Original Article

Investigating the evolution of COVID-19 research trends and collaborations in Southeast Asia: A bibliometric analysis

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A B S T R A C T

Background and aims: The publications on COVID-19 have tremendously increased. Thus, there is a need to summarize and curate this evidence from the literature. This study determined the characteristics and trends of published articles about COVID-19 in Southeast Asia (SEA) through a bibliometric analysis.
Methods: A systematic review of literature on COVID-19 in SEA countries was performed using the Scopus database from 2020 to August 2021. Bibliometric information was obtained from Scopus and network visualization was conducted using VOSviewer software.
Results: A total of 706 articles were obtained in this study. The number of publications increased exponentially from 2020 up to present. Most of the research outputs were produced by authors and institutions from Malaysia, Singapore, and Thailand. The other countries with highest cases of COVID-19 in SEA such as Indonesia and Philippines have lower scientific output in this field. GDP, research and development expenditure, number of researchers and physicians, and international collaborations were significantly correlated to research productivity in COVID-19 in SEA.
Conclusion: This study showed the trends and gaps for research in SEA and the facilitators of research productivity in COVID-19. SEA countries should consider increasing the support for COVID-19 research to generate knowledge that can be used in controlling COVID-19 in the region.

1. Introduction

Coronavirus disease 2019 (COVID-19) is a viral infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. COVID-19 has greatly affected countries in Southeast Asia (SEA). SEA remains the third most affected WHO Region with more than 41 million COVID-19 cases and 641,874 total reported deaths at the time of writing [2]. The region has been considered an emerging hotspot for COVID-19 due to the increasing number of cases and community transmission of three known variants of concern: B.1.1.7 (Alpha), B.1.351 (Beta), and B.1.617.2 (Delta) [3,4]. These numbers are expected to continue to increase due to the movement of workers between countries and limited vaccine rollout. However, little information about this crisis is seen in the media and global medical and scientific community [4].

One important strategy to curb this pandemic is to conduct more research to understand the epidemiology of COVID-19 and develop preventive and therapeutic strategies against it. Since COVID-19 pandemic started, there has been a tremendous increased in research outputs regarding this topic. Hence, there is a need to assess the current research trends in this field so we can identify important areas and gaps for future research on COVID-19 in SEA. Bibliometric analysis can be used to curate and summarize the evidence from COVID-19 publications [5]. Bibliometric analysis has been used to provide insights on the current research trends and gaps in viral outbreaks including COVID-19 [6–9]. Currently, there is still no comprehensive evaluation of existing research on COVID-19 in SEA. Thus, this research aimed to determine the characteristics and trends of published articles in COVID-19 through a bibliometric analysis. This research also identified factors that contribute to research productivity in COVID-19 in SEA.

2. Methods

2.1. Study selection

A systematic review of literature was performed using the Scopus database. The search terms (covid OR "COVID 19" OR covid-19 OR covid19 OR "2019 nCoV" OR 2019-ncov OR "SARS

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Coronavirus 2" OR sars-cov-2 OR 2019 novel AND coronavirus) were used and searched for in the title field. The search was limited to articles from SEA countries published from January 1, 2020 to August 31, 2021. All electronic searches were performed on August 31, 2021.

2.2. Data collection

A total of 702 articles were obtained from our search in Scopus database. The following information was obtained for each article: authors, year of publication, title, journal, institution, country, title, keywords, and citation frequency.

2.3. Statistical analysis

Correlations between country-specific characteristics with the different bibliometric indices were determined using Spearman's rank-order correlation. The information on the population, gross domestic product (GDP), and GDP per capita were obtained from the International Monetary Fund (IMF) website [10]. The research and development expenditure (%GDP), maternal mortality ratio (MMR), neonatal mortality ratio (NMR), physician-to-population ratio, and researcher-to-population ratio were obtained from the World Bank [11]. The total number of cases of COVID-19 per country was obtained from Worldometer last 7 September 2021 [12]. The Spearman's correlation coefficient (r) was considered significant if p-value was less than 0.05. This statistical analysis was done using GraphPad Prism software version 7 (GraphPad Software, San Diego, CA). The visualization of collaboration networks of countries and keywords related to GDM in SEA was conducted using VOSviewer version 1.6.16 (Leiden University, Leiden, Netherlands) [13].

