Global Mapping and Visualization Analysis of One Health Knowledge in the COVID-19 Context

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ABSTRACT: Globally, the COVID-19 pandemic had a significant impact on the health, social, and economic systems, triggering lasting damage and exposing the complexity of the problem beyond just being a health emergency. This crisis has highlighted the need for a comprehensive and collaborative strategy to successfully counter infectious diseases and other global challenges. With the COVID-19 pandemic pushing One Health to the forefront of global health and sustainable development agendas, this concept has emerged as a potential approach for addressing these challenges. In the context of COVID-19, this study investigates global knowledge about One Health by examining its state, significant contributions, and future directions. It seeks to offer an integrated framework of insights guiding the development of well-informed decisions. A comprehensive search using the Scopus database was conducted, employing specific terms related to One Health and COVID-19. VOSviewer 1.6.19 software was used to generate network visualization maps. Countries' research output was adjusted based on their gross domestic product (GDP) and population size. The study identified a total of 527 publications. The United States led with 134 documents (25.4%), but India topped the adjusted ranking. One Health journal stood as the most common outlet for disseminating knowledge (49 documents; 9.3%), while Centers for Disease Control and Prevention (CDC), the United States emerged as the most prolific institution (13 documents; 2.5%). Key topics were related to the virus transmission mechanisms, climate change impacts, antimicrobial resistance, ecosystem health, preparedness, collaboration, community engagement, and developing of efficient surveillance systems. The study emphasizes how critical it is to capitalize on the present momentum of COVID-19 to advance One Health concepts. Integrating social and environmental sciences, and a variety of professions for better interaction and collaboration is crucial. Additionally, increased funding for developing countries, and legislative empowerment are vital to advance One Health and boost disease prevention.

KEYWORDS: COVID-19, microbial resistance, inequalities, climate change, sustainability, resilience

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Introduction

The COVID-19 pandemic has disrupted communities on a global scale like never before, revealing the vulnerability of the human population to newly emerging infectious diseases.[1] The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has spread quickly as the cause of COVID-19, leading to millions of infections and fatalities, overburdening healthcare systems, and having a significant negative impact on the world's economies.[2] The World Health Organization (WHO) declared the COVID-19 outbreak as a global health emergency on January 30, 2020,[3] and on March 11, 2020, it was recognized as a pandemic.[4] 6 948 764 deaths and 767 726 861 confirmed cases of COVID-19 have been reported to WHO as of July 7, 2023.[5] The COVID-19 pandemic has resulted in significant social, economic, and political challenges, leaving lasting damage and underscoring the complexity of the situation beyond being solely a health disaster.[6] The crisis has highlighted the requirement for a comprehensive and collaborative framework to properly combat such infectious disease threats and other complex problems (ie, climate change, biodiversity loss or antimicrobial resistance). This is crucial, as these challenges cannot be addressed by a single discipline or country alone.[7]

In this context, the One Health approach has emerged as a promising strategy to address emerging challenges that demand interdisciplinary and multidisciplinary approaches, integrating holistic expertise.[8] The concepts of One Health have been given a boost by the COVID-19 pandemic, elevating them to the forefront of the global health and sustainable development agendas.[9] One Health is an emerging approach that uses a comprehensive strategy to efficiently address health issues such zoonotic diseases, antibiotic resistance, food-borne illnesses, and environmental concerns.[10-12] Its concept brings together 3 connected fields—ecosystems, human health, and animal health—in an effort to balance and optimize their requirements in a sustainable manner as outlined in the redefined One Health approach by The One Health High Level Expert Panel (OHHLEP) in 2021.[11,13,14] This approach unites various sectors, disciplines, and communities across society to promote well-being, combat health threats, and address collective needs such as clean water, energy, and safe food.[11,13,14] Its core principles encompass equity between sectors, multicultural parity, community engagement, and a balanced human-animal-environment interaction, valuing biodiversity and natural resources.[15] It emphasizes stewardship, urging sustainable behaviors to ensure animal welfare and ecosystem integrity for

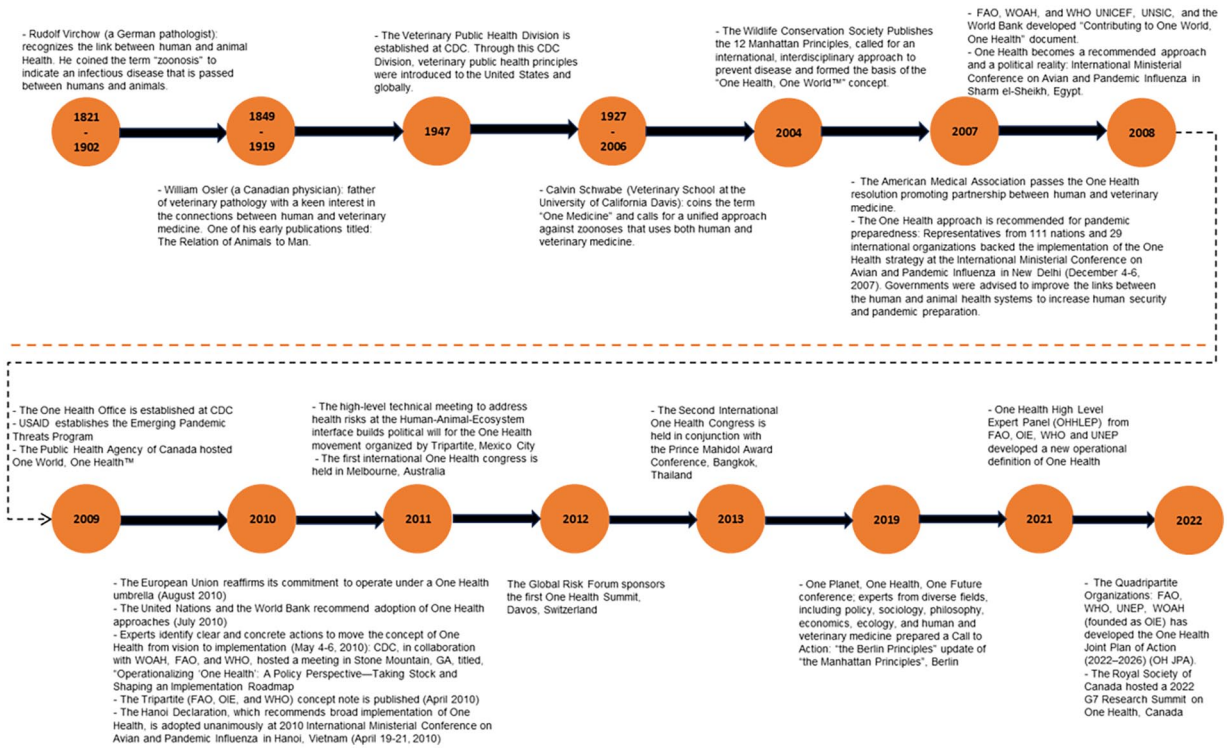

Figure 1. Timeline: people and events in One Health.

present and future generations. Moreover, it advocates for transdisciplinary collaboration, integrating both modern and traditional knowledge across diverse perspectives.[15]

With respect to infectious diseases, the philosophy of One Health places a strong emphasis on the idea that human actions that upset the ecological balance may result in virus transmission among human beings through physical contact or ingesting contaminated items.[16] Therefore, One Health specifically draws a link between the spread of infectious diseases and ecological damage.[17,18] Given the complexity of COVID-19 and its zoonotic origins, it is important to see the world from a One Health viewpoint.[19,20] The spillover incidents from animals to humans, which may have been caused by the wildlife trade or domesticated animals, highlights how crucial it is to comprehend and deal with the interaction between humans, animals, and the environment.[21,22] Stakeholders may reduce the danger of upcoming pandemics by identifying and addressing the underlying causes that lead to the emergence and spread of zoonotic diseases by adopting a One Health strategy.[23] It provides a useful platform for combining knowledge and experience from several scientific fields. A more thorough knowledge of disease dynamics can be attained by encouraging cooperation between medical experts, veterinarians, ecologists, environmental scientists, and social scientists, among others.[17] This interdisciplinary collaboration can aid in the development of efficient surveillance systems, the identification of early warning indicators, and the implementation of timely interventions to prevent or mitigate the impacts of upcoming infectious disease epidemics.[23]

Between 2003 and 2004, the spread of highly pathogenic avian influenza H5N1 and the rise of severe acute respiratory syndrome (SARS) coincided with the introduction of the phrase "One Health."[24] The "Manhattan Principles," a set of strategic objectives that were developed as a result of a meeting hosted by the Wildlife Conservation Society in 2004 also helped the idea acquire popularity.[24] While the term "One Health" may be more recent, the concept behind it has long been accepted on both a national and international scale.[25,26] Scientists started seeing connections between animal and human disease processes as early as the 1800s.[25,26] Although traditionally conducted independently, human and animal medicine did not start to come together until the 20th century.[25,26] The One Health idea has gained more traction recently among the public health, animal health and environmental sectors because of the advocacy of key figures and noteworthy incidents.[26] Currently, as reported by the One Health Commission, there are 190 academic institutions worldwide actively engaged in advancing the principles of One Health.[27] Additionally, there are 92 government/inter-governmental entities, 21 for-profit entities, and 198 non-profit entities dedicated to promoting the One Health approach.[27] Based on data retrieved from the Centers for Disease Control and Prevention (CDC) website, Figure 1 shows a chronology of significant individuals and events in One Health history.[25]

According to Humboldt-Dachroeden et al,[10] there is an increasing interest in One Health, evident not only by the growing number of publications on One Health literature but also by the escalating frequency of zoonotic disease outbreaks such COVID-19. The study conducted by de Castañeda et al[9] indicates a 137% increase in One Health discussions between 2020 and 2021 when compared to the combined data from 2018 and

2019. This surge is notable, particularly in discussions concerning infectious diseases such as COVID-19, antimicrobial resistance, and zoonoses.[9] This aligns with the extraordinary response from the global scientific community to COVID-19, motivating various researchers to track and map scientific research activities related to COVID-19 and its impacts at the country, regional, and global levels, or within specific contexts. Turatto et al,[28] for example, conducted bibliometric analysis of the scientific literature on the early phase of COVID-19 in Italy. Zyoud[6] analyzed research trends on COVID-19 linked to sustainable development goals (SDGs) while Zyoud[29] analyzed the Arab region's contribution to global COVID-19 research and Peng and Hu[30] conducted a bibliometric analysis of linguistic research on COVID-19. The COVID-19 crisis, further motivated by its disruptive impacts, has prompted researchers to analyze the role of blogs and news sites, which are expected to play a more prominent role in science communication and disseminating research on COVID-19.[31]

As the field of One Health continues to emerge, it necessitates a thorough literature review to synthesize previous research focal points and offer guidance for subsequent in-depth studies and practical applications. Various research efforts have delved into the progress of One Health research across diverse disciplines and sectors. For example, Humboldt-Dachroeden et al[10] investigated the overall state of One Health research. Miao et al[32] conducted a comprehensive descriptive study of publications in 4 domains: zoonotic diseases, antimicrobial resistance, food safety, and vector-borne infections. Meanwhile, de Castañeda et al[9] performed a bibliometric analysis using the Web of Science to gain a better understanding of the evolution of both One Health and Planetary Health. While prior studies have provided valuable insights into the developments of One Health research, the existing literature lacks a comprehensive investigation into One Health research in the context of COVID-19. The unprecedented crisis has given rise to a substantial body of literature, highlighting the necessity for a comprehensive examination within this specific context.

The present analysis intends to perform a thorough examination of the body of knowledge, characteristics, dynamics, and the present status of One Health research in the context of COVID-19. It aims to fill the gap in this regard and to provide a comprehensive overview of the issue by analyzing trends, patterns, important research subjects, and prominent contributions across countries, institutions, sources, and authors. The results of this study will further our understanding of this important subject and act as a guide for future research and policy choices that support sustainable development.

