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### Publicación anticipada

El Comité Editor de la Revista del Cuerpo Médico Hospital Nacional Almanzor Aguinaga Asenjo aprobó para publicación este manuscrito, teniendo en cuenta la revisión de pares que lo evaluaron y levantamiento de observaciones. Se publica anticipadamente en versión pdf en forma provisional con base en la última versión electrónica del manuscrito, pero sin que aún haya sido diagramado ni se le haya hecho la corrección de estilo. Siéntase libre de descargar, usar, distribuir y citar esta versión preliminar tal y como lo indicamos, pero recuerde que la versión electrónica final y en formato pdf pueden ser diferentes.

### Advance publication

The Editorial Committee of the Journal Cuerpo Medico Hospital Nacional Almanzor Aguinaga Asenjo approved this manuscript for publication, taking into account the peer review that evaluated it and the collection of observations. It is published in advance in a provisional pdf version based on the latest electronic version of the manuscript, but without it having been diagrammed or style corrected yet. Feel free to download, use, distribute, and cite this preliminary version as directed, but remember that the final electronic and pdf versions may differ.

**Citación provisional** / Mejia-Salazar MK, Cubas-Vásquez JL, Fernández-Miñope C. Comprendiendo la asignación de recursos sanitarios en situaciones de epidemias y pandemias: El papel del COVID-19 y la ética como impulsores de la investigación. Rev. Cuerpo Med. HNAAA [Internet]. 22 de noviembre de 2023 [citado 22 de noviembre de 2023];16(3).DOI: [10.35434/rcmhnaaa.2023.163.2141](https://doi.org/10.35434/rcmhnaaa.2023.163.2141)

Recibido / 27/07/2022

Aceptado / 16/10/2023

Publicación en Línea / 22/11/2023



## Understanding Healthcare Resource Allocation in Epidemic and Pandemic Situations: The role of COVID-19 and ethics as driving forces for research

### Comprendiendo la asignación de recursos sanitarios en situaciones de epidemias y pandemias: El papel del COVID-19 y la ética como impulsores de la investigación

Max Kevin Mejia-Salazar<sup>1,a</sup>; Johaana Licet Cubas-Vasquez<sup>2,b</sup>; Carlos Fernandez-Miño<sup>3,4,c</sup>

1. Escuela de Posgrado, Universidad César Vallejo, Perú.
  2. Red de Salud Chiclayo, Gerencia Regional de Salud Lambayeque, Perú.
  3. Laboratorio de Investigación en Ciencias de la Salud, Universidad Señor de Sipán, Perú.
- a. Médico Cirujano.
  - b. Obstetra.
  - c. Biólogo.

#### \*Correspondence

Max Kevin Mejía Salazar, MD

mmejias@ucv.edu.pe

Escuela de Posgrado, Universidad Cesar Vallejo

Km 3.5, Carretera a Pimentel, Perú

Postal Code 14000

Name	e-mail	ORCID
Max Kevin Mejia-Salazar <sup>1,2*</sup>	mmejias@ucv.edu.pe	0009-0004-0763-0133
Johaana Licet Cubas-Vasquez <sup>3</sup>	johaanalic2@gmail.com	0009-0002-3841-923X
Carlos Fernandez-Miño <sup>4,5</sup>	fernandezcarl@crece.uss.edu.pe	0000-0003-0427-8029

## **Declarations**

### **Ethics approval and consent to participate**

Not applicable.

### **Consent for publication**

Not applicable.

### **Availability of data and materials**

The original contributions presented in the study are included in the article or supplementary material, further inquiries can be directed to the corresponding author.

### **Competing interests**

The authors declare that they have no competing interests.

### **Funding**

Work of CAFM is funded by Universidad Señor de Sipán SAC.

### **Authors' contributions**

MKMS: Conceptualization, Methodology, Investigation, Formal analysis, Writing - Original Draft; JLCV: Investigation, Writing - Original Draft; CAFM: Conceptualization, Methodology, Software, Formal analysis, Writing - Review & Editing. All authors read and approved the final manuscript.

### **Acknowledgements**

We would like to express our sincere gratitude to all individuals who contributed to the completion of this research. We are grateful to Universidad Señor de Sipán SAC for providing financial and administrative support for this research.

## RESUMEN

**Introducción:** La asignación de recursos de atención médica durante eventos epidémicos y pandémicos es un desafío complejo que requiere una cuidadosa toma de decisiones. El racionamiento en la atención médica plantea preocupaciones éticas, especialmente para grupos vulnerables. Nuestro objetivo fue analizar el panorama de investigación en la asignación de recursos de atención médica durante epidemias y pandemias. **Material y métodos:** Realizamos un análisis bibliométrico de artículos de revistas indexados en las bases de datos Web of Science y Scopus con resúmenes en inglés. Se desarrolló una estrategia de búsqueda sistemática utilizando palabras clave relevantes. Los datos fueron procesados y analizados para obtener descripciones, análisis de citas, análisis de co-citas y análisis de redes sociales. **Resultados:** Un análisis que incluyó 124 documentos encontró un aumento significativo en la producción de investigación en este campo en los últimos años, con la mayoría de los artículos publicados entre 2019 y 2022. Estados Unidos emergió como el país líder en términos de producción de investigación. Se revelaron temas y temas prominentes como COVID-19, ética y triaje. Los hallazgos resaltan la importancia de las consideraciones éticas y el impacto de la pandemia de COVID-19 en el impulso de la investigación en la asignación de recursos de atención médica. **Conclusión:** El estudio destaca la prominencia de COVID-19 como fuerza impulsora de la investigación y la importancia de las revistas relacionadas con la ética como fuentes de conocimiento.

**Palabras clave:** revisión bibliométrica, bibliometrix, panorama de investigación, análisis de redes de colaboración, puntos calientes, fuentes de conocimiento.

## ABSTRACT

**Introduction:** The allocation of healthcare resources during epidemic and pandemic events is a complex challenge that requires careful decision-making. Fair distribution of resources like masks, ventilators, and vaccines is crucial, and allocation strategies aim to maximise efficiency. Rationing in healthcare raises ethical concerns, particularly for vulnerable groups. We aimed to analyse the research landscape in healthcare resource allocation during epidemics and pandemics, providing insights to inform researchers in developing evidence-based and ethical decision-making frameworks. **Material and methods:** We conducted a bibliometric analysis on journal articles indexed in the Web of Science and Scopus databases with English language abstracts. A systematic search strategy was developed using relevant keywords. Data were processed and analysed for descriptives, citation analysis, co-citation analysis, and social network analysis. **Results:** An analysis including 124 documents found a significant increase in research output in this field in recent years, with most articles published between 2019 and 2022. The United States emerged as the leading country in terms of research output. COVID-19, ethics, and triage were revealed as prominent themes and topics such as. The findings highlight the importance of ethical considerations and the impact of the COVID-19 pandemic on driving research in healthcare resource allocation. The study highlights the prominence of COVID-19 as a driving force for research and the importance of ethics-related journals as sources of knowledge. The analysis also identifies potential opportunities for international collaboration. **Conclusion:** the study enhances our understanding of resource allocation in healthcare during crisis events and provides valuable insights for researchers in developing informed decision-making frameworks.

