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Malaria Publications before and during COVID-19 Pandemic: A Bibliometric Analysis

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Abstract: Coronavirus disease 2019 (COVID-19) has been reported to affect malaria intervention strategies, the suspension of malaria elimination programs, and the publication of malaria research. We compared differences in authorship, affiliations, countries, funding sources, article types, keywords, languages, and citations between studies published before and during the COVID-19 pandemic. The searches were performed online using the Scopus database on 8 April 2022. The searches were limited to two periods: before the COVID-19 pandemic (2018–2019) and during the COVID-19 pandemic (2020–2021). The information of authorship, affiliations, countries, funding sources, article types, keywords, languages, and citations between studies published before and during the COVID-19 pandemic were compared using frequency and percentage. The relationships between the most productive authors, countries, affiliations, journals, and frequently used keywords were visualized using the VOSviewer (version 1.6.18) software. A total of 2965 articles were identified in two periods and, among those, 1291 relevant studies were included. There was no difference in malaria publications before and during the COVID-19 pandemic (679 articles, 52.6% vs. 612 articles, 47.4%). Compared between the two periods, the preliminary trend of malaria publications in terms of authorship, affiliations, countries, funding sources, article types, keywords, languages, and citations were different. In conclusion, the current study showed the preliminary trends in malaria publications before and during the COVID-19 pandemic. The findings of this study would encourage researchers to perform a scoping review or systematic review to better understand the direction of malaria publications during the COVID-19 pandemic.

Keywords: malaria; publications; COVID-19; pandemic; bibliometric analysis

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1. Introduction

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1], emerged in late 2019 and became a global outbreak [2,3]. As an emerging infectious disease, COVID-19 has had a significant impact across the board, including research and the number of scientific publications [4,5]. Research on COVID-19 is increasing and rapidly developing in medical fields [2]. Numerous publications relate to COVID-19 and other infectious diseases such as bacteria, respiratory viruses, and malaria [6–9]. While the world is paying attention on COVID-19, malaria is still a leading cause of morbidity and mortality among children in Africa [10]. Throughout the COVID-19 outbreaks, malaria intervention strategies such as the distribution of insecticide-treated bed nets (ITNs), indoor residual insecticide spraying (IRS), and other vector control strategies were disrupted across endemic areas [11]. The malaria intervention strategies that have been frequently delivered in developing countries with little capacity to control

and eliminate malaria were affected by the pandemic [10,12]. Besides malaria intervention measures, malaria research might be affected by the pandemic [4,10,12].

Nowadays, bibliometric analysis, which is an examination of publications in academic journals [13], is an essential method to investigate publication characteristics (e.g., citations, authors, affiliations) and other critical information [3]. This method provides an insight into the authors' and countries' research contribution and collaboration patterns [3,14]. Additionally, several bibliometric studies involved analyses of article citations [15–17]. Thus, a bibliometric analysis has the potential to provide researchers with a better understanding of the trends in malaria publications during the COVID-19 pandemic. In addition, a comparison of malaria publications between before and during COVID-19 is able to indicate the changes in malaria research. To the best of our knowledge, there is no bibliometric analysis of the impact of the COVID-19 pandemic on malaria publications. This study aims to investigate trends in authorship, affiliations, countries, funding sources, article types, keywords, languages, and citations of malaria-related publications between before (2018–2019) and during (2020–2021) the COVID-19 pandemic.

2. Methods

2.1. Data Source and Search Strategy

Two authors (MK and WM) searched an online database, Scopus, on 8 April 2022. The search terms were malaria, plasmodium, marsh fever, paludism, and remittent fever. A detailed search strategy was the combination of search terms using Boolean operators (malaria OR plasmodium OR "marsh fever" OR paludism OR "remittent fever"). The searches were filtered using titles, abstracts, and keywords provided by Scopus database. Scopus was selected for this bibliometric analysis due to its well-structured information, including authors, title, year, source, affiliations, country, keywords, funding agency, language of document, and document type. The periods of publication were divided into two periods: (i) before the COVID-19 pandemic (1 January 2018, to 31 December 2019) and (ii) during the COVID-19 pandemic (1 January 2020, to 31 December 2021). These periods corresponded to when WHO had set up a team to deal with the outbreak on 1 January 2020 [18]. The search was performed on a single day, and replicates could be performed as the final date ended on 31 December 2021. All articles published in any language were included for analysis.

2.2. Data Management and Data Analysis

The search results were exported as CSV files. We manually checked and screened the articles retrieved from the Scopus search, and irrelevant studies were excluded. Open access, publication year, author name, subject area, document type, stage of publication, source title, keyword, affiliation, funding sponsor, country, source type, and language were recorded in the search results. A comparison of authorship, affiliations, countries, funding sources, article types, keywords, languages, and citations of articles between before and during the COVID-19 pandemic were presented as frequency and percentage. A total number of studies (n) before or during the COVID-19 pandemic was used to calculate the percentages (%) of each author/affiliation/country/journal/keyword in the present study.

The relationships between the most productive authors, countries, affiliations, source titles, and frequently used keywords were analyzed using the VOSviewer (version 1.6.18) software. VOSviewer was used to execute cluster analyses and generate social network maps by analyzing the frequency of information extracted from publications [14]. Cluster analysis results were visualized as nodes and links. The size of the nodes indicated the quantity or frequency of publications; a larger node represented greater quantity of publications. The connections between nodes denoted collaboration, co-occurrence, or co-citation. The color of the nodes and lines denoted distinct clusters [14]. Network maps were created to illustrate the collaboration between various authors, institutions, countries, and keywords.