Methods

Data source

The Scopus database was chosen as the data source for this study due to several influencing factors: (1) access was provided via the "Research4Life" library; (2) its recognized comprehensive coverage of scientific literature compared to alternatives such as Web of Science and PubMed[33]; (3) It offers convenient options for exporting and analyzing data; (4) Scopus is a comprehensive database that covers citations from a wide range of fields, including social and health disciplines.[33] Consequently, the utilization of the Scopus database for this study aligns with its frequent usage in various research studies.[2,6,34,35]

Search technique

Data retrieval and export were completed within a single day (November 12, 2023) to minimize potential biases stemming from continuous updates in the Scopus database. The search interval remained open from its start and concluded upon data retrieval. The most commonly utilized One Health terms[10,36,37] and those associated with COVID-19[2,6,29,38] were incorporated into the "Title-Abstract" section within the Scopus database. It is suggested that publications engaged in One Health and COVID-19 research (conceptually, methodologically, and/or empirically) would, at a minimum, refer to One Health and COVID-19 terms within their title and/or abstract. Terms related to One Health or COVID-19 were combined using the OR operator, while linking One Health and COVID-19 terms together using the AND operator to gather associated publications. The following is the final search string: ((TITLE-ABS ("COVID 19") OR TITLE-ABS ("coronavirus 2019") OR TITLE-ABS ("2019 novel coronavirus") OR TITLE-ABS ("2019-novel CoV") OR TITLE-ABS ("coronavirus disease 2019") OR TITLE-ABS ("2019 ncov") OR TITLE-ABS ("COVID19") OR TITLE-ABS ("COVID 2019") OR TITLE-ABS ("corona virus 2019") OR TITLE-ABS ("nCoV2019") OR TITLE-ABS ("nCoV-2019") OR TITLE-ABS ("nCoV 2019") OR TITLE-ABS ("COVID-19") OR TITLE-ABS ("2019-ncov") OR TITLE-ABS ("SARS-CoV-2") OR TITLE-ABS ("Severe acute respiratory syndrome coronavirus 2") AND (TITLE-ABS ("One Health") OR TITLE-ABS ("One-Health") OR TITLE-ABS ("OneHealth")))).

To ensure reliable and accurate findings, the titles and abstracts of the obtained contributions underwent manual scrutiny. In certain cases, full texts were also reviewed. This process aimed to narrow down the analysis to documents discussing the One Health concept within the context of COVID-19. These included works advocating for a One Health approach to prevent COVID-19 and other pandemics, calling for One Health surveillance, intervention, and management strategies, or adopting a One Health perspective. Documents that merely used the term "One Health" in a generic context (eg, "one health district," "one health professional," etc.) were excluded, along with erratum documents. This procedure adhered to the PRISMA guidelines for defining inclusion and exclusion criteria.[39] The data meeting the specified criteria was exported to Excel files. It

comprised various bibliometric parameters such as document types (eg, articles, books, conference proceedings), field classification, author details, abstracts, keywords (authors' and sources' keywords), publication year, publication count, citation count (indicating how often other works referenced the publication), publication origin country, producing institution or organization, funding details, and the journals where the publications appeared, among other indexed data.

Bibliometric analysis and visualization mapping

This analysis focused extensively on the most prolific countries, institutions, sources, authors, and highly cited publications. Mapping the science concerning One Health in the context of COVID-19 involved considering a performance analysis utilizing 2 categories of bibliometric indicators: quantitative and qualitative. Quantitative indicators, such as publication count, author count, publication source count, institution count, and country count, serve to assess productivity.[40] Conversely, qualitative indicators such as citation count and h-index are employed to evaluate quality based on the bibliometric impact of identified themes and thematic areas.[40] Using an adjustment index (AI) that combined population size, gross domestic product (GDP), and publication volume, the productivity of countries was objectively evaluated. The AI is computed using the following formula: AI = [Total number of publications of the country/GDP per capita of the country] × 100, where GDP per capita is determined by dividing the GDP of the country by its population.[29,41] Population and GDP data for countries were retrieved from the World Bank Open Data portal,[42] while country classification and global region details were sourced from the SCImago Journal & Country Rank portal, incorporating journal and country scientific indicators derived from Scopus information.[43] To evaluate the quality of the most productive sources, the impact factor from Journal Citation Reports and the CiteScore from the Scopus database for these sources were considered. These indicators generally measure the frequency with which documents in a journal have been cited in a particular year or period.[44]

The VOSviewer, a mapping and visualization tool, showcases global collaboration, contributions from diverse entities, and identifies research hotspots through a co-occurrence matrix using grouping and similarity mapping algorithms.[45,46] In these knowledge maps, each node on the map represents an element, such as a country, institution, or source. several factors influence the size of an element, including the number of publications and the frequency of citations or occurrences.[47] The relationships between elements are depicted by the links between nodes, where the connecting lines signify these relationships.[47] Links connect 2 items, like co-authorship links between researchers, institutions, or countries, and co-occurrence links between terms. They possess a strength, shown as a positive numerical value, which signifies their intensity—the higher the value, the stronger the link.[46] This strength might reflect the quantity of publications jointly authored by 2 researchers, institutions, or countries (for co-authorship links), or the frequency of occurrences of 2 terms together in publications (for co-occurrence links).[46]

A two-dimensional bibliometric map of international research collaboration is displayed using VOSviewer.[46] For example, any 2 countries' distance from one another can be used to determine how closely they are connected. Maps spanning countries with higher levels of scientific collaboration will reveal a closer distance between them. Colors indicate clusters of countries that are relatively strongly connected by co-authorship links.[10] Concerning the co-occurrence matrix, each word, term, or expression within the term clusters is depicted by a frame. The size of this frame corresponds to the total number of documents associated with that specific term.[48] To effectively emphasize topics of interest within the reviewed discipline, selected terms were chosen from the titles and abstracts of documents. In this context, co-occurrence analysis analyzes how frequently two terms appear together in different publications to determine how similar they are.[10] It provides information on the important terms that are connected to One Health and COVID-19, enabling one to evaluate the field's knowledge base.

Using co-citation analysis, which looks at sources' shared citations, was used to investigate linkages between publications and gather insightful knowledge about the intellectual connections and impact within One Health and COVID-19. For example, when a publication in journal A cites works from journals B and C, it suggests similarity between B and C. The higher the number of journals citing both B and C, the stronger their similarity.[10] The proximity of 2 journals in the visualization reflects their relatedness through co-citation links.[46] This kind of analysis aids academics in grasping the key sources within a certain topic and offers insights into the disciplinary structure within the field.[6,10] Sources assigned to a specific cluster indicate closely related fields.[46] A threshold was applied regarding the minimum number of documents, citations, and occurrences to ensure proper visualization of the networks.[49]

Figure 2 presents an explanation of the methodological approach utilized for the inclusion criteria and methods of search for retrieving directly related research publications on One Health and COVID-19. Along with presenting a visual depiction of the analysis process' roadmap, which comprises data gathering, bibliometric evaluation, visualization mapping, and significant findings, Figure 2 also summarizes the full analysis process.

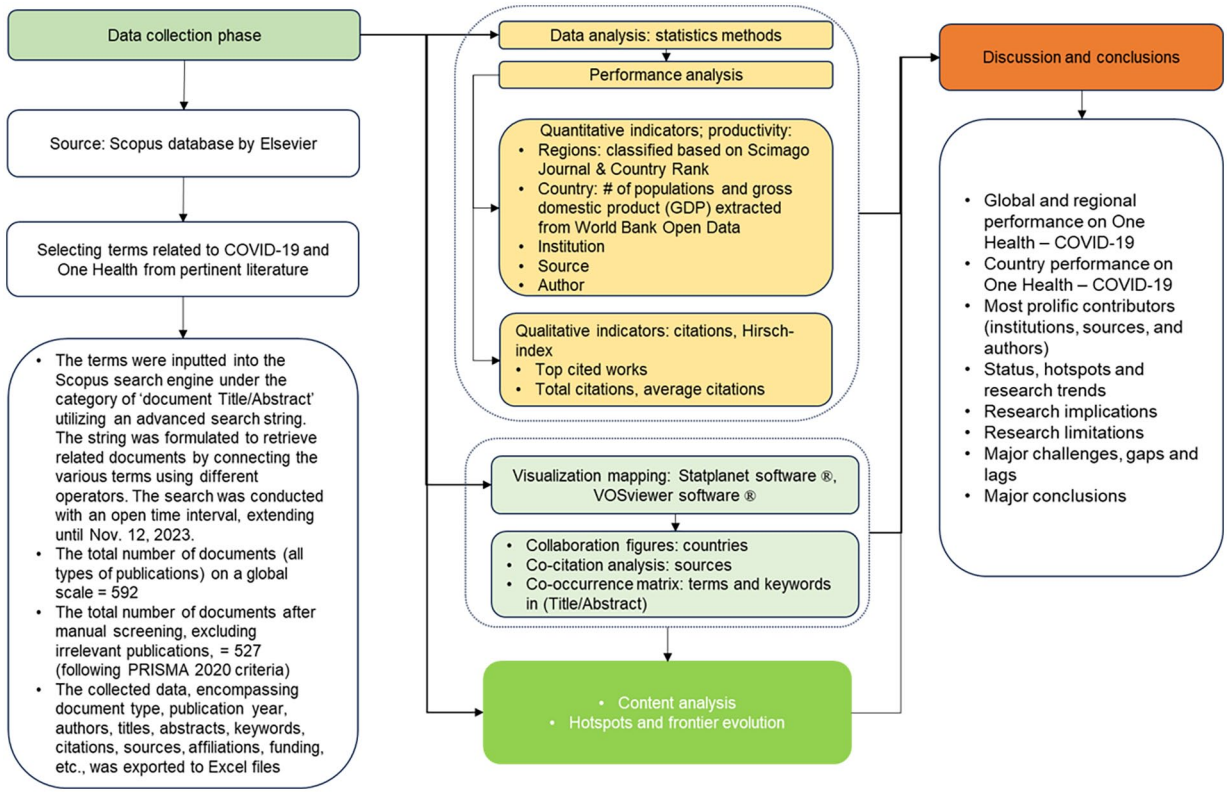

Figure 2. The roadmap outlines the entire analysis procedure of global research and knowledge on One Health and COVID-19 including data collection, bibliometric analysis, visualization mapping and major outcomes.

Results

A summary of the retrieved publications on one Health-COVID-19

A collection of 527 papers from various publishing kinds were released between 2020 and November 2023, each of which had the terms One Health and COVID-19 concurrently as a topic in their titles and/or abstracts. This figure was established after a thorough manual screening procedure by removing publications that made use of One Health outside of the scope of the concept being examined in the present analysis. The distribution of the aforementioned documents was as follows: 290 articles (55.0%), 150 reviews (28.5%), and 87 documents (16.5%) classified as other types, such as notes, book chapters, editorials, letters, conference papers, books, and short surveys.

Most studies conducted on the One Health approach in relation to COVID-19 were in the field of medicine (299 documents; 56.7%). This was followed by immunology and microbiology (102 documents; 19.4%), veterinary (87 documents; 16.5%), environmental science (70 documents; 13.3%), agricultural and biological sciences (60 documents; 11.4%), social sciences (56 documents; 10.6%), biochemistry, genetics, and molecular biology (46 documents; 8.7%), and pharmacology, toxicology, and pharmaceutics (24 documents; 4.6%). Other fields with less representation include engineering, multidisciplinary studies, nursing, earth and planetary sciences, and so on.

