Heliyon 6 (2020) e05141

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Systematic analysis of the scientific literature on population surveillance

Gregorio González-Alcaide [a,*,1], Pedro Llorente [b,c,1], José-Manuel Ramos-Rincón [d,e]

[a] Department of History of Science and Documentation, University of Valencia, Valencia, Spain
[b] Denia Public Health Center, Conselleria de Sanitat i Salut Publica, Alicante, Spain
[c] Defence Institute of Preventive Medicine, Ministry of Defence, Madrid, Spain
[d] Department of Internal Medicine, General University Hospital of Alicante, Alicante, Spain
[e] Department of Clinical Medicine, Miguel Hernandez University of Elche, Alicante, Spain

ARTICLE INFO

Keywords:
Public health surveillance
Bibliometrics
Subject areas
Research gaps
Disease outbreaks
Public health
Information science
Content analysis
Data mining
Network analysis
Knowledge representation

ABSTRACT

Introduction: Population surveillance provides data on the health status of the population through continuous scrutiny of different indicators. Identifying risk factors is essential for the quickly detecting and controlling of epidemic outbreaks and reducing the incidence of cross-infections and non-communicable diseases. The objective of the present study is to analyze research on population surveillance, identifying the main topics of interest for investigators in the area.

Methodology: We included documents indexed in the Web of Science Core Collection in the period from 2000 to 2019 and assigned with the generic Medical Subject Heading (MeSH) "population surveillance" or its related terms ("public health surveillance," "sentinel surveillance" or "biosurveillance"). A co-occurrence analysis was undertaken to identify the document clusters comprising the main research topics. Scientific production, collaboration, and citation patterns in each of the clusters were characterized bibliometrically. We also analyzed research on coronaviruses, relating the results obtained to the management of the COVID-19 pandemic.

Results: We included 39,184 documents, which reflected a steady growth in scientific output driven by papers on "Public, Environmental & Occupational Health" (21.62% of the documents) and "Infectious Diseases" (10.49%). Research activity was concentrated in North America (36.41%) and Europe (32.09%). The USA led research in the area (40.14% of documents). Ten topic clusters were identified, including "Disease Outbreaks," which is closely related to two other clusters ("Genetics" and "Influenza"). Other clusters of note were "Cross Infections" as well as one that brought together general public health concepts and topics related to non-communicable diseases (cardiovascular and coronary diseases, mental diseases, diabetes, wound and injuries, stroke, and asthma). The rest of the clusters addressed "Neoplasms," "HIV," "Pregnancy," "Substance Abuse/Obesity," and "Tuberculosis." Although research on coronavirus has focused on population surveillance only occasionally, some papers have analyzed and collated guidelines whose relevance to the dissemination and management of the COVID-19 pandemic has become obvious. Topics include tracing the spread of the virus, limiting mass gatherings that would facilitate its propagation, and the imposition of quarantines. There were important differences in the scientific production and citation of different clusters: the documents on mental illnesses, stroke, substance abuse/obesity, and cross-infections had much higher citations than the clusters on disease outbreaks, tuberculosis, and especially coronavirus, where these values are substantially lower.

Conclusions: The role of population surveillance should be strengthened, promoting research and the development of public health surveillance systems in countries whose contribution to the area is limited.

1. Introduction

The last two decades of the 20th century were marked by the spread of the HIV/AIDS pandemic. Since then, there have been numerous advances in basic research on the nature of HIV as an infectious agent, clinical research on managing AIDS with different pharmacological treatments, and public health research on interventions to prevent its transmission. However, its global impact has endured to the present, making disease

* Corresponding author.
E-mail address: gregorio.gonzalez@uv.es (G. González-Alcaide).
[1] Equal contribution.

https://doi.org/10.1016/j.heliyon.2020.e05141
Received 27 April 2020; Received in revised form 1 September 2020; Accepted 29 September 2020

prevention and control programs essential, especially in some regions like sub-Saharan Africa [1, 2]. That said, it is crucial to adapt the principle of bio-surveillance and co-epidemiology surveillance to current socioeconomic and health system characteristics.

The first two decades of the 21st century have been characterized by the emergence of different epidemic outbreaks that have increasingly transcended local or regional contexts and spread to different countries all over the world. The outbreak of influenza A (H1N1) in 2009–2010, denominated a pandemic by the World Health Organization (WHO), had the highest incidence and geographic dissemination. Even though 1.4 billion people were infected and more than 500,000 people died, the health system and political response to that virus attracted considerable criticism, with some quarters levelling accusations that the intensity of alarm declared was unnecessary because the virus was not more dangerous than the seasonal flu, and others affirming that the measures put in place responded to the economic interests of pharmaceutical companies more than to the dangers to public health [3, 4].