For parameters used in the VOSviewer software, we used fractional counting as the counting method. Fractional counting means that the weight of the link is fractionalized (splitting papers according to the weight) [19]. We did not set the maximum number of authors/organizations/countries/citations per document [19]. We set the minimum number of documents of authors/organization/country/citation as 1. We set the maximum number of citations of authors/organization/country/citation as 0. For a keyword analysis, we selected the keywords that appeared more than ten times to analyze.

We analyzed indicators such as GDP, GDP per capita, research and development expenditure, number of researchers, and number of physicians, and bibliometric indices such as total papers, total citations, and h-index, as descried previously [20]. Population, gross domestic product (GDP), and GDP per capita data were obtained from the website of the International Monetary Fund (IMF) [21]. The World Bank [22] provided the research and development expenditure (percent of GDP), physician-to-population ratio, and researcher-to-population ratio.

3. Results

A total of 2965 articles were identified from 2018 to 2021. The search results identified 1351 articles (45.6%) in 2018–2019 and 1614 articles (54.4%) in 2020–2021. After excluding 1674 irrelevant articles, 1291 studies were included in the analysis. There was a comparable total number of malaria publications before and during the COVID-19 pandemic (679 articles, 52.6% vs. 612 articles, 47.4%).

3.1. Authors

Before the COVID-19 pandemic, Bousema T. (9 articles, 1.33%), Drakeley C. (9 articles, 1.33%), and Tinto H. (8 articles, 1.18%) contributed to the highest number of malaria articles. Meanwhile, Dorsey G. (11 articles, 1.8%), Drakeley C. (9 articles, 1.47%), and Staedke S.G. (9 articles, 1.47%) contributed to the highest number of malaria articles during the COVID-19 pandemic (Supplementary Table S1).

There was a higher mean of h-index per total articles before the COVID-19 pandemic (mean 8.10) than during the COVID-19 pandemic (mean 6.52). Before the COVID-19 pandemic, strong collaborations between authors were found in groups of authors such as Bousema T. (total strength links = 9) and Rosenthal P.J. (total strength links = 9) (Figure 1A); meanwhile, strong collaborations between authors were found in groups of authors such as Dorsey G. (total strength links = 11) and Staedke S.G. (total strength links = 9) (Figure 1B).

3.2. Affiliations

Before the COVID-19 pandemic, the University of Basel, Switzerland (11 articles, 1.62%) and the Swiss Tropical and Public Health Institute, Switzerland (9 articles, 1.33%) contributed to the highest number of malaria articles. Meanwhile, the Infectious Diseases Research Collaboration, Uganda (12 articles, 1.96%) and the Centre for Tropical Medicine and Global Health, United Kingdom (9 articles, 1.47%) contributed to the highest number of malaria articles during the COVID-19 pandemic (Supplementary Table S2). Of the 2712 institutions with which authors were affiliated before the COVID-19 pandemic, 2611 institutions (96.3%) had at least one collaboration (at least one total strength link) and 101 institutions (4.7%) had no collaborations (zero total strength link).

Of the 2614 institutions with which authors were affiliated after the COVID-19 pandemic, 2539 institutions (97.1%) had at least one collaboration and 75 institutions (2.9%) had no collaborations. Before the COVID-19 pandemic, strong collaborations between affiliations were found in the groups of affiliations such as the University of Basel, Switzerland (total strength links = 11) and the Swiss Tropical and Public Health Institute, Switzerland (total strength links = 9) (Figure 2A). During the COVID-19 pandemic, strong collaborations between affiliations were found in groups of affiliations such as the Infectious Diseases Research Collaboration, Kampala, Uganda, the Centre for Tropical Medicine (total strength

links = 12), and the Global Health, Nuffield Department of Medicine, University of Oxford, United Kingdom (total strength links = 19) (Figure 2B).

