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SCIENCE FIGHTS PANDEMIC: RELATIONSHIP BETWEEN COVID-19 RELATED PUBLICATIONS AND EPIDEMIOLOGICAL DATA FROM 200 COUNTRIES WORLDWIDE

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ABSTRACT. **Background:** The coronavirus disease 2019 (COVID-19) has been an unprecedented challenge for the worldwide community also in terms of the access to reliable information. In that, scientific publications have represented the only trustworthy source of information about the challenges of the pandemic and the way COVID-19 and its related infection can be defeated. This study sought to analyze the correlations between 200 worldwide country-based data about scientific publications and those concerning the impact of COVID-19 to understand whether more scientifically productive countries were able to better manage the pandemic. **Methods:** We made use of open-access, country-based data concerning the pandemic impact and compared them with the nation-based COVID-19-related scientific production. Scientific production was obtained from PubMed for papers published until April 15, 2021, whereas epidemiological data were retrieved from the OurWorldInData portal. Statistical correlations were performed by SPSS v. 23 using two-tailed Spearman's Test. After Bonferroni post-hoc analysis, $p < 0.05$ was deemed as significant. **Results:** Publications data are strongly, and positively correlated with the coronavirus cases, highlighting a greater scientific attention in those countries where COVID-19 had more impact on the population, overall. In addition, the normalized number of publications per inhabitant was negatively correlated with mortality, suggesting a possible higher treatment efficacy in those countries where health literacy was higher. **Conclusions:** Results obtained probably suggest a higher pandemic penetration in countries with a higher degree of education, where also scientific research is more largely developed, and which are also more ready to successfully treat the affected individuals.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has represented an unprecedented challenge for the global community in various aspects concerning everyday's life of entire countries around the world, including behavioral changes (Meyer *et al.* 2020), environmental variations (Barouki *et al.* 2021), as well as modifications in the wellbeing status of entire professional categories and beyond that (Bansal *et al.* 2020; Godeau *et al.* 2021). In many countries worldwide, the role of Information and Communication Technologies (ICT) was pivotal in keeping essential services operating to the benefit of the majority of citizens. As

such, ICT enabled entire working categories performing their daily tasks more or less as usual, with a massive resort to the smart- or remote-working (Marino and Capone 2021), and also driving millions of students towards the new model of "distance learning" (Camargo *et al.* 2020) , without lacking in significant consequences on their social status (Goudeau *et al.* 2021), as well as psychological and psychophysical well-being (Mheidly *et al.* 2020). Within this completely changed scenario with respect to the usual habits of entire populations, the massive spread of information played the starring role much more than occurred before the pandemic outbreak. In fact, during the pandemic, a massive "infodemic" has occurred. This overload of information has had a dual impact: from one side, it had the undoubtful merit to fight against the social isolation, particularly for those at major risk for it, including elderly individuals, patients with neurological or neurodegenerative diseases, and other categories (Roy *et al.* 2021), but from the other side it has represented a major risk for misinformation for the entire population. In fact, this phenomenon started from the production and sharing of news of different reliability and truthfulness on the Internet, mainly on the social media, often properly conceived to bias the entire population towards some ideas, often going against the scientific evidence, in turn leading to a further massive risk for pandemic waves spread throughout several worldwide countries (Mylan and Hardman 2021). To efficiently fight this phenomenon, several approaches have been followed, among which the use of Artificial Intelligence appears to be one of the most promising ones (Hayawi *et al.* 2022); however, its large scale use is far from being achieved, and the consequences of such influences on everyday's behavior of various parts of the global community are already tangible and often irreversible (Armitage 2021; Goldberg 2021). On the other side with respect to the various sources of misinformation, the scientific community has attempted to carry out its normal duties at a much faster speed than occurred before. This hurry to the spread of the most recent evidence in the scientific world led to a significant increase of the scientific production throughout the world. In particular, this last phenomenon has attempted at responding to the increasing demands for clear, evidence-based data about the pandemic spread, the infection effects and their possible treatments, by the scientists and the citizenship from any country, often representing a true "light into the dark" of this particular period, often driving most countries towards the implementation of policies to slow down the pandemic impact on the population and the health services more in general. Despite the still existing limitations about data collection and data sharing, needed to be solved in the near future (Iskander and Bianchi 2021), scientific production has therefore covered a two-fold role, representing a source of information exchange within the scientific community, as well as towards the citizenship, challenging, as much as possible, with rigor and reliability the wide amount of propaganda news and misinformation often occurring within the Internet, particularly on the social medias (Ahmed *et al.* 2020; Mheidly and Fares 2020; Orso *et al.* 2020). Beyond such pivotal role, to a broader extent, the scientific production is also capable of offering a mirror over the attention paid to the research about the COVID-19 in a given country. Reasonably, countries where the COVID-19 impact was more important within the citizenship, with more profound consequences on the daily life and the healthcare systems, would have probably paid more attention to the scientific production, trying to find a way to cope as fast and as well as possible with the pandemic-related issues. However, to the best of our knowledge, no quantitative research has been published to date, attempting to find a relationship between the scientific production and the impact of the pandemic on

the different countries of the world. Therefore, in the present article, we tried to fill in this scientific knowledge gap by means of a quantitative analysis of open source, web-based data concerning the pandemic and the scientific production in all the countries of the world, in order to seek for eventually existing relationships between the two, at the same time keeping the investigation and the methodology simple, repeatable and understandable by the broader audience, also made up of the general public.