This experience, plus other successful experiences in controlling subsequent outbreaks with a global impact, including the 2012 Middle East respiratory syndrome (MERS) coronavirus outbreak, the Ebola virus epidemic outbreak of 2013–2016, and the Zika outbreak of 2015–2016 [5], probably contributed to generating a false sense of security. This overconfidence likely led to Western health authorities' initial underestimation of the outbreak caused by the SARS-CoV-2 coronavirus (COVID-19) and delayed action to mitigate its impact.

Although epidemic outbreaks have been a recurrent part of human history, the increasingly rapid diffusion is a new feature. Choi [6] described how the cholera epidemic that started in India in 1846 took 17 years to get to North and Central America. The pace of COVID-19 expansion stands in stark contrast, with the US Centers for Disease Control and Prevention (CDC) confirming the first US case of human-to-human transmission on 30 January 2020 [7], that is, just three weeks after China notified WHO that a novel coronavirus was behind a new outbreak in Wuhan. The virus had probably traveled aboard a passenger aircraft for a few hours several days before and begun to generate local infections more than 12,000 km from its place of origin.

It is increasingly evident that public health problems transcend national borders, so they must be addressed in a coordinated and global way [8]. For that to happen, it is necessary to strengthen public health surveillance systems in countries of all income levels. This can help governments to tackle epidemic outbreaks of infectious diseases that could potentially spread across the globe, but moreover, it can also aid in the control of non-communicable diseases (NCDs). These illnesses are traditionally known as diseases of affluence and associated with high-income countries, but they also have a global impact and an increasing effect on low- and middle-income countries [9]. Furthermore, a global commitment and coordinated efforts are also necessary to address neglected tropical diseases along with diseases related to malnutrition, behavioral risk factors, and health inequalities—which all disproportionately affect countries with less developed health and research systems [10, 11].

Until the mid-20th century, health surveillance focused on individuals in order to identify symptoms of communicable diseases that would trigger the person's isolation in order to stop the chain of transmission. From then, disease surveillance was carried out more at a population level, making essential the collection, analysis and dissemination of data that could have relevance for public health [12]. This shift, which marked the modernization of public health surveillance, had two prominent milestones [6, 13]. First, in 1946, the USA established the Communicable Diseases Center, the precursor to the CDC, to actively promote surveillance through monitoring disease incidence in populations [14]. The then-director of the epidemiology branch, AD Langmuir, defined disease surveillance as “the continued watchfulness over the distribution and trends of incidence through the systematic collection, consolidation, and evaluation of morbidity and mortality reports and other relevant data” [15]. Then, at an international level, 1965 saw the creation of the epidemiological surveillance unit within the WHO Division of Communicable Diseases. Three years later, participants at the 21st World Health Assembly endorsed the idea that surveillance was an essential function of public health practice, defining it as “the epidemiological study of a disease as a dynamic process involving the ecology of the infectious agent, the host, the reservoirs, and the vectors, as well as the complex mechanisms concerned in the spread of infection and the extent to which this spread occurs” [16, 17]. They also adopted the concept of population surveillance, understood as “the systematic collection and use of epidemiologic information for the planning, implementation, and assessment of disease control” [18]. The epidemiological surveillance unit thus assumed an active role in the processes to monitor disease transmission and control.

One of the main debates at the time was whether surveillance organisms should have any direct responsibility for disease control [15, 16, 19]. The fact that surveillance was not a clearly differentiated field from epidemiology also generated controversy. Thacker & Berkelman [17] recognized this problem of terminology, proposing “public health surveillance” as a term to define “the ongoing systematic collection, analysis, interpretation and dissemination of health data … [that] does not include administration of the prevention and control programs, but does include an intended link with those programs.” Thacker et al. [20] highlighted the relevance of the latter aspect, which could facilitate the rapid implementation of measures to prevent and control epidemics. This link represented a step forward with regard to population surveillance, implying that the information collected should serve for decision-making on public health action. The WHO adopted this term, which was already increasingly in circulation, emphasizing the methodological approaches that characterized surveillance activities. Unlike other types of data collection, surveillance was concerned with practicability, uniformity, and rapidity over precision [21]. Today, WHO defines public health surveillance as “the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice. Such surveillance can: (1) serve as an early warning system for impending public health emergencies; (2) document the impact of an intervention, or track progress towards specified goals; and (3) monitor and clarify the epidemiology of health problems, to allow priorities to be set and to inform public health policy and strategies” [22].

Authors like El Allaki et al. [12] have merged the concepts of “population surveillance” and “public health surveillance” under the single term of “population health surveillance,” defined as “the surveillance of population health indicators, diseases, infections, pathogens, risk factors and any factor or determinant that may provide an indication on the health status of a population.” Other concepts have also emerged around specific aspects of population surveillance. For example, sentinel surveillance describes the assessment of potential changes in the incidence rates of a disease or other condition that could affect the health status of a specific population or geographical area [23], while biosurveillance has to do with the relevance of monitoring specific information sources that could be relevant to detect epidemic outbreaks derived from accidents, bioterrorism, or based on the deliberate release of virus, bacteria, toxins, or other harmful agents [24]. It is also important to note the One Health approach, whose purpose is to promote a “worldwide strategy for expanding interdisciplinary collaborations and communications in all aspects of health care for humans, animals and the environment” [25], “with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment” [26].