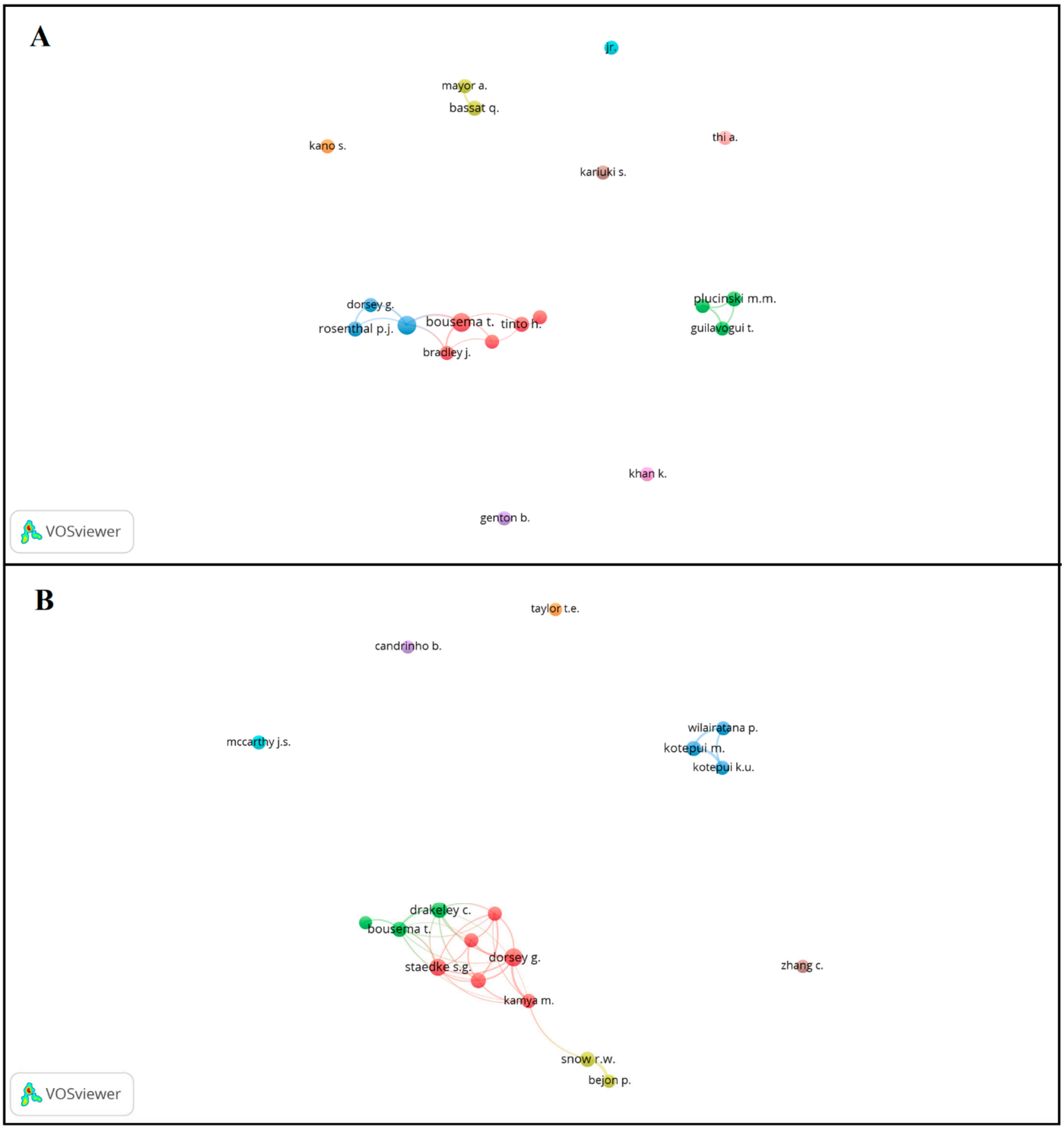

Figure 1. Authors that contributed to malaria publications. (**A**) before the COVID-19 pandemic, (**B**) during the COVID-19 pandemic.

