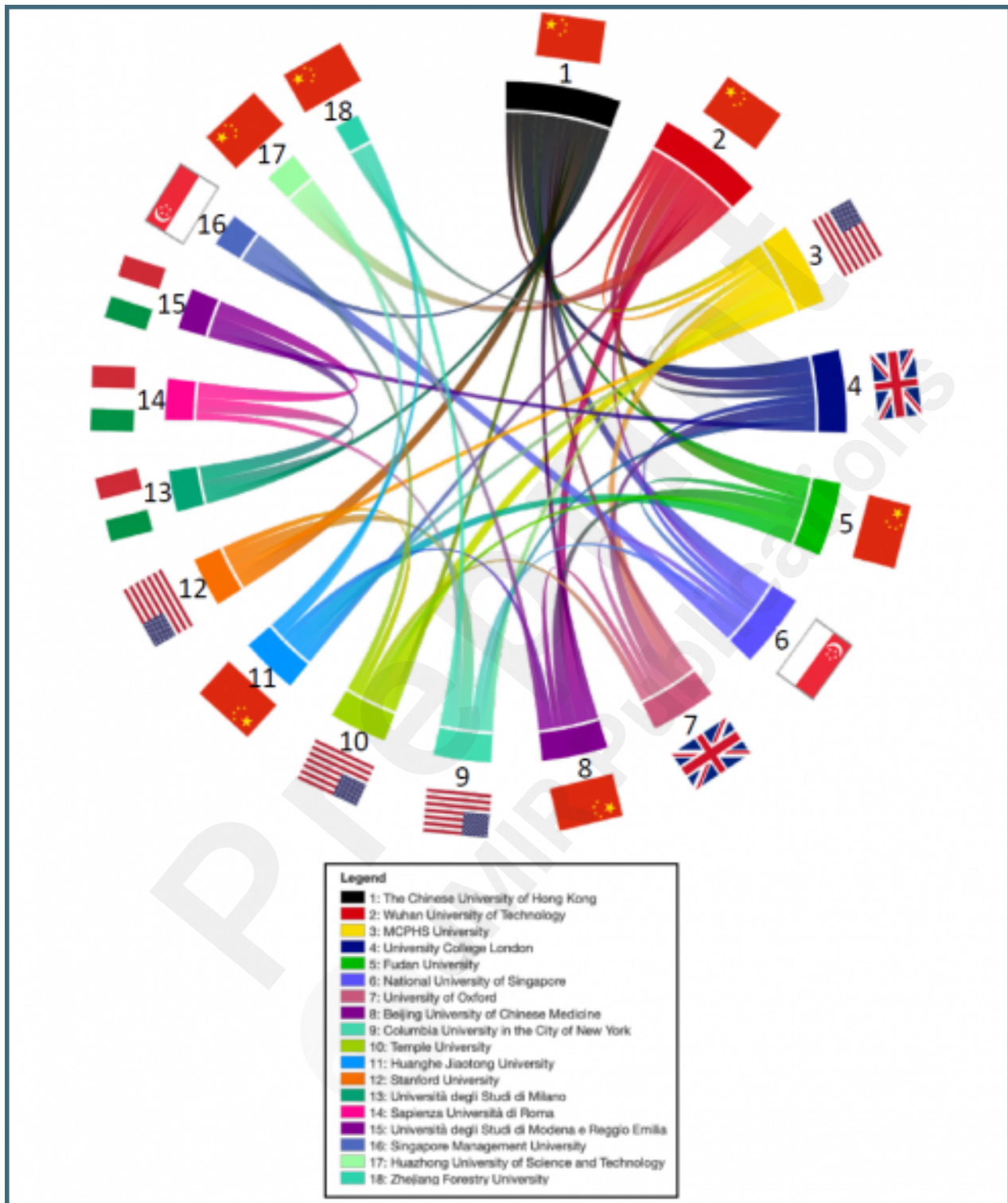
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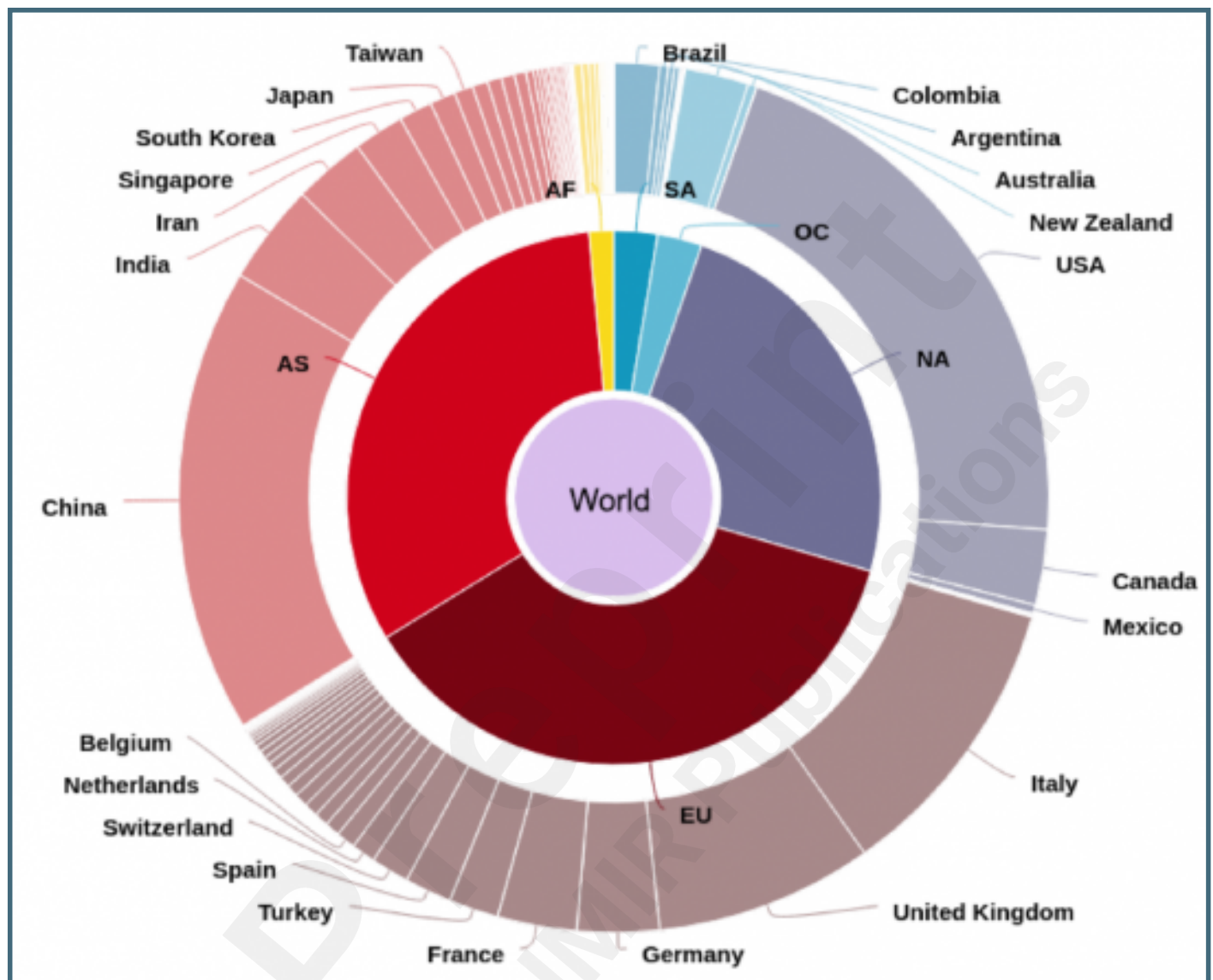
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The collaborative analysis applied to institutes. Each edge now connects two institutes that share a publication. The flags in the middle represent the countries where the institutes are located.