1.1. Literature review

Few bibliometric studies have analyzed research on population surveillance or its related sub-topics. Below, we describe the studies identified in our review.

Although Durando et al. [27] did not specifically examine health surveillance, they did characterize the scientific output of European countries and the major research topics in the field of epidemiology, surveillance, prevention and control of infectious diseases between 1995 and 2005.

Dang et al. [28] studied the productivity of researchers, institutions, and countries, applying different knowledge mapping techniques to represent research groups and their main topics of interest in the global literature on bioterrorism published up to 2005. This topic is closely related to biosurveillance, a field which saw intense research development following the terrorist attack on 11 September 2001 in New York and the anthrax attacks in the USA in the following weeks [28, 29, 30].

Jia et al. [31] analyzed 11,299 papers published from 1978 to 2012 and indexed in PubMed/MEDLINE under the Medical Subject Headings (MeSH) "urban health"; population surveillance has a prominent presence in this subject area. The authors categorized the group of MeSH assigned to the documents, analyzing the evolution of the research topics by generating co-occurrence word maps.

Khalil et al. [32] analyzed 1387 papers, indexed on the Web of Science, published from 1990 to 2012, and linked to the US Behavioral Risk Factor Surveillance System. The study identified the topics, journals, and publishing institutions with the closest links to this system.

Cox et al. [33] calculated the *h*-index of the pathogens registered in North America based on documents from the Web of Science that mentioned them in order to identify and rank the pathogens that were most likely hazardous to human health and to use that information as an indicator of pathogen emergence.

Reaves et al. [34] analyzed 651 publications derived from research projects financed by the US Department of Defense's Global Emerging Infections Surveillance and Response System (GEIS) from 2006 to 2012.

Finally, Musa et al. [35] identified 14,680 papers on syndromic surveillance at a global level, indexed in the Web of Science Core Collection and Scopus from 1993 to 2017. Authors analyzed the scientific production by country and institution, identifying the main author clusters and their scope of publications along with the most-cited works and trending topics.

More specifically, the appearance of different epidemic outbreaks coincides with the publication of several bibliometric studies that characterize the research development, including in areas like population surveillance, for example as this relates to SARS I, Ebola, or more recently SARS II [36, 37, 38, 39].

Our Discussion analyzes the contributions of all of these papers comparatively in relation to the results of the present study.

1.2. Objectives

The overarching objective of this study was to identify the main research subject areas in population surveillance, characterizing the weight that the different public health-related aspects have in the field, the type of studies undertaken, and the diseases that have attracted the most attention. Specifically, our research questions were as follows:

- How has scientific production in the area evolved over the past two decades, and what disciplines or specialties have made the largest contributions?
- How is research in the area distributed among regions and countries?
- Are there differential features among the topic areas identified with regard to scientific output, collaboration, and citation?
- What weight does HIV, disease outbreaks such as influenza, and the coronavirus research have in the context of population surveillance?

2. Methods

The methodological process was as follows:

2.1. Identification of the dataset

The search strategy was based on the descriptor "population surveillance" included in the MeSH thesaurus from the National Library of Medicine. This descriptor also included all of the more specific terms included in the thesaurus: "public health surveillance," "sentinel surveillance" (which includes as synonyms "syndromic surveillance," "biosurveillance system," and "sentinel health event"), and "biosurveillance." Table 1 shows the definitions for each of the MeSH. The specific descriptors used to characterize the content of the documents have been included in the thesaurus relatively recently, while the umbrella term of "population surveillance" has classically referred to all the aspects described.

The search was performed using the Web of Science (Clarivate Analytics), which includes the MEDLINE database. The analysis included only the documents indexed in the Web of Science Core Collection databases; even though this source does not include all the documents in MEDLINE, it has some additional functions that are useful to bibliometric analyses like ours. For example, it is possible to classify documents by area of knowledge or discipline based on the scope of the journals publishing them. Moreover, the Web of Science Core Collection has available data on all authors' institutional affiliations and countries for the study period, as well as the number of citations that the documents received.

The search was restricted to the 2000–2019 period in order to analyze the most recent developments in the field. The only document types considered were articles, reviews, letters, and proceedings papers, as these are the main document types that report original research results. The search took place on 5 February 2020.

2.2. Analysis and treatment of bibliographic data

Once the included documents were identified, we downloaded all bibliographic records, reviewed the homogeneity of data, and standardized the entries to enable their quantitative analysis. Specifically, we individualized the multiple entries for some fields (like authors and MeSH terms); extracted the country information from the field for institutional affiliation (unifying entries from England, Scotland, Wales, and Northern Ireland under the UK); and classified the MeSH terms related to different aspects of public health, diseases, and types of studies. By establishing these groups, it was possible to analyze the results in a more standardized and coherent way. Documents' geographical affiliations were based on authors' institutional affiliations.