**Keywords:** bibliometric review, bibliometrix, research landscape, collaboration network analysis, hotspots, knowledge sources

## **BACKGROUND**

The allocation of healthcare resources during epidemic and pandemic events is a complex and critical challenge that necessitates careful consideration and informed decision-making. In such events, the availability of medical and human resources can become severely limited, emphasising the need for effective planning strategies that mitigate public health impacts while optimising resource utilisation (1).

In emergency situations like the COVID-19 pandemic, healthcare providers may reach a threshold where they exhaust their capacity to deliver critical care, relying heavily on adequately trained personnel, efficient supply chains for clinical consumables and medications, and advanced equipment (2,3). In this context, the fair distribution of resources such as face masks (4), mechanical ventilators (5,6) and vaccines (7) emerged as crucial priorities. When confronted with scarce medical resources like limited vaccines, public health authorities have predominantly prioritised the development of allocation strategies that maximise efficiency, aiming to reduce both the spread and severity of the infection (8).

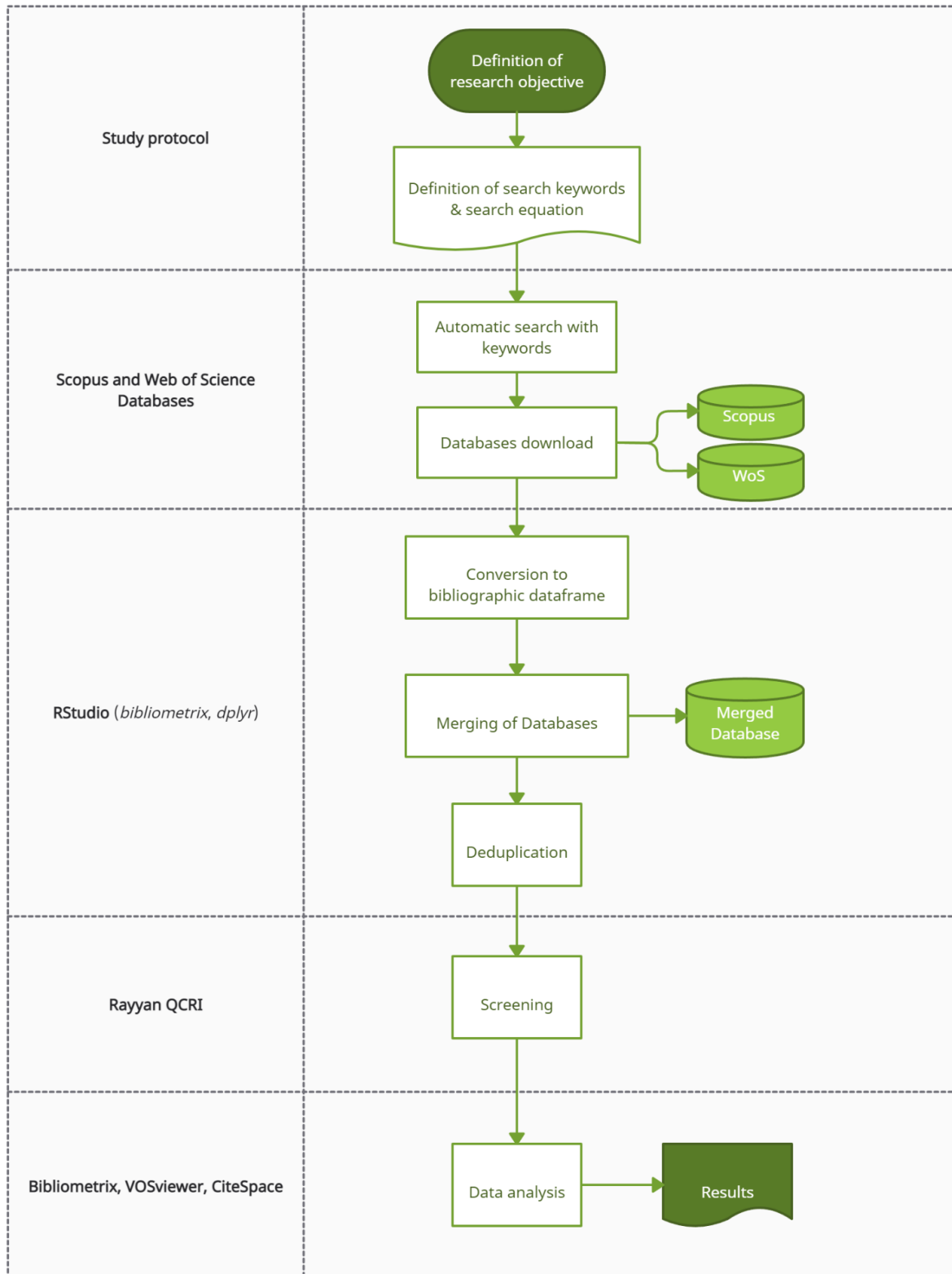
Rationing in healthcare is a contentious issue, particularly when it pertains to inherently vulnerable groups such as paediatrics (9,10) and geriatrics (11). Additionally, the strain on healthcare services has indirect implications for the treatment of unrelated conditions such as cardiovascular disorders (12) and cancer (13,14). The emergence of COVID-19 exposed the weaknesses in the supply chain and rationing, particularly in Latin America. For instance, modifications to chemotherapy regimens in paediatric cancers have been reported to address deficiencies in the supply chain (15). Additionally, misguided ideological beliefs and a refusal to acknowledge reality among political leaders have wreaked havoc on pandemic preparedness and responsiveness, exacerbating long-standing disparities in access to healthcare services (16). This was evident in the widespread use of treatments with little to no scientific evidence supporting their use in COVID-19, such as the indiscriminate use of ivermectin and chlorine dioxide in Peru (17), as well as the misuse of diagnostic tools like serological tests (18).

