Science in One Health 3 (2024) 100077

Contents lists available at ScienceDirect

Science in One Health

journal homepage: www.journals.elsevier.com/science-in-one-health

Full length article

A bibliometric analysis of One Health approach in research on antimicrobial resistance

Zheyi Fang [a,b], Shiyi Tu [a,b], Jiayan Huang [a,b,*]

[a] Shanghai Institute of Infectious Disease and Biosecurity, School of Public Health, Fudan University, Shanghai 200032, China
[b] Global Health Institutes, Fudan University, Shanghai 200032, China

ARTICLE INFO

Keywords:
Antimicrobial resistance
One Health
Bibliometric analysis

ABSTRACT

Background: Antimicrobial resistance (AMR) is a global public health threat that requires actions through One Health intervention. This study aims to trace the historical development of One Health research on AMR to provide evidence supporting future research and actions.

Methods: A bibliometric analysis is conducted with One Health articles in the field of antimicrobial resistance (AMR-OH articles) retrieved from the Web of Science Core Collection (WoSCC). AMR-OH articles refer to articles in the field of AMR that simultaneously involve elements from human health and at least one other domain, including animals, environment, or plants. Three research periods were identified based on the development of global actions in combating AMR. Descriptive analysis of publications, keyword cluster analysis, annual trending topic analysis, and co-authorship analysis were conducted using R software, *VOSViewer*, and *Pajek*.

Results: The results indicated that the percentage of AMR-OH articles among all AMR articles increased from 5.21% in 1990 to 20.01% in 2023. Key topics in the current AMR-OH articles included the mechanism of AMR, AMR epidemiology, and public health control strategies. Epidemiological research initially focused on human and animal health and then shifted to environmental factors in the third period. Research at the molecular level focused on the mechanisms of AMR transmission in various domains, along with the dynamics and diversity of antibiotic resistance genes (ARGs). The co-authorship analysis suggested a significant increase in cooperation among low- and middle-income countries in the third period.

Conclusion: The scope of epidemiological research on AMR has expanded by including human, animal, and environmental areas. Moreover, genetic and molecular level research represents the forefront of this field, offering innovative tools to combat AMR in the future. This study suggests further research to translate existing findings into practical implementation of the One Health strategy, and to support globally consistent action in combating AMR.

1. Introduction

Antimicrobial resistance (AMR) occurs when drugs lose effectiveness in inhibiting the growth of microorganisms such as bacteria, fungi, and viruses, making infections difficult to cure. The global burden directly attributable to AMR infections has been estimated at 127 million deaths, making it the 12th leading cause of death at Global Burden of Disease (GBD) Level 3, surpassing both HIV and malaria [1]. The widespread presence of antibiotic resistance genes (ARGs) across diverse media poses risks to human health [2,3]. ARGs can accumulate, migrate, and potentially become pathogenic to humans [4]. The extensive use and misuse of antibiotics in medicine, agriculture, and veterinary practices further promote the spread and evolution of ARGs [5]. Given the profound global impact of AMR, it is recognized as a critical health threat necessitating coordinated action through the One Health approach [6]. The One Health approach is defined as an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems [7,8].

Global efforts have fostered robust political commitment and established structured foundations for One Health initiatives aimed at

Abbreviations: AMR, Antimicrobial resistance; AMR-OH articles, One Health articles in the field of antimicrobial resistance; ARGs, antibiotic resistance genes; GBD, Global Burden of Disease; FAO, Food and Agriculture Organization of the United Nations; WOAH, World Organization for Animal Health; WHO, World Health Organization; UNEP, United Nations Environment Programme; WoSCC, Web of Science Core Collection; TTA, Trend topics analysis; GLASS, Global Antimicrobial Resistance and Use Surveillance System.

* Corresponding author. Shanghai Institute of Infectious Disease and Biosecurity, School of Public Health, Fudan University, Shanghai 200032, China.
E-mail addresses: zyfang23@m.fudan.edu.cn (Z. Fang), sytu@fudan.edu.cn (S. Tu), jiayanhuang@fudan.edu.cn (J. Huang).

https://doi.org/10.1016/j.soh.2024.100077
Received 9 July 2024; Accepted 1 September 2024
Available online 3 September 2024

combating AMR. In 2010, the Food and Agriculture Organization of the United Nations (FAO), the World Organization for Animal Health (WOAH), and the World Health Organization (WHO) formed a tripartite alliance to enhance their long-standing partnership in addressing zoonoses and animal affecting food security [9]. In 2018, the tripartite alliance renewed its focus on tackling AMR through a One Health approach. In 2022, the alliance was formally expanded to include the United Nations Environment Programme (UNEP), thereby forming the quadripartite alliance. This expansion aims to accelerate the coordinated strategy on human, animal, plant, and ecosystem health [10]. As One Health actions involve multiple sectors and stakeholders, there is an urgent need for robust research evidence to inform interdisciplinary collaboration and resource mobilization [11,12]. The quadripartite's strategic framework for collaboration on AMR underscores research and research investment as a pivotal component of global efforts on AMR [13, 14]. In July 2023, the WHO released a document entitled *A One Health Priority Research Agenda for Antimicrobial Resistance*, highlighting future research priorities from a One Health perspective.