2.3. Indicators and analysis

2.3.1. Bibliometric analysis of scientific production

To characterize research development in the field of population surveillance, we calculated the following indicators:

- N documents published per year.
- N documents published by document type.
- N documents published by subject category. This was determined by looking at the Web of Science subject category classification for journals; for journals publishing papers in several subject categories, we used a proportional assignment.
- N documents published per journal.
- N documents published by geographical region (Africa, Asia, Europe, Latin America and the Caribbean, North America, and Oceania).
- N documents published per country.

2.3.2. Characterization of research topics: MeSH cluster analysis

To identify the main research topics in the field of population surveillance, a co-word analysis was performed to determine the frequency and co-occurrence of MeSH terms assigned to the documents. To do this, we generated a matrix that quantified the joint appearance of the 11,271 MeSH terms assigned to the documents. This matrix, in turn, was used to

Table 1. Description of the Medical Subject Headings (MeSH) included in the search strategy.

MeSH term	Description
Population surveillance (year introduced: 1967)	Ongoing scrutiny of a population (general population, study population, target population, etc.), generally using methods distinguished by their practicability, uniformity, and frequently their rapidity, rather than by complete accuracy.
Public Health surveillance (Year introduced: 2013, use Population Surveillance 1990–2012)	The ongoing, systematic collection, analysis, and interpretation of health-related data for the purpose of preventing or controlling disease or injury, or of identifying unusual events of public health importance, followed by the dissemination and use of information for public health action. (From *Am J Prev Med* 2011; 41 (6):636).
Sentinel surveillance (year introduced: 1995)	Monitoring the rate of occurrence of specific conditions to assess the stability or change in health levels of a population. It is also the study of disease rates in a specific cohort such as in a geographic area or population subgroup to estimate trends in a larger population. (From Last, *Dictionary of Epidemiology*, 2d ed).
Biosurveillance (year introduced: 2009)	Monitoring of information sources of potential value in detecting an emerging epidemic, whether naturally occurring or the result of bioterrorism.

generate a co-occurrence network showing the relationships between the high-frequency MeSH terms (>100 documents). Persson's Party Clustering algorithm [40] was then applied to identify the topic-area clusters among the existing documents; these were labeled with concepts that described their overall topic focus, encompassing all the MeSH terms included in the clusters. A bibliometric analysis was then performed on the scientific output, collaboration, and citation degree in each cluster, using the following indicators.

- N documents.
- Authors' collaboration index.
- % of documents produced through international collaboration.
- N citations.
- Mean citations per document.
- *H*-index.

To complement this aggregated topic analysis, we performed individual analyses of the MeSH descriptors based on an estimation of the frequency with which they were assigned to the documents (N documents). This indicator was calculated for the study period as a whole (2009–2019) as well as by five-year periods in order to analyze the evolution of research interests. We also specifically analyzed the frequency of the MeSH descriptors referring to "humans" and "animals" and considered the variables related to gender and age group.

2.3.3. Coronavirus and population surveillance

The performance of this study coincided with the worldwide spread of COVID-19, declared a pandemic on 11 March 2020. As of 1 September 2020, there were over 25 million confirmed cases and over 800,000 deaths. Research on population surveillance has occasionally examined the topic in relation to different coronaviruses, but before the latest outbreak it did not appear in any of the initial topic clusters we identified. However, given the great relevance that this topic acquired in the months after our first bibliographic search, we carried out a subsequent analysis focusing specifically on documents using the MeSH terms "population surveillance" and "coronavirus" (including papers related both to the infectious agent and to the associated infections, as shown in Table 2). This analysis generated a thematic network illustrating the different aspects covered by research on this topic. As above, this process entailed the creation of a co-occurrence matrix for the descriptors assigned to the documents about population surveillance and coronavirus. The constructed network shows the most frequent ties (co-occurrence intensity ≥3). In addition, we performed a bibliometric analysis of research activity in this area (output, collaboration, and citation), comparing these variables in relation to the rest of the clusters identified.

3. Results

3.1. Scientific production on population surveillance

A total of 52,887 documents were identified from the MEDLINE database; 79.97% (n = 42,293) of these were also included in the Web of Science Core Collection databases. After excluding the non-eligible document types, there were 39,184 total documents: 35,706 (91.12%) articles, 1804 reviews (4.6%), 1491 letters (3.8%) and 183 proceeding papers (0.47%). These papers comprised the population of documents used in the analyses described below.

The evolution of the number of documents per year of publication (Figure 1) shows the steady growth in scientific output, corresponding to a linear model of growth ($r^2 = 94$) with important surges in the number of publications in the years 2006–2007, 2010, and 2012–2013.