2. Materials and methods

Under such premises, the work presented here made use of open source, easy-to-retrieve data (Ritchie *et al.* 2020) concerning the pandemic impact throughout the various countries of the world (*i.e.*, cases, cases per million inhabitants, deaths, deaths per million inhabitants, mortality, calculated as the ratio between deaths and cases) and compared them with the COVID-19-related scientific production. In order to understand the impact of the first pandemic year, where pandemic represented a complete novelty for the global and scientific community, as well as for the governments, the data concerning COVID-19 epidemiological impact, as well as the related scientific production, were collected up to April 15th, 2021. More specifically, data about the scientific production was obtained by searching the PubMed database for papers published until the aforementioned date, according to the following string: ("covid-19" or "coronavirus" or "covid" or "sars-cov-2" or "sars-cov2") and ("COUNTRY" [LocationID]). Research shared between countries were considered for each country separately. Such referenced data were considered as both the overall number of papers published dealing with COVID-19 and considering a given country, and its ratio per million inhabitants of the selected country. From the statistical analysis point of view, for the present study, in order to keep such analysis easily replicable and intellegible by the scientific community and the global public at large, data correlations were performed by SPSS v.23 (IBM Corporation, Armonk, NY, USA) using a two-tailed Spearman's Test. Because of the presence of non-normal data distribution throughout the dataset. This choice would allow exploring the direction of the correlation eventually retrieved between the variables compared. In order to control for false positive responses, therefore conveying possibly misleading information, we decided to keep the investigation as much conservative as possible. Therefore, for the correlation analysis, Bonferroni post-hoc test was applied to the results to retrieve reliable, robust significant results, considered to be those with $p < 0.05$.

3. Results

As reported before, the analysis conducted attempted at finding correlations between the epidemiological data and the records of the scientific literature extracted from PubMed. Data were retrieved from 200 countries in the world, located throughout the six continents. As such, in order to give an overview of the results obtained at a glance, the outputs from the correlation analysis, including the r and p-values, are displayed, already processed according to the Bonferroni's post-hoc Test, in Table 1.

Concerning the data retrieved, apart from the obvious relationships concerned with epidemiological data within each other (*e.g.*, cases *vs*. deaths) or between original and normalized parameters, it comes to the eye that data concerning scientific publications are significantly (and positively) correlated with the epidemiological data, taking into account

TABLE 1. Correlation analysis between publications (pubs.) and COVID-19 epidemiological data (**: $p < 0.01$, *: $p < 0.05$, after Bonferroni post-hoc correction).

	Cases	Cases per 1M	Deaths	Deaths per 1M	Mortality	Pubs.	Pubs. per 1M
Cases	–	$\rho = 0.571$ $p < 0.001$**	$\rho = 0.960$ $p < 0.001$**	$\rho = 0.629$ $p < 0.001$**	$\rho = 0.289$ $p < 0.001$**	$\rho = 0.735$ $p < 0.001$**	$\rho = 0.066$ $p = 0.355$
Cases per 1M		–	$\rho = 0.513$ $p < 0.001$**	$\rho = 0.896$ $p < 0.001$**	$\rho = 0.040$ $p = 0.574$	$\rho = 0.204$ $p = 0.004$*	$\rho = 0.491$ $p < 0.001$**
Deaths			–	$\rho = 0.660$ $p < 0.001$**	$\rho = 0.512$ $p < 0.001$**	$\rho = 0.702$ $p < 0.001$**	$\rho = -0.010$ $p = 0.891$*
Deaths per 1M				–	$\rho = 0.374$ $p = 0.001$**	$\rho = -0.263$ $p = 0.001$**	$\rho = 0.368$ $p < 0.001$**
Mortality					–	$\rho = 0.188$ $p < 0.008$*	$\rho = -0.242$ $p = 0.001$**
Pubs.						–	$\rho = 0.314$ $p < 0.001$**

both their absolute values, as well as their normalized counterparts. In particular, both the number of publications and its ratio per inhabitants are strongly correlated both to the original or normalized number of cases and to the number of victims in a given country respectively. More specifically, the largest correlation values were found with the number of cases than with the number of victims, probably because of the latter being a more indirect estimate of the pandemic burden within a territory. In fact, the latter relies with more complex phenomena affecting the impact of pandemic in a given country, including socio-economic aspects, the quality level of national healthcare systems, the clinical readiness to the healthcare treatment of a given nation and so forth. The same analysis was carried out also after splitting the countries into four classes according to their GDP Per Capita level in order to understand the eventual presence of different dynamics depending on the economic status of the countries evaluated. Among the countries with the highest values of the GDP Per Capita, direct correlations remain significant between cases and number of publications ($\rho = 0.554, p < 0.001$) and between their per inhabitant counterparts ($\rho = 0.402, p = 0.001$). Concerning victims, significant correlations remained only between total deaths and overall number of publications ($\rho = 0.607, p < 0.001$), whereas the significance was lost, after Bonferroni's post-hoc for their respective normalized values. Finally, as occurring with the global analysis, mortality remained negatively correlated with the number of publications per inhabitants ($\rho = -0.436, p < 0.001$). Concerning the middle-high income countries, significance remained concerning the relationships between number of cases and number of publications ($\rho = 0.703, p < 0.001$), the latter being also related to the number of victims in the country ($\rho = 0.697, p < 0.001$). Same relationships were seen when taking into account middle-low income countries, with the statistical values

