



## Research article

## Knowledge mapping of population health: A bibliometric analysis

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## ABSTRACT

In recent years, population health has aroused great interest, especially after the outbreak of Covid-19. The related research increases substantially year by year. There are many kinds of research about population health, but few scholars use the bibliometric method to discuss them. Motivated by keeping abreast of emerging trends and critical turns in population health, this study adopts the bibliometric method to analyze the development history and status quo of population health, providing a summary description for it. This study adopts CiteSpace to conduct a bibliometric analysis of publications related to population health in Web of Science from 1971 to 2021. The most productive countries, authors, institutions, and research direction changes are analyzed. The research results show that: First, the number of publications and citations related to population health increases for years, especially in Canada, the United States, the United Kingdom, and Australia. Second, the number of publications by different countries or institutions in population health varies greatly, and they cooperate closely. Third, the co-occurrence of disciplines and keywords in population health is displayed. Finally, this study reveals the primary research force, the major themes, significant milestones, landmarks, and the evolution of the hot fronts. In all, the comprehensive analysis of this study would provide some enlightenment for future research.

## 1. Introduction

Population health refers to a broad range of topics affecting health, including the concept of health and a field of study of health determinants. It spans different disciplines such as medicine, epidemiology, economics, and sociology [1]. It also involves health outcomes, disparities, patterns of health determinants, risk factors, and policies and interventions relating to health outcomes and health patterns [2]. Population health is a topic of greatest concern to mankind. Since 1971, the Population, Health and Family Group set some goals and offered implementation strategies for population health [3]. In recent years, with the rapid development of big data, artificial intelligence, and biomedical technologies, the level of disease prevention, treatment, and health care has been significantly improved [4, 5]. In particular, significant progress has been made in life science technology, cell research, brain science, gene-editing technology, synthetic biology, tissue and organ manufacturing technology, and so on [6, 7]. Thousands of academic papers have been published about population health. Different scholars have done various discussions from different perspectives and fields, such as income inequality [8, 9], social capital [10], macroeconomic determinants [11, 12], and physical activity [13, 14]. The literature on

population health evolves from information systems [15], and health promotion [16] to the global burden [17], physical activity, structural racism [18], etc. Extracting useful information from existing publications and identifying the development trends is of great value.

There have been some systematic literature reviews on this topic, but few have analyzed it using bibliometric methods. A comprehensive understanding of the history and current situation of population health research, especially the research trends and hot fronts, is conducive to future research. Therefore, this study uses a visualization tool to analyze the knowledge of population health to grasp the primary knowledge of population health. It analyzes population health from the perspective of the total number of publications, the publications countries and regions, topics, research disciplines, authors, the citation and cooperation of institutions and countries/regions, and other aspects systematically. In particular, the basis, hot spots, and trends of population health research are clarified through reference co-citation analysis.

The rest of the paper is organized as follows. The second section introduces the database and research methods. The third section is the results of the bibliometrics analysis, including the analysis of the reference co-citation clusters, emerging trends, and references with high betweenness centrality and high citation. The final section gives a discussion.

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## 2. Materials and methods

### 2.1. Materials

This study takes two steps in building the CiteSpace database. The first step is to select the database. It selects the publications covering articles and review articles from the core database of the Web of Science (WoS). In order to clearly track the theme trends, this study set the keyword of population health as the search term. In detail, if the term appears in the title, abstract, or keywords of a publication, the publication will be chosen to be analyzed. The specific search strategy is as follows: topic = (population health), and the period is set from 1971 to 2021 [19]. The document types are set as “article” and “review article”. Finally, a total of 13,205 valid publications are collected for this study. The proceeding paper, book chapters, early access, and data paper are excluded as invalid records. The second step is to draw different network maps through CiteSpace. The data are imported into CiteSpace and each map is generated with different parameters.

### 2.2. Methods

This study uses CiteSpace to delineate the structure and dynamics of population health. CiteSpace is citation visualization analysis software developed by Chen [20]. It is developed in the context of scientometrics and can facilitate the detection of potential knowledge and visualize the structure, rules, and distribution of some research areas. It is widely applied for analyzing and visualizing co-citation networks, which can label co-citation clusters and improve the timelines of visualized co-citation networks. As a quantitative analysis tool, it can analyze the structure, rules, and distribution of scientific knowledge and display the results through the scientific knowledge map. It can also mine knowledge, such as emerging trends, knowledge structures, subject hotspots, and landmark references [21, 22]. For example, in the research cooperation network, the node size reflects the number of publications published by authors, countries, regions, or institutions. In the co-occurrence analysis, the node size reflects the frequency of topics, keywords, or scientific disciplines. In the co-citation network, the node size represents the citation times of references, journals, or authors. The time slicing is set from 1971 to 2021 and a slice includes five years.

## 3. Results

### 3.1. Quantitative analysis of publications

The number of publications can reflect the importance of a research topic. In this section, this study conducts a quantitative analysis of the total number of publications and the publications of countries or regions.

#### 3.1.1. Publications by year

Figure 1 shows the number of publications and citations in population health research from 1971 to 2021. The number of publications on population health has been increasing, and the number of citations has also increased with the number of publications. It shows that population health has received extensive attention from academics.

In particular, population health research can be divided into three stages in terms of the total number of publications. The period from 1971 to 1994 is the initial stage. The first publication on the topic of population health was published in 1971 [3]. The author put forward some goals and strategies for protecting the biosphere. The number of publications in this stage is less than 20 each year, indicating that population health has not received enough attention. The second stage is a rising stage. During the years from 1995 to 2016, the number of publications increases gradually, and by 2016, the number of publications has reached 804. The third stage is the research explosion stage. It is from 2017 to 2021. During this period, more than 1000 publications are published each year. Especially, since the Covid-19 outbreak, more than 1500 publications have been published in the past two years. The topic of population health has received unprecedented attention.

Concerning the number of citations, it can also be divided into three stages. The first stage is from 1971 to 1994, with a few citations. The second stage is also a rising stage. During the years from 1995 to 2014, the number of citations increases rapidly, and the increment reaches its highest point at 28926 in 2014. The third stage is from 2015 to 2021. The citation increment decreases gradually.

#### 3.1.2. Publications by countries or regions

The number of publications reflects the importance attached to this field by countries or regions. The networks reflect the cooperation among countries. This study selects the top 50 countries or regions that occurred

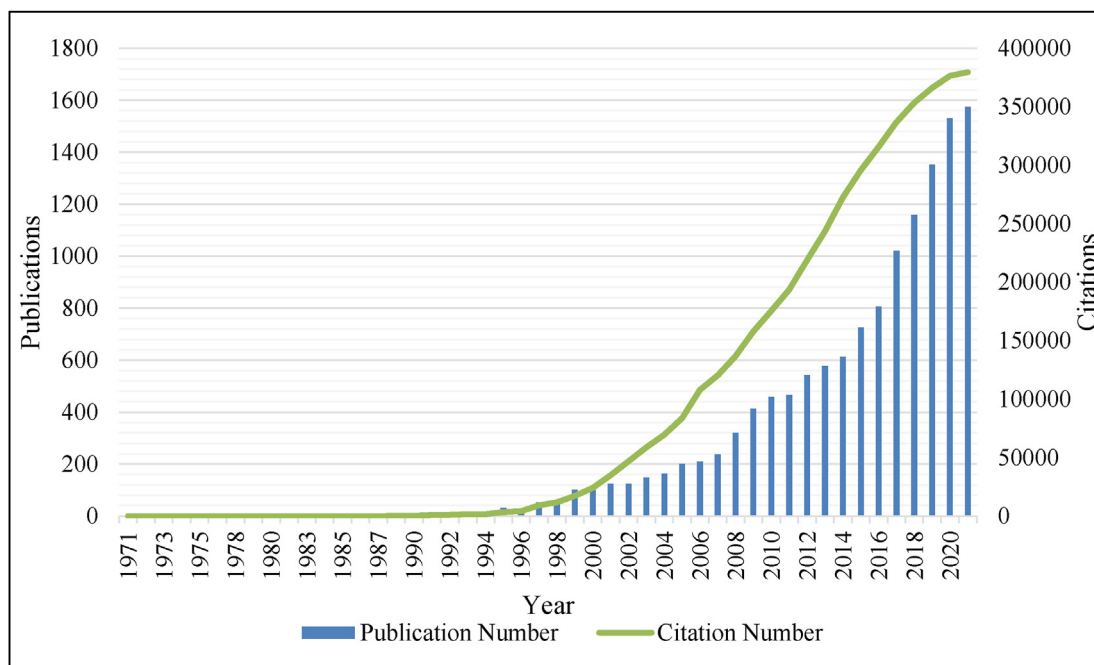


Figure 1. The number of publications and citations in population health from 1971 to 2021.

in publications and constructs the current national or regional cooperation networks. 148 nodes and 68 links are obtained in Figure 2. Each node represents a country or region, and the link means a cooperative relationship. The node size represents the number of publications of the country or region, and the node color represents the corresponding year when the publications appeared. The link color corresponds to the cooperation year. The thickness of the links represents the strength of the cooperative relationship.