The major thematic categories reflected in the scientific output for the area were "Public, Environmental & Occupational Health," pertaining to 21.62% of the documents; followed by "Infectious Diseases" (10.49%) and "Medicine, General & Internal" (6.6%). At least 1% of the documents were related to 17 other categories; altogether, these minor categories made up 38.8% of total scientific output (Table 3). The rest of the documents (21.57%) are distributed at the tail, consisting of 144 categories. There was a notable concentration of documents in journals in the areas

Table 2. MeSH terms linked to coronavirus and included in the search strategy that generated the coronavirus network linked to population surveillance (descriptors assigned to at least one document are in cursive).

Coronaviridae
Coronavirus
Alphacoronavirus
Alphacoronavirus 1
Coronavirus, Canine
Coronavirus, Feline
Transmissible gastroenteritis virus
Porcine Respiratory Coronavirus
Coronavirus 229E, Human
Coronavirus NL63, Human
Porcine epidemic diarrhea virus
Betacoronavirus
Betacoronavirus 1
Coronavirus OC43, Human
Coronavirus, Bovine
Coronavirus, Rat
Middle East Respiratory Syndrome Coronavirus
Murine hepatitis virus
SARS Virus
Gammacoronavirus
Coronavirus, Turkey
Infectious bronchitis virus
Coronaviridae Infections
Coronavirus Infections
Enteritis, Transmissible, of Turkeys
Feline Infectious Peritonitis
Gastroenteritis, Transmissible, of Swine
Severe Acute Respiratory Syndrome

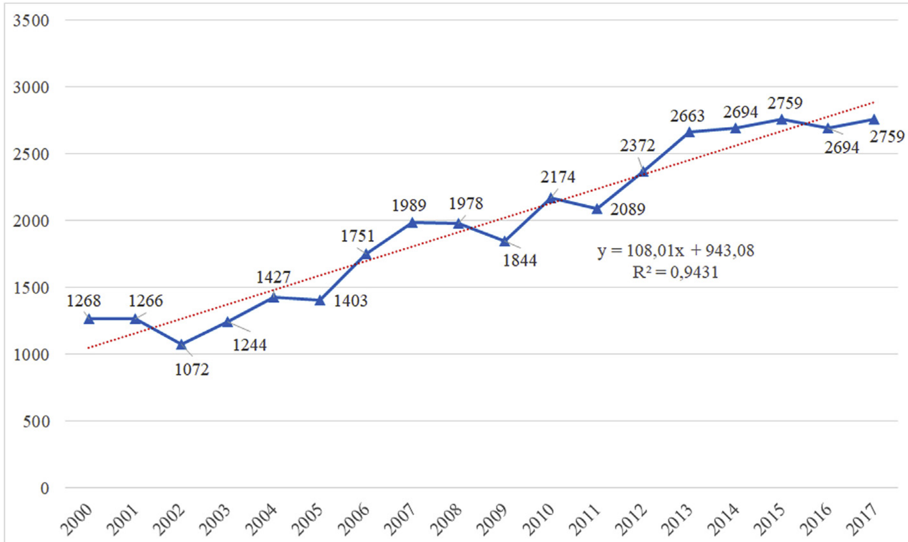

Figure 1. Evolution in the number of documents on population surveillance (2000–2017*) and retrieved from the Web of Science Core Collection databases. *The documents published in 2018 (n = 2578) and 2019 (n = 1160) were not included in the figure due to the delay in the assignment of descriptors and in the updating of the databases; thus for these years, data were incomplete at the time of the bibliographic search.

Table 3. Distribution of the number of documents on population surveillance (2000–2019) by thematic category.

Web of Science subject category	N docs	%	N journals	N docs/journal
Public, Environmental & Occupational Health	8473.28	21.62	277	30.59
Infectious Diseases	4111.17	10.49	104	39.53
Medicine, General & Internal	2584.92	6.60	163	15.86
Oncology	1778.55	4.54	142	12.52
Multidisciplinary Sciences	1672.33	4.27	28	59.73
Immunology	1460.45	3.73	99	14.75
Veterinary Sciences	1440.35	3.68	84	17.15
Pediatrics	1019.67	2.60	109	9.35
Cardiac & Cardiovascular Systems	916.08	2.34	101	9.07
Gastroenterology & Hepatology	821.83	2.10	75	10.96
Microbiology	818.95	2.09	74	11.07
Psychiatry	777.55	1.98	130	5.98
Clinical Neurology	626.20	1.60	118	5.31
Surgery	591.50	1.51	143	4.14
Health Care Sciences & Services	581.03	1.48	127	4.57
Urology & Nephrology	545.67	1.39	66	8.27
Tropical Medicine	516.70	1.32	26	19.87
Obstetrics & Gynecology	441.25	1.13	74	5.96
Pharmacology & Pharmacy	427.00	1.09	109	3.92
Medicine, Research & Experimental	397.47	1.01	74	5.37

of Infectious Diseases (39.53 documents per journal), Tropical Medicine (19.87 documents per journal), and Multidisciplinary Sciences (59.73 documents per journal) (Table 3).