3. Results

3.1. COVID-19 publications by country

In less than two years since the declaration of COVID-19 as a global pandemic, there were already a total of 706 COVID-19 articles conducted in SEA or published by authors from SEA were obtained from Scopus database. These publications were from ten countries in SEA. Fig. 1A shows the top countries that published research in COVID-19. Malaysia published the greatest number of research articles in COVID-19 (231 publications) while Singapore had the highest impact as shown by the *h*-index of 33 and total citations of 6993. There were few publications (<10 research published) on COVID-19 from Brunei Darussalam, Myanmar, Cambodia, and Laos. No COVID-19 research articles were obtained from Timor Leste.

SEA countries had a lot of collaborative research with other countries within and outside SEA. Malaysia had the greatest number of collaborations with other SEA countries (collaboration with seven countries), followed by Indonesia and Singapore (collaboration with six countries). Laos had no collaborations with other SEA countries (Fig. 1B). In terms of international collaborations outside SEA, Malaysia still had the highest number of country collaboration (58 countries), followed by Thailand (53 countries), and Singapore (52 countries) (Fig. 1C).

The number of single country and multiple country publications for COVID-19 in SEA was also documented. There was an increase in the percentage of multiple country publications in 2021 (58.61%) compared to 2020 (51.63%) (Supplementary Fig. 1).

3.2. COVID-19 publications by institution

To determine the top institutions that published COVID-19 research, the number of publications, citations, and h-index per institution were analyzed. Fig. 2 shows the top 10 institutions with the highest ranking of productivity. National University of Singapore had the highest productivity (80 publications) and impact (4107 citations and *h*-index of 21) for COVID-19 research. Six institutions were based in Singapore and two institutions each were based in Malaysia and Thailand.

3.3. COVID-19 publications by author

The researchers with the greatest number COVID-19 publications in SEA and total citations was "Harapan, H" with seven publications and 461 total citations. Six researchers were based in Malaysia. Two researchers were based in Singapore and one author each were based in Indonesia and Thailand (Supplementary Fig. 2).

3.4. COVID-19 publications by journal

The top journals that published COVID-19 research in SEA were presented in Fig. 3. Out of a total of 147 journals, *Frontiers in Public Health* (impact factor: 3.709) published the highest number of papers (10 publications). The *Science of the Total Environment* (impact factor: 7.963) only published six COVID-19 publications but received 266 total citations. The *Annals of the Academy of Medicine Singapore* (impact factor: 2.473), based in Singapore, was the only local journal included in top 10 journals that published the greatest number of COVID-19 research in SEA. Moreover, the journals were classified based on their publishing models. Most of the COVID-19 articles from SEA were published in open access journals (69.66%), followed by standard subscription-based journals (24.5%), and lastly hybrid open access journals (5.84%).

3.5. Keyword visualization

Keyword co-occurrence was performed to determine the research hotspots in COVID-19 in SEA (Fig. 4). The size of the circles represented the frequency of occurrence of keywords. Circles with the same color belonged to the same topic cluster among all COVID-19 publications in SEA. The most frequently used keywords include humans and coronavirus disease 2019. The keywords network showed four distinct clusters representing different areas of research in COVID-19. The keywords included in the blue cluster represents the symptomatology of COVID-19. Some of the keywords in this cluster included dyspnea, fever, coughing, aged, risk factors, and clinical features. The keywords included in the red cluster represents the pathophysiology and treatment of COVID-19. The keywords related to the pathophysiology of COVID-19 include angiotensin converting enzyme, sars-cov-2, virus rna, virus replication, coronavirus spike glycoprotein, and virus replication while the keyword related to COVID-19 treatment included remdesivir, hydroxychloroquine, favipravir, azithromycin, and drug effect. The green cluster represented the keywords related to the epidemiology and public health aspects of COVID-19. The keywords included pandemic, infection prevention, practice guideline, disease transmission, infection control, and public health. The yellow cluster included general terms such as coronaviruses, viruses, diseases, disease control, and world health organization.