Examining the prevailing themes and topics in the literature on healthcare resource allocation during pandemics provides valuable insights into the multifaceted nature of decision-making processes. Understanding the gaps, trends, and key sources of knowledge is essential for informing policymakers and stakeholders involved in resource allocation decisions. Therefore, this study aims to comprehensively analyse the research landscape in healthcare resource allocation during epidemic and pandemic situations. The findings of this study contribute to the existing body of literature and can guide policymakers, researchers, and stakeholders involved in resource allocation during public health crises, facilitating the development of evidence-based and ethically informed decision-making frameworks.

## **METHODS**

### **Study design**

This study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to establish a dependable bibliometric approach for analysing and identifying global research trends, hot spots, scientific frontiers, and output characteristics of health care-resources allocation research during pandemic and epidemic events. A detailed scheme of our review protocol is shown in Figure 1.



**Figure 1.** Scheme of review protocol





## **Eligibility criteria**

The inclusion criteria for analysis were defined as follows: (i) journal articles indexed in the Web of Science and Scopus databases; (ii) articles in which search terms appeared in the title, abstract, or keywords; and (iii) articles that had an English language abstract available for analysis in the bibliometric review. The inclusion and exclusion criteria are both listed in Box 1.

**Table 1. Inclusion and exclusion criteria**

<b>Inclusion criteria</b>	<b>Exclusion criteria</b>
<ul style="list-style-type: none"> <li>● Journal articles indexed in the Web of Science and Scopus databases;</li> <li>● Search terms appear in the title, abstract, or keywords of article;</li> </ul>	<ul style="list-style-type: none"> <li>● Proceedings paper, book chapter, editorial material, book, review articles, grey literature, commentaries and letters to the editors;</li> <li>● Language is not English OR Spanish</li> <li>● Article abstract not available (after contacting corresponding authors);</li> <li>● Not related to the scope of the study</li> </ul>

## **Information sources**

To identify sources for this review, we searched the Scopus and Web of Science (WoS) databases without any time restriction. We considered studies with several designs, including experimental and quasi-experimental designs, as well as analytical observational studies, such as prospective and retrospective cohort studies, case-control studies, and analytical cross-sectional studies. Additionally, we included qualitative studies, such as phenomenology, grounded theory, ethnography, qualitative description, action research, and feminist research. However, we excluded proceedings papers, book chapters, editorial material, books, review articles, grey literature, commentaries, and letters to the editors.

## **Search strategy**

We conducted a preliminary literature search to identify suitable keywords to use in our systematic search. As a result, we identified several appropriate keywords and descriptors, including "Allocation of Health Care Resources," "Allocation of Healthcare Resources," "Healthcare Rationing," "Rationing," "Epidemic," and "Pandemic." These terms were used to develop two specific database-adapted systematic search queries: (TITLE-ABS-KEY ("Allocation of Health Care Resources" OR "Allocation of Healthcare Resources" OR "Healthcare Rationing" OR "Rationing") AND TITLE-ABS-KEY (Epidem\* OR Pandem\*)), used for the Scopus Database; and similarly for the Web of Science database: (TS=("Allocation of Health Care Resources" OR "Allocation of Healthcare Resources" OR "Healthcare Rationing" OR "Rationing") AND TS=(Epidem\* OR Pandem\*)). We utilised the TITLE-ABS-KEY field for the search strategy in the Scopus database and similar with the Topic field (TS) in the Web of Science database; we decided to use this configuration towards a more

sensitive search. The initial dataset was composed of 1704 documents, from which 70% were original articles (Supplementary table 1).

### **Selection process**

The screening stage involved two reviewers (MKMS and JLCV) who used the defined search strategy, inclusion, and exclusion criteria to search for publications. They worked independently to determine if a study met the inclusion criteria and to collect data using structured data extraction forms. If discrepancies arose, the reviewers resolved them by jointly reviewing the study in question. In cases where no consensus was reached, a third reviewer (CAFM), who was not aware of the other reviewers' determinations, acted as an arbitrator.

### **Data collection and data cleaning**

Databases were searched from their inception to April 2023, and the results were exported in "full record" format, which included details such as Publication Type, Authors, Document Title, Publication Name, Language, Document Type, Author Keywords, Abstract, Author Address, Cited References, Publisher, Publication Date, Digital Object Identifier (DOI), and others, and saved as either a Comma Separated Values (CSV) or plain text file, depending on the database used. To avoid bias resulting from database updates, all records were retrieved on the same day (May 1st, 2023). The CSV and plain text files were then imported into R (v4.2.1) and Rstudio (v. 2022.07.2+576) and processed using the *bibliometrix* package (v4.0.1). Each file was converted into a bibliographic data frame and then merged using the *mergeDbSources* function. Duplicated records were removed using the *distinct* function from *dplyr* package. The data frame was then exported as a CSV file for manual deduplication using an online spreadsheet in Google Workplace. After manual deduplication, data was exported as a CSV file and a first screening by Document Type was done using the filter function from *dplyr* package in R. Dataframe was then exported from R to a CSV file and column names were edited properly to be used in Rayyan QCRI (15). Once in Rayyan, titles and abstracts were screened to identify documents not related to the scope of the study. Full bibliographic info was retrieved for all documents that successfully passed the screening stage. In a final step, all records lacking Authors information, Authors Keywords, and Author Address were filtered out.

### **Effect measures**

The effect was evaluated through descriptive analysis, citation analysis, co-citation analysis, and social network analysis. Performance was measured at both individual and institutional levels. Science mapping was developed based on citation analysis, co-citation analysis, bibliographic coupling, co-word analysis, and co-authorship analysis.

### **Synthesis methods**

Performance analysis and plotting was conducted using the *bibliometrix* and *ggplot2* packages within R and Rstudio. A general analysis of the publication corpus was done, including the timespan, sources (journals, books, etc), documents, subject categories, annual growth rate,

document average age, average citations per doc, and references. We also explored the annual trends of research publication quantity and the countries/regions that contributed the most in the field, as well the institutional publications volume and number of publications and impact of journals. Analysis of the most influential authors included the authors of single-authored docs, co-authors per doc and international co-authorships percentage, analysis and visualisation of co-cited references, co-cited authors, co-cited journals, cited reference bursts, co-occurrence of keywords, keyword clusters and timelines. Analysis of research hotspots included the frequency of keyword occurrence (Author's Keywords (DE)) and clustering analysis.

### **Reporting bias assessment**

In this review, we did not include grey literature, conference proceedings, book chapters, editorial material, books, review articles, commentaries, and letters to the editors; instead, we searched the two largest scientific publication databases for articles irrespective of their country of origin. Although we cannot completely rule out the possibility of reporting bias, we believe that our comprehensive search strategy has minimised this risk.