Table 1 lists the top 20 most productive countries or regions. The United States published 6264 articles, accounting for almost half of the total number of publications. It is followed by Canada, which published 2417 articles. In addition, Australia, England, New Zealand, Germany, and Spain have published a lot of articles. The United States and Canada have discussed population health earlier. The United States published the first article in 1971, followed by Canada in 1972. Figure 2 displays the cooperation networks of population health research by countries or regions. Australia, France, Spain, Denmark, the United States, England, and Scotland formed close academic networks. The cooperation relationship occurred between Norway and Denmark, Colombia and Mexico, and Thailand and Switzerland.

### 3.2. Analysis of productive authors and institutions

#### 3.2.1. Analysis of productive authors

The top 50 productive authors of every slice are selected to analyze the productive authors in population health. Table 2 reports the top 10 productive authors in population health, including Christopher JLM, Martin M, Theo VOS, Sandro G, Scott BP, Alan DL, Johan PM, Mohsen N, Bilie G, and Carles M. Christopher JLM has published 45 articles, and his first publication was in 2006. Judging from the number of published articles, he has the richest research experience in this field. Martin M and Theo VOS rank the second with 38 publications and their first articles were in 2007. Sandro G has 37 publications, and the first was published in 2006. Scott BP has published 36 articles with the first article published

Table 1. Top 20 productive countries or regions in population health.

Country or regions	Publications	Country or region	Publications
The United States	6264	Italy	261
Canada	2417	Scotland	248
England	1468	Brazil	245
Austria	1339	Switzerland	223
Peoples R China	448	South Africa	194
Netherlands	364	New Zealand	192
Germany	360	Iran	191
Spain	318	Australia	157
Sweden	280	Denmark	149
France	277	Belgium	145

in 2007. The number of publications of Christopher JLM accounts for 1.11% of the total publications by productive authors. The number of publications of Martin M and Theo VOS accounts for 0.94%. The number of publications of Sandro G accounts for 0.91%. Among them, Christopher JLM, Sandro G, Alan DL, and Carles M published their first articles in 2006. Sandro G and Martin M started their population health research earlier than other authors and kept their research on this topic longer.

Figure 3 displays the cooperation networks of authors in population health. There are 693 nodes and 846 links. Each node represents an author, and the link represents the cooperative relationship. The node size represents the number of publications of authors. The larger the node is, the more publications the author published. The color in the center of the circles indicates the year when the author first published an article in this field. The outermost color represents the latest time when the authors publish their articles. The links between the nodes indicate the cooperative relationship between authors. The color of the link shows the time of the first cooperation. The red link means front-edge cooperation. As shown in Figure 3, Sandro G and Martin M have published many articles but cooperated less with different authors. Alan DL, Christopher

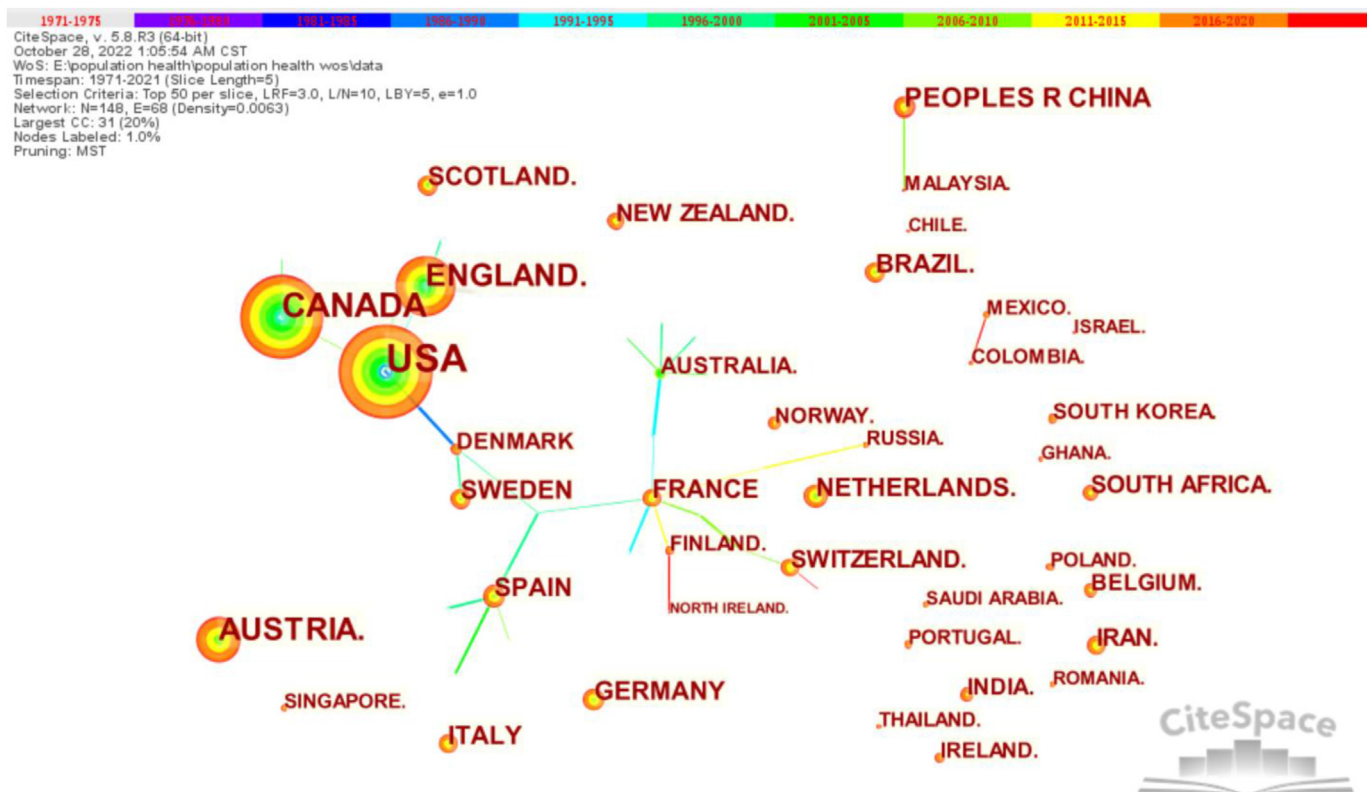


Figure 2. The cooperation networks of productions by countries or regions.

**Table 2.** Top 10 productive authors in population health.

Authors	Publications	Institution Country	The proportion of the total number	First published time
Christopher JLM	45	the United States	1.11%	2006
Martin M	38	England	0.94%	2007
Theo VOS	38	Australia	0.94%	2007
Sandro G	37	the United States	0.91%	2006
Scott BP	36	Canada	0.89%	2007
Alan DL	35	the United States	0.86%	2006
Johan PM	30	England	0.74%	2011
Mohsen N	25	the United States	0.62%	2011
Billie G	25	Australia	0.62%	2013
Carles M	25	Canada	0.62%	2006

JLM, Theo VOS, and Mohsen N have cooperated with other authors more closely. Generally speaking, Figure 3 shows close cooperative networks among authors. Most of the cooperation happened from 2011 to 2020.

**3.2.2. Analysis of productive institutions**

The more articles an institution publishes in the field, the more influence it is likely to have. This study selects the top 50 institutions to discuss the distribution of productive institutions. Table 3 presents the top 15 most productive institutions. The University of Toronto published the most articles (529), accounting for 2.40% of the total publications. It is far ahead of the University of Washington and Harvard University (323). The others published between 194 and 277 articles in the field. All of the leading institutions are from Canada, the United States, and Australia. Six of the top 15 institutions are from Canada and the United States. They attach great importance to population health research.

Figure 4 presents the cooperation networks of institutions. There are 789 nodes and 4418 links. Each node represents an institution, and the links between nodes represent the cooperative relationship. The node size represents the number of articles published by institutions. The link color corresponds to the year of the first cooperation. Figure 4 reveals that the University of Toronto, the University of British Columbia, the University of Michigan, the McMaster University, and the University of Queensland published articles as early as 1997. The institutions cooperated closely, especially from 2011 to 2020.

**3.3. Co-occurrence analysis of disciplines and keywords**

Co-occurrence analysis has been widely used in bibliometrics. It means something co-occurs in the same article. If the content of an article belongs to two disciplines, the two disciplines co-occur. If two or more keywords appear in one article, the two or more keywords co-occur. CiteSpace also counts the most occurred disciplines and keywords. Through analyzing the occurrence times, the research hotspots and trends are known.