Examining the published literature is crucial for understanding the global and regional progress in One Health initiatives aimed at combating AMR [15,16]. Previous literature review and bibliometric analysis have revealed the development of AMR research [17–19]. Some studies have focused exclusively on specific disciplines or topics within the field of AMR, such as AMR in the natural environment or wildlife. Others have adopted a broader One Health perspective, addressing a wide range of health issues beyond AMR [20,21]. Research has indicated the persistent silos between the disciplines of human health, veterinary medicine, and the environment. However, few studies focus on One Health research in the field of AMR, which seeks to connect multiple domains and bridge these disciplinary silos [19,22].

Therefore, this study aims to trace the historical development of One Health research in the field of AMR. Bibliometric analysis has significant advantages in identifying key research frontiers within a vast body of literature. Based on this, the study conducts a bibliometric analysis of One Health articles in the field of AMR (AMR-OH articles), which refers to studies that address the issue of AMR in two or more domains, to provide evidence for future research and actions through the One Health approach.

2. Methods

2.1. Data resource

The study used the Web of Science Core Collection (WoSCC) database to retrieve literature. The WoS offers the advantage of collecting literature from multiple disciplines and tracing reference and citation activity [23, 24].

Search formulas were generated by limiting relevant keywords to Titles or Authors' Keywords. Using keywords including "antimicrobial resistance", its synonyms, and various writing formats, 66,332 articles in the field of AMR were obtained from the WoSCC. This study then selected and combined keywords representing elements from four domains — humans, animals, the environment, and plants — to fetch the One Health related publications in the field of AMR. Details of the search formulas can be found in Supplemental Table 1.

The inclusion criteria of literature are as follows: (1) literature involving elements from human health and at least one other domain; (2) the document type is "articles". The search time span is from January 1969 to December 2023. After removing duplicates and excluding certain literature, a total of 11,194 AMR-OH articles were extracted for the bibliometric analysis (Fig. 1).

2.2. Data analysis

2.2.1. Division of research period

To analyze the historical evolution of global AMR research, this study divided all literature into three periods: 1969–2001, 2002–2010, and 2011–2023. These periods were determined based on the timeline of the Global Action Initiative against AMR and the first period ended in 2001 with the adoption of a global strategy by the WHO to combat AMR, which increased global attention. In 2011, the WHO issued a policy package

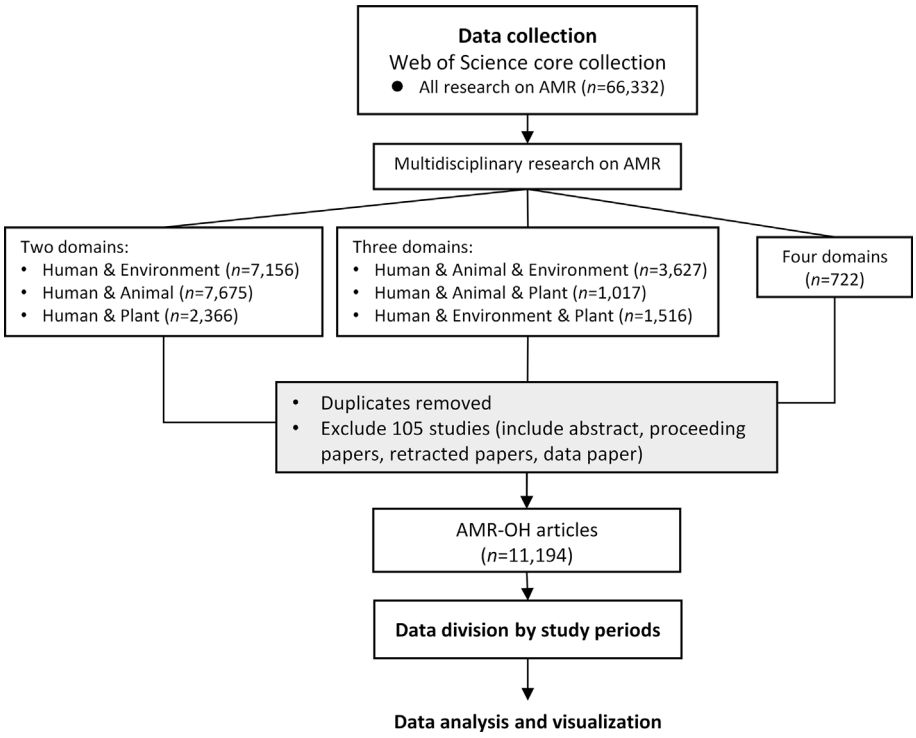

Fig. 1. The scheme of the data collection and analysis flow. Abbreviations: AMR, antimicrobial resistance; AMR-OH articles, One Health articles in the field of AMR.

emphasizing "multisectoral collaboration in the fight against AMR", marking the start of the third period.