slightly changed ($\rho = 0.783, p < 0.001$ for correlations between publications and cases, $\rho = 0.813, p < 0.001$ between publications and victims). Finally, poorer countries displayed the same significant relationships as the two former groups, with values slightly modified ($\rho = 0.711, p < 0.001, \rho = 0.683, p < 0.001$ for correlations between publications and cases and between publications and victims, respectively), see supplementary file.

4. Discussion

This simple statistical analysis of data coming from 200 worldwide countries enabled drawing some significant considerations about the attention drawn by the COVID-19 on the scientific community and its relationship with the impact of the pandemic spread on the civil society. The number of scientific publications a country is involved into is strongly related to the overall number of cases and deaths within its territory, as already seen partially when just European countries were previously analyzed (Tonacci *et al.* 2021). However, this trend is much more pronounced when taking into account all the 200 countries, and apparently independent from the economic level of the territory analyzed. Indeed, such findings were retrieved for all the groups in which the worldwide countries were divided regardless of their GDP Per Capita. The only big difference observed throughout the groups concerns the relationship between publications (per inhabitant) and mortality, where the countries belonging to "Group 1", *i.e.*, the wealthiest ones, reported a negative correlation between the two variables, relationship not observed in the other study groups. This could be due to the higher healthcare services levels in those countries, with better economic status, where the scientific production is also higher. This extends to a country-based rationale, possibly more related to the overall quality of the healthcare services, what was already observed among single individuals, in this case more focused on the access to care services with an adequate qualitative level, that is to say higher COVID-19-related fatalities for those with lower education levels and, to a much larger extent, worse socio-economic status (see Fig. 1) (Hawkins *et al.* 2020; Cifuentes-Faura 2021).

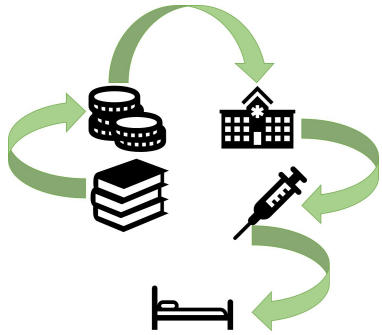

FIGURE 1. Hypothetical scenario about the relationship between scientific publications and COVID-19 impact worldwide. Higher ratio of scientific publications could be related to higher socio-economic status of a country, in turn leading to better healthcare services and access care, leading to a reduced mortality due to COVID-19 in the country.

The data presented here were purposely tailored to investigate the dynamics of the relationship between scientific publications and pandemic impact in the very first phase of the COVID-19 spread worldwide. In order to study the longitudinal trend of the virus circulation throughout the globe, taking into account not only the first waves, but also the following ones, more complex relationships and models should be adopted. Such models should consider social distancing and control policies (VoPham *et al.* 2020; Tran *et al.* 2021), as well as the impact of different types of vaccines administered in different timing and dosage, depending on the country investigated (Lopez Bernal *et al.* 2021).

5. Conclusions

Taken together with previously published data concerning the ways COVID-19 has been spreading worldwide, such results probably suggest a higher pandemic penetration in countries with a higher degree of education, where also scientific research is more largely developed, and where other determinants, including indoor social interactions, urban population concentrations, travels, and so forth, could have represented further risk factors to be taken into account (Gangemi *et al.* 2020). Interestingly, the relationship between the pubblications per inhabitant and the COVID-19 mortality was negative, particularly in wealthier countries. This might occur because of the increased success in treating the infection in countries where the higher scientific awareness, matched by the number of scientific publications per inhabitant, possibly linked to higher clinical knowledge and readiness about the pandemic, is present. Despite the methodological limitations of the present research, the results obtained suggest that, although a higher penetration of the COVID-19 diffusion is highlighted within those countries with higher scientific production, likely to be those where more indoor social interactions, travels abroad and other risky behaviors are present, the importance of scientific awareness can be pivotal in successfully challenging more dramatic consequences of the SARS-CoV-2 infection. Still pointing out that a simple correlation analysis does not imply consequentiality between phenomena, future works should attempt at demonstrating the effectiveness, in terms of cases and deaths reduction, achieved by the early attention and the valuable scientific production paid to reliably challenge the pandemic. Such results would find their application both to successfully challenge the persisting COVID-19 pandemic worldwide, or to avoid future contagion waves, as well as for future pandemic and similarly challenging global events where the reliable knowledge of the scientific aspects of the event, and of the ways it could be properly faced will be essential for the good success of the policies eventually established.

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