**3.3.1. Disciplines Co-occurrence analysis**

To generate the co-occurrence networks of disciplines, this study selects the top 50 disciplines. Figure 5 presents the co-occurrence networks of disciplines. There are 95 nodes and 443 links in total. Each node represents a discipline, and the links between nodes represent co-occurrence relationships. The node size represents the number of articles published in the discipline, and the color of the links corresponds to the year of co-occurrence of disciplines. The more times the disciplines co-occur, the closer relationships among the disciplines are.

As can be seen from Figure 4, among all disciplines related to population health, “public, environmental and occupational health” published the most articles, 4841 in total. It is followed by the discipline of “Health Care Sciences & Services”, which published 2501 articles. The discipline of “General & Internal Medicine” is with 1360 articles. The discipline of

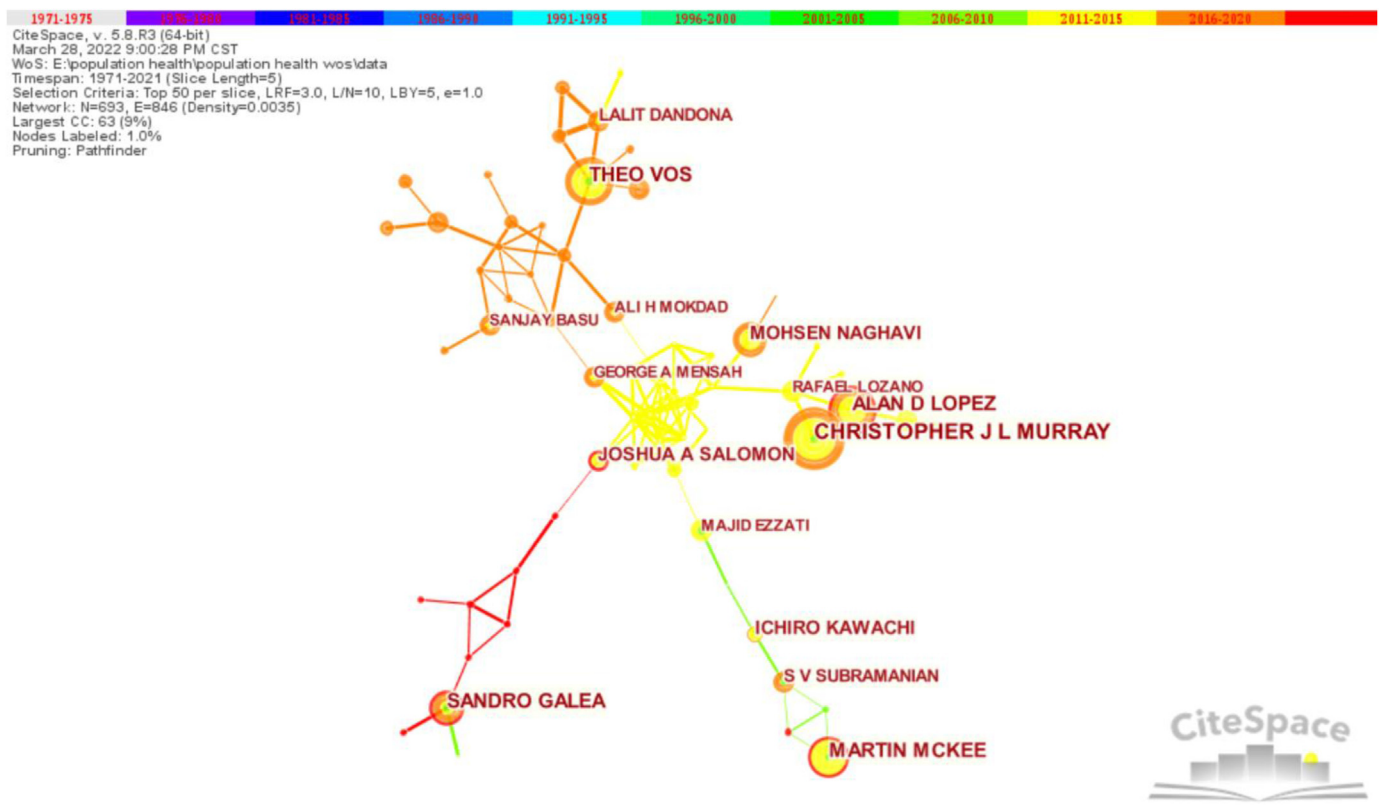


Figure 3. Cooperation networks of authors.

**Table 3.** Top 15 productive institutions in population health.

Institution	Country	Publications	The proportion of the total number	First published year
University of Toronto	Canada	529	2.40%	1997
University of Washington	the United States	323	1.47%	2002
Harvard University	the United States	323	1.47%	1998
University of British Columbia	Canada	277	1.26%	1997
University of Sydney	Australia	268	1.22%	2001
University of Michigan	the United States	255	1.16%	1997
University of Ottawa	Canada	251	1.14%	1998
University of Calgary	Canada	232	1.05%	1998
University of Melbourne	Australia	227	1.03%	2001
McMaster University	Canada	226	1.03%	1997
University of North Carolina	the United States	206	0.94%	1998
University of Queensland	Australia	205	0.93%	1997
McGill University	Canada	202	0.92%	1998
Columbia University	the United States	201	0.91%	2002
Harvard Medical School	the United States	194	0.88%	2016

“Environmental Sciences & Ecology” is with 861 articles. The discipline of “Biomedical Social Sciences” is with 543 articles. The discipline of “Multidisciplinary Sciences and Science & Technology” published its first article on population health in 1971, which is the earliest one. It is followed by the disciplines of “Science & Technology” and “Public,

Environmental & Occupational Health”. The disciplines do not co-occur frequently, which indicates the loose cooperation among disciplines.

**3.3.2. Keywords co-occurrence analysis**

The keywords reflect the main content of the research in the field. This study uses the keyword co-occurrence networks to reveal the correlation of keywords. The top 50 keywords with the highest occurrences are chosen to construct the current keyword’s co-occurrence networks. The network pruning method is “MST + Pruning the merged network”. A total of 115 nodes and 129 links are obtained. Each node represents a keyword, and the links between the keywords indicate that they appear together in an article. The size of the node represents the number of the appearance of keywords. The thickness of the link represents the strength of the co-occurrence relationship. Figure 6 presents the co-occurrence networks of keywords in population health.

Figure 6 shows that the “population health” node is the largest in the networks. It appears 2581 times, followed by “morality”, which appears 1361 times. “Health” appears 1091 times and “public health” appears 1081 times. In addition, other keywords, such as “health status”, “quality of life”, “health care”, and “income inequality”, also appear frequently. The nodes of “public health”, “inequality”, “income inequality”, “health care”, “population health”, and “mortality” co-occur with different nodes, indicating they are research hotspots in this field.

Burst keywords are the keywords that emerge intensely in a period. It represents the research fronts and hotspots in the corresponding period. Figure 7 presents the top 20 keywords with the strongest citation bursts in population health. The keyword with the strongest citation burst is “self-rated health”. It began in 2001 and ended in 2015. “Life expectancy” is the first burst keyword and it began in 1991 and ended in 2010. In addition, “morbidity” and “health status” also began to burst in 1991. “Income inequality”, “coronary heart disease” and “epidemiology” burst in 1996 and ended in 2015. The burst keywords in the latest years are the research fronts, including “social determinants of health”, “framework”, “health disparity”, “social determinant” and “burden”. These burst