The analyzed documents on population surveillance were published in 2,772 different scientific journals, with 39.09% of output concentrated in the 71 most productive journals (publishing >99 documents). Table 4 presents the top 15 journals with the highest number of papers published, as well as their impact factors for 2018 according to the JCR classification.

The distribution of participation in the publications by geographical regions (Table 5) reveals the concentration of scientific output in North America (36.41% of the documents) and Europe (32.09%). At some distance, Asia's contributions follow at 15.07%, while research from Africa and Latin America and the Caribbean has a limited presence (4%–6%).

With regard to the distribution of the scientific output among the top-producing countries (Table 6), the USA has contributed the largest proportion (40.14%), with the UK (11.94%), Australia (7.13%), Canada (6.64%), France (5.35%), and Germany (5.25%) trailing at some distance. The most significant aspect of the evolution of research on population surveillance is the emergence of China, which ranks third in scientific output in the most recent period (2015–2019).

3.2. Thematic research clusters in the field of population surveillance

The cluster analysis, carried out on the MeSH descriptors assigned to the included documents, enabled the identification of 10 topic groups. Each had a specific conceptual development and made a prominent scientific contribution to population surveillance literature. There was also a specific presence of different diseases (Figure 2).

Table 4. Top 15 most productive journals in population surveillance (2000–2019).

Top 15 journals	N docs	%	Impact factor 2018	Journal category (ranking within subject category)
PLOS ONE	1275	3.25	2.776	Multidisciplinary Sciences (24/69)
Emerging Infectious Diseases	1032	2.63	7.185	Immunology (23/158) Infectious Diseases (5/89)
BMC Public Health	531	1.36	2.567	Public, Environmental & Occupational Health (59/186)
Infection Control and Hospital Epidemiology	487	1.24	2.856	Infectious Diseases (41/89) Public, Environmental & Occupational Health (48/186)
Vaccine	411	1.05	3.269	Medicine, Research & Experimental (57/136) Immunology (78/158)
American Journal of Public Health	388	0.99	5.381	Public, Environmental & Occupational Health (12/186)
Epidemiology and Infection	367	0.94	2.047	Infectious Diseases (66/89) Public, Environmental & Occupational Health (85/186)
Clinical Infectious Diseases	318	0.81	9.055	Immunology (11/151) Infectious Diseases (3/89) Microbiology (11/133)
American Journal of Epidemiology	304	0.78	4.4.73	Public, Environmental & Occupational Health (20/186)
Eurosurveillance	300	0.77	7.421	Infectious Diseases (4/89)
Communicable Diseases Intelligence	293	0.75	-	
Scientific Reports	287	0.73	4.011	Multidisciplinary Sciences (15/69)
Journal of Infectious Diseases	286	0.73	5.049	Immunology (33/151) Infectious Diseases (10/89) Microbiology (23/133)
International Journal of Cardiology	275	0.70	3.471	Cardiology & Cardiovascular systems (48/136)
Public Health Reports	274	0.70	2.039	Public, Environmental & Occupational Health (86/186)

Table 5. Number of documents on population surveillance, by region and five-year period (2000–2019).

Geographic area	2000–2004		2005–2009		2010–2014		2015–2019		TOTAL	
	N	%	N	%	N	%	N	%	N	%
North America	3012	41.93	4,037	37.51	5377	36.12	5224	33.40	17,650	36.41
Europe	2509	34.93	3,711	34.48	4672	31.38	4665	29.83	15,557	32.09
Asia	706	9.83	1,277	11.86	2285	15.35	3038	19.42	7306	15.07
Oceania	396	5.51	738	6.86	1001	6.72	1026	6.56	3161	6.52
Africa	341	4.75	510	4.74	859	5.77	986	6.30	2696	5.56
Latin America & Caribbean	219	3.05	490	4.55	694	4.66	702	4.49	2105	4.34
TOTAL	7,183	100	10,763	100	14,888	100	15,641	100	48,475	100

Table 6. Documents on population surveillance by the top 15 most productive countries (2000–2019).