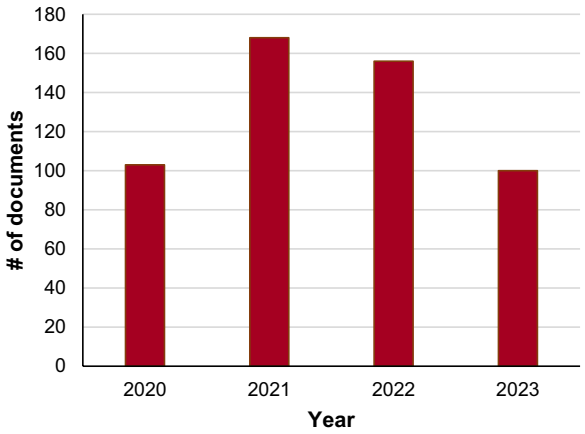

Figure 3. Evolution of publications on One Health in the context of COVID-19.

Evolution of publications on One Health-COVID-19

Figure 3 displays the growth of publications on One Health-COVID-19 with time. One Health and COVID-19 publishing started in 2020 with 103 documents, concurrent with a sharp rise in COVID-19 publications. The productivity of One Health-COVID-19 peaked in 2021 with 168 documents, followed by a decline in 2022, which recorded 156 documents. Although the year 2023 remains open for new publications, the trend indicates a decline, with only 100 documents registered

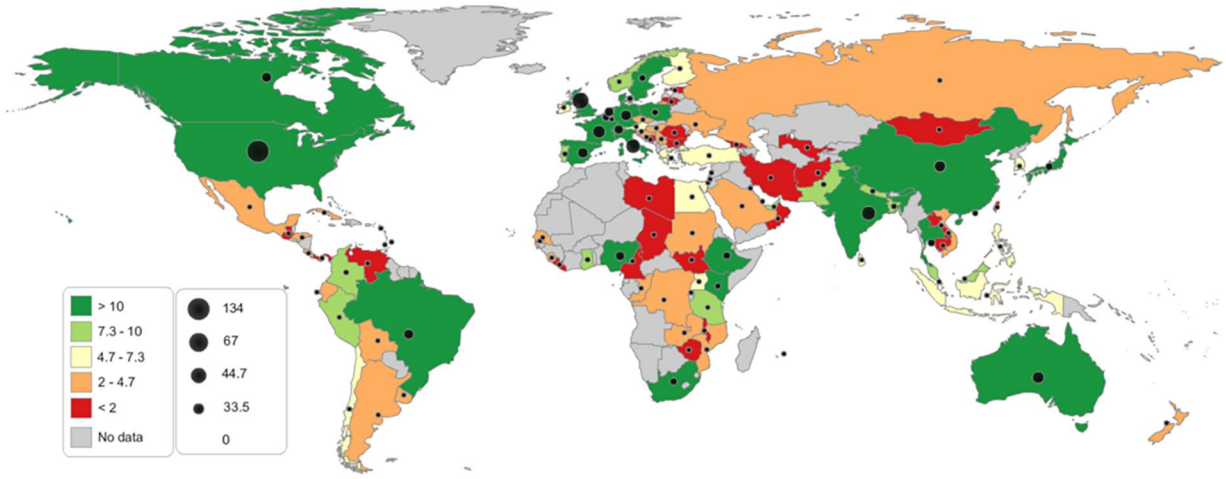

Figure 4. Nation-level production on One Helath-COVID-19; a worldwide perspective of the research productivity at the country level. The size of black circles represents the output of each country (ie, the larger the circle, the higher the performance of the country with respect to the number of publications). The global map was created using Statplanet Interactive Mapping and Visualization Software, www.statsilk.com, free license.

until November 12th, the date of data retrieval from the Scopus database, nearing the end of the year. In general, publications on One Health-COVID-19 made up around 10% of all One Health documents during the time period under consideration, whereas they made up just 0.1% of all COVID-19 publications during the same timeframe. In conclusion, despite the advancements achieved, One Health-COVID-19 continues to get just a small amount of interest in comparison to the entire research done on One Health or COVID-19.

Productivity of countries and collaboration figures

A comprehensive overview of the One Health-COVID-19 research output is shown in Figure 4. Research on One Health and its association with COVID-19 is being supported in various capacities by 110 countries distributed across different regions of the world. The most productive region is Western Europe (365 documents; 69.0%), followed by Asiatic region (211 documents; 40.0%), Northern America (161 documents; 30.6%), Africa (123 documents; 23.3%), Latin America (80 documents; 15.2%), Pacific region (42 documents; 8.0%), Middle East (39 documents; 7.4%), and Eastern Europe (37 documents; 7.0%). Africa has the most contributing countries (25), followed by Asiatic region (21), Latin America (18), Western Europe (17), Eastern Europe (14), Middle East (11), and 2 from each of the Pacific region and Northern America. The United States stands out as the top contributor in terms of publications on One Health-COVID-19 at the country level, with a total of 134 papers (25.4%), according to Table 1, which shows the top 20 most prolific countries. With 79 papers (15.0%) and 56 documents (10.6%), respectively, the United Kingdom and India occupy the second and third spots in the rankings behind the United States. Collectively, the top 20 countries contributed 444 documents (84.3%). Out of the 20 countries listed, the majority of the most productive ones, specifically 13 countries, are developed nations with well-established scientific capabilities. India emerged on top in the AI rankings of nations based on GDP per capita and quantity of publications, followed by Ethiopia, Nigeria, and Brazil. Figure 5 shows the global network of One Health-COVID-19 research collaboration, with each country contributing a minimum of 10 documents and a minimum of 100 citations per country. The co-authorship relationships between 24 nations are displayed on the visualization map, demonstrating how closely they are linked. The United States, the United Kingdom, and Germany emerge as the top 3 countries in terms of prevalent collaboration, as evidenced by their high number of links on the visualization map. Specifically, these countries exhibit 23 links of collaboration per country out of a total of 201 collaboration links. The United States stands out with the strongest links, boasting a total link strength of 167 out of 588—the cumulative link strength for all countries. Most co-authorship links were between the United States and the United Kingdom (the thickest link on the map), followed by links between the United States and Germany.

Institutions with the highest productivity in One Health-COVID-19

A collective of 2237 institutions has contributed a total of 527 documents on the topic of One Health-COVID-19. The top 20 institutions, as shown in Table 2, collectively contributed 141 documents (26.8%). The CDC from the United States held the top position with 15 documents (2.8%), followed by the Indian Veterinary Research Institute and the Indian Council of Agricultural Research in India, each with 13 documents (2.5%). The United States and France, each with 4 institutions per country, led the count, followed by the United

Table 1. Top 20 countries with prolific contributions on One Health-COVID-19.

RANK	COUNTRY	NUMBER OF PUBLICATIONS	%	POPULATION (THOUSANDS)	GDP (MILLIONS-US$)	AI	AI RANK
1st	United States	134	25.4	331 893.74	23315 080.56	190.8	8th
2nd	United Kingdom	79	15.0	67 326.57	3 131 377.76	169.9	9th
3rd	India	56	10.6	1 407 563.84	3 176 295.07	2481.6	1st
4th	Italy	52	9.9	59 109.67	2 107 702.84	145.8	10th
5th	France	42	8.0	67 749.63	2 957 879.76	96.2	12th
6th	Australia	39	7.4	25 688.08	1 552 667.36	64.5	13th
7th	China	37	7.0	1 412 360.00	17 734 062.65	294.7	5th
8th	Germany	30	5.7	83 196.08	4 259 934.91	58.6	14th
8th	Spain	30	5.7	47 415.75	1 427 380.68	99.7	11th
10th	Canada	27	5.1	38 246.11	1 988 336.33	51.9	15th
11th	Brazil	26	4.9	214 326.22	1 608 981.46	346.3	4th
12th	Netherlands	24	4.6	17 533.04	1 012 846.76	41.5	16th
12th	Switzerland	24	4.6	8703.41	800 640.16	26.1	19th
14th	Nigeria	23	4.4	213 401.32	440 833.58	1113.4	3rd
15th	Belgium	17	3.2	11 592.95	594 104.18	33.2	18th
16th	Thailand	16	3.0	71 601.10	505 947.04	226.4	6th
17th	South Africa	15	2.8	59 392.25	419 015.02	212.6	7th
18th	Ethiopia	14	2.7	120 283.03	111 271.11	1513.4	2nd
18th	Japan	14	2.7	125 681.59	4 940 877.78	35.6	17th
20th	Sweden	13	2.5	10 415.81	635 663.80	21.3	20th

Abbreviations: AI; adjustment index; GDP; gross domestic product.
The following formula was used to calculate an adjustment index (AI): AI = [Total number of publications for the country/GDP per capita of the country] × 100, where GDP per capita is the country's GDP divided by its population.

Kingdom and India, each with 3 institutions per country, housing the largest number of highly productive institutions.

Most productive sources and journals

Among the 340 sources that contributed to the research works on One Health-COVID-19, Table 3 lists the 20 top-ranked peer-reviewed journals and sources. About 36.0% of all publications in this discipline were published in these 30 journals (the top 20 prolific sources are shown in Table 3). The list was headed by the One Health journal, which had 49 documents (9.3%), then Viruses (15.0 documents; 2.8%), and Frontiers in Public Health, which had 11 documents (2.1%). Twenty-four out of the 30 journals listed as the most prolific have impact factors. The Lancet journal stands out as the most influential journal with an impressive impact factor of 168.9. While all sources have CiteScore, the Lancet journal stands out with the highest CiteScore of 133.2.

Top cited works on One Health-COVID-19

At the time of data extraction, there were a total of 7538 citations for research papers on One Health-COVID-19. The h-index was 41, which means that 41 papers, out of all those published on One Health-COVID-19, had at least 41 citations each. On average, each document earned 14.3 citations. Table 4 lists the top 20 publications in the field under consideration that have received the most citations (there are 13 articles, 6 reviews, and 1 editorial included with these works), with citation counts ranging from 68 to 381.[21,50-68] At the time of data extraction, a review article from the journal Trends in Molecular Medicine had the most citations, with 381.[21] It offers a summary of the virus's evolutionary history in intermediate hosts and its adaptive development, and it suggests a coordinated response to the epidemic using a One Health strategy combining veterinarians and animal specialists.[21]

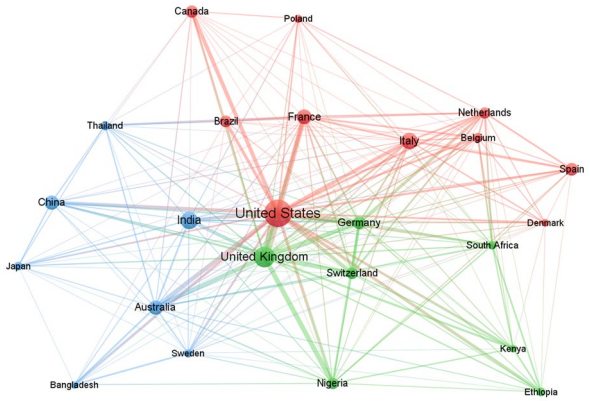

Figure 5. Network visualization map illustrating international research collaboration among countries on One Health-COVID-19, featuring a minimum research output of 10 documents per country and a minimum of 100 citations per country. Full counting is employed, where each co-authorship link is assigned equal weight. Twenty-four countries out of 110 countries met the threshold. For each of 24 countries, the total strength of the co-authorship links with other countries was calculated. The more important an item, the larger its label and its circle. The countries with the greatest total link strength were selected. The map categorizes countries into 3 clusters, each represented by distinct colors based on their frequent collaborations. Cluster 1, highlighted in red, consists of 10 countries with the United States at its core. Cluster 2, marked in green, includes 7 countries with the United Kingdom as its core. The final cluster, distinguished by a blue color, encompasses 7 countries with India at its core. The map was created using VOSviewer software version 1.6.19.