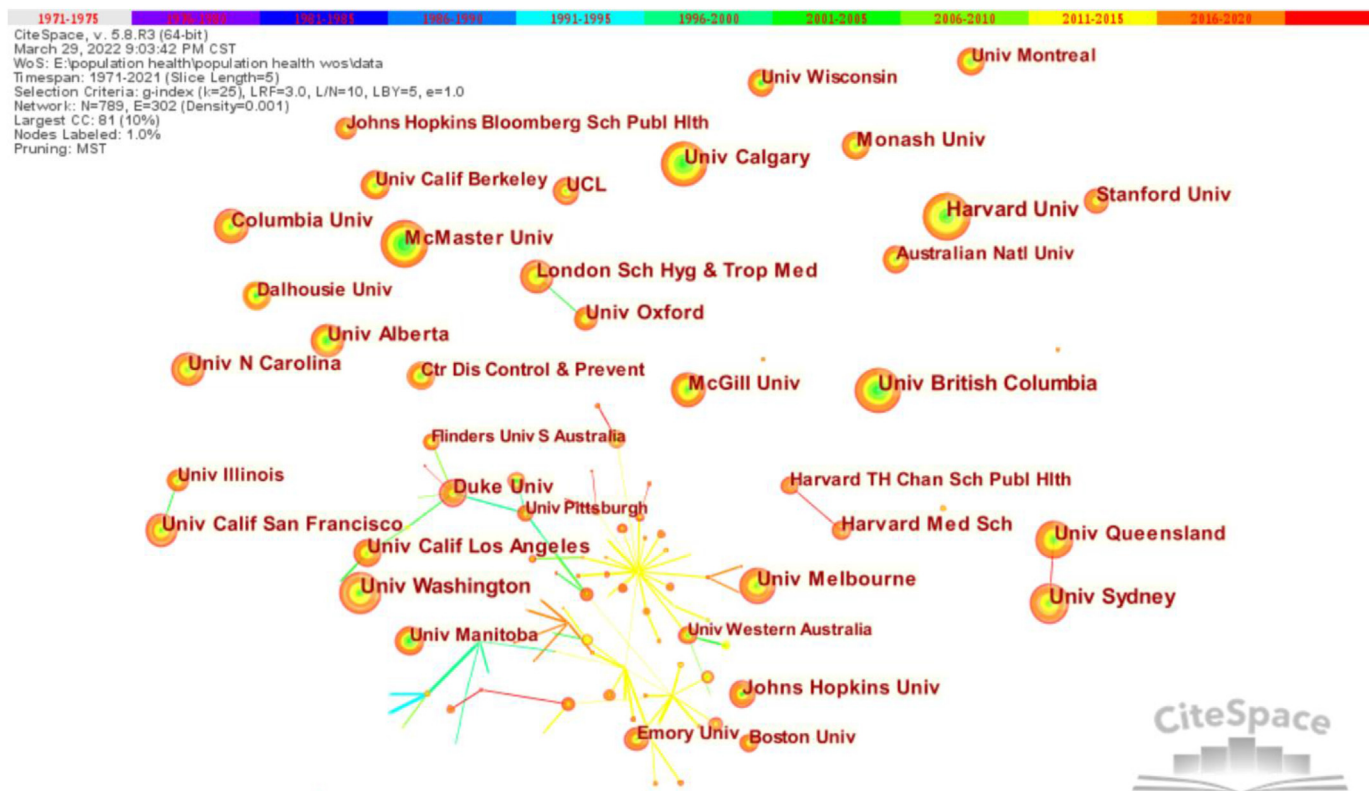


Figure 4. Cooperation networks of institutions.

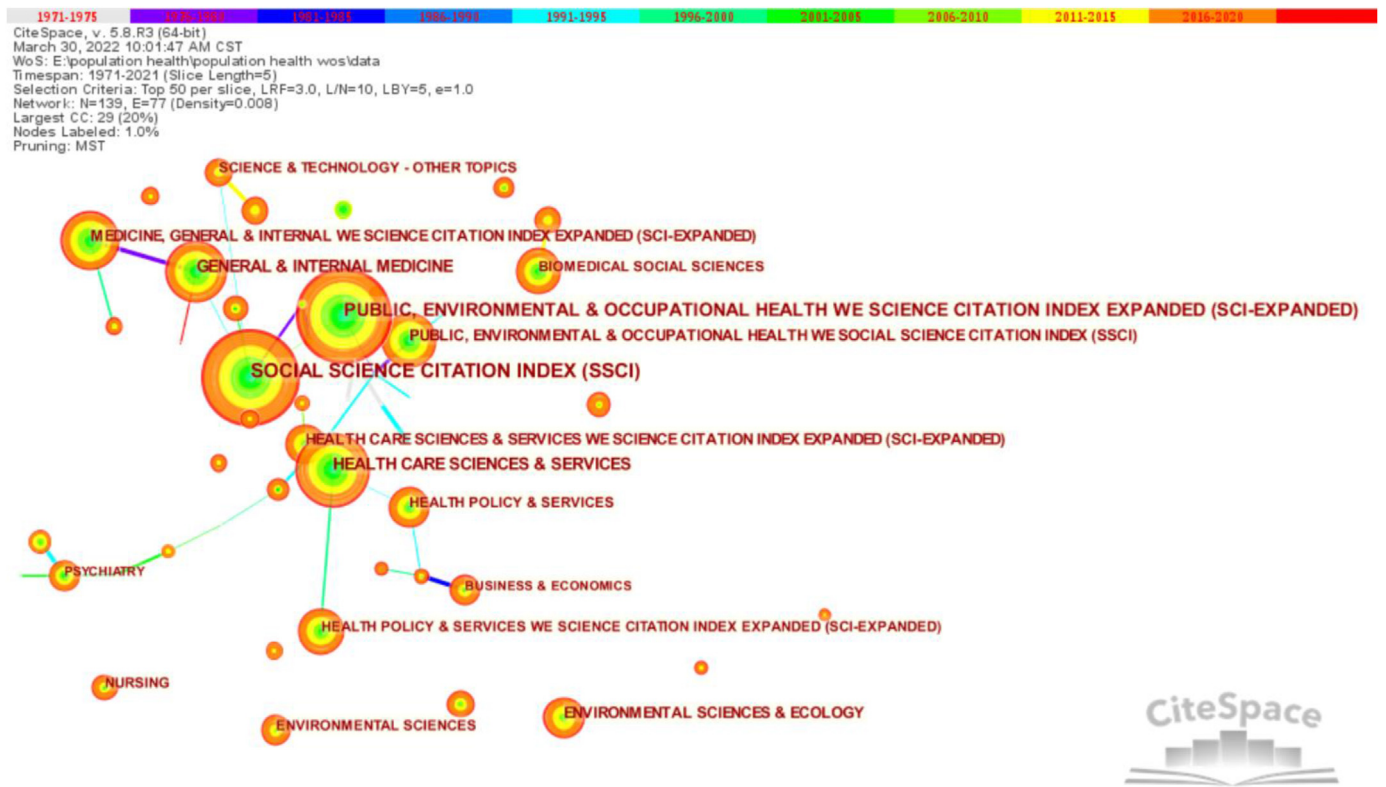


Figure 5. Co-occurrence networks of disciplines.

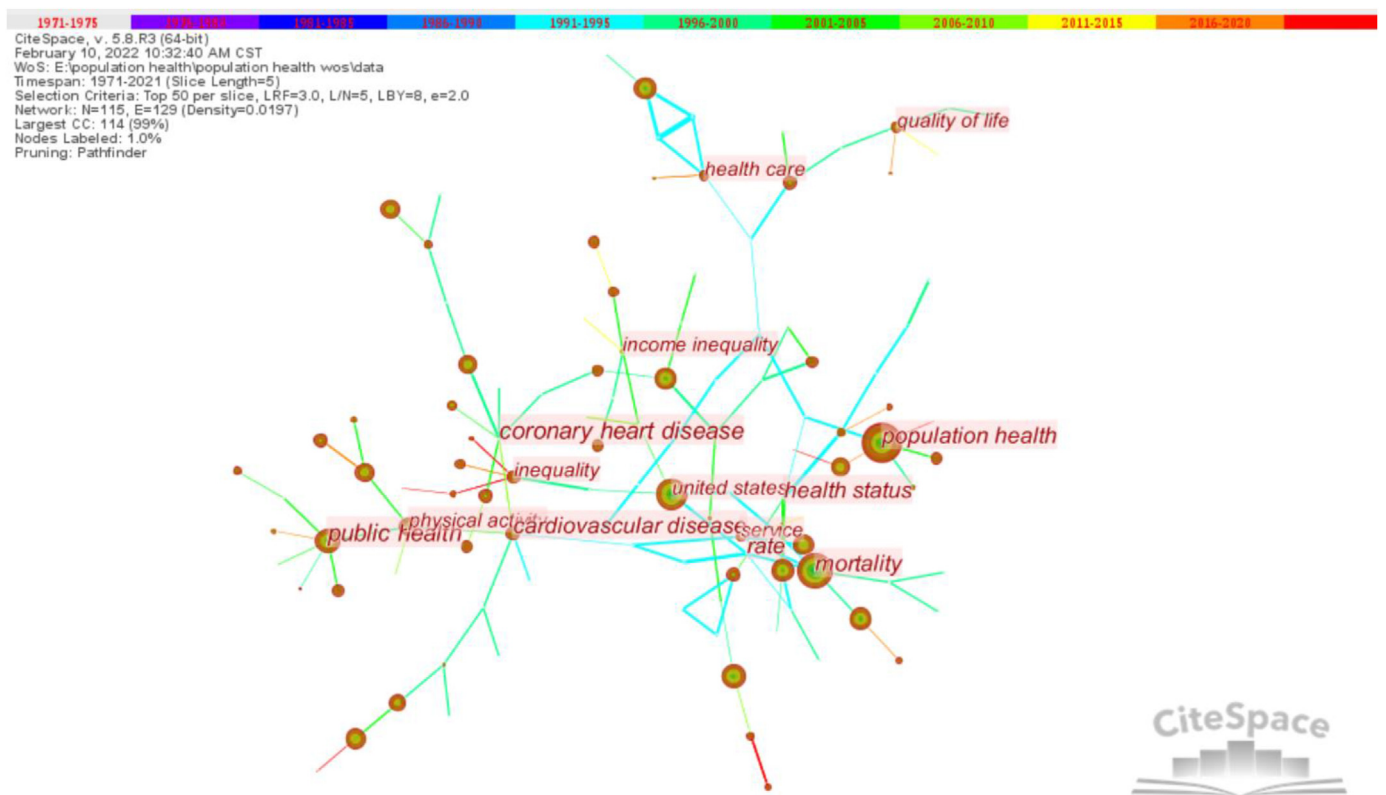


Figure 6. Co-occurrence networks of keywords.