2.2.2. Descriptive analysis of literature

The purpose of conducting a descriptive analysis of the literature is to uncover the overall progress of research in the field of AMR. The annual number of AMR-OH articles and their percentage among all AMR articles were calculated to demonstrate the volume and growth of AMR-OH articles. The average number of citations per article per year was used to reveal the academic influence of the articles included and their changing trend. Highly-cited papers are defined as those that rank in the top 1% by citations for a specific field and publication year in the WoS.

2.2.3. Hot topic analysis

Hot topic analysis aims to detect hot topics and annual trending topics in the existing One Health studies in the field of AMR [25].

Keyword cluster analysis was performed on articles published during each study period to detect hot topics over time. A keyword cluster refers to a group of keywords with close relationships between each other. When two keywords occur in one article, they can be defined as having a co-occurrence relationship. Based on the co-occurrence relationships between all keywords in the selected literature, co-occurrence networks can be developed. In this network, keywords will be grouped into clusters according to the strength of their relationships. A keyword cluster usually represents a specific hot research topic in the selected literature. This study used *VOSViewer* (1.6.16, *Centre for Science and Technology Studies, Leiden University, The Netherlands)* and *Pajek* to visualize and optimize the keywords' co-occurrence network. The researchers reviewed the initial keyword list generated by *VOSViewer*. Synonyms, different spellings, search terms used in the retrieval strategy, and irrelevant words (e.g., "a" and "1st") were detected and removed from the keyword list for the subsequent analysis.

Trend topics analysis (TTA) was used to analyze specific **annual trending topics** and their duration of popularity. The "biblioshiny" package in R software was employed to extract the top five keywords that appeared most frequently each year, as well as the period over which they were studied. An annual trending topic map was created to reveal these trends [26]. On the map, the x-axis represents time, and the topics are represented on the y-axis. The circle is placed on the median year of the period the keyword was studied. Its size is related to the keyword's K/A ratio in the median year. The K/A ratio is the ratio of the frequency of keywords to the total number of publications in the same year. The length of the lines indicates how long a keyword has been studied [27].

2.2.4. Co-authorship analysis

Co-authorship analyses were conducted to analyze international research cooperations in different periods. All countries were categorized into four groups, high-income countries, upper-middle-income countries, lower-middle-income countries, and low-income countries. The grouping of the country income level was based on the report released by the World Bank in 2024. This study then analyzed the co-authorship relationships between countries with different income levels. The *VOSViewer* (1.6.16) was used to draw the co-authorship network.

3. Results

3.1. Overview of AMR-OH articles

A total of 11,194 AMR-OH articles were published between 1969 and 2023. In 2015, 375 articles were published, marking the start of a continuous and rapid increase in publications. The average number of citations per year peaked at 5.12 in 2016 and has been decreasing annually. There are 78 highly-cited papers in the WoS database, representing 0.70% of all AMR-OH articles. All highly-cited papers were published after 2015. The percentage of AMR-OH articles among all AMR articles has been increasing since 1990, rising from 5.21% in 1990 to 20.01% in 2023 (Fig. 2).

3.2. Hot topics of AMR-OH articles

Research hotspots of AMR-OH articles across all three periods can be divided into three categories: mechanisms of AMR, AMR epidemiology, and strategy of AMR control (Figs. 3–5). Detailed information about keyword clusters can be found in Supplemental Table 2.

Research on "AMR epidemiology" continued to develop across the three periods, with different focuses in each. In the first period, the majority of hot topics were closely related to human health, including hospital and intensive care unit (ICU)-related AMR (cluster #2, Fig. 3), children (cluster #5, Fig. 3), and specific AMR infections like *Haemophilus influenzae* disease (cluster #3, Fig. 3). In the second period, the focus shifted to AMR related to animals and food. Hot topics including food animals (cluster #7, Fig. 4), food safety (cluster #4, Fig. 4), veterinary medicine (cluster #3, Fig. 4), and zoonotic diseases (cluster #5, Fig. 4) have become hot topics in this period. The third period was dominated by topics related to the environment. The research delved into the specific environmental factors contributing to AMR transmission, such as aquatic (cluster #7, Fig. 5) and farm environments (cluster #8, Fig. 5). Research on the AMR gene in the environments also gained