Legend
1: The Chinese University of Hong Kong
2: Wuhan University of Technology
3: MCPHS University
4: University College London
5: Fudan University
6: National University of Singapore
7: University of Oxford
8: Beijing University of Chinese Medicine
9: Columbia University in the City of New York
10: Temple University
11: Huanghe Jiaotong University
12: Stanford University
13: Università degli Studi di Milano
14: Sapienza Università di Roma
15: Università degli Studi di Modena e Reggio Emilia
16: Singapore Management University
17: Huazhong University of Science and Technology
18: Zhejiang Forestry University

A. Research collaborations identified by joint publications. Each edge corresponds to a joint publication between the connected countries. B. The same diagram as in A highlighted for the leading countries USA, UK, China and Italy.
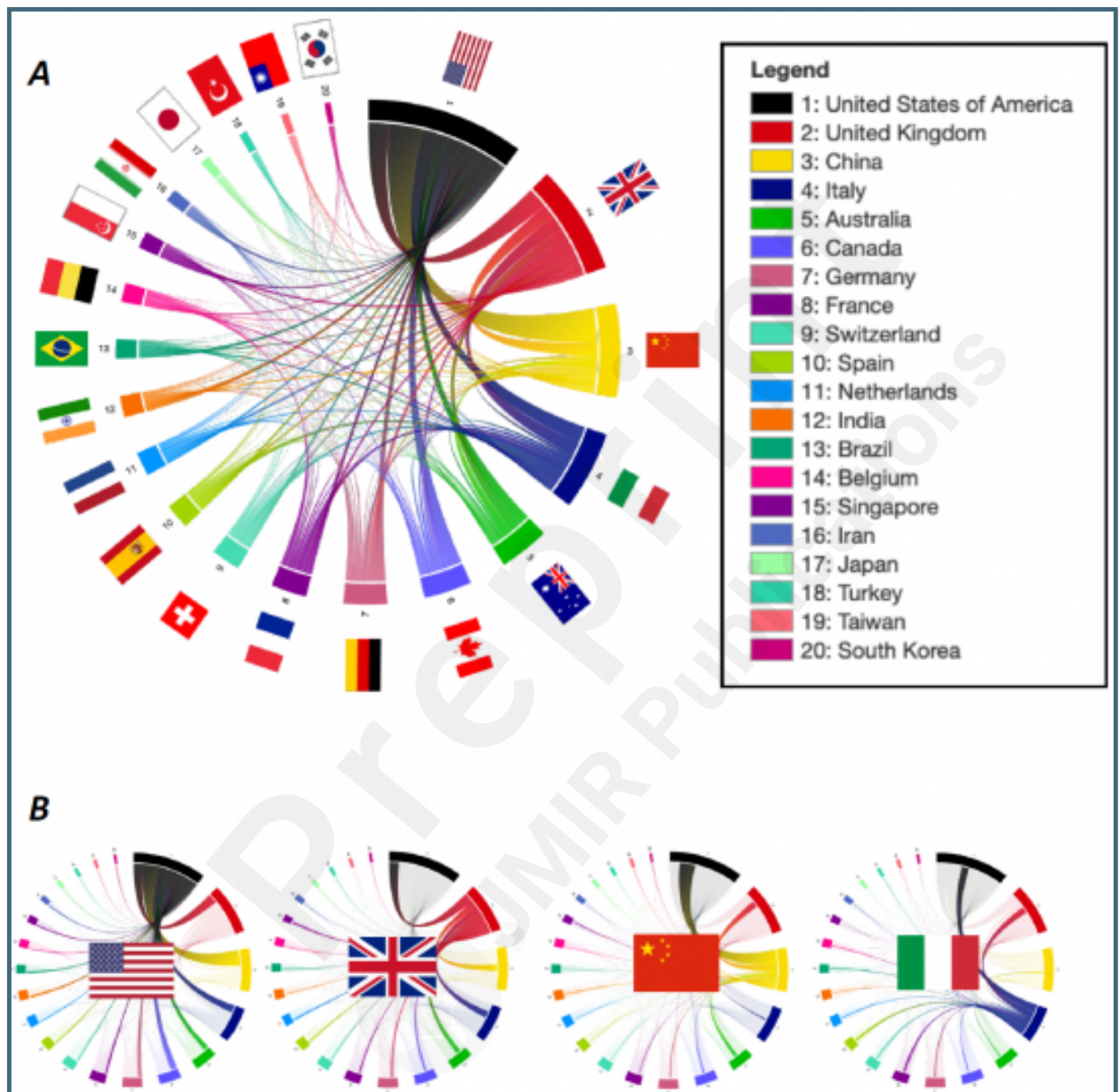
Multimedia Appendixes

Heatmap representing Italy. The numbers denote the publication count in the corresponding region and are color-coded. (Search date: June 14th 2020).
URL: https://asset.jmir.pub/assets/6764f39a3892841ee88c0afe432e2f92.png

Heatmap representing China. The numbers denote the publication count in the corresponding region and are color-coded. (Search date: June 14th 2020).
URL: https://asset.jmir.pub/assets/4c6dc85c29511d4d98d12fa73cd1192e.png

Heatmap representing France. The numbers denote the publication count in the corresponding region and are color-coded. (Search date: October 25th 2020).
URL: https://asset.jmir.pub/assets/ce6a2e7b9d1f0173179d88d8408f9b6c.png

Heatmap representing the USA. The numbers denote the publication count in the corresponding region and are color-coded. (Search date: October 25th 2020).
URL: https://asset.jmir.pub/assets/b9582ad78408298c4820decf096ead82.png

Heatmap representing China. The numbers denote the publication count in the corresponding region and are color-coded. (Search date: October 25th 2020).
URL: https://asset.jmir.pub/assets/0f2acdf34c1fcb323aca7c575e93554f.png

Heatmap representing Italy. The numbers denote the publication count in the corresponding region and are color-coded. (Search date: October 25th 2020).
URL: https://asset.jmir.pub/assets/931a94a2d9e0d97c4eabf863a736b6ed.png

Heatmap representing France. The numbers denote the publication count in the corresponding region and are color-coded. (Search date: June 14th 2020).
URL: https://asset.jmir.pub/assets/f461dcb726d17102dd7182fef2e57d6e.png

Heatmap representing the USA. The numbers denote the publication count in the corresponding region and are color-coded. (Search date: June 14th 2020).
URL: https://asset.jmir.pub/assets/d3f35a374ecb5adce9256768b252c4c3.png