keywords show the emerging research trends of population health. Based on the beginning year, the research trends can be divided into four stages. “Life expectancy”, “Canada”, “morbidity” and “health status” are the first

research stage. “Income inequality”, “coronary heart disease”, “men”, “epidemiology”, “disability”, and “disability” are in the second research stage. The “self-rated health”, “disorder”, “health inequality”, “multilevel

### Top 20 Keywords with the Strongest Citation Bursts

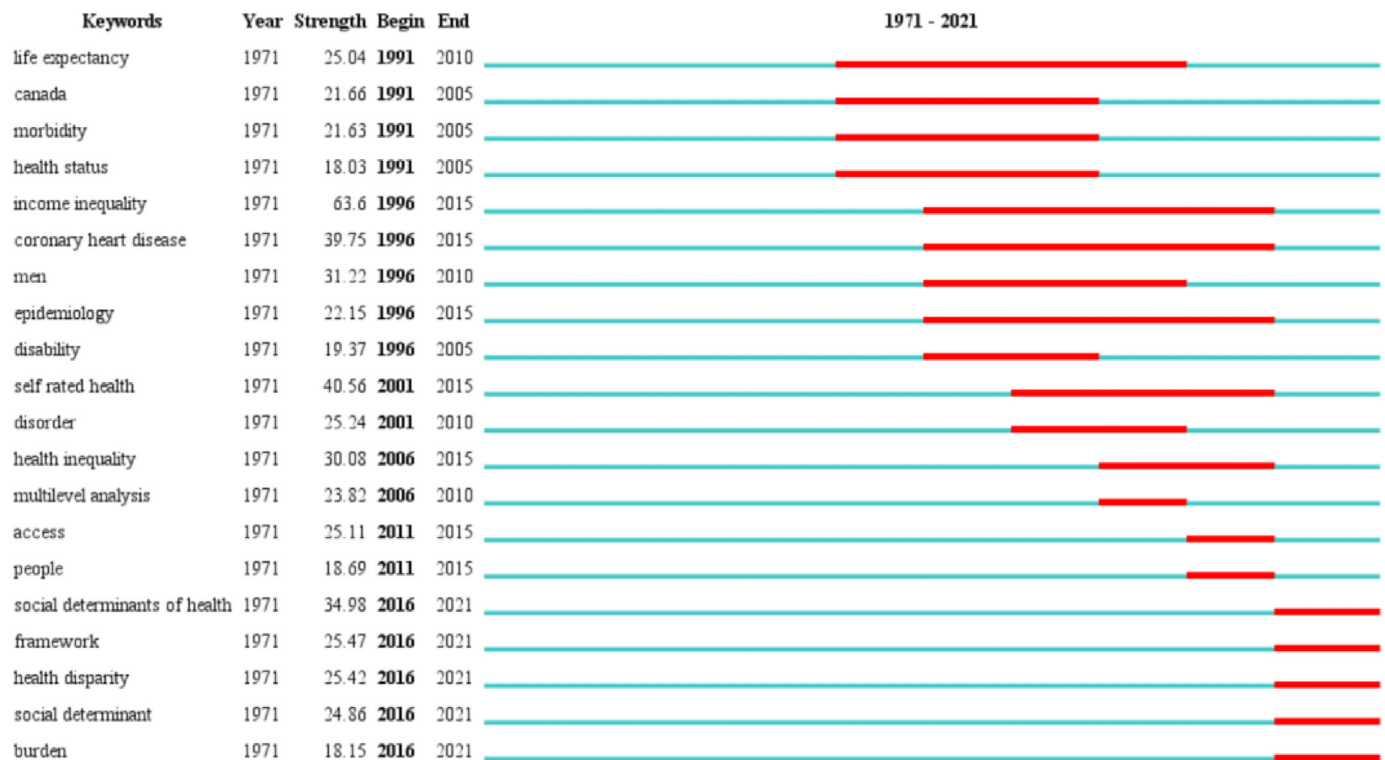


Figure 7. The top 20 keywords with the strongest citation bursts.

analysis”, “access” and “people” are in the third research stage. “Social determinants of health”, “framework”, “health disparity”, “social determinant” and “burden” are in the latest research stage, and they are the research trends in population health.

#### 3.4. The intellectual structure analysis

Co-citation refers to two or more references appearing simultaneously in the bibliography of the same article. This section conducts the intellectual structure analysis based on the reference co-citation relationship. To build current reference co-citation networks, the top 50 references are chosen. The network pruning mode is “Pathfinder + Pruning sliced networks”, and finally, a total of 335 nodes and 358 links are obtained. Each node represents a reference, and the links between the nodes indicate that two references appear in the same article. The node size represents the number of citations. The bigger the node is, the more frequently the reference is cited. This section includes the analysis of references co-citation cluster, the betweenness centrality, the most cited references, and the strongest citation bursts. The references with high betweenness centrality are essential in the research of population health. The most cited references can be regarded as milestones in population health. The references with the strongest citation bursts display the emerging trends of population health research.

##### 3.4.1. Co-citation cluster analysis

This subsection adopts a co-citation cluster to analyze the classification of population health. After constructing the reference co-citation networks, the reference co-citation clusters can be obtained by clicking the cluster button. The topics of the same cluster are closely related. Representative references for each cluster can be obtained and the specific research on population health in each cluster can be known through data analysis. Modularity is an index to evaluate the structural strength of co-citation networks and is represented by Q. The higher the Q value is, the better the network clustering is. When  $Q > 0.3$ , the obtained network

community structure is remarkable. The average contour value is an index to measure the co-citation network’s homogeneity and is represented by S. When  $S > 0.5$ , the clustering result is considered reasonable. When  $S > 0.7$ , the clustering results are highly reliable [20].

Figure 8 presents the clusters of reference co-citation networks in population health. The Q value is 0.8579, and the average S value is 0.9439, indicating the clustering is highly reliable. In particular, there are 14 clusters, including “income quality”, “social capital”, “global burden”, “disease study”, “physical activity”, “structural racism”, “health promotion”, “purchasing population health”, “information system”, “health inequalities”, “healthy cities”, “planning”, “macroeconomic determinant”, and “causal review”. All the cluster names are derived from the title of cited references.

Table 4 reports 14 clusters and they are arranged based on their size. The bigger the size is, the more references in the cluster are cited. The more references are cited, the more influential the cluster is. Silhouette represents cluster quality, and its value measures the homogeneity of the network. The closer the score is to 1, the higher the homogeneity of the network is. The results from Table 4 illustrate that all clusters are highly credible, among which the Silhouette scores of #8, #10, and #13 are 1. The average publication year of a cluster shows recentness. Cluster #5 is the most recently formed cluster on population health, with an average year of 2017. Cluster #11 and cluster #12 are the least recently formed clusters, with an average year of 1988.

Four major clusters are analyzed according to their importance, including clusters #0, #1, #5, and #12. Cited references and citing articles are analyzed in each cluster.

##### (1) Cluster #0 income inequality

Cluster #0 is the biggest cluster and includes 39 references. Income inequality is an important factor influencing population health. For example, income inequality may cause many people not to complete treatment for tuberculosis [23]. Income inequality will be reduced by the