Co-citation analysis of sources

The co-citation network visualization map, Figure 6, revealed 11 major sources as most co-cited sources with a minimum number of citations of a source was set as 100. These sources are crucial for the dissemination of knowledge and play a key role in delivering information on One Health concepts in the context of COVID-19. The map categorized these sources into 2 clusters with distinctive colors. Each cluster consists of sources that have shared characteristics in relation to the subject of the investigation. The most notable links were observed between the journals Nature and Science, represented by the thickest link on the map. This was followed by the link between Nature and the Lancet, and finally, the link between Nature and Viruses journals. The map demonstrates the lack of significant social sciences journals serving as central outlets for research on One Health-COVID-19. The co-citation analysis density visualization map, represented in Figure 7, revealed that Nature, Science, Lancet, Viruses, Plos One, and One Health journals were the most frequently cited sources, (as indicated by their appearance in the red color zone on the map).

The most prolific authors

The most active One Health-COVID-19 authors are listed in Table 5. Those authors collectively contributed 54 documents, accounting for 10.3%. Countries with the most prolific authors are the United States (6 scholars), India (4 scholars), and Switzerland (3 scholars). Through an investigation of co-authorship links, it was discovered that the most collaborative authors, co-authoring at least 5 publications on One Health-COVID-19, were Dhama, K. from India; Sharun, K. from India, Rodriguez-Morales, A.J. from Colombia; Bonilla-Aldana, D.K. from Peru; and Tiwari, R from India. This demonstrates notable collaboration between institutions in India (Asiatic region) and both Colombia and Peru (Latin America), as evidenced by the strong co-authorship ties among 5 authors from the list of productive authors. In the list of most prolific authors, 5 out of 6 authors from the United States are affiliated with the CDC. Scholars in the field of veterinary medicine constitute the most productive authors, along with specialists in infectious diseases, biomedicine, and clinical medicine who maintain strong connections to both zoonosis and veterinary domains. Most of the prolific authors' work is dedicated to investigating transmission mechanisms of the virus from animals to humans. The findings show a dearth of social science researchers in the list of most productive authors.

One Health-COVID-19 primary topics

The co-occurrence analysis was conducted to uncover the most frequently mentioned and interconnected topics and concepts. The research domains were classified into 2 major clusters (cluster 1 with red color and cluster 2 with green color) by analyzing the co-occurrence of terms in the titles and abstracts of publications on One Health-COVID-19 (Figure 8). The most frequently occurring terms and their respective clusters (after excluding the general terms related to COVID-19 and other general terms such as article, paper, research, and example) are as follows: Health (333 occurrences; cluster 1), approach (292 occurrences; cluster 1), animal (247 occurrences; cluster 2), human (235 occurrences; cluster 2), SARS COV (205 occurrences; cluster 2), infection (149 occurrences; cluster 2), transmission (139 occurrences; cluster 2), environment (123 occurrences; cluster 1), system (119 occurrences; cluster 1), response (113 occurrences; cluster 1), impact (108 occurrences; cluster 1), challenge (106 occurrences; cluster 1), and threat (99 occurrences; cluster 1). The topics with the highest relevancy were related to the possible transmission of the virus from domestic and wild animals (cat, pet, dog, bat, etc.), climate change impacts, antimicrobial resistance as a global concern, environmental and ecosystems health, major challenges and future preparedness, collaboration and community engagement, and the significance of efficient surveillance systems as efficient techniques for preparedness and response to pandemics, Figure 9.

The terms employed in research publications focused on One Health in the context of COVID-19 related to the progression over time were also identified within the titles and abstracts in the investigation of term co-occurrence (Figure 10). In particular, studies examining environmental and ecosystem health, the significance of collaboration and societal engagement, as well as the impacts of climate change and challenges of

Table 2. Top 20 productive institutions on One Health-COVID-19.

RANK	INSTITUTION	COUNTRY	NUMBER OF PUBLICATIONS	%
1st	Centers for Disease Control and Prevention	United States	15	2.8
1st	Indian Veterinary Research Institute	India	13	2.5
2nd	Indian Council of Agricultural Research	India	13	2.1
2nd	CNRS Centre National de la Recherche Scientifique	France	11	2.1
5th	Fundacao Oswaldo Cruz	Brazil	11	1.7
5th	University of Montreal	Canada	9	1.7
5th	Universität Zürich	Switzerland	9	1.7
5th	Royal Veterinary College University of London	United Kingdom	9	1.7
5th	Organisation Mondiale de la Santé	Switzerland	9	1.7
5th	The University of Edinburgh	United Kingdom	9	1.7
5th	The University of Queensland	Australia	9	1.7
5th	London School of Hygiene & Tropical Medicine	United Kingdom	9	1.7
13th	United States Department of Agriculture	United States	8	1.5
13th	Johns Hopkins Bloomberg School of Public Health	United States	8	1.5
13th	Universiteit Utrecht	Netherlands	8	1.5
13th	Chinese Center for Disease Control and Prevention	China	8	1.5
13th	Tribhuvan University	Nepal	8	1.5
18th	Université de Montpellier	France	7	1.3
18th	INSERM (National Institute for Health and Medical Research)	France	7	1.3
18th	University of California, Davis	United States	7	1.3
18th	College of Veterinary Science India	India	7	1.3
18th	IRD Centre de Montpellier	France	7	1.3
18th	University of Oxford	United Kingdom	7	1.3
18th	USDA Animal and Plant Health Inspection Service APHIS	United States	7	1.3
18th	EcoHealth Alliance	United States	7	1.3
18th	Fundación Universitaria Autónoma de las Américas	Colombia	7	1.3
18th	Université Paris Cité	France	13	2.5

antimicrobial resistance, have surfaced in more recent periods. Earlier publications predominantly concentrated on the origin of the virus and its transmission mechanisms.

Discussion

Insights on global One Health-covid-19-related research

In this analysis, a comprehensive examination of the development of One Health-COVID-19, along with global trends and research horizons were all thoroughly examined. The significant interest of researchers in this field is evident, particularly during the proliferation of the pandemic. The reduced interest in COVID-19-related research lately is attributed to the efficacy of vaccines and treatments in mitigating the severity of the pandemic. As a result, the surge in pandemic-related publications witnessed in 2020 and 2021 is expected to decline significantly.[69] Moreover, this trend is linked to the WHO lifting the Public Health Emergency of International Concern (PHEIC) for COVID-19 in 2023, and the conclusion of the federal COVID-19 Public Health Emergency by the United States in 2023.[70] These decisions

Table 3. Top 20 most productive sources on One Health-COVID-19.

RANK	SOURCE	NUMBER OF PUBLICATIONS	%	IMPACT FACTOR: IF[a]	CITESCORE[b]
1st	One Health	49	9.3	5.0	7.8
2nd	Viruses	15	2.8	4.7	7.1
3rd	Frontiers in Public Health	11	2.1	5.2	3.8
4th	Frontiers in Veterinary Science	9	1.7	3.2	3.8
5th	Animals	6	1.1	3.0	4.2
5th	International Journal of One Health	6	1.1	NA	1.7
5th	Pathogens	6	1.1	3.7	5.1
5th	Science of the Total Environment	6	1.1	9.8	16.8
5th	Transboundary and Emerging Diseases	6	1.1	4.521	7.4
10th	American Journal of Primatology	5	0.9	2.4	4.6
10th	Antibiotics	5	0.9	4.8	5.5
10th	Lancet	5	0.9	168.9	133.2
10th	Plos One	5	0.9	3.752	6.0
10th	Veterinary Quarterly	5	0.9	6.4	13.8
15th	Bulletin De L Academie Veterinaire De France	4	0.8	NA	0.3
15th	Emerging Infectious Diseases	4	0.8	11.8	15.6
15th	Indian Journal of Medical Research	4	0.8	4.2	5.6
15th	Microorganisms	4	0.8	4.5	6.4
19th	Bulletin De L Academie Nationale De Medecine	3	0.6	0.3	0.4
19th	Chinese Journal of Parasitology and Parasitic Diseases	3	0.6	NA	0.5
19th	Derecho Animal	3	0.6	NA	1.3
19th	Emerging Microbes and Infections	3	0.6	13.2	23.1
19th	Eurosurveillance	3	0.6	19.0	27.7
19th	Indian Journal of Public Health	3	0.6	1.7	2.3
19th	International Journal of Environmental Research and Public Health	3	0.6	NA	5.4
19th	Journal of the American Veterinary Medical Association	3	0.6	1.9	1.6
19th	Microbes and Infection	3	0.6	5.8	13.3
19th	Pan African Medical Journal	3	0.6	NA	1.4
19th	Veterinary World	3	0.6	2.2	3.2
19th	Zoonoses and Public Health	3	0.6	2.4	5.1

[a]Impact Factor (IF): is calculated by dividing the number of current year citations to the source items published in a journal during the previous 2 years (these comprise articles, reviews, and proceedings papers); (2022 Journal Citation Reports®, Clarivate 2023).
[b]CiteScore: CiteScore 2022 counts the citations received in 2019 to 2022 to articles, reviews, conference papers, book chapters, and data papers published in 2019 to 2022, and divides this by the number of publications published in 2019 to 2022 (CiteScore 2022, Scopus database 2023).

align with the high global vaccination rates, with around 70% of the world's population receiving at least one COVID-19 vaccine dose by mid-2023.[70]

The economic situation, population size, degree of development, scientific capabilities, and national scientific infrastructure of each individual country are only a few of the variables that

Table 4. Top 20 cited works on One Health-COVID-19.

RANK	AUTHORS	YEAR	TITLE	SOURCE	TIMES CITED	TYPE OF DOCUMENT
1st	Sun et al.	2020	COVID-19: Epidemiology, Evolution, and Cross-Disciplinary Perspectives	Trends in Molecular Medicine	381	Review
2nd	El Zowalaty and Järhult	2020	From SARS to COVID-19: A previously unknown SARS- related coronavirus (SARS-CoV-2) of pandemic potential infecting humans – Call for a One Health approach	One Health	271	Article
3rd	McAloose et al.	2020	From people to panthera: Natural sars-cov-2 infection in tigers and lions at the bronx zoo	mBio	226	Article
4th	Tiwari et al.	2020	COVID-19: animals, veterinary and zoonotic links	Veterinary Quarterly	199	Review
5th	Rahman et al.	2020	Zoonotic diseases: Etiology, impact, and control	Microorganisms	176	Article
6th	Hale et al.	2022	SARS-CoV-2 infection in free-ranging white-tailed deer	Nature	173	Article
7th	Amirian and Levy	2020	Current knowledge about the antivirals remdesivir (GS-5734) and GS-441524 as therapeutic options for coronaviruses	One Health	152	Review
8th	Dhama et al.	2020	SARS-CoV-2 jumping the species barrier: Zoonotic lessons from SARS, MERS and recent advances to combat this pandemic virus	Travel Medicine and Infectious Disease	141	Review
9th	Majumder et al.	2020	Antimicrobial stewardship: Fighting antimicrobial resistance and protecting global public health	Infection and Drug Resistance	136	Article
10th	Leroy et al.	2020	The risk of SARS-CoV-2 transmission to pets and other wild and domestic animals strongly mandates a one-health strategy to control the COVID-19 pandemic	One Health	127	Editorial
11th	Bonilla-Aldana et al.	2020	Revisiting the one health approach in the context of COVID-19: A look into the ecology of this emerging disease	Advances in Animal and Veterinary Sciences	115	Article
12th	Trilla	2020	One world, one health: The novel coronavirus COVID-19 epidemic; [Un mundo, una salud: la epidemia por el nuevo coronavirus COVID-19]	Medicina Clinica	105	Article
13th	Kuchipudi et al.	2022	Multiple spillovers from humans and onward transmission of SARS-CoV-2 in white-tailed deer	Proceedings of the National Academy of Sciences of the United States of America	99	Article
14th	Espejo et al.	2020	Environment and COVID-19: Pollutants, impacts, dissemination, management and recommendations for facing future epidemic threats	Science of the Total Environment	98	Article
15th	Tilocca et al.	2020	Comparative computational analysis of SARS-CoV-2 nucleocapsid protein epitopes in taxonomically related coronaviruses	Microbes and Infection	94	Article
16th	Hobbs and Reid	2021	Animals and SARS-CoV-2: Species susceptibility and viral transmission in experimental and natural conditions, and the potential implications for community transmission	Transboundary and Emerging Diseases	91	Review