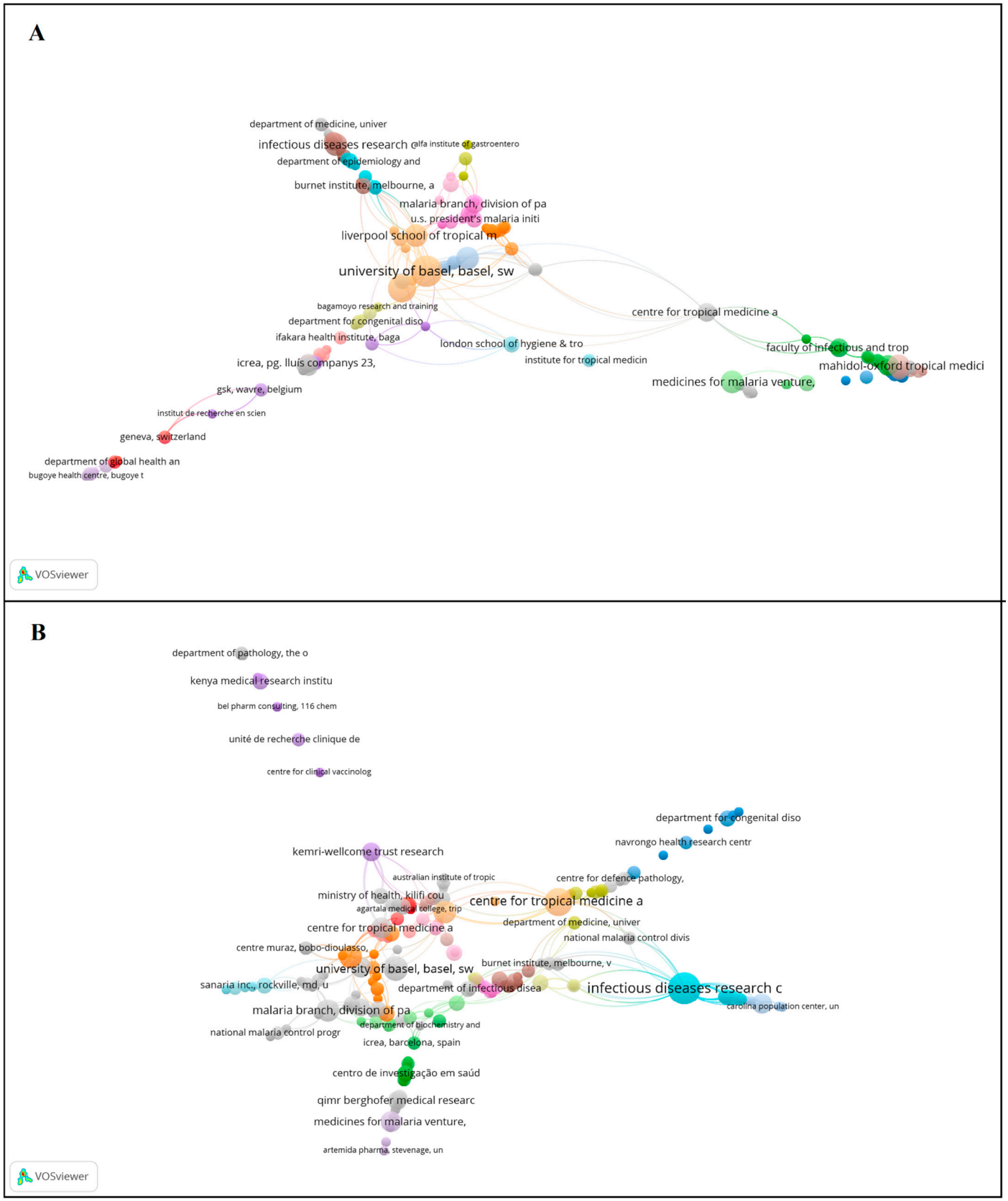

Figure 2. Affiliations of authors that contributed on malaria publications. (**A**) before the COVID-19 pandemic, (**B**) during the COVID-19 pandemic.

3.3. Countries

Before the COVID-19 pandemic, the United States (182 articles, 26.8%), the United Kingdom (117 articles, 17.2%), and India (70 articles, 10.3%) were the countries contributing to the highest numbers of malaria articles. Similarly, the United States (165 articles, 27%), the United Kingdom (117 articles, 19.1%), and India (70 articles, 11.4%) contributed to the highest numbers during the COVID-19 pandemic. There were higher proportions of malaria publications from Germany, Uganda, and Thailand during the COVID-19 pandemic (Supplementary Table S3).

Before the COVID-19 pandemic, Switzerland, France, the Netherlands, and Australia had the highest GDP per capita (USD per capita) per total articles, research and development expenditure (percent of GDP) per total articles, and researchers (per million people) per total articles. Meanwhile, France, Germany, Australia, and Switzerland had the highest GDP per capita (USD per capita) per total articles, research and development expenditure (percent of GDP) per total articles, and researchers (per million people) per total articles during the COVID-19 pandemic.

Before the COVID-19 pandemic, the strong collaborations between countries were found in the United States (total strength links = 134), the United Kingdom (total strength links = 103), and Switzerland (total strength links = 49) (Figure 3A). Meanwhile, during the COVID-19 pandemic, the strong collaborations between countries were found in the United States (total strength links = 134), the United Kingdom (total strength links = 107), and Kenya (total strength links = 33) (Figure 3B).

3.4. Source Titles

Before the COVID-19 pandemic, *Malaria Journal* (articles 93, 13.7%), *American Journal of Tropical Medicine and Hygiene* (41 articles, 6%), *PLoS ONE* (27 articles, 4%), *Clinical Infectious Diseases* (12 articles, 1.8%), and *PLoS Neglected Tropical Diseases* (11 articles, 1.6%) were the journals with the most malaria articles. Meanwhile, *Malaria Journal* (89 articles, 14.5%), *American Journal of Tropical Medicine and Hygiene* (30 articles, 4.9%), *PLoS ONE* (17 articles, 2.8%), *PLoS Medicine* (9 articles, 1.5%), *Pathogens* (8 articles, 1.3%), *PLoS Neglected Tropical Diseases* (8 articles, 1.3%), and *Scientific Reports* (8 articles, 1.3%) were the top journals publishing malaria articles during the COVID-19 pandemic (Supplementary Table S4).

The average CiteScore of journals publishing malaria articles before the COVID-19 pandemic (mean CiteScore = 6.95) was lower than those published during the COVID-19 pandemic (mean CiteScore = 11.1). Before the COVID-19 pandemic, the citation analysis showed that *Malaria Journal* (total strength links = 34) and *American Journal of Tropical Medicine and Hygiene* (total strength links = 13) had the strongest connections (Figure 4A). Meanwhile, *Malaria Journal* (total strength links = 13), *PLoS Neglected Tropical Diseases* (total strength links = 8), and *PLoS ONE* (total strength links = 7) had the strongest connections during the COVID-19 pandemic (Figure 4B).

3.5. Keywords

Before the COVID-19 pandemic, human (562 articles, 82.8%), malaria (511 articles, 75.2%), and humans (462 articles, 68%) were the most common keywords for malaria articles. Meanwhile, human (522 articles, 85.3%), malaria (471 articles, 76.9%), and fever (410 articles, 67%) were the most common keywords for malaria articles during the COVID-19 pandemic (Supplementary Table S5). The cluster of keywords before the COVID-19 pandemic is demonstrated in Figure 5A. Meanwhile, the cluster of keywords during the COVID-19 pandemic is demonstrated in Figure 5B.