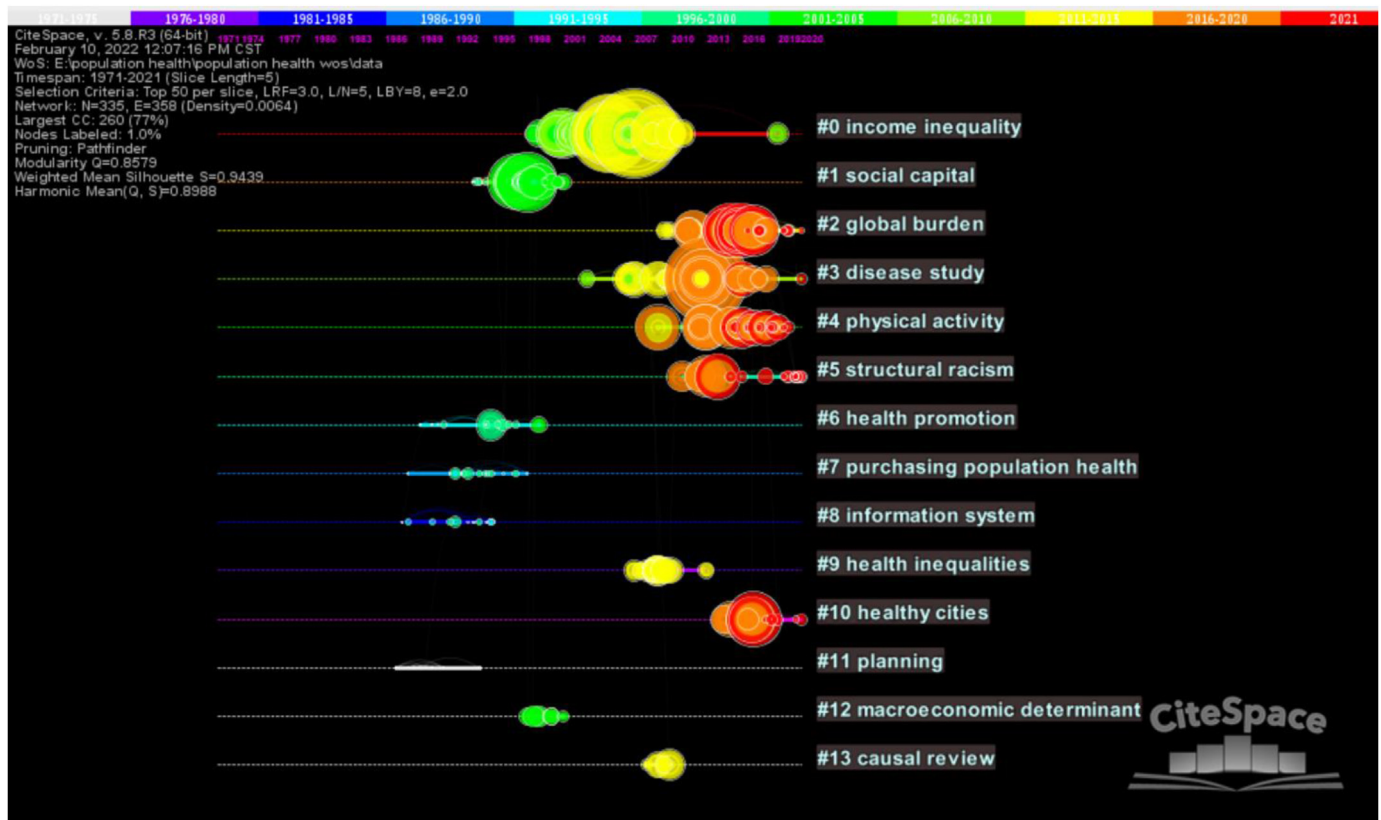


Figure 8. Clusters of reference co-citation networks.

Table 4. Major clusters of co-cited references.

ID	Size	Silhouette	Label (LSI)	Label (LLR)	Label (MI)	Year Ave.
0	39	0.964	Income inequality	Income inequality	Evaluating wilkinsons income inequality hypothesis	2003
1	34	0.960	Income inequality	Social capital	Heat island effect	1996
2	30	0.895	Population health	Global burden	Heat island effect	2015
3	26	0.994	Global burden	Global burden	Heat island effect	2011
4	25	0.751	Systematic review	Physical activity	Heat island effect	2015
5	22	0.978	Covid-19 pandemic	Structural racism	Inequality-related health	2017
6	15	0.962	Health promotion	Health promotion	Global burden	1992
7	13	0.944	Aligning financial incentive	Purchasing population health	Global burden	1992
8	13	1.000	Information system	Information system	Global burden	1991
9	12	0.987	Health inequalities	Health inequalities	Deteriorating self-rated health	2008
10	11	1.000	Physical activity	Healthy cities	Heat island effect	2016
11	9	0.987	Planning	Planning	Global burden	1988
12	6	0.958	Income inequality	Income inequality	Global burden	1988
13	5	1.000	Income inequality	Causal review	Unequal developing country	2008

Note: Clusters are represented according to the labels selected by the log-likelihood ratio test method (LLR).

financial system, but the financial system may lead to more environmentally unfriendly emissions, which are harmful to population health [24]. A research article that cites several references is called a citing article. The cited references are the intellectual base of the cluster, and the citing articles are the research fronts of the cluster. The five most cited references and five citing articles are selected in this cluster. Table 5 gives the five most cited references and citing articles in Cluster #0 income inequality.

The core references of Cluster #0 represent major milestones concerning income inequality. The most cited references of this cluster, written by Wilkinson RG and Pickett KE [9], have been cited 971 times on WoS and can be considered the most important milestone in

population health. They explained the relationship between income inequality and population health and found that the relation between income and health depended on the scale of social class differences in society. The second most cited reference is written by Lynch J et al., which has been cited 574 times on WoS [25]. The authors found little evidence to support the direct impact of inequality on health. But they argued that reducing income inequality would reduce health inequality. The other three most cited references are written by Subramanian SV and Kawachi I [26], Lynch JW et al. [27], and Ross NA et al. [28], which have been cited 512 times, 870 times, and 305 times respectively. The rest citing articles written by Chang VW and Christakis NA [29], Mellor JM and Milyo J [30], Bechfield J [31], and Veenstra G [32] are research



**Table 5.** Cited references and citing articles of Cluster #0 income inequality.

Cited references	Citing articles
Wilkinson RG and Pickett KE, 2006, SOC SCI MED, V62, P1768 [9]	Lynch J et al., 2004, MILBANK Q, V82, P5099 [25]
Lynch J et al., 2004, MILBANK Q, V82, P5099 [25]	Chang VW and Christakis NA, 2005, SOC SCI MED, V61, P83 [29]
Subramanian SV and Kawachi I, 2004, EPIDEMIOL REV, V26, P78 [26]	Mellor JM and Milyo J, 2001, J HEALTH POLIT POLIC, V26, P487 [30]
Lynch JW et al., 2000, BMJ-BRIT MED J, V320, P1200 [27]	Beckfield J, 2004, J HEALTH SOC BEHAV, V45, P231 [31]
Ross NA et al., 2000, BRIT MED J, V320, P898 [28]	Veenstra G, 2002, CAN J PUBLIC HEALTH, V93, P374 [32]

fronts in Cluster #0. The cited references and citing articles are listed in Table 5.

(2) Cluster #1 social capital

Cluster #1 is the second biggest cluster with 34 references, and its theme is social capital. Social capital has positive effects on physical and mental health [10]. The five most cited references and five citing articles are selected in this cluster. Table 6 gives the five most cited references and citing articles of Cluster #1 social capital. The most cited reference in Cluster #1 social capital is written by Kawachi I et al., with 1772 citations on WoS [33]. It explored the relationship between income inequality and mortality and found that income inequality led to increased mortality via disinvestment in social capital. The second most cited reference is written by Kaplan GA et al., which discussed the impact of income inequality on mortality in the United States [34]. Their findings showed that inequality in income distribution was significantly associated with health outcomes, social indicators, and mortality trends. Thus economic policies that affected income might have an important impact on countries' health. The other three most cited references are written by Kennedy BP et al. [35], Lynch JW et al. [36], and Judge K et al. [37], which have been cited 527 times, 329 times, and 136 times respectively. The citing articles in Cluster #1 are listed in Table 6. They are written by Hayes M [38], Mellor JM and Milyo J [30], Veenstra G [32], Lynch J [25], and Dunn JR and Hayes MV [39].

(3) Cluster #5 structural racism

There are 25 references cited in Cluster #5. The average year of Cluster #5 is 2017, which is the latest cluster for population health. The top five cited references and citing articles are presented in Table 7.

The most cited reference in Cluster #5 is written by Hatzenbuehler ML et al., which has been cited 1053 times on WoS [40]. It provided evidence on the health consequences of stigma and illustrated how stigma influences health. As Cluster #5 is the latest cluster, its citing

**Table 6.** Cited references and citing articles of Cluster #1 social capital.

Cited references	Citing articles
Kawachi I et al., 1997, AM J PUBLIC HEALTH, V87, P1491 [33]	Hayes, M, 1990, PROG HUM GEOG, V23, P289 [38]
Kaplan GA et al., 1996, BRIT MED J, V312, P999 [34]	Mellor JM and Milyo J, 2001, J HEALTH POLIT POLIC, V26, P487 [30]
Kennedy BP et al., 1996, BRIT MED J, V312, P1004 [35]	Veenstra G, 2002, CAN J PUBLIC HEALTH, V93, P374 [32]
Lynch JW et al., 1998, AM J PUBLIC HEALTH, V88, P1074 [36]	Lynch J et al., 2004, MILBANK Q, V82, P5099 [25]
Judge K et al., 1998, SOC SCI MED, V46, P567 [37]	Dunn JR and Hayes MV, 2000, SOC SCI MED, V51, P563 [39]