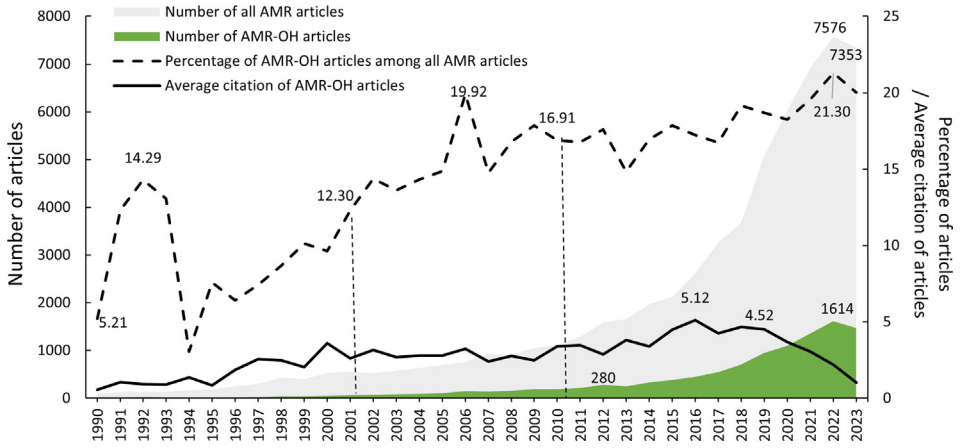

Fig. 2. The trend of total publication and average citations per year of One Health study in the field of AMR. Abbreviations: AMR, antimicrobial resistance; AMR-OH articles, One Health articles in the field of antimicrobial resistance. *Note: The data from years prior to 1990 are not included in this figure for clearer presentation of the results, due to the small number of articles published during those years.

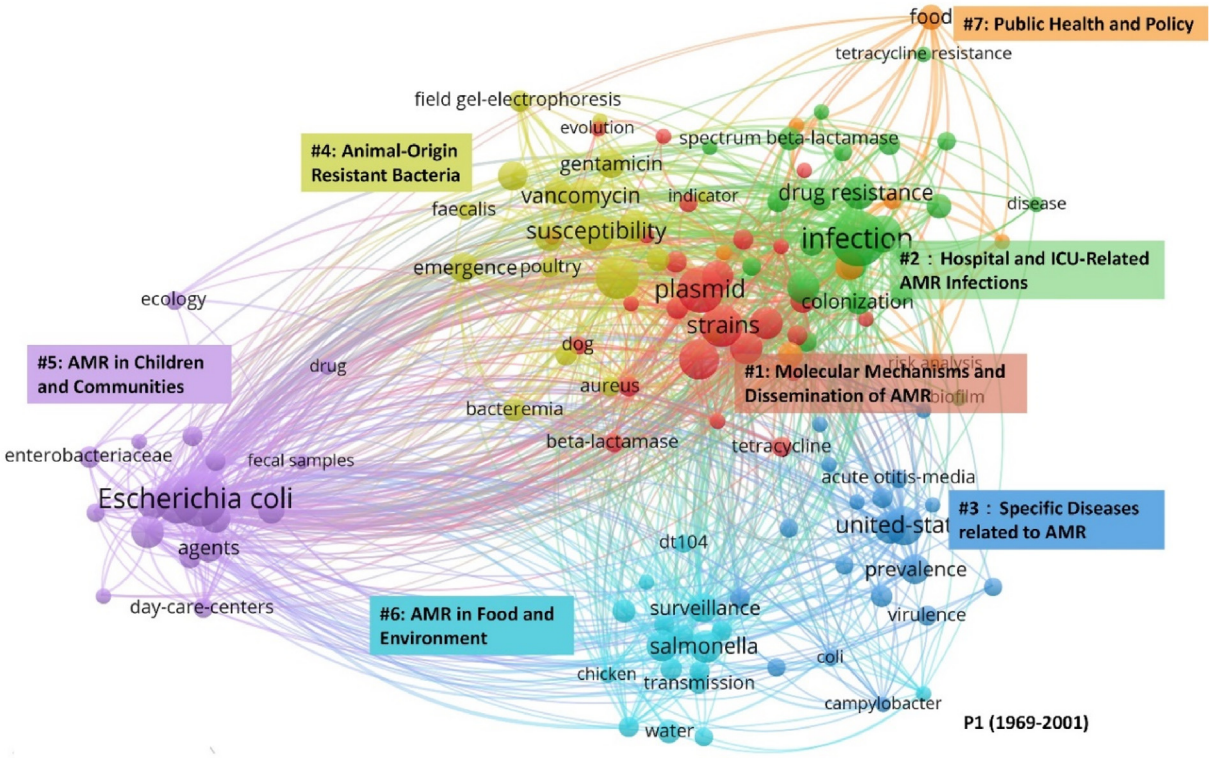

Fig. 3. Hot topics in the AMR-OH articles in the 1st period. Abbreviations: AMR, antimicrobial resistance; AMR-OH articles, One Health articles in the field of antimicrobial resistance; ICU, intensive care unit.