2000–2004			2005–2009			2010–2014			2015–2019			Total (2000–2019)		
Country	N	%	Country	N	%	Country	N	%	Country	N	%	Country	N	%
USA	2752	43.84	USA	3572	39.84	USA	4743	39.55	USA	4660	39	USA	15727	40.14
UK	765	12.19	UK	1059	11.81	UK	1382	11.52	UK	1473	12.33	UK	4679	11.94
Australia	354	5.64	Australia	636	7.09	Australia	867	7.23	China	941	7.87	Australia	2797	7.14
France	339	5.4	Canada	618	6.89	Canada	848	7.07	Australia	940	7.87	Canada	2603	6.64
Canada	325	5.18	Germany	504	5.62	Germany	636	5.3	Canada	812	6.79	France	2097	5.35
Germany	294	4.68	France	479	5.34	France	606	5.05	France	673	5.63	Germany	2058	5.25
Sweden	260	4.14	Netherlands	390	4.35	China	572	4.77	Sweden	672	5.62	China	1861	4.75
Netherlands	243	3.87	Italy	348	3.88	Netherlands	550	4.59	Germany	624	5.22	Sweden	1781	4.55
Italy	214	3.41	Sweden	333	3.71	Sweden	516	4.3	Netherlands	584	4.89	Netherlands	1767	4.51
Denmark	165	2.63	Switzerland	307	3.42	Italy	500	4.17	Italy	505	4.23	Italy	1567	4
Switzerland	161	2.56	Brazil	258	2.88	Spain	390	3.25	Spain	417	3.49	Switzerland	1251	3.19
Spain	155	2.47	Japan	255	2.84	Switzerland	377	3.14	Switzerland	406	3.4	Spain	1182	3.02
Japan	146	2.33	China	233	2.6	Brazil	353	2.94	Brazil	372	3.11	Brazil	1078	2.75
Finland	141	2.25	Spain	220	2.45	Japan	298	2.48	Japan	367	3.07	Japan	1066	2.72
Norway	130	2.07	Denmark	215	2.4	Taiwan	292	2.43	Denmark	356	2.98	Denmark	1016	2.59

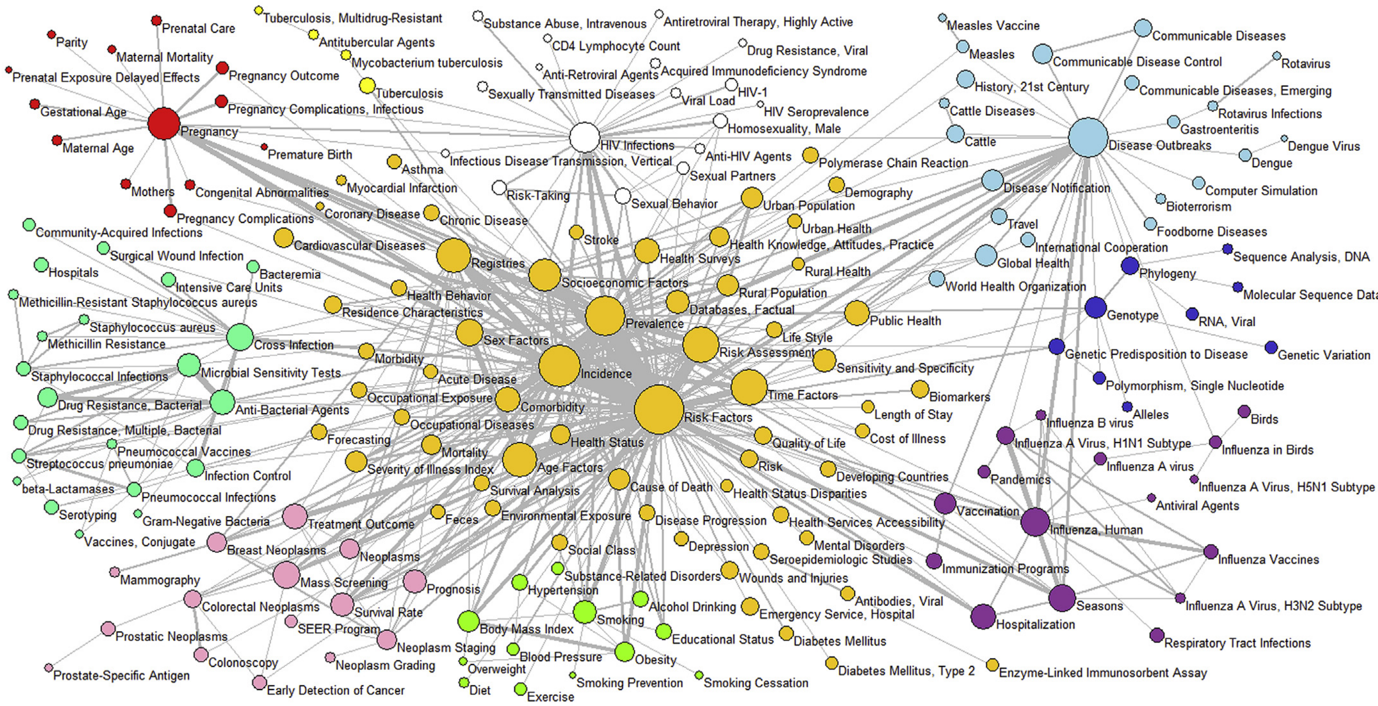

Figure 2. Main topic clusters linked to research on population surveillance. Each color represents a different cluster; the size of the nodes is proportional to the number of documents that have been assigned the descriptor, and the thickness of the ties reflects the intensity of the co-occurrence between linked descriptors.

3.2.1. General concepts around public health and specific diseases

In the center of the network is the cluster encompassing numerous but generic public health concepts related to population surveillance. Three descriptors are particularly prominent, linked to all of the clusters and defining the research aim of the studies: risk factors, prevalence, and incidence. Risk factors are defined as any behavioral aspect, environmental exposure, congenital or genetic characteristic with a known association to a health-related condition. Prevalence is a measure of the number of existing cases of a certain disease or condition in a given population, while incidence is the rate of appearance of new cases during a defined time period and in a defined population.