**Table 7.** Cited references and citing articles of Cluster #5 structural racism.

Cited references	Citing articles
Hatzenbuehler ML et al., 2013, AM J PUBLIC HEALTH, V103, P813 [40]	Amato KP et al., 2021, P NATL ACAD SCI USA, V118, P1 [45]
Barnett K et al., 2012, LANCET, V380, P37 [41]	Wakeel F and Njoku A, 2021, HEALTHCARE-BASEL, V9, P145 [18]
Mackebach JP, 2012, SOC SCI MED, V75, P761 [42]	Garciaet MA et al., 2021, J GERONTOLOG B-PSYCHOL, V76, PE75 [46]
Bailey ZD et al., 2017, LANCET, V389, P1453 [43]	Tan SB et al., 2021, J RACIAL ETHN HEALTH, V9, P236 [47]
Dong ES et al., 2020, LANCET INFECT DIS, V20, P533 [44]	Zanettini C et al., 2021, VACCINES-BASEL, V9, P427 [48]

articles indicate the new research trends in population health. It can be found from Table 7 that all the citing articles are published in 2021, and most of the topics are related to Covid-19. For example, Wakeel F and Njoku A investigated the effect of racism, stigma, and Covid-19 on the disease and mortality risk of African Americans and found that Covid-19 would have profound health implications as a stressful life event for African Americans [18]. The other four most cited references are written by Barnett K et al. [41], Mackebach JP [42], Bailey ZD et al. [43], and Dong ES et al. [44], which have been cited 3134 times, 457 times, 1234 times, and 3715 times respectively. The rest of the citing articles in Cluster #5 are listed in Table 7, written by Amato KR et al. [45], Garcia MA et al. [46], Tan SB et al. [47], and Zanettini C et al. [48].

(4) Cluster #12 macroeconomic determinant

Cluster #12 macroeconomic determinant, consisting of six references with an average publication year of 1988, is the earliest cluster of the 14 clusters. Table 8 presents the five major cited references and citing articles.

The most cited reference in this cluster is written by Kennedy BP et al., which has been cited 479 times on WoS since 1998 [11]. They found that inequality in the distribution of income is associated with an adverse impact on health independent of household income. The second most cited reference is written by Fiscella K and Franks P [49], which identified that family income inequality can predict mortality independently, instead of community income inequality. The other three most cited references are written by Daly MC et al. [50], Kawachi I and Kennedy BP [51], and Soobader MJ and LeClere FB [52], which have been cited 161 times, 420 times, and 165 times respectively. The citing articles in Cluster #12 are listed in Table 8, and they are written by Chang VW and Christakis NA [29], Sohler NL et al. [53], Subramanian SV et al. [54], Lynch J et al. [25], and Mellor JM and Milyo J [30].

3.4.2. Betweenness centrality analysis

Betweenness centrality is the most direct measure to describe node centrality in network analysis. The higher the centrality degree of the node is, the greater the influence of the node in the network is. The influential node plays a vital role in connecting other nodes or several different clusters. Nodes located between different node groups may have higher centrality values. Such nodes can be regarded as landmarks in the field of population health and are likely to reflect emerging trends [55, 56]. After the reference co-citation networks are obtained, the betweenness centrality of references can be calculated.

Table 9 shows the top 10 references with the highest betweenness centrality. These references are important in connecting individual node in the networks and connecting groups of nodes. Table 9 reveals that the three references with a high ranking of betweenness centrality in the field of population health are written by Banyal HS and Inselburg J [57], Bjorkman A et al. [58], and Ambroise-Thomas P and Rossignol JF [59]

**Table 8.** Cited references and citing articles of Cluster #12 macroeconomic determinant.

Cited references	Citing articles
Kennedy BP et al., 1998, BRIT MED J, V317, P917 [11]	Chang VW and Christakis NA, 2005, SOC SCI MED, V61, P83 [29]
Fiscella K and Franks P, 1997, BRIT MED J, V314, P1724 [49]	Sohler NL et al., 2003, J URBAN HEALTH, V80, P650 [53]
Daly MC et al., 1998, MILBANK Q, V76, P315 [50]	Subramanian SV et al., 2002, ANNU REV PUBL HEALTH, V23, P287 [54]
Kawachi I and Kennedy BP, 1999, HEALTH SERV RES, V34, P215 [51]	Lynch J et al., 2004, MILBANK Q, V82, P5099 [25]
Soobader MJ and LeClere FB, 1999, SOC SCI MED, V48, P733 [52]	Mellor JM and Milyo J, 2001, J HEALTH POLITIC, V26, P487 [30]

respectively, and their betweenness centrality values reach 86. The betweenness centrality value of the five references is 50. They are written by Ankley GT et al. [60], Alsabti K et al. [61], Bengtsson A et al. [62], Benson WH and Birge WJ [63], and Belinsky SA et al. [64]. Finally, the betweenness centrality of references written by Bjorkman A and Willcox M [65] and Hirsch and Killingsworth G [66] is relatively lower, and their values are 35 and 15 respectively.

### 3.4.3. The most cited references

The most cited references indicate their high recognition in the field of population health [67]. They are regarded as landmarks in this field, making groundbreaking contributions. Accurately identifying the most cited references is one of the effective methods to analyze the research progress in this field [68]. The top ten most cited references in the field of population health are given in Table 10.

The most cited reference is authored by Wilkinson RG and Pickett KE [9]. It is the first cited reference in Cluster #0 income inequality. They reviewed the evidence on whether income inequality is a determinant of population health and tried to find a consistent interpretation of positive and negative findings. The second most cited reference is written by Giles-Corti B et al [69]. They explained the relationship between city planning and population health. Encouraging walking, cycling, and using public transport, and reducing private motor vehicle use will create

**Table 9.** Ten references with the highest betweenness centrality.

Rank	Betweenness Centrality	References
1	86	Banyal HS and Inselburg J, 1986, EXP PARASITOL, V62, P61 [57]
2	86	Bjorkman A et al. 1985, ANN TROP MED PARASIT, V79, P597 [58]
3	86	Ambrose-Thomas P and Rossignol JF, 1986, PARASITOL TODAY, V2, P79 [59]
4	50	Ankley GT et al., 1986, AQUAT TOXICOL, V9, P91 [60]
5	50	Alsabti K, 1985, J FISH BIOL, V26, P13 [61]
6	50	Bengtsson A et al., 1988, J FISH BIOL, V33, P517 [62]
7	50	Benson WH and Birge WJ, 1987, ENVIRON TOXICOL CHEM, V6, P623 [63]
8	50	Belinsky SA et al., 1987, ENVIRON TOXICOL CHEM, V76, P3 [64]
9	35	Bjorkman A and Willcox M, 1986, T ROY SOC TROP MED H, V80, P572 [65]
10	15	Hirsch G and Killingsworth WR, 1975, INQUIRY, V12, P126 [66]

**Table 10.** Top 10 most cited references.

Rank	Citation number	References
1	90	Wilkinson RG and Pickett KE, 2006, SOC SCI MED, V62, P1768 [9]
2	79	Giles-Corti B et al., 2016, LANCET, V388, P2912 [69]
3	72	Lynch J et al., 2004, MILBANK Q, V82, P5099 [25]
4	71	Lim SS et al., 2012, LANCET, V380, P2224 [70]
5	67	Stevenson M et al., 2016, LANCET, V388, P2925 [71]
6	59	Pickett KE and Wilkinson RG, 2015, SOC SCI MED, V128, P316 [72]
7	58	Chetty R et al., 2016, JAMA-J AM MED ASSOC, V315, P1750 [73]
8	52	Alley DE et al., 2016, NEW ENGL J MED, V374, P8 [74]
9	49	Shamseer L et al., 2015, BMJ-BRIT MED J, V350, Ph1793 [75]
10	46	WHO, 2014, Global status report on violence prevention [76]

healthier and more sustainable compact cities. Thus establishing a set of indicators to benchmark and monitor progress toward the achievement of more compact cities will promote health and reduce health inequities. The third most cited reference is written by Lynch J et al. and it has been discussed in Cluster#0 [25]. They also studied the relationship between income inequality and population health. The rest references are written by Lim SS et al. [70], Stevenson M et al. [71], Pickett KE and Wilkinson RG [72], Chetty R et al. [73], Alley DE et al. [74], Shamseer L et al. [75], and WHO [76]. All of those references have inspired intense interest in population health.

### 3.4.4. The strongest citation bursts

The strongest citation bursts refer to those references that are cited suddenly over a period. It contains two dimensions: burst value and burst time. The nodes with high citation burst values mean that these references are cited intensely. The burst time displays how long the burst status lasts. The research hotspots of different periods constitute the emerging trends in population health.

Emerging trends in population health can be found by analyzing the burst value and burst time of references. Figure 9 displays the top 20 references with the strongest citation bursts. The earliest citation burst reference is written by Evans RG et al., which was published in 1994 and burst in 1996 [77]. They believed that traditional health care plays a small role in the overall population health. This reference attracted academic attention from 1996 to 2000. The second earliest citation burst reference is written by Kawachi I et al., which drew attention immediately after its publication in 1997 [33]. The discussion of this reference lasts nine years from 1997 to 2005. Some in-depth studies are based on this reference. For example, Sun TT et al. explored how economic fluctuations affected the mortality of infectious diseases in 2021 [78].