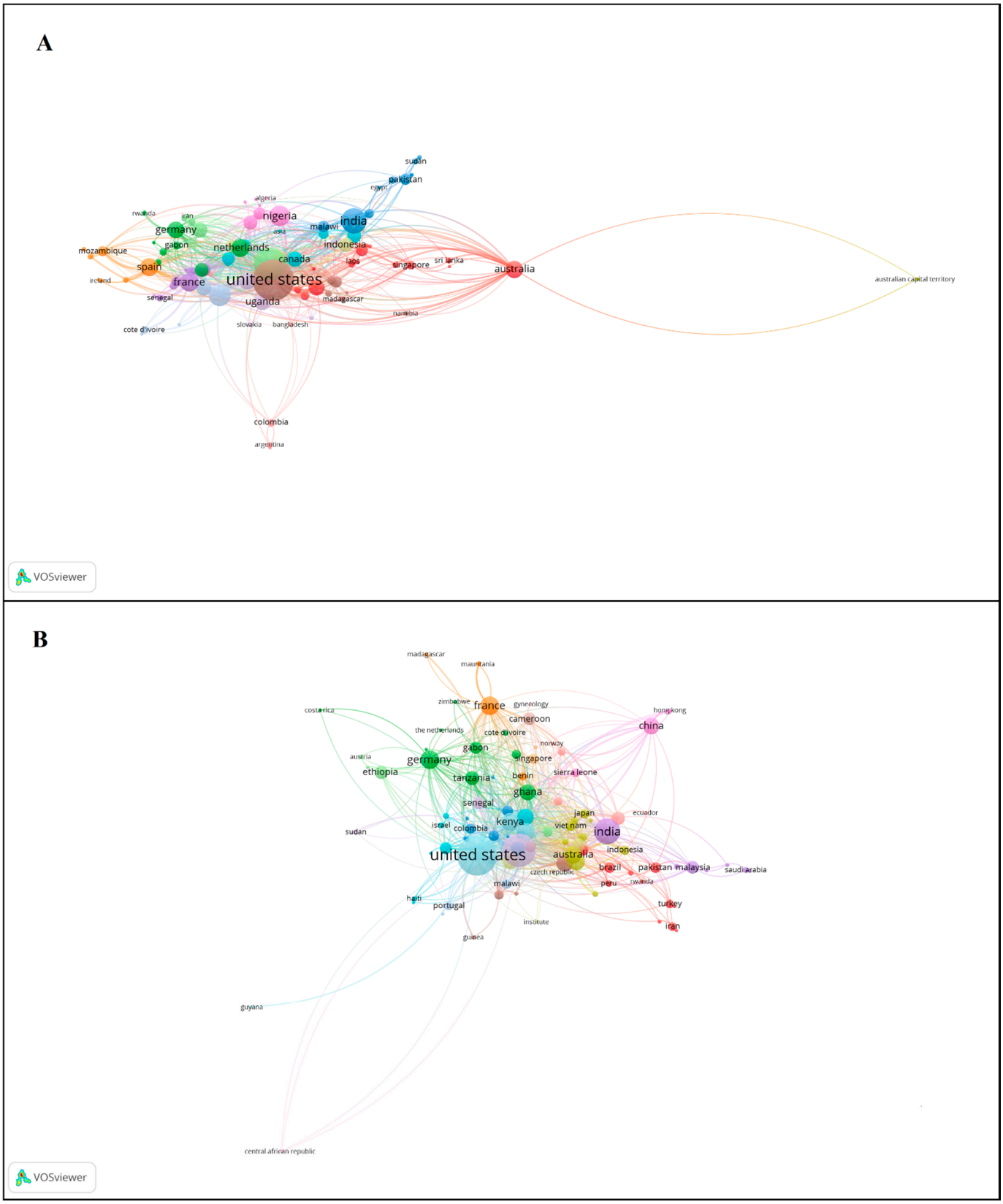

Figure 3. Countries that contributed significantly to malaria publications (**A**) before the COVID-19 pandemic, (**B**) during the COVID-19 pandemic.