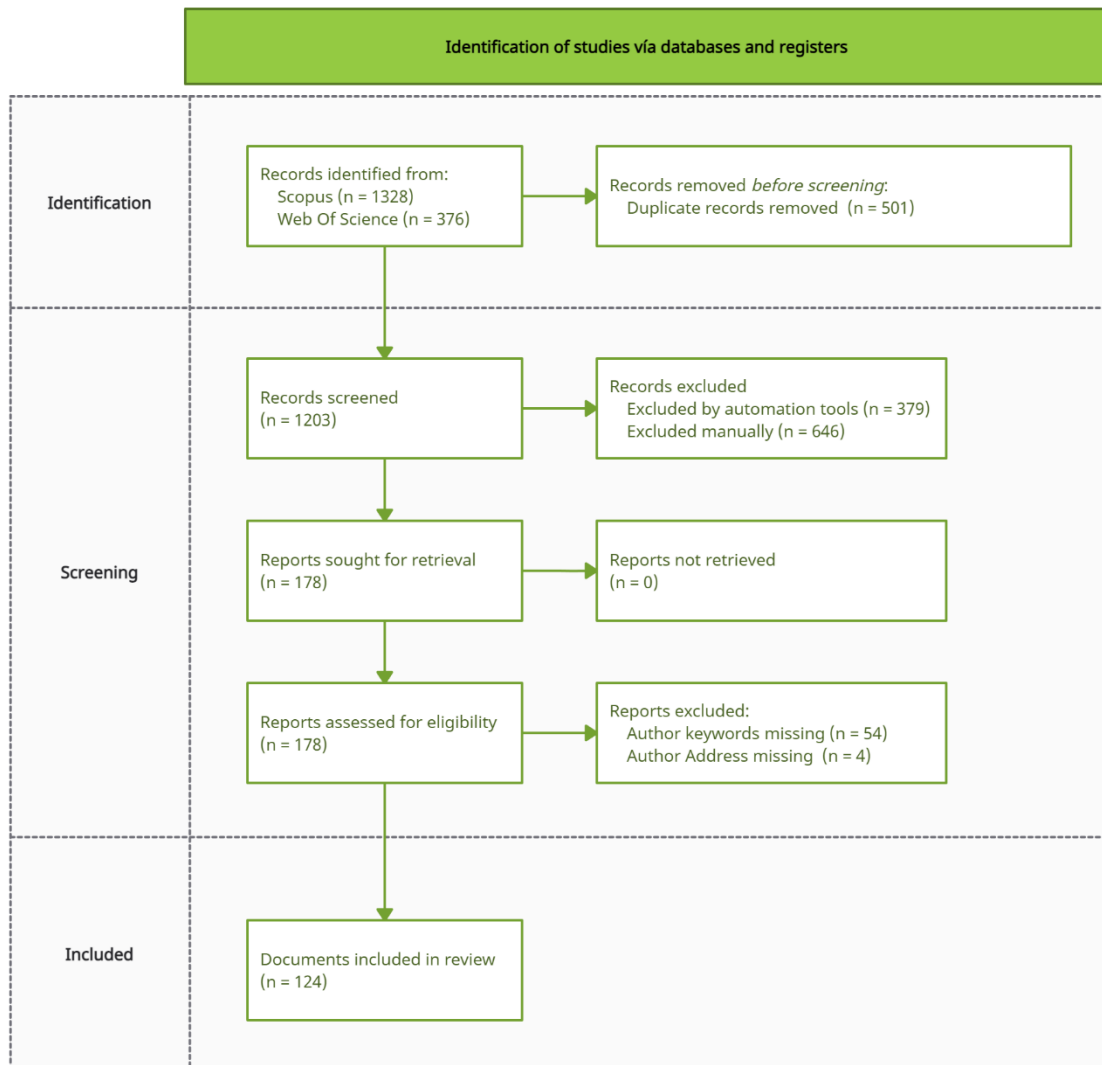
### **Certainty assessment**

The available data has limitations, which include the possibility that relevant publications were missed by our search strategy. Additionally, we cannot completely rule out the potential for publication bias, as studies with negative or null results may have been less likely to be published or cited.

## RESULTS

### Records selection

The PRISMA Flow Diagram of this study can be seen in Figure 2. In the initial search, a total of 1704 records were identified (1328 and 376 records from Scopus and Web of Science databases, respectively). 501 duplicated records were removed, and 1203 documents were screened. After automated and manual screening, 178 records were sought for retrieval of full bibliographic information. Records with incomplete Authors, Author Keywords, Year Published and Author Address field were then excluded. The final dataset contained 124 documents to be included in this study (Supplementary file 1). An overview of the main body of data is shown in Supplementary table 3.