3.6. COVID-19 publications by subject area

The distribution of COVID-19 publications studies in SEA based on the subject area was presented in Supplementary Fig. 3. As expected, majority of the articles were related to clinical medicine (31.88), followed by biochemistry, genetics, and molecular biology (7.52%), immunology and microbiology (5.38%), engineering
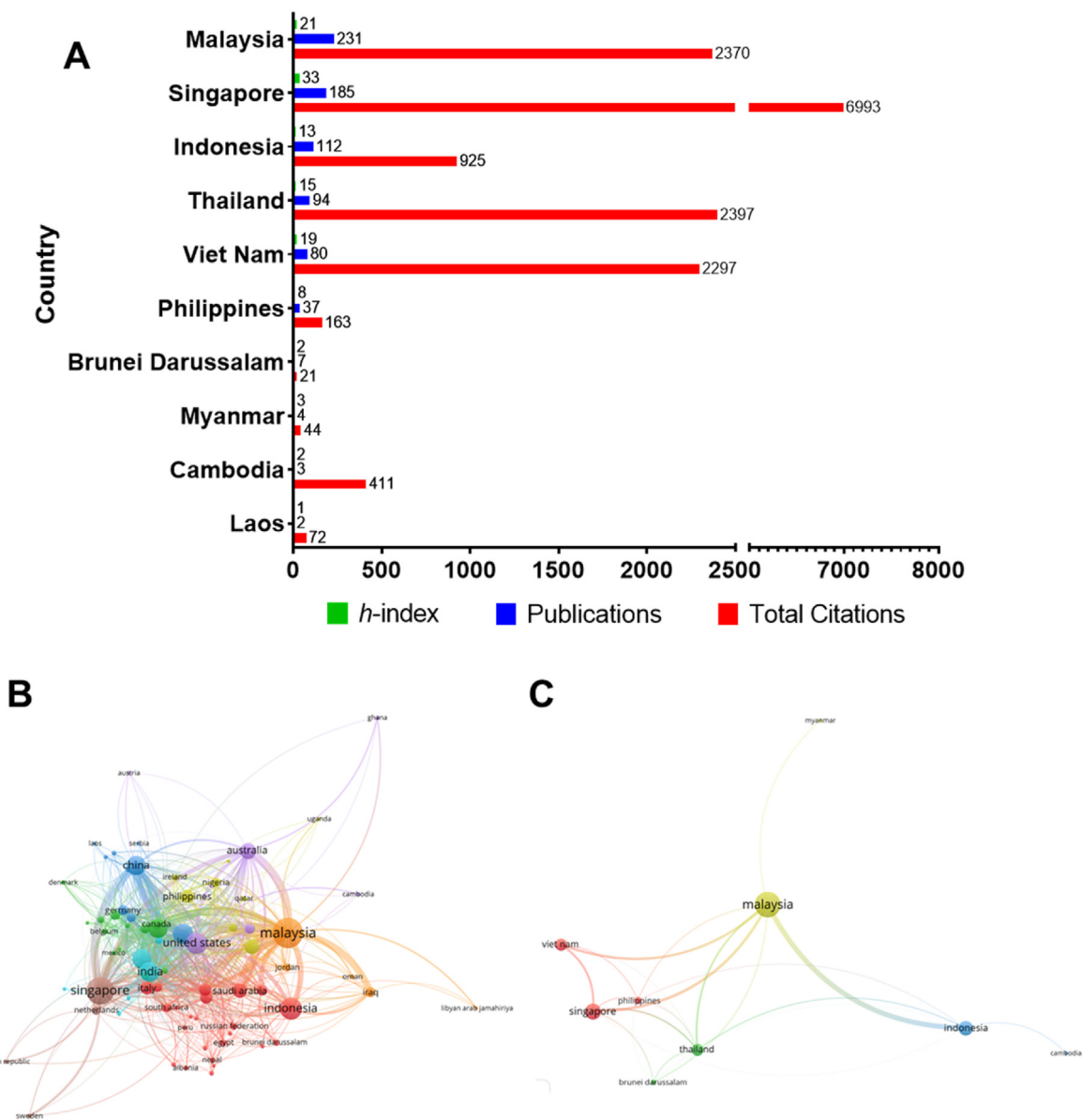
Fig. 1. (**A**) The top countries that published COVID-19 research articles in Southeast Asia. (**B**–**C**) Network visualization of collaborations within Southeast Asia and worldwide for COVID-19 research. The size of the circles is proportional to the number of links/collaborations of each country in the cooperation network. The thickness of the lines indicates the strength of the connection between countries/regions.