Nine references burst in 2016 and ended in 2020 or 2021, which means they are emerging trends. The reference written by Giles-Corti B et al. obtained the highest strength value (28.61) among the nine references. This reference also emerged immediately when it was published in 2016, which is the second most cited reference. Based on this reference, researchers discussed how to solve the problems in population health from the perspective of city planning [69]. The second reference written by Alley DE has been cited 310 times on WoS. This reference indicated that the Centers for Medicare and Medicaid Services announced \$157 million for Accountable Health Communities to accelerate the development of a scalable delivery model for addressing upstream determinants

## Top 20 References with the Strongest Citation Bursts

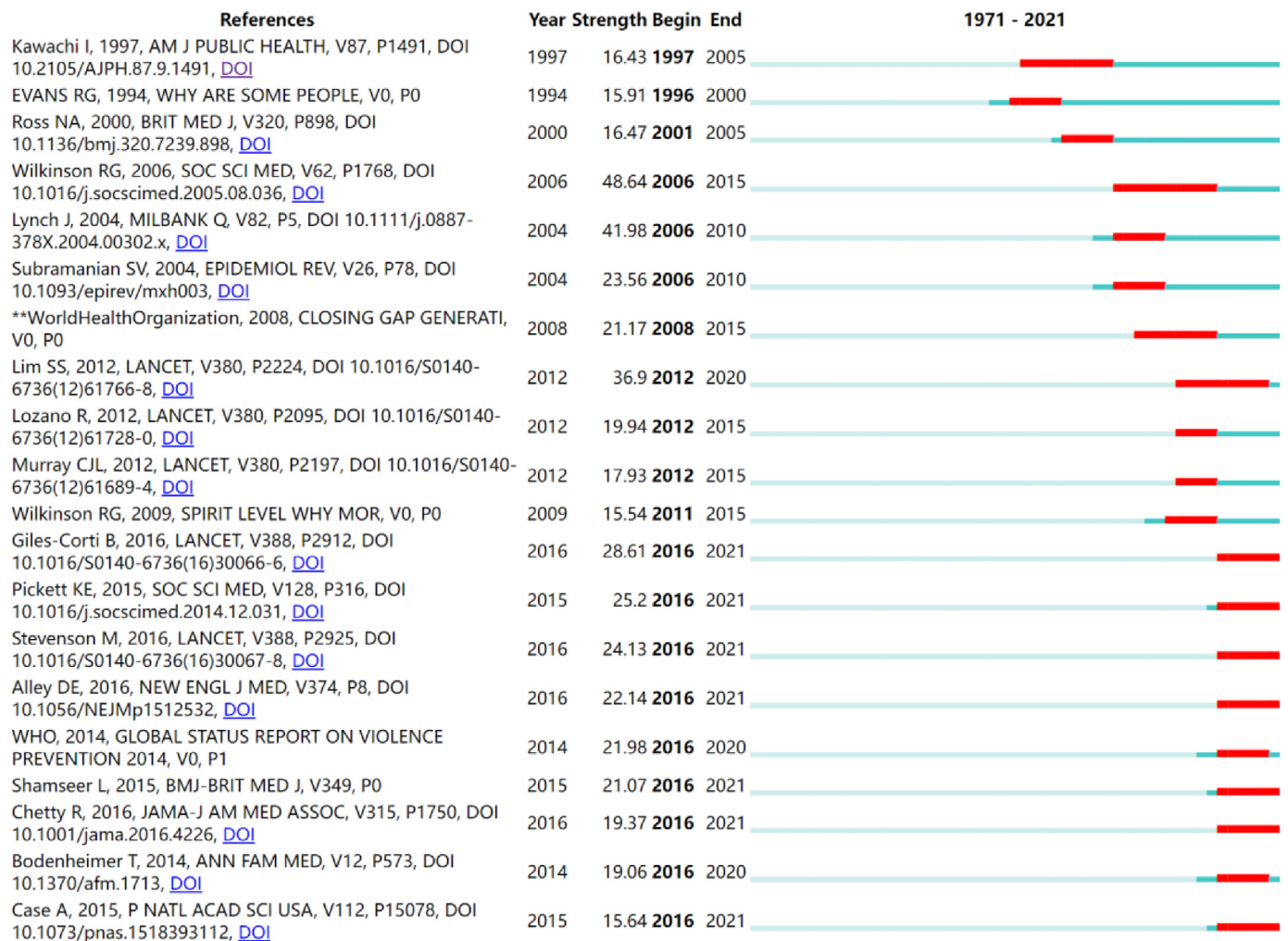


Figure 9. Top 20 references with the strongest citation bursts.

of health [74]. The last reference in Figure 9 is written by Case A and Deaton A. They documented a marked increase in the mortality of middle-aged white non-Hispanic Americans between 1999 and 2013, and identified drug and alcohol poisoning, suicide, chronic liver diseases, and cirrhosis were the possible causes [79].

#### 4. Discussion

This study has provided a comprehensive bibliometric analysis of population health research in WoS from 1971 to 2021. CiteSpace is chosen as the bibliometric tool to find the main achievements and research trends.

Firstly, the publication number and country are analyzed. This study finds out that the number of publications and citations of population health has been increasing quickly since the year of 1995. It shows that population health has been attracting much attention from researchers. From the perspective of national contribution, the United States published the most articles. Judging from the number of publications, the United States is the leading country in population health research and far beyond other countries. Canada ranks second with 2417 publications, followed by England, Austria, China, and the Netherlands.

Secondly, the productive authors and institutions are analyzed. Christopher JLM published the most articles related to population health. Martin M and Theo VOS ranked second and they have published 38

publications. They are followed by Sandro G, Scott BP et al. Four of the top 10 productive authors and six of the top 15 productive institutions are from the United States. The other top 15 productive institutions are in Canada, Australia, and England. The top 10 productive authors and top 15 institutions are all from developed countries, which means they pay more attention to population health to some extent.

Thirdly, the co-occurrence of disciplines and keywords is analyzed. The articles on population health are mainly published on the subjects of “Public, Environmental and Occupational Health”, “General and Internal Medicine”, “Environmental Sciences and Ecology”, “Biomedical Social Sciences”, and “Public, Environmental and Occupational Health”. It can be seen that the topic of population health is mostly related to the environment, ecology, and medicine. The keywords can reflect the topics and hotspots in population health. The keywords “life expectancy”, “morbidity”, and “health status” appeared more frequently. “Cardiovascular disease”, “coronary heart disease”, “income inequality”, and “physical activity” co-occurred more frequently with other keywords, indicating they draw more attention in this area. The top 20 keywords with the strongest citation bursts reflect the evolution of hotspots and the research trends. “Life expectancy”, “morbidity”, and “health status” attracted attention in 1991. “Income inequality”, “coronary heart disease”, “epidemiology”, and “disability” began to attract attention in 1996. “Social determinants of health”, “health disparity”, and “burden” are the present hotspots.

Fourthly, through the analysis of the co-citation cluster, betweenness centrality, most cited references, and strongest citation bursts, research hotspots, and new development trends are revealed. “Income inequality”, “social capital”, “structural racism”, and “macroeconomic determinant” are the major clusters and research hotspots. The references with high betweenness centrality are important in connecting other clusters, and they are an important pivot for population health. The reference with the highest betweenness centrality is related to plasmodium falciparum. The most cited references are the foundation of population health. The reference with the highest citation is a review of income inequality and population health. The emerging trends of population health can be detected clearly from the references citation burst. It can be seen that nine of the top 20 references bursts in 2016 and last till 2021, which means they are the hotspots and trends in the coming years.

We have to acknowledge that there are some limitations to this study. First, due to the complexity of population health, this study only applies a single search term for bibliometric analysis. In the future, we can expand search terms or focus on smaller areas of bibliometric analysis. Second, this study only selects the publications from WoS by referring to the existing main literature. In future research, more databases, such as Scopus, can be introduced for analysis. Third, this study outlines the evolutionary trajectory of population health from a few aspects. In future research, more aspects should be carried out.

Generally speaking, the findings of this study provide insights for future population health research. The information about the publication number, countries or regions, authors, institutions, disciplines, keywords, and cited references form the basic knowledge of population health. Population health hotspots have shifted over time in the order of “life expectancy”, “income inequality”, “self-rated health”, “health inequality”, etc. The future research trends are “global burden”, “physical activity”, “structural racism”, “healthy cities”, and other aspects. Researchers might benefit from this study and find more effective and novel methods to further explore population health issues from different perspectives.

## Declarations

### Author contribution statement

Limei Guo: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Weike Zhang: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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The authors declare no competing interests.

### Additional information

No additional information is available for this paper.

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