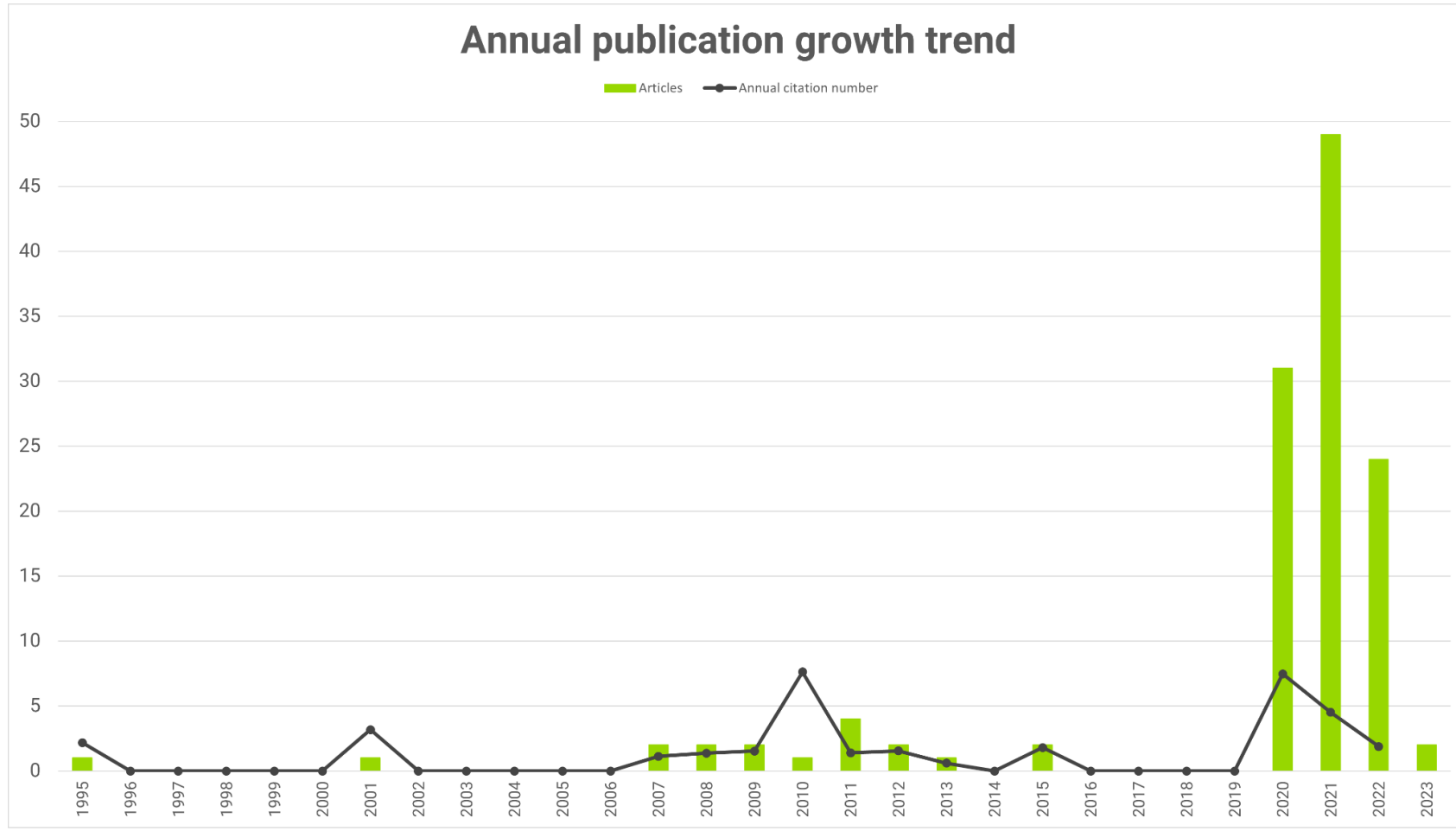


**Figure 2.** PRISMA Flow Diagram of this study

### **Annual publication trend**

Figure 3 illustrates the annual production of research papers focusing on the allocation of healthcare resources published between 1995 and April 2023. The annual growth rate was 2.51 % and the most frequent language was English (n = 121; 97.6%). Notably, from 1995 to 2019, only 25 papers were published, making up a mere 15% of the total articles analysed. In contrast, an impressive 85% of the analysed articles were published in the last three years (Document Average Age = 3.74 years). The highest annual publication count was recorded in 2021, with 49 articles published. The data reveals two significant peaks in annual citation numbers, occurring in 2010 and 2020.