(Continued)

Table 4. (Continued)

RANK	AUTHORS	YEAR	TITLE	SOURCE	TIMES CITED	TYPE OF DOCUMENT
17th	Decaro et al.	2020	COVID-19 from veterinary medicine and one health perspectives: What animal coronaviruses have taught us	Research in Veterinary Science	76	Article
18th	Wade	2022	Understanding and managing uncertainty and variability for wastewater monitoring beyond the pandemic: Lessons learned from the United Kingdom national COVID-19 surveillance programs	Journal of Hazardous Materials	73	Article
19th	Sharun et al.	2021	SARS-CoV-2 infection in farmed minks, associated zoonotic concerns, and importance of the One Health approach during the ongoing COVID-19 pandemic	Veterinary Quarterly	71	Review
20th	Gollakner and Capua	2020	Is covid-19 the first pandemic that evolves into a panzootic?	Veterinaria Italiana	68	Article

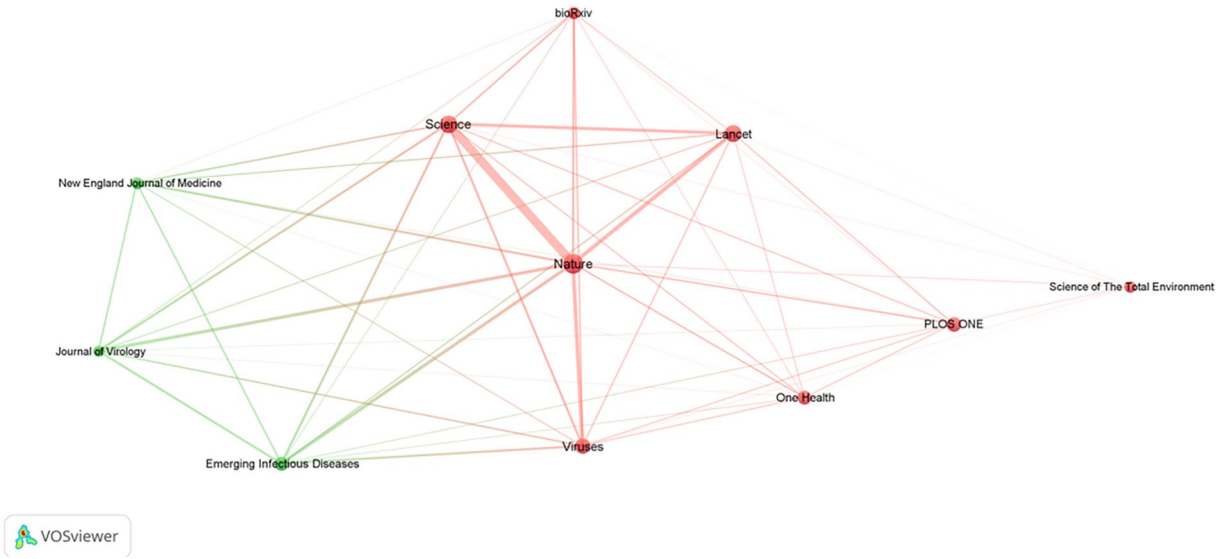

Figure 6. Network visualization map. The minimum number of citations of a source was set as 100. Full counting is employed, where each co-citation link is assigned equal weight. Of the 8347 sources, 11 met the threshold. For each of the 11 sources, the total strength of the co-citation links with other sources was calculated. The sources with the greatest total links strength were selected. The map was created using VOSviewer software version 1.6.19.

contribute to the differences in research output between countries. Due to their early adoption of One Health concepts, developed countries fare better than other countries in the One Health-COVID-19 research. The leading role of certain major countries on this topic, such as the United States, the United Kingdom, India, Italy, France, Australia, China, and Germany, could be attributed further to the high prevalence rates of COVID-19 in those countries, with some of them having witnessed the first outbreak.[5] Regarding the United States, it is widely acknowledged as a significant contributor in terms of research productivity and collaboration, which is evident across various scientific fields. The United States is home to numerous organizations and institutions that demonstrate a strong interest in the development of guidelines, initiatives, projects, and the practical implementation of the One Health approach. This includes, but is not limited to, the CDC, the United States Environmental Protection Agency (US EPA), the US Department of State, the US Department of Agriculture, the United States Geological Survey (USGS), the American Public health Association (APHA), the American Veterinary Medicine Association (AVMA), and the One Health Commission. Numerous initiatives led by United States institutions, primarily the CDC, aim to support the One Health approach to public health science in developing countries, collaborating with various partners.[71] Furthermore, the United States experienced the greatest impact of COVID-19 worldwide, both in terms of the number of deaths (1 127 152) and the number of confirmed cases (103 436 829).[5]

Despite facing challenges in implementing the One Health strategy in developing countries, such as structural weaknesses or a lack of financial, human, and material resources,[72] several developing countries have made significant contributions to

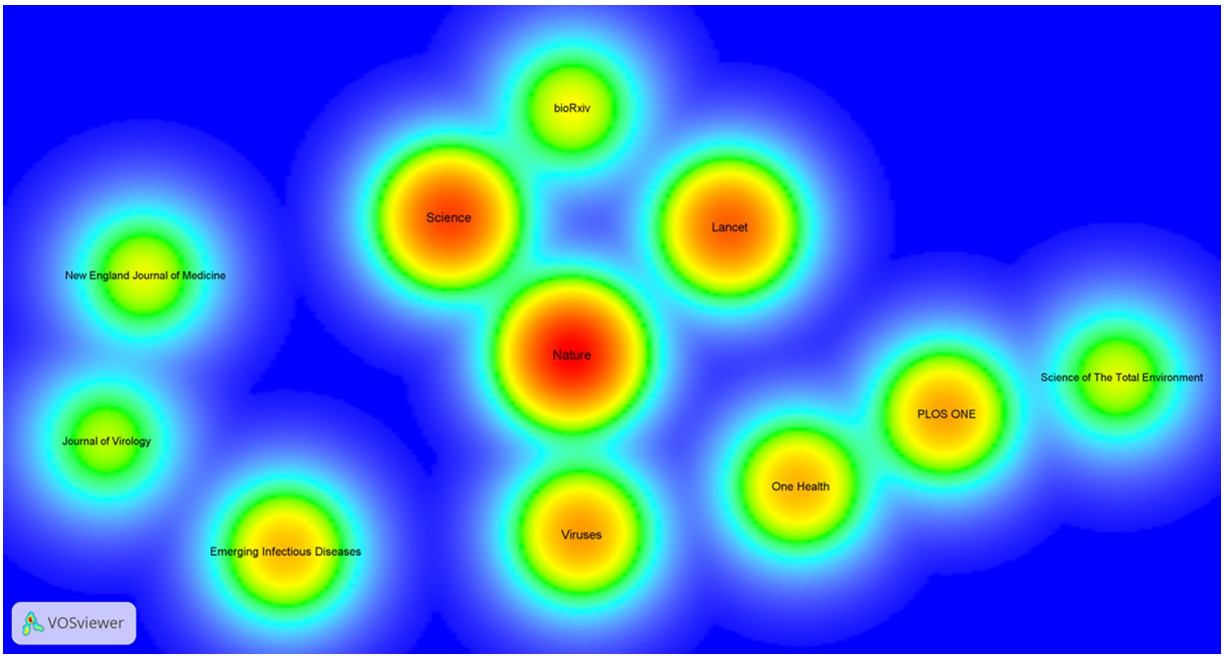

Figure 7. Density visualization map of co-citation of cited sources. The minimum number of citations of a source was set as 100. Full counting is employed, where each co-citation link is assigned equal weight. Of the 8347 sources, 11 met the threshold. For each of the 11 sources, the total strength of the co-citation links with other sources was calculated. The sources with the greatest total links strength were selected. The red color corresponds with the highest item density and blue corresponds with the lowest item density. The map was created using VOSviewer software version 1.6.19.

One Health within the context of COVID-19. India's strong performance, which led the world after accounting for AI, may be attributable to several key factors. First off, it has been determined that South Asia is a key hub for infectious diseases, with India bearing the greatest burden of zoonoses, poverty, and reliance on livestock.[73] In addition to having regional impacts, the emergence of India as a zoonotic hotspot raises problems for global health, posing concerns regarding global readiness, particularly in the context of emerging and re-emerging diseases with epidemic potential.[73] India furthermore came in third place internationally for the COVID-19 pandemic in terms of both the number of confirmed cases (44 994 351) and deaths (531 908).[5] As indicated by Asaaga et al,[74] India presents a compelling case for studying the dynamics of One Health concepts due to its prominent global ranking in terms of the burden and diversity of endemic and emerging zoonotic diseases. Moreover, India's national and state-level initiatives aimed at promoting cross-sectoral action for zoonotic disease control further highlight the significance of examining the country as a case study in this context.[74]

The adoption of policies and research initiatives has catalyzed action on One Health across the African region, resulting in approximately 315 initiatives across sub-Saharan African countries.[75,76] Moreover, it has elevated various African nations like Nigeria, South Africa, and Ethiopia as significant contributors to One Health and COVID-19-related research. The co-funding of One Health initiatives by national governments, however, has been inadequate, with more than 90% of the funding coming from stakeholders outside the continent.[75,76] China has showcased significant contributions to One Health-COVID-19 related research across various levels. The country is acknowledged for making substantial strides in enhancing the application of the One Health approach in both policy and practice.[77] Despite these advancements, China grapples with challenges stemming from the complexity of eco-environmental changes, both domestically and globally, particularly at the primary level.[77] Brazil, on the other hand, has tools for integrated planning and intervention through the One Health initiative. However, the country faces numerous challenges, including inadequate resources, professional disconnection, and insufficient recognition of the importance of animal and environmental health for human and planetary well-being.[72] In the case of Thailand, it's recognized for embracing a comprehensive One Health strategy in public health and for establishing efficient surveillance systems in collaboration with various health agencies.[78] It is well noted that the majority of the most productive countries in One Health-COVID-19 related research are the same as those identified in various other studies on COVID-19 in different contexts.[2,6]

While COVID-19 presents a global crisis, there has been a crucial need for international collaboration aimed at advancing our understanding of this pandemic and mitigating its impacts across diverse contexts.[79] This collaborative effort offers significant benefits in generating impactful scientific research through the integration of complementary practices, skills, and experiences.[80] The partnership between countries and research centers worldwide is highly advantageous in devising effective solutions to address the pandemic.[2] The analysis highlights the significant role played by major developed countries in spearheading collaboration both amongst themselves and with other developing nations. The substantial percentage of documents

Table 5. Top prolific authors on One Health-COVID-19.