(5.30%), and pharmacology, toxicology, and pharmaceutics (5.21%).

3.7. Most cited COVID-19 publications in SEA

The top 10 most cited COVID-19 articles in SEA were mostly on the origin and transmission of COVID-19, immune response to COVID-19, use of deep neural networks to diagnose COVID-19 using X-ray images, and the impact of COVID-19 in the management of cancer, diabetes, and pregnancy. Half of the most cited papers were from Singapore, two from Vietnam, and one paper each from Indonesia, Malaysia, and Thailand. All papers were published in open access journals.

3.8. Country-specific socioeconomic factors and correlation with bibliometric indices

Correlations between country-specific characteristics (Supplementary Table 1) with the different bibliometric indices were shown in Table 1. The population per country, GDP (in billions), and the number of cases of COVID-19 per country did not significantly correlate with scientific productivity and impact for GDM research. However, GDP per capita (p-value = 0.039) and physicians per 1000 population (p-value = 0.035) were significantly correlated with h-index of COVID-19 publications in SEA. Moreover, research & development expenditure (total publications: p-value = 0.005; total citations: p-value = 0.005, and h-index: p-value = 0.001), research in R&D (total publications: p-value = 0.03; total citations: p-value = 0.049, and h-index: p-value = 0.004), and the number of international research collaborations (total publications: p-value = 0.002; total citations: p-value = 0.007, and h-index: p-value = 0.0008) were significantly correlated with all bibliometric indices included in this study.
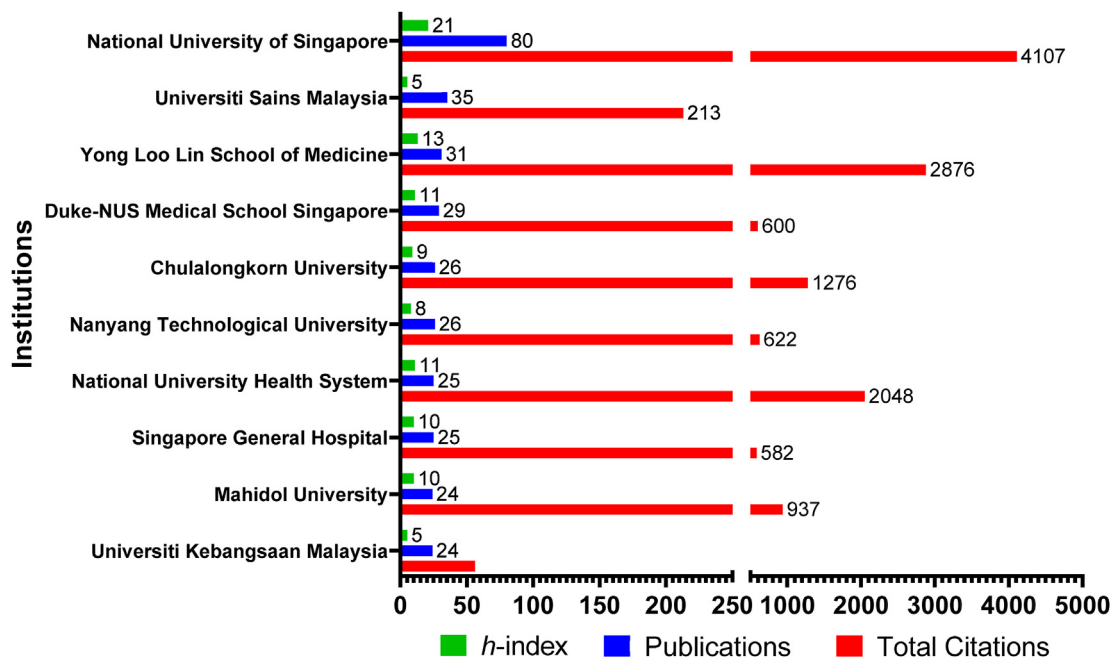
Fig. 2. The top institutions that published COVID-19 research articles in Southeast Asia.
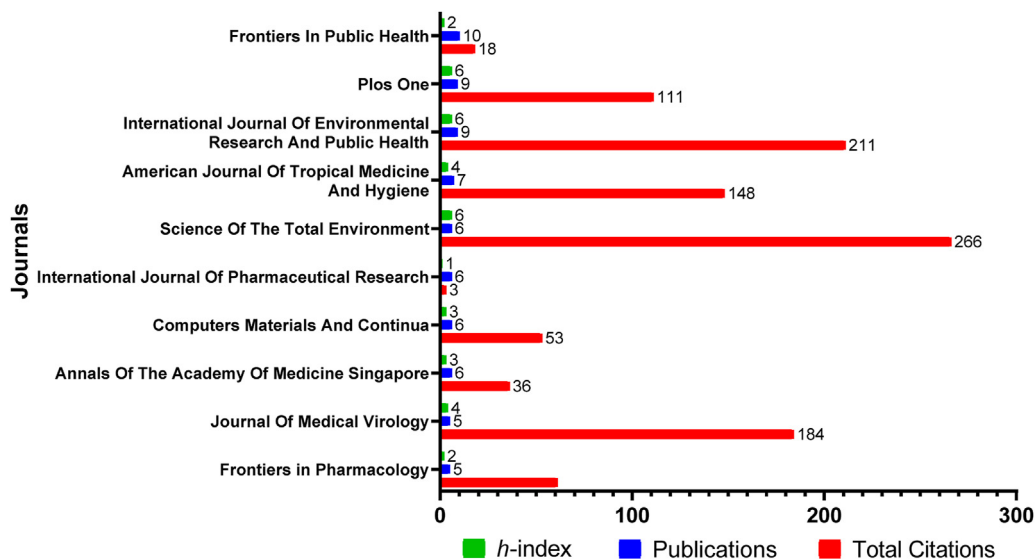