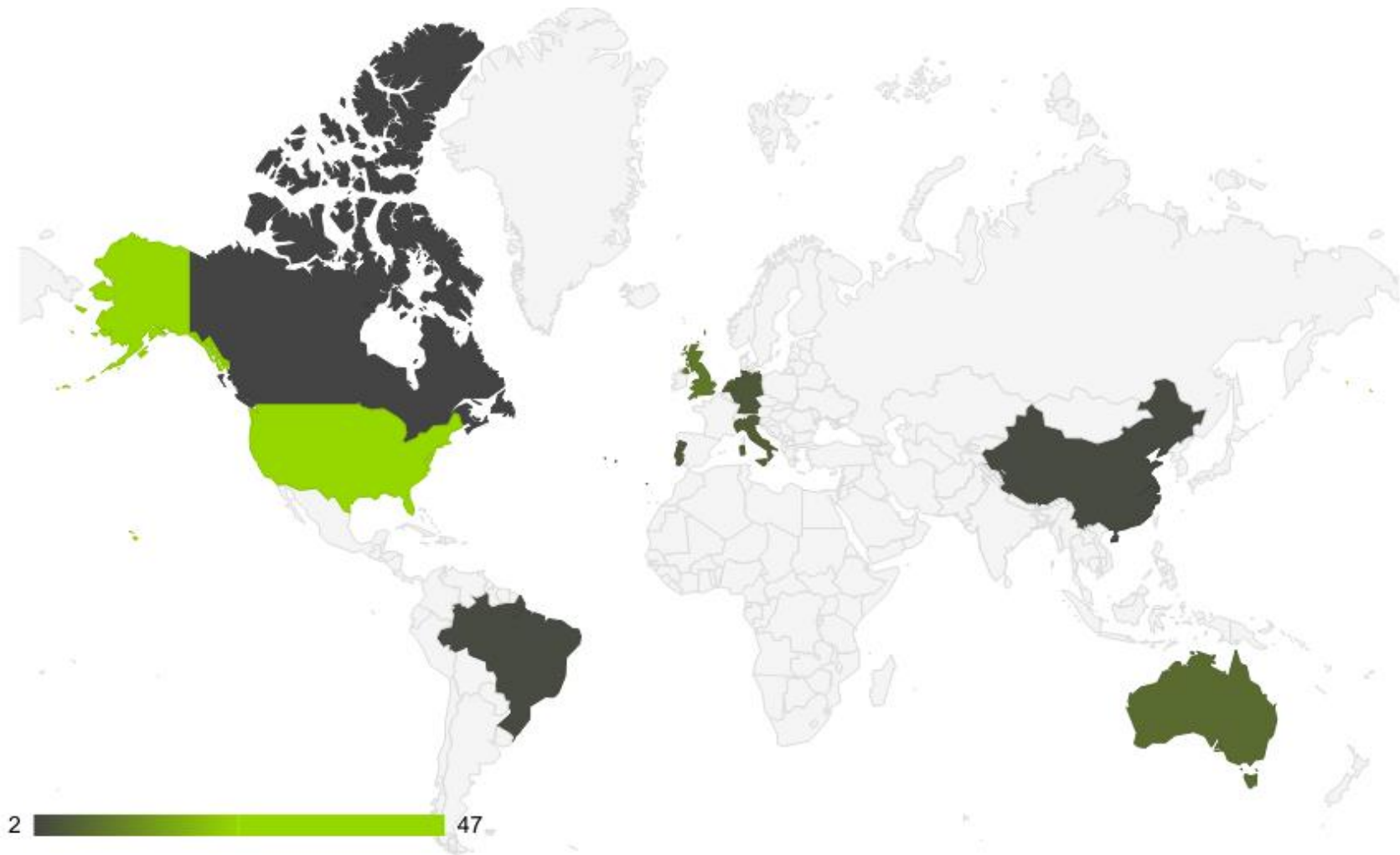




**Figure 3.** Yearly output of primary research papers released between 1995 and April 2023

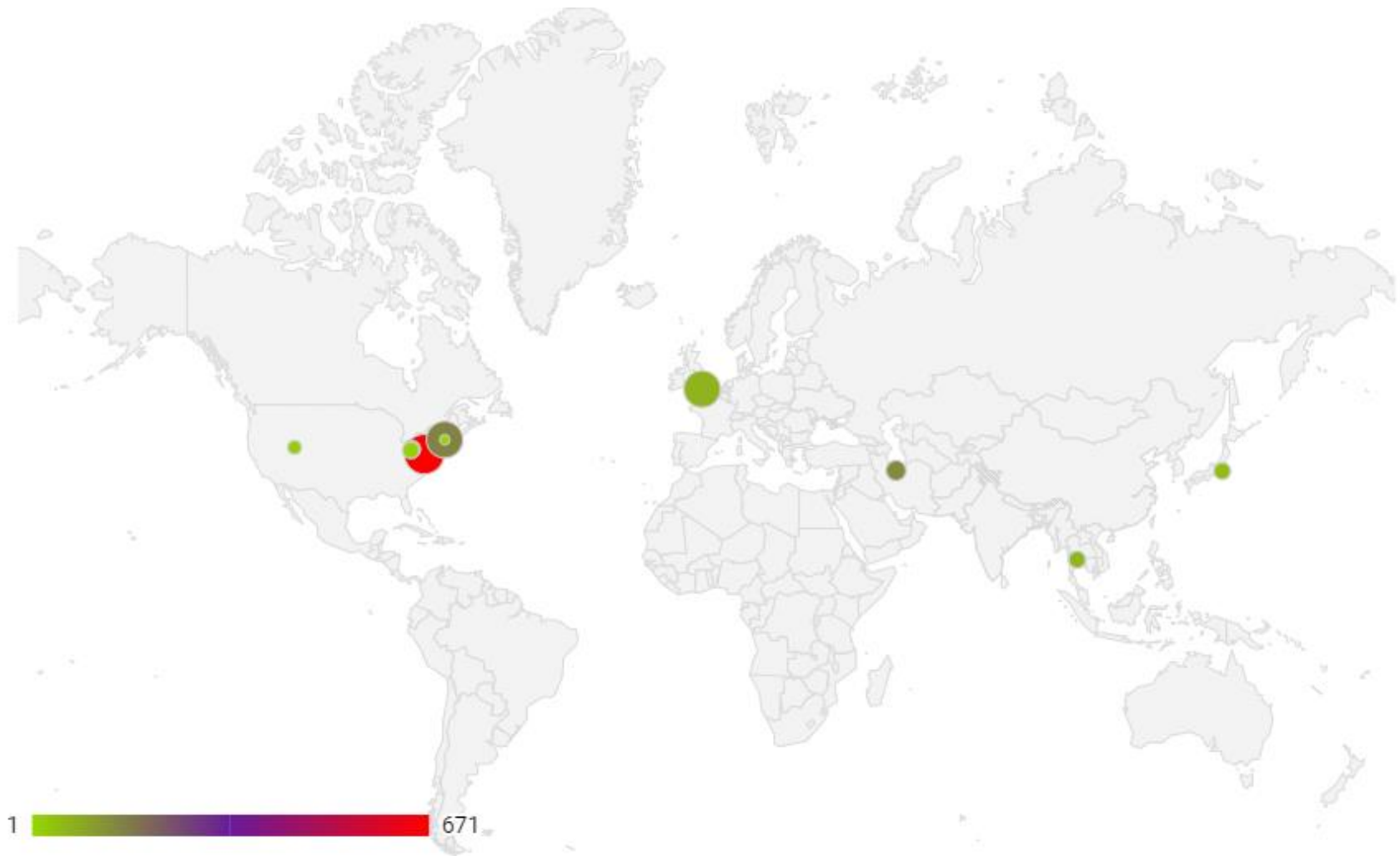
### **Geographic positioning of countries/regions, institutions, and collaborative efforts.**

We aimed to examine the global landscape of collaborative research in the field. Figure 4 and Figure 5 presents a comprehensive overview of research production across different countries and territories. The results revealed that the United States, Germany, and China emerged as the leading countries in terms of research output, with a notable concentration of institutions in these regions. Notably, the United States of America and the United Kingdom emerged as the leading contributors in terms of research output with 47 and 10 publications, respectively (Table 2). These countries also received the highest citation counts, with the United States garnering 671 citations and the United Kingdom obtaining 151 citations. Italy, despite having only 6 publications, received a remarkable 136 citations. Surprisingly, our analysis revealed a lack of international collaboration within the countries in the dataset indicating potential opportunities for international research partnerships; this was later confirmed by the collaboration network analysis of institutions (Supplementary figure 1). There was also a notable concentration of institutions in the United States of America, where 70% of institutions with the highest number of documents were situated. The institution with the highest publication count was Johns Hopkins University, with 23 papers, followed by Boston University with 20 papers, and The University of Oxford with 19 papers. The remaining institutions had fewer than 10 documents. Both Johns Hopkins University and The University of Oxford are placed within the first 30 places in the QS World University Ranking 2022 and Times Higher Education World University Ranking.



**Figure 4.** A global map illustrating the contribution of each country based on the number of publications.





**Figure 5.** A world map visualising the geographic distribution of the top ten institutions with the highest number citations in the field.

**Table 2.** Top 5 institutions contributing to original research in healthcare resource allocation

<b>Rank</b>	<b>Institutions</b>	<b>QS World University Ranking 2022</b>	<b>Times Higher Education World University Ranking</b>	<b>Country</b>	<b>Number of publications</b>	<b>Total citations</b>	<b>Average citations per article</b>
1	Johns Hopkins University	28	25	United States of America	23	671	29.17
2	Boston University	93	112	United States of America	20	151	7.55
3	University of Oxford	3	2	United Kingdom	19	64	3.37
4	Shahid Beheshti University of Medical Sciences	n.d.	n.d.	Iran	9	136	15.11
5	International Health Policy Program	n.d.	n.d.	Thailand	8	60	7.5