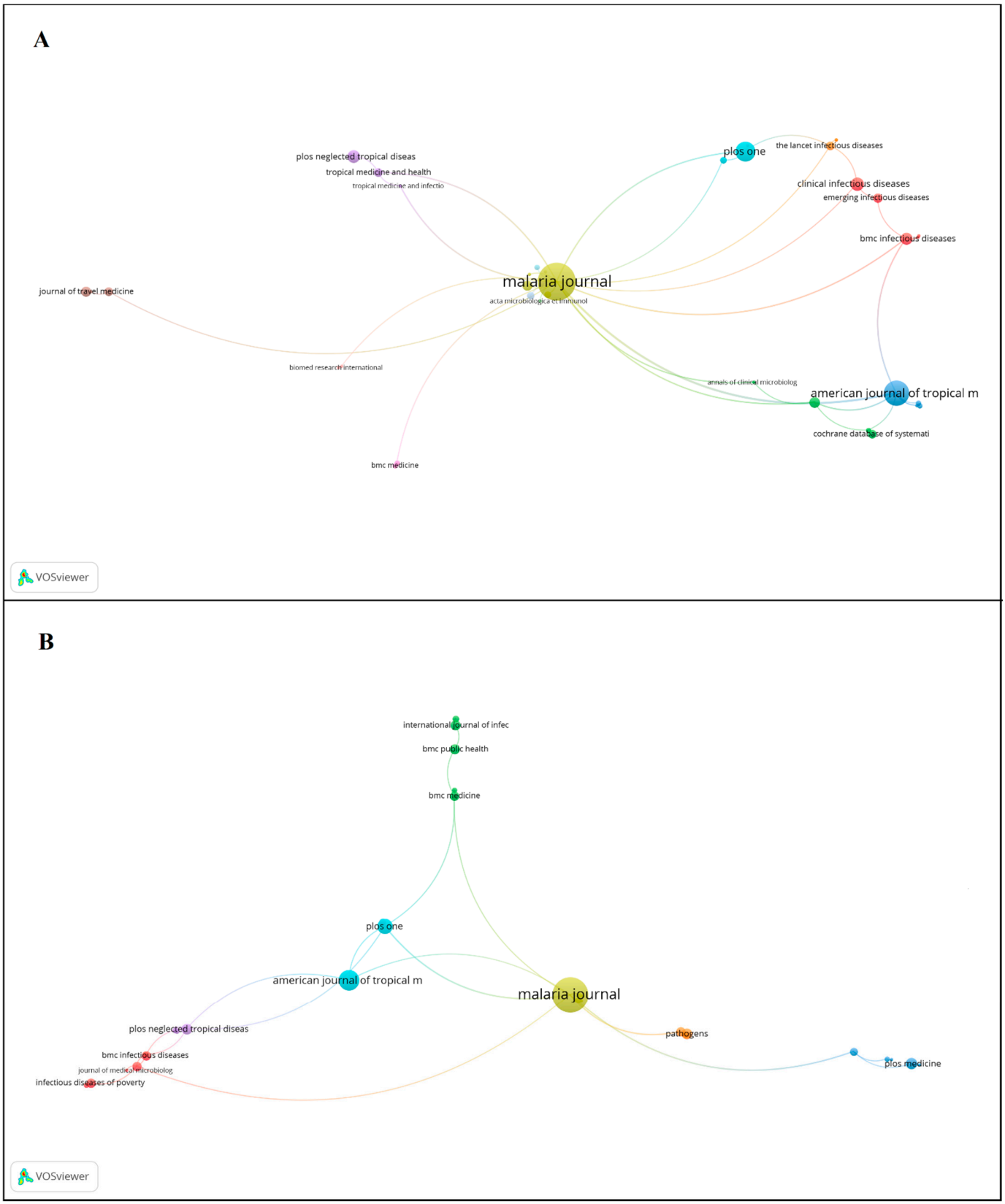

Figure 4. Journals that published malaria publications (**A**) before the COVID-19 pandemic, (**B**) during the COVID-19 pandemic.