RANK	AUTHOR	INSTITUTION, COUNTRY	NUMBER OF PUBLICATIONS	%	TOTAL AUTHOR'S PUBLICATIONS
1st	Dhama	Indian Veterinary Research Institute, Bareilly, India	11	2.1	913
2nd	Rodriguez-Morales	Info Fundación Universitaria Autónoma de las Américas, Medellin, Colombia	8	1.5	783
3rd	Behravesh	National Center for Emerging and Zoonotic Infectious Diseases, Atlanta, United States	7	1.3	106
4th	Bonilla-Aldana	Universidad Continental, Huancayo, Peru	6	1.1	121
4th	Tiwari	U.P. Pandit Deen Dayal Upadhyaya pashu Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, Mathura, India	6	1.1	212
4th	Zhou	Chinese Center for Disease Control and Prevention, Beijing, China	6	1.1	713
7th	Carabin	University of Montreal, Montreal, Canada	5	0.9	161
7th	Carpenter	Centers for Disease Control and Prevention, Atlanta, United States	5	0.9	17
7th	Morand	CNRS Centre National de la Recherche Scientifique, Paris, France	5	0.9	513
7th	Hofmann-Lehmann	Universität Zürich, Zurich, Switzerland	5	0.9	326
7th	Killian	USDA APHIS National Veterinary Services Laboratories, Ames, United States	5	0.9	95
7th	Koopmans	Erasmus MC, Rotterdam, Netherlands	5	0.9	775
7th	Sharun	Indian Veterinary Research Institute, Bareilly, India	5	0.9	142
7th	Meli	Universität Zürich, Zurich, Switzerland	5	0.9	180
15th	Ghai	National Center for Emerging and Zoonotic Infectious Diseases, Atlanta, United States	4	0.8	33
15th	Klaus	Universität Zürich, Zurich, Switzerland	4	0.8	5
15th	Kock	Royal Veterinary College University of London, London, United Kingdom	4	0.8	205
15th	Malik	Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India	4	0.8	264
15th	Tong	Centers for Disease Control and Prevention, Atlanta, United States	4	0.8	117
15th	Wendling	Centers for Disease Control and Prevention, Atlanta, United States	4	0.8	8

published on this subject, stemming from collaboration among the most productive countries (444 documents out of a total of 527; 84.3%), underscores their leadership in shaping and advancing research in this field. This trend is expected to persist in the foreseeable future, reaffirming their responsibility in fostering research collaboration and disseminating related knowledge. The importance of the examined topic is further underscored by the involvement of esteemed institutions and authors on a global scale in generating knowledge and fostering collaboration. This is further evidenced by the dissemination of crucial information on this topic through influential sources, the prestigious status of most co-cited sources, and the high citation rates for works published in esteemed sources, despite the emerging nature of the topic.

Insights from content analysis and major themes in One Health–COVID-19–related research

If COVID-19 is a One Health issue. COVID-19 is most likely a zoonotic disease developing from a coronavirus residing in an animal reservoir, similar to about 75% of known emerging human diseases.[23,81] As more animals are reported to be

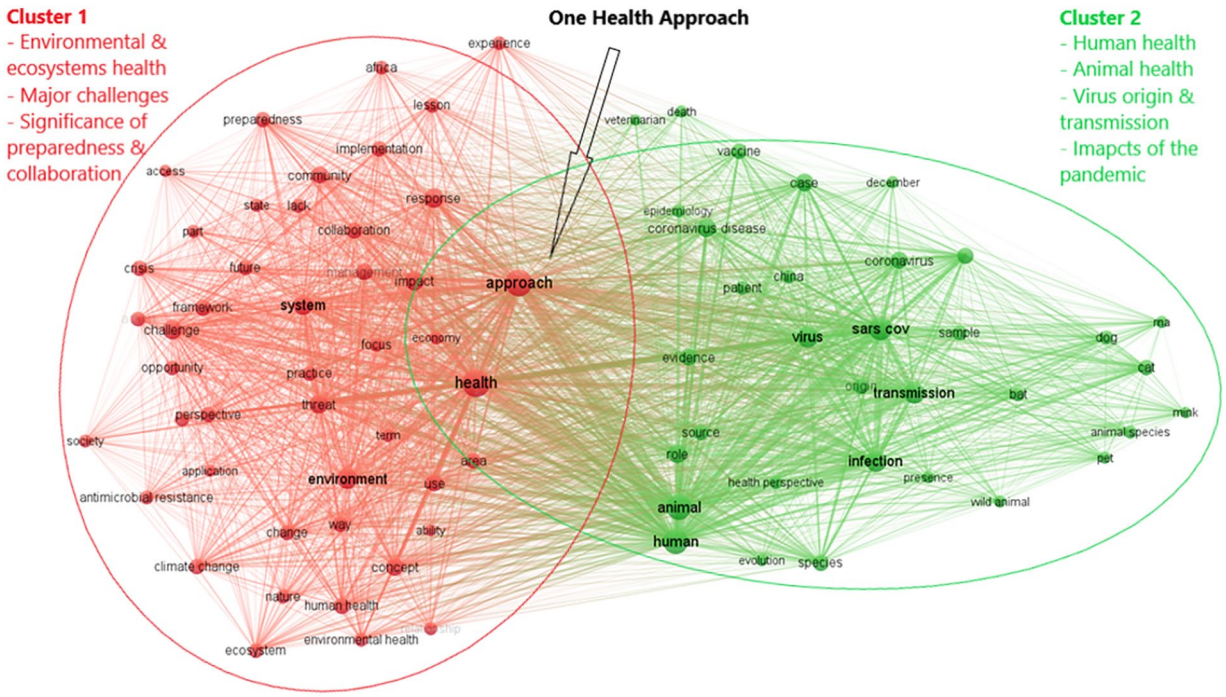

Figure 8. The network visualization map of terms co-occurrence in titles and abstracts of One Health-COVID-19 publications. Twenty occurrences of a term were set as the minimum number (Binary counting: involves assessing the presence or absence of a term in the titles and abstracts of documents, with the frequency of occurrences within a document being disregarded). A total of 140 terms out of 12650 terms met the set threshold. A relevance score was set to assess the most relevant terms: 60%. The most relevant terms were 80 terms categorized into 2 major clusters; cluster 1: red color (46 terms) concerned mainly with One Health approach and preparedness for challenges including future pandemics, climate change and antimicrobial resistance, and the importance of collaboration, and cluster 2: green color (34 terms) concerned primarily with the origin of virus causing COVID-19 and its transmission mechanisms. The map was created using VOSviewer software version 1.6.19.

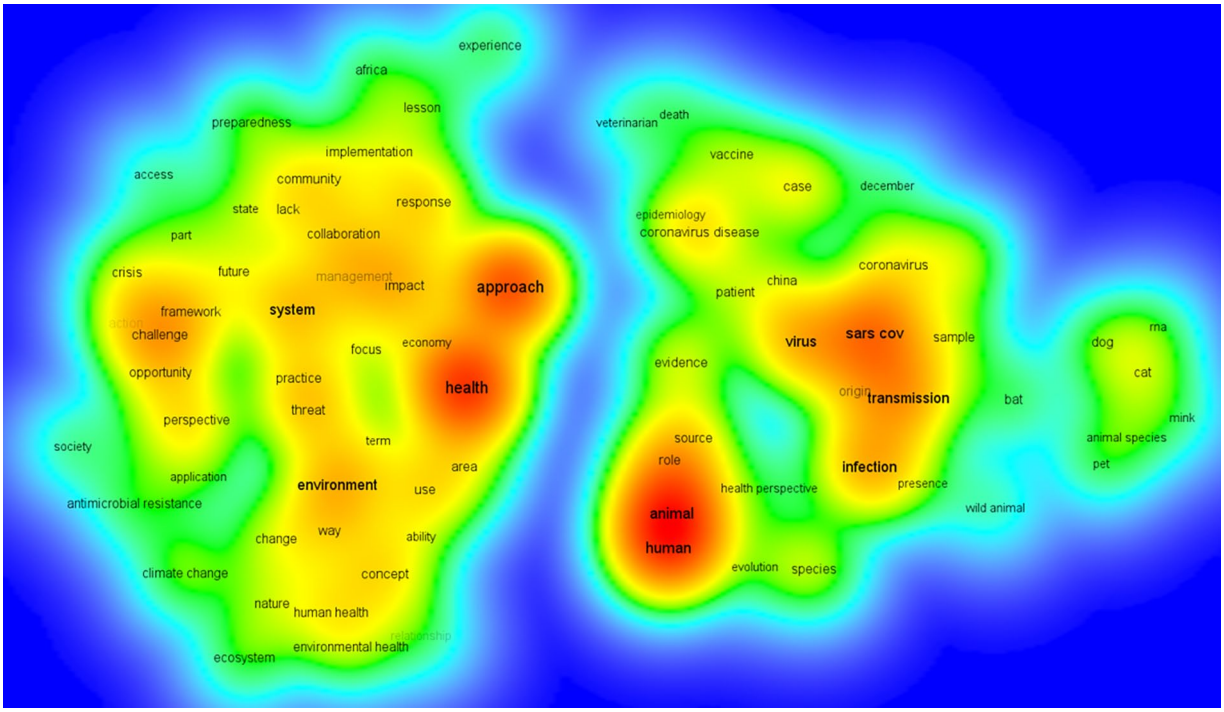

Figure 9. The density visualization map of terms co-occurrence in titles and abstracts of One Health-COVID-19-related publications. Twenty occurrences of a term were set as the minimum number (Binary counting: involves assessing the presence or absence of a term in the titles and abstracts of documents, with the frequency of occurrences within a document being disregarded). The red color indicates the most frequently occurring terms, corresponding to the highest item density, while blue represents the lowest item density. The map was created using VOSviewer software version 1.6.19.

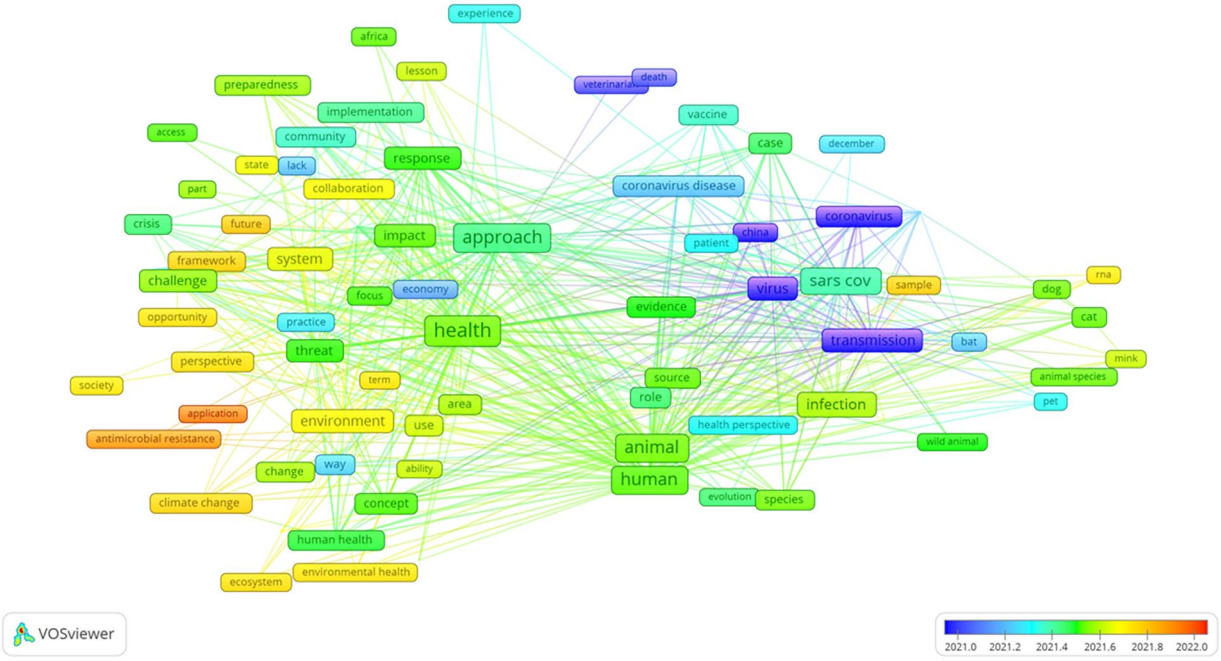

Figure 10. Mapping term co-occurrence over time: a visual representation of term frequency in titles and abstracts of One Health-COVID-19-related publications (Binary counting: involves assessing the presence or absence of a term in the titles and abstracts of documents, with the frequency of occurrences within a document being disregarded). The blue nodes represent earlier occurrences, and the red nodes represent later occurrences. The map was created using VOSviewer software version 1.6.19.