### **Key sources of knowledge**

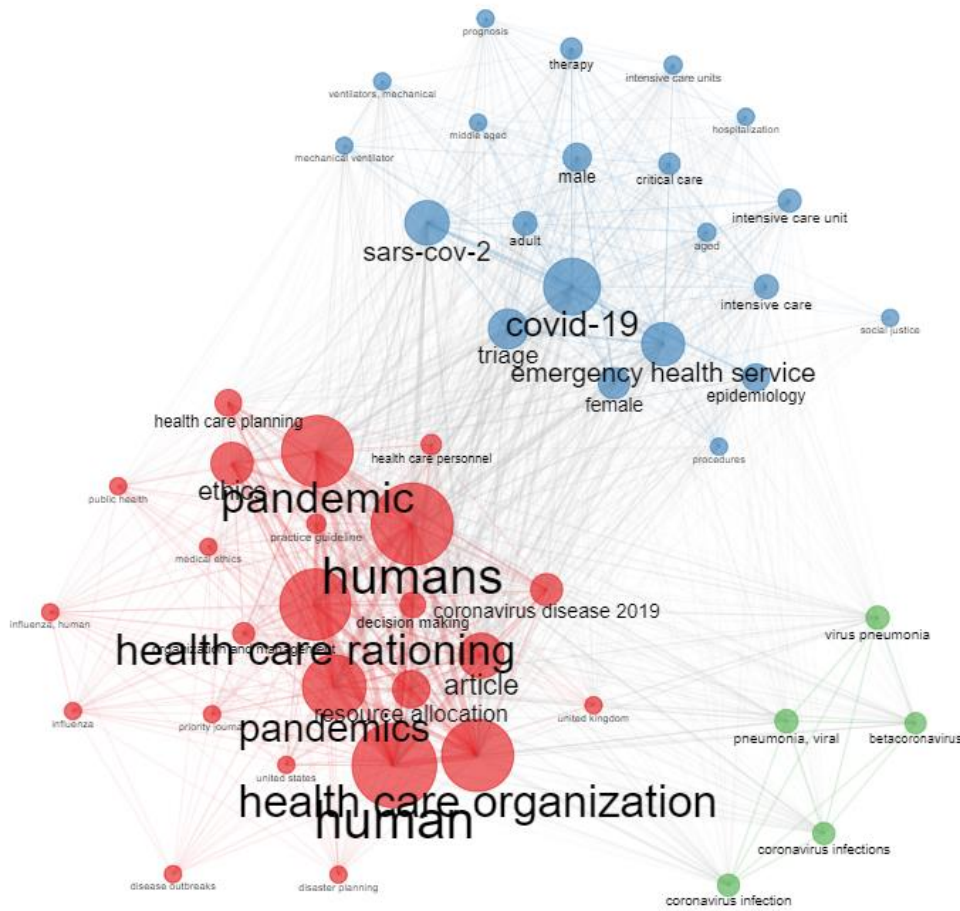
The analysis of higher-impact journals, influential documents, and most influential authors provides a comprehensive understanding of the key sources of knowledge dissemination and the researchers shaping advancements in the field. The two journals with the highest number of documents were the "Journal of Medical Ethics" (Q1 in Arts and Humanities; SJR 2022: 1.11) and "Bioethics" (Q1 in Philosophy; SJR 2022: 0.58). These journals published 15 and 6 research papers, respectively, and are edited by the BMJ Publishing Group and Wiley-Blackwell Publishing Ltd (Supplementary table 2). Among the 124 documents assessed, the globally most highly cited paper was titled "A computer simulation of vaccine prioritisation, allocation, and rationing during the 2009 H<sub>1</sub>N<sub>1</sub> Influenza A Virus pandemic", which had accumulated 99 citations since its publication in 2010 (Average citations per doc in the dataset = 13.48). In the aforementioned study, the University of Pittsburgh's Models of Infectious Disease Agent Study (MIDAS) team utilised a computer simulation model to assist the Office of the Assistant Secretary of Public Preparedness and Response in addressing vaccine allocation during the H<sub>1</sub>N<sub>1</sub> influenza pandemic, following the Advisory Committee on Immunization Practices' (ACIP) recommendation to prioritise at-risk individuals. The study concluded that adhering to the ACIP's prioritisation recommendations, with children receiving the highest priority within the at-risk groups, was the most effective strategy when the vaccine supply was limited. As shown in Supplementary table 3, 580 authors contributed research papers in the field. Notably, the most influential author was Dr. Dominic Wilkinson, with 7 publications. His expertise revolves around the ethical dilemmas faced during epidemic and pandemic events.

### **Key themes and topics**

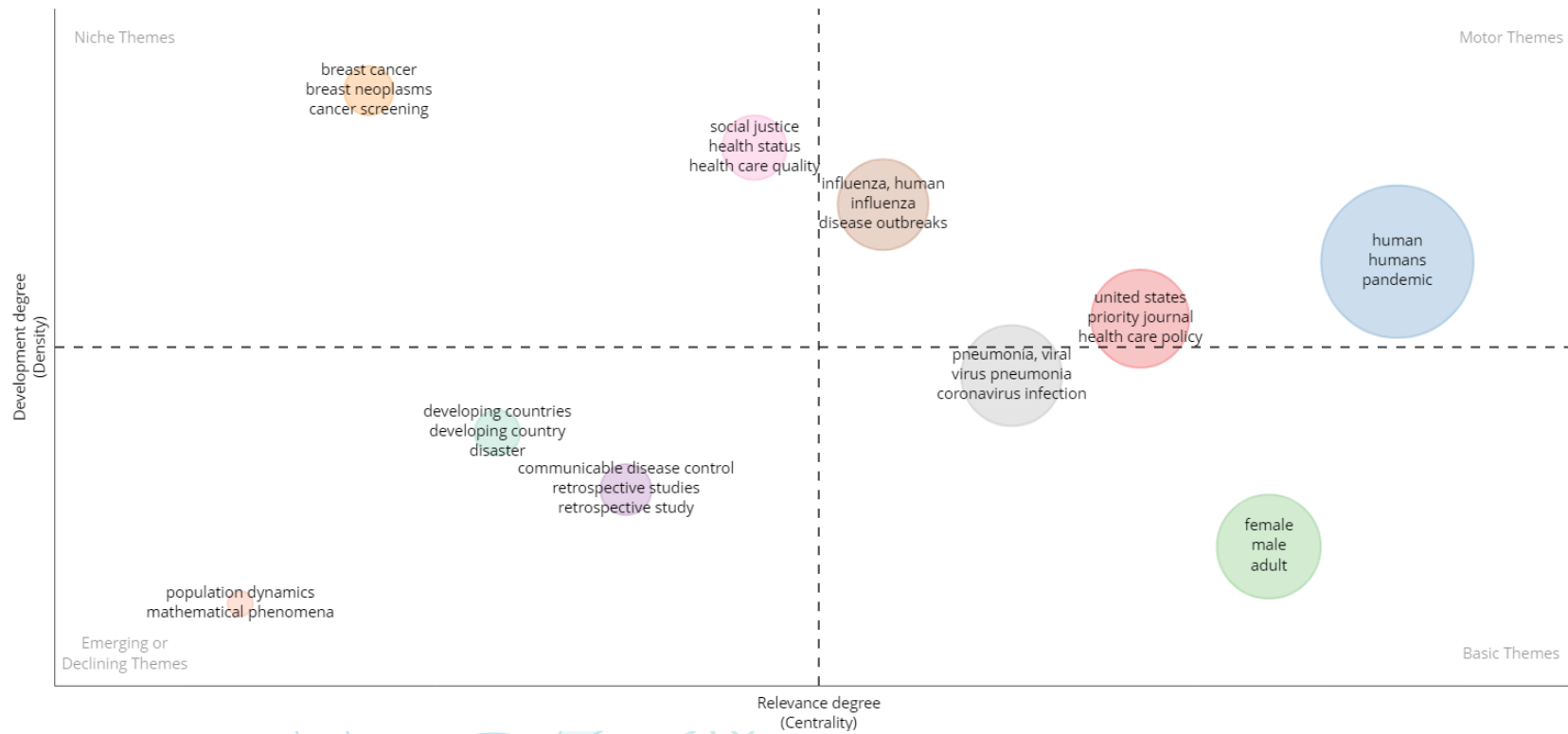
In the study of conceptual structure, we initially employed a Word Cloud (Figure 6) to visually represent the authors' keywords that appeared most frequently in the dataset. The size of each word in the Word Cloud corresponds to its frequency of occurrence, with larger words indicating higher frequency. Prominent keywords such as "covid-19" (n = 62), "rationing" (n = 25), "ethics" (n = 23), "resource allocation" (n = 22), and "triage" (n = 20) encapsulate the prevailing themes and topics within the literature. Additionally, the utilisation of a network approach revealed three distinct clusters (Figure 7). One cluster primarily focuses on the organisation of health services, while another cluster revolves around the aetiology of epidemics and pandemics. Lastly, there is a cluster encompassing terms associated with the coronavirus pandemic. The analysis of thematic evolution (Supplementary figure 2) indicates the emergence of ethics and COVID-19 as major themes after the year 2019. Furthermore, a thematic map (Figure 8) illustrates the significance of COVID-19 as a driving force for research, with social justice remaining a central aspect. Additionally, cancer emerges as a theme garnering scientific interest within the context of resource allocation.