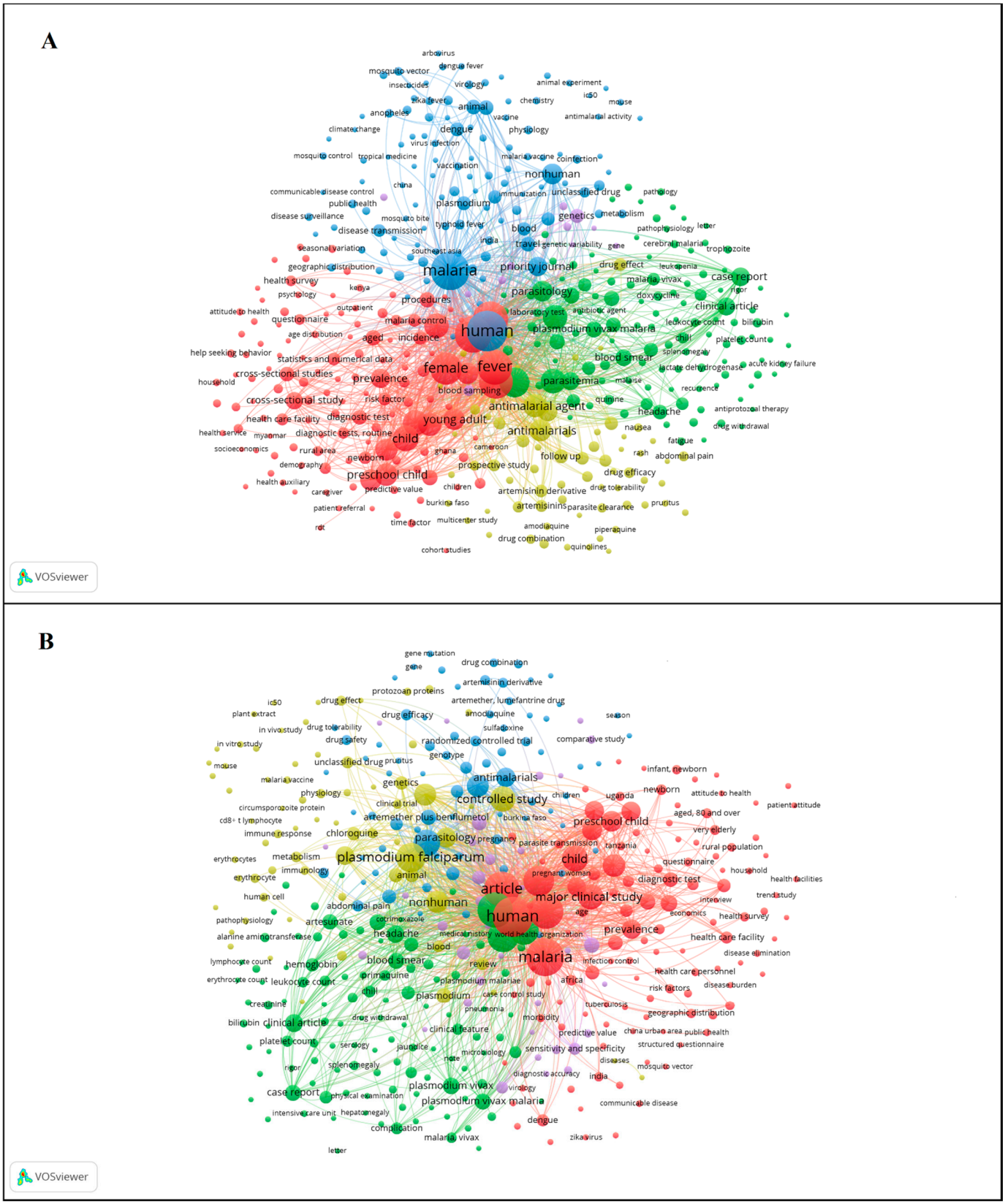

Figure 5. Keywords frequently used in malaria publications (**A**) before the COVID-19 pandemic, (**B**) during the COVID-19 pandemic.

3.6. Funding Sponsors

There was a slightly higher proportion of malaria publications that were supported by funding sponsors during the COVID-19 pandemic (307 articles, 50.2%) than those publications before the COVID-19 pandemic (310 articles, 45.7%). Before the COVID-19 pandemic, malaria publications were supported by the National Institutes of Health (NIH), the USA (74 articles, 10.9%), the National Institute of Allergy and Infectious Diseases (NIAID), the USA (43 articles, 6.3%), and the Bill and Melinda Gates Foundation (BMGF), the USA (34 articles, 5%). Similarly, malaria publications were supported by NIH (51 articles, 8.3%), NIAID (45 articles, 7.4%), and BMGF during the COVID-19 pandemic (38 articles, 6.2%) (Supplementary Table S6).

3.7. Languages, Publication Types, and Subject Areas

Before the COVID-19 pandemic, English (642 articles, 94.6%), French (7 articles, 1%), and Spanish (7 articles, 1%) were the most common languages for malaria articles. Meanwhile, English (586 articles, 95.8%), Chinese (7 articles, 1.1%), and French (3 articles, 0.5%) were the most common languages for malaria articles during the COVID-19 pandemic (Supplementary Table S7). Before the COVID-19 pandemic, research articles (640 articles, 94.3%), reviews (17 articles, 2.5%), and book chapters (14 articles, 2.1%) were the most frequent publication types for malaria articles. Meanwhile, research articles (575 articles, 94%), reviews (22 articles, 3.6%), and notes (5 articles, 0.8%) were the most frequent publication types for malaria articles during the COVID-19 pandemic (Supplementary Table S8). Before the COVID-19 pandemic, medicine (223 articles, 32.8%) was the most common subject area for malaria articles. Similarly, medicine (199 articles, 32.5%) was the most common subject area for malaria articles during the COVID-19 pandemic (Supplementary Table S9).

4. Discussion

During the COVID-19 pandemic, there was an increase in COVID-19 publications while there was a substantial decrease in non-COVID-19 research production [23]. For malaria publications, the current study showed that there was a comparable total number of malaria publications before and during the COVID-19 pandemic. The reasons behind the trend of the comparable number of malaria publication is unknown. Based on the findings from another study, a decrease in the number of original articles published during the COVID-19 pandemic was observed [23]. However, there was a comparable proportion of research articles before and during the pandemic (94.3% vs. 94%) in the present study. There was evidence that publications of peer-reviewed COVID-19 articles without original data grew exponentially in comparison to original articles [24].

For malaria publications, there might be an increased trend of non-research articles during the COVID-19 pandemic such as systematic reviews, reviews, case reports, case series, and letters to the editors. This explanation was supported by the results of the current study, that some of the top authors/affiliations/countries potentially published more non-research articles related to malaria during the COVID-19 pandemic as they might have limitations to perform their experiments during the shutdown or admit uncomplicated malaria patients for studies in hospitals due to inpatient-bed constraints for COVID-19 patients. Non-malaria publications such as COVID-19 publications showed that most COVID-19 publications were written by a small number of authors of small countries, indicating either the difficulty of conducting international studies during the pandemic or the fact that countries conducted a substantial amount of COVID-19 research [25,26]. Additionally, a recent study discovered that more authors focused on case reports involving COVID-19 than on non-COVID-19 publications [23].

For malaria publications during the COVID-19 pandemic, there were several publications indicating that the effects of chloroquine and hydroxychloroquine, both used to treat malaria, were considered as candidate drugs for treating COVID-19 at the beginning of the pandemic [27–31]. There was a trend of publishing the information about the protective factors against COVID-19 among populations in malaria-endemic areas, for

example, genetic variations in Angiotensin-Converting Enzyme 2 (ACE2) [32–34]. Additionally, the increased awareness of the COVID-19 pandemic in malaria-endemic areas was emphasized [35–38]. The COVID-19 pandemic affected malaria service delivery in many settings. Malaria patients may face delayed care during the lockdown, increasing their risk of becoming severely ill and dying [39].