infected with the COVID-19 virus, it becomes increasingly evident that adopting a One Health approach is crucial in addressing emerging disease threats that impact both humans and animals.[81] Epidemiological and virological studies indicate that the virus, believed to have originated in bats, underwent adaptive evolution in intermediate hosts before transmitting to humans from a concentrated source.[21] The receptor sequence similarities between humans and animals regarding SARS-CoV-2 suggest a limited species barrier, potentially allowing the virus to transmit to farm animals.[21] Additionally, the involvement of diverse mammalian species—domestic, farmed, and wild—in SARS-CoV-2 circulation holds significant, potentially dramatic implications.[82] Hence, a critical approach to combating this epidemic involves establishing cross-disciplinary collaboration between veterinarians and animal specialists, based on the One Health model.[21] Conducting One Health investigations and implementing animal surveillance are of utmost importance in assessing the transmission of SARS-CoV-2.[54]

However, the lack of reliable early warning systems, prompt stakeholder cooperation, and a lack of understanding of the overall SARS-CoV-2 adaptation process to new hosts resulted in 2 important outcomes. First, the precise mechanisms or variables influencing the development and adaptation of the virus are not fully understood.[23] Second, claims regarding the origin of the virus that caused the pandemic have been made without a solid scientific basis.[23] To address the knowledge gaps and inadequate levels of preparation, particularly regarding surveillance and warning systems, it was crucial to recognize the COVID-19 situation as a One Health issue.[23] This is primarily due to the identification of the lack of comprehensive One Health knowledge, preventive measures, and integrated approaches as major contributing factors to the outbreak of the pandemic.[83]

Pandemic prevention guided by One Health principles

A change from the reactive strategy of fear and neglect is required to properly handle the difficulties posed by pandemics. The emphasis should be on prevention rather than disease containment and management after it has already manifested. To prevent pandemics from spreading, this entails minimizing the risk factors for pandemics. The crucial relevance of pandemic prevention has, however, received little funding and acknowledgment.[84] The only way to end the cycle of fear and indifference brought on by pandemics is to invest in One Health-based prevention initiatives.[84] Inaction now will prolong the repeated and taxing process of organizing responses to the next pandemics. The prevention of pandemics is a universal public good that benefits all nations.[85] Nevertheless, because of the belief that nations may gain without contributing, it frequently suffers from underinvestment.[86] Low investment is also a result of the advantages of prevention being unseen and unmeasured, the links between pandemic drivers and income producing, and the preference for response over prevention.[85]

Three critical entrance points may be used to make the transition to an efficient preventative strategy based on One Health initiatives.[84] First off, there is a good chance to promote

this change given the continued effects of COVID-19 and talks around international agreements and pandemic preventive financial structures.[84] Second, compared to the costs of crisis response, prevention, driven by One Health principles, is thought to be comparatively inexpensive.[87] Investments in public veterinary services, farm biosecurity, and a decrease in deforestation in high-risk nations are all examples of this.[84] For example, in the year 2020, the expenses incurred for prevention measures amounted to less than 1% of the total costs associated with responding to the COVID-19 pandemic. An annual investment of between US$10.3 and US$11.5 billion is thought to be necessary for prevention, driven by the principles of One Health.[88] Amounts included in this investment range from US$3.2 to US$4.4 billion for decreasing deforestation in high-risk nations, US$2.1 billion annually to improve public veterinary services to match international standards, and US$5 billion to improve farm biosecurity measures.[84,87] Additionally, investing in preventative and One Health measures results in a variety of side benefits, including less CO_2 emissions, enhanced food safety and nutrition, and expanded market access.[84] These investments not only improve preparation and strengthen health systems, but they also lessen the socioeconomic effects of pandemics. Coordinated efforts, strong leadership, and financial backing from technical organizations, financial institutions, the public sector, the corporate sector, and civil society are necessary for the One Health investment framework to be implemented at the national, regional, and global levels.[85,87,89] The framework should be adopted and put into action by each nation in accordance with its unique goals, risk factors, available resources, and initiatives that support the One Health agenda.[84,86]

Governance of One Health

The evident shortcomings of global health security in preventing or preparing for the COVID-19 pandemic have emphasized the necessity for well-established governance models.[90] Over the past few years, policymakers and researchers at the international, regional, and national levels have increasingly recognized the significance of One Health governance.[91] They emphasize the application of good governance theory to promote health across all policies within a country, highlighting its importance.[91] Li et al[92] conducted a study evaluating One Health governance in 146 countries worldwide. They utilized the One Health governance index (OHGI) based on the One Health global index (OHGI).[13] The study's findings indicated a significant correlation between the capacity for One Health governance and factors such as political stability, the rule of law, and economic conditions across different regions.[92] The study revealed that the average OHGI score was 34.11, with a median score of 31.49, spanning a range from 8.50 to 70.28. Most countries with higher OHGI scores were in Europe and Central Asia, East Asia and the Pacific, and North America. Conversely, countries with lower OHGI scores were primarily found in sub-Saharan Africa. Notably, 6 countries, namely Australia, Sweden, Germany, the Netherlands, the United States, and Finland, achieved scores exceeding 65 points, indicating their relative maturity across various aspects of One Health governance.[92]

The governance of One Health faces challenges including sectoral divisions, legal system compatibility, power dynamics among countries, and insufficient investment in prevention and preparedness.[86] The variety of institutions, processes, regulatory frameworks, and legal instruments engaged in the global governance of One Health has resulted in a fragmented, worldwide, multilateral health security structure.[86,93,94] Moreover, One Health faces limited support due to entrenched hierarchies, institutional inertia favoring single sectors, personnel capacity concerns, and funding aligned with global health securitization agendas.[95] These challenges impede practical implementation, sustaining a Northern-dominated, top-down, control-oriented approach that obscures diverse perspectives on human-animal-environment-health interactions.[95]

To improve governance of One Health, it is crucial to prioritize significant efforts in addressing the social-ecological factors that contribute to health emergencies, such as emerging, re-emerging, and endemic infectious diseases.[96] These factors encompass climate change, biodiversity loss, and land-use change, emphasizing the need for effective and enforceable legislation, investment, capacity building, and collaboration with professionals from various sectors beyond the health domain.[14,96] Facilitating the development of localized communities that adapt One Health to unique contexts is crucial for successful governance.[97] These interconnected communities contribute to global efforts by emphasizing links and building social capital.[97] Vital to this process is the facilitation of knowledge transfer and the conversion of social capital into local capabilities, particularly in economically limited countries.[97] Moreover, fostering greater interaction and communication between research and policy-making communities is crucial for adopting more policy-relevant research.[98] This is essential in developing a strategic research agenda aimed at combating pandemics[98] and promoting the One Health approach, particularly in developing countries.

One Health and future pandemics

The COVID-19 pandemic has imparted a conclusive insight - the enduring reality of emerging zoonotic infectious diseases. Therefore, effectively combating new disease threats necessitates collaborative efforts through the framework of One Health.[81,99] The significance of the One Health approach in combating future pandemics lies from its focus on early detection and surveillance, comprehension of disease transmission,[100,101] preventing zoonotic disease outbreaks, stimulating interdisciplinary collaboration, along with making environmental protection a priority.[99] The early detection and surveillance systems play a crucial role in effective containment and

control.[89] Potential hazards can be quickly detected by keeping track of and exchanging information on disease outbreaks in both animal and human populations.[102] Early warning systems and cross-disciplinary cooperation between the human and animal health sectors make it easier to identify and address emerging infections before they spread globally and become pandemics.[103]

In relation to interdisciplinary collaboration, it holds a fundamental role in combating future pandemics within the One Health approach. It acknowledges the essential need for collaboration across diverse sectors, encompassing human health, animal health, environmental science, wildlife management, and agriculture.[54,102] This is vital because disciplinary fragmentation remains a significant challenge in implementing practical One Health policies.[90] Despite a decade of international and cross-sectoral efforts, concerns persist among both advocates and critics of One Health regarding insufficient engagement from all relevant disciplines in crucial research and policymaking.[90] Particularly overlooked are experts from social, ecological, and environmental health sciences, whose practical involvement remains neglected to some extent.[90]

By fostering interdisciplinary collaboration, the expertise of different disciplines can be leveraged, facilitating the sharing of knowledge and the development of integrated strategies to effectively prevent, detect, and respond to pandemics.[104] When it comes to environmental concerns, the One Health approach emphasizes the importance of environmental conservation and the adoption of sustainable practices as crucial measures in mitigating the risk of future pandemics.[105]

The significance of social and environmental sciences in promoting One Health concepts within the context of COVID-19 and other pandemics

According to the findings of this analysis, research on One Health-COVID-19 primarily focuses on the fields of medical sciences, and immunology and microbiology studies. This emphasis stems from the significant impact of the pandemic on human health. As a result, considerable efforts are being dedicated to saving lives through the development of preventive vaccines and curative medicines.[2,6] The significant and far-reaching social and economic impacts of COVID-19, which have implications for psycho-social, behavioral, governance, environmental, and technological aspects, serve as strong motivation for further multidisciplinary research.[2] Although social and environmental sciences are given less emphasis compared to medical sciences, they still hold significant importance.

In the context of COVID-19 and future pandemics, social sciences play a crucial role in advancing the One Health approach. They provide valuable insights into the impact of human behavior, societal factors, and systemic challenges on disease dynamics and responses.[106] While biological and medical sciences are essential for understanding the nature of infectious diseases, incorporating social science concepts is vital for effective pandemic preparedness and response within the One Health paradigm. Social sciences provide important contributions to the One Health concept in several essential areas. First, social sciences aid in our knowledge of human behavior and risk perception by revealing how people perceive and react to health threats, which affects their adherence to preventive interventions and readiness to embrace behavioral adjustments[106] and may put them at risk.[107] As well as addressing the disproportionate effect of pandemics on disadvantaged groups and highlighting structural injustices to be addressed, social sciences offer light on health inequalities and vulnerable populations.[108-110] The study of governance and policy frameworks by the social sciences also aids in efficient coordination and fact-based decision-making in pandemic response.[91] Another significant area where social sciences offer insights into community dynamics and enable the creation of culturally sensitive interventions is in engaging communities and increasing participation.[111,112]

While related to environmental sciences, there has been significant progress in the collaboration between human and veterinary and medical sciences. However, there is still room for improvement in establishing connections with environmental sciences.[113] Their integration into the One Health concept results in a comprehensive knowledge of the connection between the environment, human health, and the formation of pandemics, leading to more successful disease prevention and control efforts.[23,110] These sciences help in understanding the environmental elements that influence the onset and spread of diseases, such as the destruction of natural habitats, climate change, and biodiversity loss, which collectively disrupt ecological balances.[105] They support risk reduction strategies, identify potential infection sources, and advance zoonotic disease research.[114] Environmental sciences also support the creation of surveillance systems, ecosystem management plans, and early warning systems.[114] They underline the need of using sustainable practices, protecting biodiversity, and combating environmental degradation as essential elements of pandemic preparedness.[114]

An expanded role for environmental sciences would make it possible to include geographic and meteorological information to forecast probable hotspots or new endemic regions brought on by climate changes.[115] Additionally, control approaches must be evaluated for their influence on other ecological characteristics in addition to their direct impact on disease prevalence.[113] For instance, while assessing vector control strategies, it is important to take into account both the effectiveness of these strategies in lowering vector and pathogen populations as well as their effects on the ecosystems of other species.[113]