**Figure 6.** Word Cloud depicting the frequency of authors' keywords in the dataset.



**Figure 7:** Co-Occurrence Map of Keywords. Clusters are represented by three distinct colours: Red (cluster1), Green (cluster2), and Blue (cluster3).



**Figure 8:** Thematic Map. Each cluster showcases the three keywords with the highest frequency of occurrence.

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## DISCUSSION

In this study, our objective was to analyse the research landscape in healthcare resource allocation during epidemic and pandemic situations. The findings of our study highlight the emergence of a field where the COVID-19 theme plays a significant role in driving research. We also identified ethics-related journals as the primary sources of knowledge in this area. Furthermore, our collaboration network analysis of institutions revealed potential opportunities for future international collaborative research.

The analysis of annual publications revealed that the years 2010 and 2021 had the highest number of publications, which is not surprising considering that they followed the last two pandemics (Influenza A H1N1 and COVID-19). However, the lack of publications during inter-pandemic periods is a matter of concern. This absence may reflect a decrease in interest in the field when not facing an immediate emergency.

While there is research conducted in Low- and Middle-Income Countries (LMICs) such as Thailand (20), the majority of research occurs in the United States of America, with both the largest number of publications and citations, as it also concentrates the most productive institutions in the field.

In recent years, there has been a resurgence of interest in developing statistical and mathematical models to predict various scenarios. Computational models have proven to be valuable tools for guiding resource allocation decisions and optimising the utilisation of limited resources. Consequently, there has been an increasing focus on conducting hypothetical examinations of prioritisation protocols through the use of simulated scenarios (21), including the production of models for distributing epidemic control resources among a wide range of interventions (22,23). Additionally, there is a growing interest in incorporating new factors, such as community engagement and information dissemination to the public, into the decision-making process (24).

Our examination of key knowledge sources has uncovered the significant role played by the "Journal of Medical Ethics" and "Bioethics" in disseminating research findings and fostering scholarly discussions regarding ethical considerations and philosophical perspectives in resource allocation decision-making. The substantial number of publications in these journals signifies the attention dedicated to ethical aspects in resource allocation, highlighting the imperative of adopting a principled and morally sound approach when allocating scarce resources during crises. The emergence of ethics and COVID-19 as prominent themes subsequent to 2019 indicates the evolving research landscape and the urgent requirement for ethical guidance in resource allocation decisions. The thematic map has shed light on the interconnectedness between resource allocation and social justice, underscoring the significance of equitable resource distribution to ensure fairness and mitigate disparities.

Public policy decisions related to healthcare are not dictated by a singular, uncomplicated moral theory (25). The progress in medical science must adhere to an evidence-based framework that prioritises saving the greatest number of lives (26). In light of the pandemic,

it is vital for response measures to capitalise on the opportunity to promote equity, prioritising initiatives that have the potential for long-term sustainability beyond the immediate crisis (27). The COVID-19 pandemic has exposed the disparities in approaches adopted by medical centres when it comes to distributing limited resources (28). The emergence of anti-vaccine movements has introduced new ethical dilemmas in resource allocation for the unvaccinated population (29). Furthermore, the inclusion of cancer as a thematic area of scientific interest within the context of resource allocation highlights the expanding realm of research beyond infectious diseases, acknowledging the broader healthcare needs that necessitate considerations in resource allocation.

This study is not exempt from the limitations inherent in a bibliometric analysis. Our focus on original research articles may introduce a bias in representing the overall research landscape. Additionally, we cannot dismiss the possibility of publication bias towards positive results, overlooking negative or null findings. Being a quantitative approach, bibliometric analysis places a strong emphasis on citations, potentially oversimplifying the evaluation and failing to capture the intricate nuances, complexities, and qualitative aspects of research, such as the significance, societal impact, or originality of individual studies. In the context of multidisciplinary fields, the distinct publication patterns and citation practices across different disciplines may restrict the accuracy and comparability of the analysis.

In conclusion, this study offers a comprehensive analysis of the research landscape in healthcare resource allocation during epidemic and pandemic situations. Our findings emphasise the significant role of the COVID-19 theme in driving research endeavours and highlight the importance of ethics-related journals as primary sources of knowledge in this field. Furthermore, our analysis reveals potential avenues for future international collaborative research. Collectively, these findings enhance our understanding of resource allocation in healthcare during epidemic and pandemic events and provide valuable insights for researchers in developing evidence-based and ethically informed decision-making frameworks.



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