The current study demonstrated a shift in the countries contributing to malaria publications. Although the United States, the United Kingdom, and India substantially contributed to malaria publications both before and during the COVID-19 pandemic, the remaining top countries contributing to malaria publications were altered. For instance, there was a higher proportion of malaria publications from Germany, Uganda, and Thailand during the COVID-19 pandemic. In addition, some countries produced fewer malaria publications during the COVD-19 pandemic. It reflected that the COVID-19 pandemic may disrupt the capability of malaria research productivity in those countries. Interestingly, the present study observed that there were few malaria-endemic countries included in the top countries for malaria research. Only four countries in malaria-endemic areas—Nigeria, Kenya, Uganda, and India—were in the top contributors of malaria publications. This imbalance and lack of representation of countries with the highest morbidity and mortality from malaria might be due to the limited number of researchers in malaria-endemic countries. The ratios of the researchers (per million people) per total articles in candidate countries such as Nigeria, Kenya, Uganda, and India were less than 10 in these countries, indicating a lack of researchers in malaria research. Other possible explanations were the low GDP of the country (e.g., Kenya), or limited research and development expenditure such as Nigeria and Uganda which had the lowest research and development expenditure (percent of GDP) per total articles.

For the trend of journals for malaria publications, the present study showed that *Malaria Journal*, *American Journal of Tropical Medicine and Hygiene*, and *PLoS ONE* remained the most frequently published journal for malaria research in both periods. Nevertheless, a higher number of journals publishing malaria research has been observed during the COVID-19 pandemic than before the COVID-19 pandemic, implying the acceptability trends of these journals for malaria research. Interestingly, there was a higher average CiteScore of journals during the COVID-19 pandemic than before the COVID-19 pandemic, implying that a majority of journals had a higher CiteScore due to COVID-19 publications during the COVID-19 pandemic. From the citation analysis, *Malaria Journal* contributed as the "central journal" for malaria and it was the most common journal for malaria publication. It was also the "central journal" that received the citations from several related-journals in the field. Considering that there was a chance that high-ranking journals would publish more COVID-19 research than low-ranking journals [26], malaria-related COVID-19 research might be one of several reasons to describe the trend of malaria publication in a higher rank journal.

There was an interesting finding that half of malaria publications were not supported by any funding sponsors though there was a slightly higher proportion of malaria publications that were supported by funding sponsors during the COVID-19 pandemic than those publications before the COVID-19 pandemic. A previous study found that Tanzania, Uganda, and Kenya received the highest research investment while Central African Republic and Sierra Leone received the lowest funding [40]. From the finding of the present study, malaria publications in both periods (before and during the COVID-19 pandemic) were mostly supported by three funding sponsors: NIH, NIAID, and BMGF. The previous study indicated that two funders, NIH and BMGF, provided the greatest investment in malaria among five African countries: Tanzania, Kenya, Uganda, Malawi and Nigeria [40]. Although these countries received funding sponsors, several countries in malaria-endemic area such as central Africa received little or no funding investments for malaria as some other socioeconomic and political factors such as corruption, conflict, crime, and economic considerations might influence funding allocation in low- and middle-income countries where malaria is endemic [40,41]. As there might be the potential for inequalities in funding

allocation among countries where malaria is endemic, there is the need of more funding sponsors and improvement in carefully allocating funding for malaria research.

There was also a shift in publication languages during the COVID-19 pandemic. We found that the Chinese language became the second most frequent language for malaria publication during the COVID-19 pandemic. This finding indicates the attribution to the spread of the COVID-19 pandemic within this country, and publications in the Chinese language aided local medical practitioners in comprehending the essential and critical information necessary to manage COVID-19 in China's relatively remote regions [15].

The present study had some limitations. First, we used a single database for searching the publications in Scopus. However, as Scopus covered more articles than Web of Science and PubMed, a single database search provided more unique data sets than using more databases. Second, certain institutions/countries' results might be over-estimated because Scopus counts a document once for each author. Third, because the bibliometric analysis did not examine the contents of publications such as scoping reviews or systematic reviews, the present study did not capture the in-depth trend in malaria publications during the COVID-19 pandemic. Fourth, since the bibliometric analysis was performed in the short periods of time, between two years before and two years during the COVID-19 pandemic, it is possible that studies which were conducted before the pandemic may have been published during the COVID-19 pandemic. Therefore, it would be interesting to know whether there is in any trend change in malaria publications in the future with the remaining COVID-19 pandemic. Therefore, we propose additional studies to conduct a scoping review or systematic review of the direction of malaria research between the two time periods to fill a gap for malaria researchers.

5. Conclusions

The current study showed the preliminary trends in malaria publications before and during the COVID-19 pandemic. The findings of this study would encourage researchers to perform a scoping review or systematic review to better understand the direction of malaria publications during the COVID-19 pandemic.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/publications10030028/s1, Table S1: Top authors that contributed on malaria research publications before and during the COVID-19 pandemic.; Table S2 Top affiliations that contributed on malaria research publications before and during the COVID-19 pandemic; Table S3: Top countries that contributed on malaria research publications before and during the COVID-19 pandemic; Table S4: Top journals that contributed on malaria research publications before and during the COVID-19 pandemic; Table S5: Top keywords that contributed on malaria research publications before and during the COVID-19 pandemic; Table S6: Top funding sources for malaria research publications before and during the COVID-19 pandemic; Table S7: Top languages for malaria research publications before and during the COVID-19 pandemic; Table S8: Publication types of malaria research publications before and during the COVID-19 pandemic; Table S9: Subject areas of malaria research publications before and during the COVID-19 pandemic.

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Conflicts of Interest: The authors declare that there are no conflicts of interest regarding the publication of this article.

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