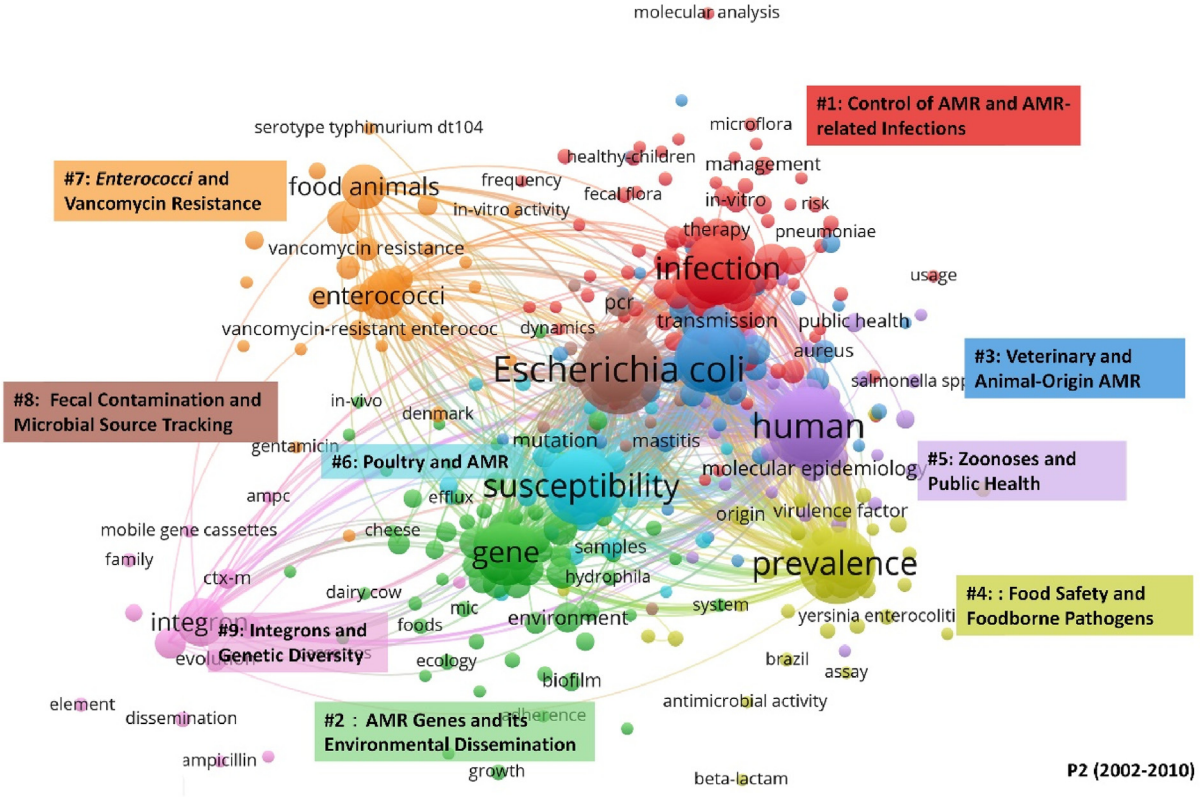

Fig. 4. Hot topics in the AMR-OH articles in the 2nd period. Abbreviations: AMR, antimicrobial resistance; AMR-OH articles, One Health articles in the field of antimicrobial resistance.

significant attention from the second period to the third one (cluster #8, Fig. 5).

Research on the "mechanisms of AMR" focused on revealing the transmission of AMR from genetic and molecular biology perspectives. Throughout the three research periods, plasmids (cluster #1, Fig. 3), integrons (cluster #9, Fig. 4), and biofilms (cluster #1, Fig. 5) emerged as key hotspots in AMR mechanism research.

The "strategy of AMR control" did not form distinct clusters across the three periods. In the first period, it overlapped with the cluster about "hospital and ICU-related AMR infections" (cluster #2 and cluster #7, Fig. 3). In the latter periods, the keywords of this topic were closely related to "AMR epidemiology" (cluster #5, Fig. 4) and "mechanism of AMR" (cluster #1, Fig. 5). Notably, "infections" consistently appeared as one of the most frequent keywords in research on the "strategy of AMR control". Furthermore, the keyword "One Health" was frequently studied in the third period. It was clustered in cluster #3, which represents research on "AMR epidemiology and public health strategies" (Fig. 5).

According to the annual trending topic analysis, before 2011, most high-frequency keywords were related to AMR infections and their treatment. Many typical antimicrobials and resistant bacteria strains were trending topics during this period. In the third period, gene transfer emerged as a hotspot, and topics related to gene and molecular characteristics began to gain more attention. In 2021, the popularity of water, abundance, and resistome significantly increased. In the past two years, attention has shifted to environmental pollutants like microplastic and metal (Fig. 6).