Fig. 3. The top journals that published COVID-19 research articles in Southeast Asia.

4. Discussion

This is the first bibliometric analysis on COVID-19 research in SEA. The scientific literature on COVID-19 has exponentially increased since the WHO declared it as a global pandemic. This significant increase in COVID-19 literature in SEA is also similar to what was observed all in different countries including Latin America and South Asia [14–16]. This is due to the worldwide effort of the scientific community to develop possible treatments to save lives and produce vaccines for future prevention of COVID-19 [17]. Most of the COVID-19 research in SEA were from authors and institutions in Malaysia, Singapore, and Thailand. These countries played a role in the generation of knowledge regarding the epidemiology of COVID-19 in the SEA region. There were limited research

outputs from other SEA countries such as Brunei Darussalam, Cambodia, Laos, and Philippines.

This study showed that the factors that facilitate COVID-19 research productivity and impact in SEA were higher GDP per capita, physicians per 1000 population, research & development expenditure, research in R&D, and number of international research collaborations. This explains why Malaysia, Singapore, and Thailand were the top contributors of knowledge regarding COVID-19 in SEA region. The results of this study agree with previous studies in Asia that demonstrated an association between GDP and funding for R&D with greater research productivity and scientific impact [18–20]. Moreover, these countries have the greatest number of collaborations with other countries inside and outside the region. Malaysia, Singapore, and Thailand had the highest
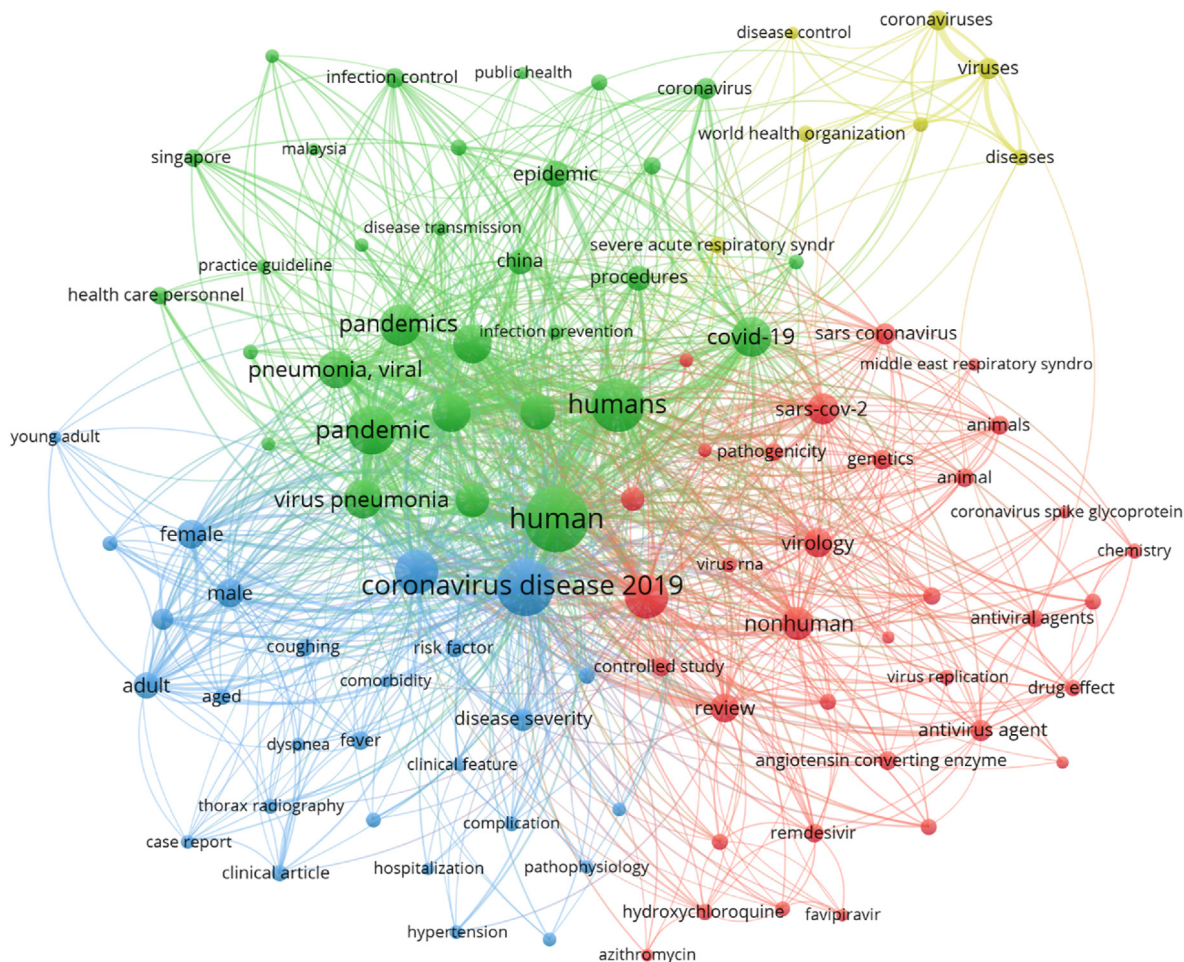
Fig. 4. Network visualization of keywords linked to COVID-19 research in Southeast Asia. The size of the circles is proportional to the number of articles containing the indicated keyword in the network. The thickness of the lines indicates the strength of the connection between keywords.

Table 1
Correlation analysis between country-specific characteristics and bibliometric indices for COVID-19 research in Southeast Asia.