Climate change's association with One Health in the context of COVID-19 and other pandemics

Climate change impacts how diseases spread and raises the possibility of zoonotic spillover incidents.[23] By altering ecological

dynamics, climate change caused by human activities (eg, habitat degradation and wildlife trade) aids in the formation and spread of infectious illnesses, particularly zoonotic diseases like COVID-19.[86] Pandemics like COVID-19 have similar risk factors and effects along climate change.[23] Both disproportionately harm the most vulnerable populations, escalating already-existing health inequities. For instance, climate change-related extreme weather and increased air pollution can impair the cardiovascular and respiratory systems of people, increasing their susceptibility to infectious diseases.[116]

Moreover, ecosystems are disrupted by land use changes like deforestation, which also raises the danger of zoonotic disease transmission and the proximity of humans to wildlife.[117,118] This danger is made greater by biodiversity loss.[118] Deforestation affects disease vectors and ecological dynamics while causing changes in land use and biodiversity loss.[117] It also contributes to climate change by releasing carbon held in trees and decreasing their capacity to absorb greenhouse gases.[117]

The One Health approach argues for all-encompassing actions that consider the connections between ecosystems, climate change, and public health.[119,120] To address the intricate linkages between infectious diseases, climate change, and public health, the One Health approach encourages collaboration, information integration, and holistic methods. By embracing the ideas of One Health, stakeholders may collaborate to avoid future pandemics, mitigate the health effects of climate change, and promote a sustainable and resilient future.[119] Furthermore, by prioritizing proactive monitoring and early disease outbreak identification through the lens of the One Health approach, public health authorities may improve their capacity to recognize and effectively address emerging risks.[119,120] These authorities may remain attentive and take prompt action by regularly monitoring changes in land use, biodiversity loss, and deforestation and recognizing their potential impact on disease transmission.[117] Moreover, applying a One Health approach to both human and animal health systems involves adopting climate-smart practices, reassessing impacts on and relationships with the environment.[121] This fosters collaborative efforts to mitigate and address the escalating threat and burden of infectious diseases.[121]

Challenges of antimicrobial resistance

The findings of the present analysis indicate that antimicrobial resistance emerged as a noteworthy and recent topic that attracted significant attention within the framework of One Health. This approach is widely utilized and recommended in the ongoing battle against antimicrobial resistance during the COVID-19 pandemic.[122] The need for antibiotics in pandemic response has been stressed further by COVID-19. Even though antimicrobials do not directly cure viral infections like COVID-19, they are crucial for controlling secondary bacterial infections that may develop in serious instances.[123] The escalating indiscriminate use of antibiotics during the COVID-19 pandemic worsens bacterial resistance, ultimately leading to a higher mortality rate.[60,123] The pandemic exacerbated the problem of antimicrobial resistance, mainly due to the irrational off-label use of antivirals, anthelmintics, antimalarials, and, notably, macrolide antibiotics.[122]

During the COVID-19 pandemic, the excessive consumption of pharmaceuticals and disinfectants led to the release of chemicals into the urban environment, imposing an unprecedented selective pressure on antimicrobial resistance.[124] Therefore, it is essential to avoid the emergence and spread of antibiotic resistance, which poses a significant global health threat. By 2050, it is predicted that antimicrobial-resistant infections would cause 10 million yearly deaths.[125] The World Bank also predicts that by 2050, the world economy may lose up to 3.8% of its annual GDP, with a $3.4 trillion yearly loss by 2030 associated with antimicrobial-resistant infections.[125]

The One Health strategy strives to maintain the efficacy of antibiotics for future generations by encouraging responsible use of antibiotics, putting infection prevention and control measures in place, and funding research and development of novel antibiotics.[125,126] It promotes enhancements in policies and regulations related to antimicrobial use, consumption, surveillance, stewardship, infection control, sanitation, animal husbandry, and alternatives to antimicrobials.[122] Furthermore, it emphasizes a collective effort rather than advocating individual actions to address future concerns about antimicrobial resistance.[122] To guarantee the right and prudent use of antibiotics in both human and animal health, it is necessary for healthcare professionals, veterinarians, researchers, politicians, and the general public to work together.[126]

Significance of collaboration and community engagement

Collaboration is crucial for bridging gaps, stimulating innovation, effectively allocating resources, and promoting fairness in pandemic response in the context of COVID-19 and other pandemics.[127] Through teamwork, the One Health approach can successfully handle the complex issues of pandemics and build a more resilient and sustainable future because it understands the interdependencies of human, animal, and environmental health. Integrating stakeholders from many sectors, such as healthcare professionals, veterinarians, environmental scientists, policymakers, researchers, and communities, is a key component of the One Health concept.[127] The resources and expertise of each industry are used in this multidisciplinary effort to address the complex problems that pandemics present.[128,129]

Collaboration offers several benefits. Primarily, because it makes it possible for different sectors to share information and data, which makes it easier to spot diseases early and to keep an eye on them so that prompt treatments can be made.[128,129] In a

study by Fitzpatrick et al,[130] for example, they explored the One Health approach for cost-effective rabies control in India. Implementing One Health practices at the provider level improved communication between physicians and veterinarians, potentially reducing wasteful postexposure prophylactic (PEP) allocation.[130] In addition, cooperation results in the creation and application of integrated plans and policies. Stakeholders may collaborate effectively by setting similar objectives and open lines of communication.[128] The development of diagnostics, treatments, vaccinations, and other crucial tools for pandemic preparedness and response is accelerated by collaboration because it increases research and innovation by combining resources and experience.[129]

Encouraging adaptability and responsiveness, instead of endorsing standardized approaches, is crucial for One Health.[131] This entails creating international guidelines to build capacities and provide flexibility for national program managers in selecting a One Health model aligned with their specific needs, fostering the emergence of sustainable collaborations.[131] The approach should be adaptable to diverse agendas of collaborating actors within their respective political contexts.[131] The extension of collaboration to community engagement and participation is crucial in promoting One Health in the context of COVID-19 and other future pandemics. It entails tackling social and cultural issues, improving health education, and involving communities in decision-making.[128,132] As a result, communities are better equipped to stop the spread of viruses and support initiatives aimed at preventing zoonotic illnesses in the future.[132] Furthermore, community involvement aids in the early identification of outbreaks by ensuring that important reports are received through reliable communication channels and a relationship of trust with health officials.[132] Additionally, it promotes evidence-based methods, combats disinformation, and assures correct information transmission that is adapted to local circumstances. Community participation improves decision-making, resulting in better policies and actions by embracing a variety of viewpoints and local expertise.[128,132]

Gaps and lags

Despite the One Health approach's tremendous potential for combating pandemics like COVID-19 and other environmental health issues, there are substantial gaps in its implementation, mainly in developing and least developed countries. These shortcomings include poor coordination, insufficient data sharing mechanisms, limited resources and funding, a lack of public awareness, and an absence of regulatory frameworks that are helpful.[16,133] To fully benefit from the rewards of the One Health approach in reducing pandemic risks in the future and safeguarding the health of people, animals, and the environment, it is imperative to address these difficulties.

Lefrançois et al[23] suggested several crucial steps for the strategic and global implementation of One Health concepts. Enhancing both upstream and operational research is one of these actions in creating a successful One Health surveillance system.[23,134] They also stress the significance of comprehending the effects of and prospective evolutionary processes through reverse viral zoonosis.[23,117] It is also essential to create resilient socioecological systems and to set up a quick decision-making process with institutionalized support.[23,135] Additionally, it is crucial to promote a global, comprehensive, and unified view of health, provide proper One Health education, and aligning One Health objectives with the SDGs on a global scale.[23] Investing in education not only raises awareness of One Health principles but also should offer practical frameworks for implementing these principles at local, national, and international levels.[136] This investment should be expanded to include tertiary education, addressing the absence of comprehensive programs specifically focused on One Health approaches.[90]

In developing countries, there's a pressing need to establish resilient, evidence-based frameworks within their governance structures.[136] Cultivating a robust One Health workforce that mobilizes experts across diverse disciplines becomes imperative.[136] This workforce aims to prepare for, coordinate responses to, implement and manage One Health strategies effectively.[136] The complexity of One Health creates challenges in forming effective government structures, especially in developing countries.[137] Various approaches recommend setting up specialized units at the national level with defined roles, potentially replicable at the state level.[137] In a study conducted by Abuzerr et al[138] to explore implementation challenges of an integrated One Health surveillance system in a developing country, 4 major themes emerged to explain barriers: lack of policy coherence, limited financial resources, poor governance and leadership, and absence of One Health training programs.

The substantial global underinvestment in One Health is apparent.[88] Highlighting prevention costs at approximately $11.0 billion annually, this example underscores the importance of investing in this area.[88] In contrast, pandemic management costs, estimated by the G20 Joint Finance and Health Taskforce, amount to roughly $30.1 billion per year.[88] This underscores the urgent need for enhanced sector coordination, communication, collaboration, and capacity building.[88] Equitably distributing the costs of global One Health implementation is crucial to encourage investments.[88]

Limitations

While this represents the first analysis to evaluate global research output on One Health concerning COVID-19, this study had several limitations. It is essential to acknowledge these limitations to ensure transparency and to encourage further research in the field. First, this analysis may not capture all the relevant publications because not all journals are indexed in Scopus, despite its extensive coverage, and some

pertinent publications might have been published in non-indexed or non-English language journals. Second, in the calculation of AI for countries, the analysis considered the total documents registered for each country in the Scopus database without addressing issues related to the ordering of authors, collaboration among authors from different countries, etc. This approach was also followed in estimating the productivity of institutions and might impact the outcomes of the analysis. Third, ranking publications by total citations instead of annual averages might have excluded recent high-quality studies. Fourth, the current analysis didn't address issues related to authors having multiple affiliations, which could somewhat impact the outcomes. Lastly, a bias might arise from the use of specific terms related to One Health and COVID-19 in titles or abstracts, potentially as a strategy to submit to One Health outlets. However, this issue was largely mitigated by reviewing both the abstracts and, in some cases, the entire content of the considered publications to ensure relevance. This significantly reduced the risks linked to false positive results. It's crucial to note that the limitations identified in this analysis could affect the precision and completeness of the obtained results. However, these limitations do not notably undermine the validity of the study.

Conclusion

This analysis offers a comprehensive evaluation of One Health research in relation to COVID-19. In-depth analysis of scholarly works has allowed for the comprehension of both fundamental advancements and future research prospects. The findings of the study show that there is significant interest in using One Health principles to improve pandemic prevention and sustainability while fulfilling the requirements of humans, animals, and ecosystems. The advancements of One Health concepts should leverage the existing momentum gained from the increasing prevalence of infectious diseases such as COVID-19 and their substantial impacts on every aspect of life. Furthermore, recognizing the impact of climate change on ecosystems and public health should be utilized to advance One Health concepts. While the findings of this analysis point to the successes of One Health, it is still essential to acknowledge and effectively address the ongoing challenges that come with integrating social scientific disciplines, the environmental sector, and researchers from different professions in order to improve engagement, collaboration, and information dissemination. The concluding policy recommendations encompass promoting One Health concepts and strengthening resilience in infectious disease prevention programs, necessitating increased investments in One Health initiatives, especially in developing countries. This includes further efforts to stimulate community engagement, empower governance, and establish reliable surveillance systems. Additionally, a pivotal policy recommendation is the establishment of formal governing bodies in developing countries that engage relevant policymakers.

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Author Contributions

SH. Z. initiated the study, designed, and performed the analysis, interpreted the data, and wrote the main paper.

Ethics Approval and Consent to Participate

This analysis is without human involvement. There was no need for ethical approval.

Consent for Publication

Not applicable.

Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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