3.3. Collaboration between countries on AMR-One Health related studies

International collaboration in AMR-OH articles between countries of different income levels is shown in Fig. 7. Countries with strong collaborations are grouped in the same clusters, with each cluster placed in the same row.

In the first period, researchers from high-income countries led the AMR-One Health research, collaborating with researchers from countries of different income levels. For instance, Australia, India, South Africa, Switzerland, and Sweden formed a productive cluster. In the second period, while cooperation across countries at different income levels grew, the participation of low- and middle-income countries remained relatively weak.

In the third period, closer cooperation between low- and middle-income countries was established. For example, Cameroon, Kenya, Mali, and the Republic of the Congo formed closer collaboration, mainly focusing on the impact of wastewater discharges from agriculture and livestock farming on the storage and transmission of ARGs. In addition, inter-country cooperative relationships at this stage also seem to be influenced by geographic location factors. Geographic proximity also influenced collaborations in the third period. For example, Middle Eastern countries including Egypt, Jordan, Morocco, and Saudi Arabia constitute a cluster.

4. Discussion

The results suggest significant advancements in One Health research in the field of AMR. Over the past three decades, AMR-One Health research has made significant progress in the epidemiology of AMR and the transmission mechanisms of AMR. These advancements have provided crucial insights for developing effective AMR control strategies.

The percentage of AMR-OH articles among all AMR articles has been increasing, especially after 2015, when more and higher quality articles were published. In 2015, WHO formally launched the WHO Global Action Plan on AMR and introduced the Global Antimicrobial Resistance and Use Surveillance System (GLASS), which may have led to increased multidisciplinary efforts on this issue [28,29].

The developments mark not only an increase in the amount of research but also a deepening of its focus. The results of the hot topic analysis show that epidemiological research on AMR maintained its prominence in AMR-OH research from the first period to the latest one. Its scope expanded with ongoing studies that included humans, animals, plants, and the environment. The promising progress in AMR epidemiology showed the widespread prevalence of AMR and ARGs across all domains. This consistently reaffirms the necessity of adopting a One Health approach to combat AMR [30]. Additionally, AMR epidemiological research reveals the possible

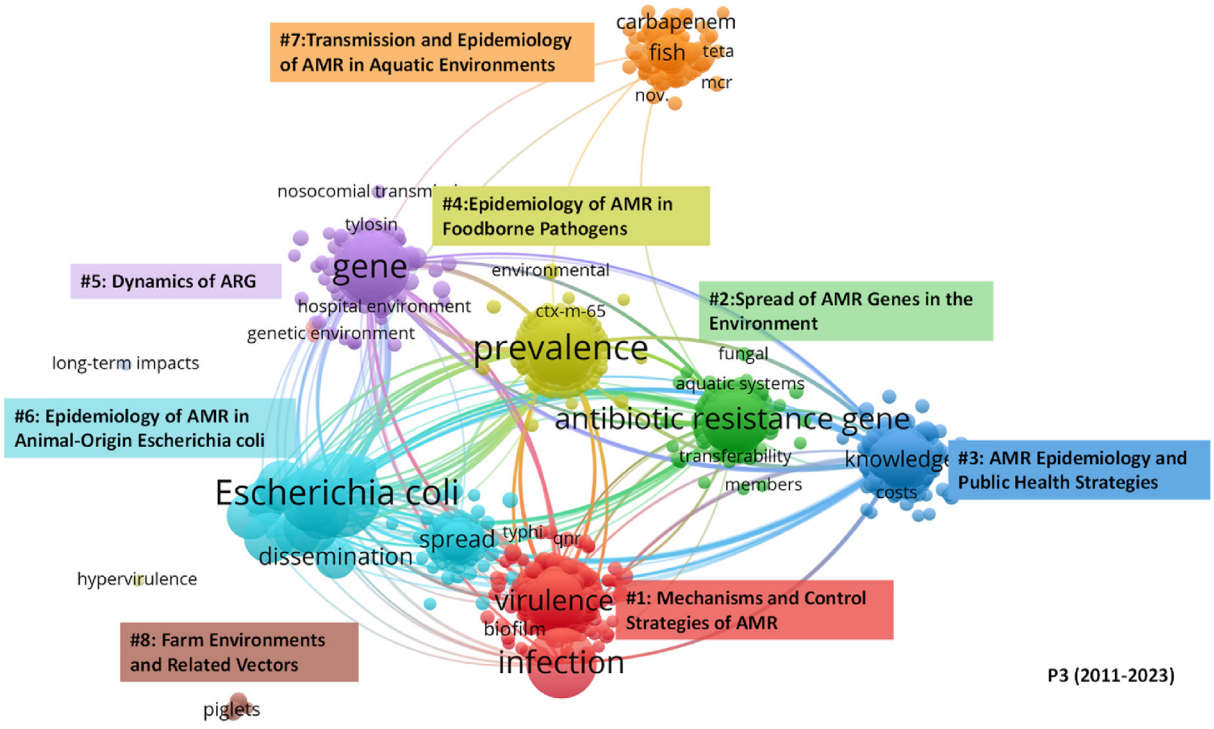

Fig. 5. Hot topics in the AMR-OH articles in the 3rd period. Abbreviations: AMR, antimicrobial resistance; AMR-OH articles, One Health articles in the field of antimicrobial resistance.