Country-specific characteristics	Bibliometric indices	r	p-value
Gross domestic product (in USD, billions)	Total publications	0.486	0.154
	Total citations	0.6	0.073
	h-index	0.431	0.214
Gross domestic product per capita (in USD)	Total publications	0.475	0.166
	Total citations	0.503	0.144
	h-index	0.657	**0.039**
Population (in millions)	Total publications	0.127	0.727
	Total citations	0.176	0.632
	h-index	0.079	0.827
Research & Development Expenditure (% GDP)	Total publications	0.808	**0.005**
	Total citations	0.821	**0.005**
	h-index	0.863	**0.001**
Researchers in R&D (per million people)	Total publications	0.683	**0.03**
	Total citations	0.649	**0.049**
	h-index	0.819	**0.004**
Physicians (per 1000 people)	Total publications	0.6	0.067
	Total citations	0.342	0.332
	h-index	0.668	**0.035**
COVID-19 Cases	Total publications	0.364	0.301
	Total citations	0.358	0.313
	h-index	0.158	0.663
International research collaborations	Total publications	0.856	**0.002**
	Total citations	0.809	**0.007**
	h-index	0.88	**0.0008**

Bold values denote statistical significance at the p < 0.05 level.

number of international collaborations for COVID-19 research. Previous reports showed that countries with more local and international collaborations tend to produce scientific articles that have greater scientific impact than those countries that are less open to collaboration [21,22].

The number of multiple country publications for COVID-19 in SEA also increased in 2021 compared to 2020. This result agrees with a previous publication on scientific collaboration on COVID-19 which revealed a high and growing incidence of international collaboration during this pandemic. Since the start of this pandemic, there has been an increasing number of countries and institutions that participated in scientific cooperation on COVID-19. This shows that the scientific community recognizes that collaboration is a way to stop this pandemic [23].

This study also showed that the top journals that published COVID-19 research in SEA were mostly international journals. A previous study showed that medical professionals perceived that publishing in international journals was more important than publishing in national journals. Their main reason is usually to reach a wider global readership [24]. Local journals are also perceived as low-quality, since the most important research work is often published in international journals [25]. Moreover, most of the COVID-19 articles from SEA were published in paid, open access journals. There are several reasons that may explain this: 1) Article processing charges (APC) remains to be a major obstacle in publishing research in open access journals [26]. Perhaps, more affluent countries like Singapore, Malaysia, and Thailand, which contributed to a lot of COVID-19 publications in SEA, could afford to pay the APC of open access journals; 2) There was a significant increase in the percentage of multiple country publications on COVID-19 research in SEA since the start of the pandemic. Previous studies showed that papers resulting from international collaborations were more likely to be published in open access journals compared to single-country papers [27].

The keyword visualization showed that the COVID-19 research outputs from SEA focused on symptomatology, pathophysiology, treatment, epidemiology, and public health aspects of COVID-19. These are important areas of research and have big impact in the control and prevention of COVID-19 in SEA. However, the regional imbalance in the generation of knowledge on COVID-19 in SEA may hinder us from completely understanding the epidemiology of this disease in our region. It is also alarming that the despite the skyrocketing cases of COVID-19 in Philippines, research outputs from this country remains low. This may also prevent us from developing preventive and therapeutic strategies tailored to our individual countries. Hence, the result of this study emphasizes the need for more research funding, increase in the number of researchers, and cross-country collaborations to improve the research outputs in SEA countries.

The COVID-19 research articles included in this study were only limited to those available in Scopus database. However, Scopus is the world's largest abstract and citation database. This study still captured most of the relevant literature in COVID-19 research in SEA. Despite this limitation, this study still showed the research trends, gaps, and future directions in this field in SEA.

5. Conclusion

In summary, this bibliometric analysis showed an exponential increase in COVID-19 research in SEA countries. However, most of the research outputs were produced by authors and institutions from Malaysia, Singapore, and Thailand. The other countries with highest cases of COVID-19 in SEA such as Indonesia and Philippines have lower scientific output in this field. GDP, research and development expenditure, number of researchers and physicians, and

international collaborations are positively correlated to research productivity in COVID-19 in SEA. Therefore, administrators and policy makers in SEA countries should consider increasing the support for COVID-19 research to generate knowledge that can be used in curbing this global pandemic.

Author contributions

OAGT conceived the review, contributed to analysis and interpretation of available literature, and prepared the manuscript.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2021.102325.

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