Fig. 6. The annual trending topics in AMR One Health studies. Abbreviation: AMR, antimicrobial resistance.

causal relationships between AMR factors in domains. For instance, studies demonstrating the close links between antimicrobial consumption and AMR in critical pathogens highlight the importance of antimicrobial stewardship [31]. Research revealing the connection between ARGs in livestock waste and humans emphasizes the significance of farm interventions [32]. Based on the existing evidence, further investigation into the interface between different domains is still needed to devise and prioritize the optimal strategy to combat AMR through the One Health approach [33].

The consistent evolution of research on AMR epidemiology and mechanisms also demonstrates that there has been a growing focus on genetic and molecular studies. Over the past two years, keywords related to genetic and molecular studies, such as horizontal gene transfer, resistome, and abundance, have garnered increasing attention. On the one hand, research at the molecular level offers valuable insights into the mechanisms of AMR transmission and ARGs evolution in the whole ecosystem [34,35]. On the other hand, this research also demonstrated the application of novel technological tools, which can support future One Health research and practices. For example, resistome deciphering, gene abundance, and metagenomic sequencing data were increasingly used in many newly-published and highly-cited AMR-OH research [36, 37]. It can be implied that incorporating these molecular technologies

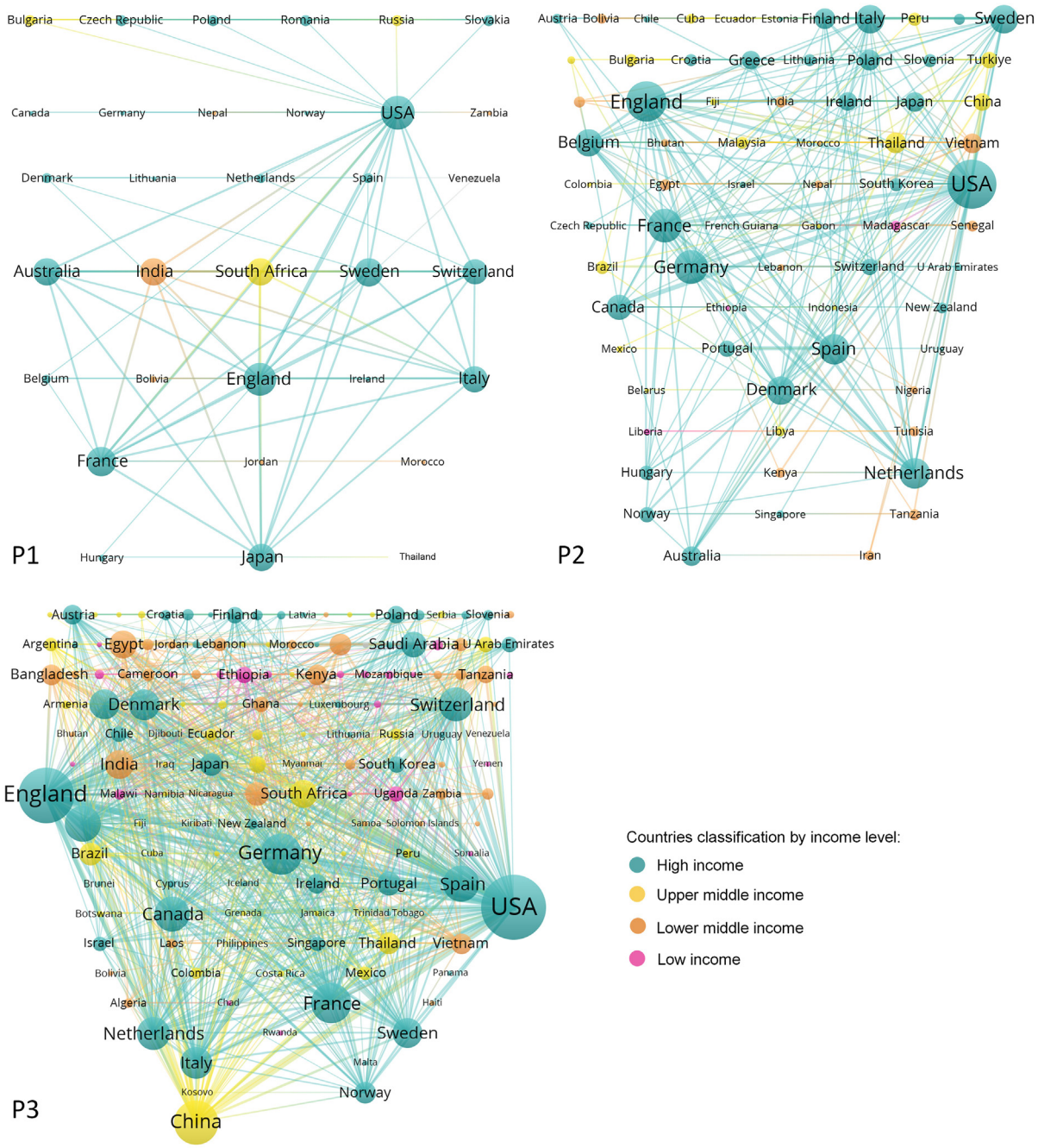

Fig. 7. International cooperation networks in AMR-One Health studies in three study periods. Abbreviation: AMR, antimicrobial resistance.

into research and actions will remain a significant direction of the future [38,39].

Another important aspect of the One Health action involves international cooperation. The co-authorship analysis shows that low- and middle-income countries have established cooperation networks in the AMR-OH research in the third period, whereas high-income countries played a dominant role in international cooperation since the initial period. This may lead to limited evidence on intervention effectiveness in lower-middle-income countries [40–42]. Furthermore, as novel and cutting-edge technologies become more prevalent in research and initiatives to combat AMR, it is essential to assess their true global impact [43,44]. This particularly involves focusing on lower-middle-income countries, where the basic conditions such as laboratory testing of AMR, and trained staff for combating AMR are still lacking [45–47].

A comparison between the research hotspots identified in this study and the future priorities outlined in *A One Health Priority Research Agenda for Antimicrobial Resistance* revealed a gap in research evidence. This gap primarily concerns the implementation of interventions, behavioral insights, as well as the economic and policy impact of AMR combating efforts. Therefore, this study suggests that future research should focus more on translating knowledge into tangible and implementable interventions.

First, this study proposes future research to explore the causal relationship of AMR across different domains, providing more evidence from a One Health perspective. Further investigations should focus on the interfaces between various domains, utilizing cutting-edge novel genetic and molecular technologies to deepen our understanding of AMR dynamics.

Second, the findings of AMR epidemiological studies underline the importance of an integrated One Health surveillance system, and thus this study suggests future research to focus on the implementation of One Health strategies [48]. For example, as researchers have identified an expanding range of ARGs in more samples and vectors, the increasing numbers of variables might also complicate the development of AMR surveillance strategies. Therefore, it is important to further define practical standards for selecting samples and technology in surveillance strategies and evaluating their effectiveness and cost-effectiveness [49].

Last but not least, the results indicated stronger collaborative research relationships between geographically proximate countries. Despite numerous challenges, regional cooperation is critical to solving health security issues including AMR [50]. This study suggests more research cooperations within specific regions to focus on common policies, economic impacts, and practical context related to combating AMR, to promote One Health actions within regions and to foster a coordinated global response to AMR.

5. Limitations

The current research has several limitations. First, while this study has made efforts to design comprehensive search strategies to capture all relevant literature on AMR within each domain, there is still a possibility of missing some literature. Second, as stated in the methodology, this study took a public health perspective and only included One Health studies related to humans. Therefore, the results may not fully represent the efforts and findings in the environmental, animal, and plant disciplines, potentially weakening the overall understanding of AMR to some extent. Third, the representation of results might be incomplete since this study only included published scientific research in English and collected by WoSCC. This may cause linguistic bias. In addition, government policies and other grey literature were not analyzed, which could lead to an underestimation of the One Health approach application in this field.

6. Conclusion

The One Health research in the field of AMR has advanced significantly in the past decade. Specifically, AMR epidemiological research has consistently remained a pivotal topic in AMR One Health research. The scope of this research has expanded to include humans, animals, plants, and the environment. Genetic and molecular level research represents the forefront of this field, offering innovative tools to combat AMR in the future. Co-authorship analysis reveals that AMR research has traditionally been dominated by developed countries; however, there is an increasing trend of collaboration with low- and middle-income countries. This shift is likely to result in more studies tailored to the specific conditions prevalent in these regions. Despite these advancements, there is a lack of research evidence regarding the implementation of interventions. Therefore, this study underscores the necessity of translating existing findings into practical implementation of the One Health approach, to provide enough evidence for supporting a cohesive global effort in combating AMR.

Authors contributions

JH designed the study. ZF conducted the data analysis, interpreted the data, wrote, and conducted a wide revision of the manuscript. JH and ST carefully reviewed and edited the manuscript. All the authors have read and approved the final version of the manuscript.

Funding statement

This research received no specific grants from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability statement

Data supporting this study are available within the article and the supplementary materials.

CRediT authorship contribution statement

Zheyi Fang: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation. **Shiyi Tu:** Writing – review & editing. **Jiayan Huang:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.soh.2024.100077.

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