Other descriptors were related to the identification of an incident disease, its registry, the assessment of its epidemiological incidence, intensity, consequences, and factors affecting its impact. Also in this cluster were descriptors for various diseases, which do not have a specific development in terms of the MeSH used or which appear in a generic way: coronary and cardiovascular diseases, stroke, diabetes, mental disorders, asthma, and wounds and injuries.

3.2.2. Disease outbreaks

Epidemic outbreaks, that is, the measurement of the sudden increase in disease incidence, constitutes the main concept around the development of another prominent topic cluster. In turn, this cluster is closely tied to two others: on influenza and genetics (described below).

In quantitative terms, the most-studied disease descriptors in this cluster were rotavirus, dengue, measles, cattle diseases, and foodborne diseases. Other concepts covered in this cluster refer to the relevance of surveillance programs designed for communicable disease control, disease notification, travel, global health, international cooperation, and the WHO.

3.2.3. Genetics

The studies related to genetic sequencing of the viruses, the analysis of their variations, and the genetic predisposition to diseases conformed a specific area of research development, albeit one that was closely related to disease outbreaks.

3.2.4. Influenza

Infections due to influenza viruses, in their different types and subtypes, make up a specific research cluster, related to epidemic outbreaks. These documents focus on immunization and vaccination programs, hospitalization, and the consideration of influenza outbreaks as pandemics.

3.2.5. Cross-infections and anti-bacterial agents

Bacterial cross-infections acquired in a health care institution, such as staphylococcus, pneumococcus, and streptococcus, are the main focus of this topic cluster. The papers address aspects related with specific settings like hospitals and intensive care units as well as infections derived from surgical interventions, control and therapeutic approaches for infections through antibacterial agents, and the problems derived from resistance to chemotherapeutic agents, antimicrobial agents, or antibiotics.

3.2.6. HIV

Among the main aspects occupying this cluster—also closely linked to the cluster on disease outbreaks—are those related to risky sexual behaviors, transmission from intravenous drug use, and mother-to-child transmission (a line of research also linked to the cluster on pregnancy). Other concepts present in this cluster include the development of antiretroviral agents and the study of viral resistance to chemotherapeutic agents or antiviral agents.

3.2.7. Neoplasms

In addition to the generic concept of neoplasms, tumors of the breast, colon/rectum, and prostate have a specific presence in this document cluster. Some of the most prominent descriptors refer to procedures, diagnostic methods, outcome measurement, treatment outcomes, and the survival rate.

3.2.8. Substance-related disorders/obesity

This cluster brings together the studies on tobacco use and its prevention and cessation, along with alcohol intake and obesity.

3.2.9. Pregnancy

This cluster covers a wide range of subtopics on aspects related to gestation and pregnancy complications such as congenital anomalies; the incidence of nutritional conditions; the consequences of fetal exposure *in utero* to risks like physiological stress, drugs or radiation; infections during pregnancy (particularly HIV); and premature births.

3.2.10. Tuberculosis

In addition to the main aerobic bacteria that produce tuberculosis in humans (mycobacterium tuberculosis), this cluster also contains studies on treatment and resistance to chemotherapy with two or more antitubercular agents.

3.3. Coronavirus research in relation to public health surveillance

Research into coronavirus infections has also been present over the last two decades in connection with population surveillance, albeit it has had a much lower quantitative weight than other topics. Indeed, it does not appear among the main topic clusters or among the disease descriptors presented in Table 9. We identified just 143 documents related to these viruses or infections caused by them. Of these, 85 dealt with severe acute respiratory syndrome (SARS), and 27 with MERS.

Figure 3 presents the network of MeSH descriptors with the topics covered in all of the papers on population surveillance and coronavirus. In general, this area of study follows a similar pattern as the cluster on disease outbreaks, and in fact, this is the top descriptor related to coronavirus infections in the case of both SARS and MERS. Other topics of interest have to do with globalization (travel, global health), identification of the origin of the virus, genetic characteristics, and viral evolution. Moreover, several lines of inquiry that have become especially relevant in the current COVID-19 pandemic were in the center of the network, including infection control, contact tracing, and quarantine. Clinical approaches were also prominent, for instance public health practice, hospitalization, infectious disease transmission from patient to professional, and personal protective equipment for health professionals. At the top of the network are terms like “influenza,” which appears as the most frequent reference to a communicable disease associated with coronavirus.

The size of the nodes is proportional to the number of documents assigning the descriptor, and the thickness of the ties reflects the intensity of the co-occurrence.

3.4. Bibliometric analysis of research topic clusters

Table 7 presents the results of the bibliometric analysis of the topic clusters identified in the literature on population surveillance, including on coronavirus. Those with the most scientific output were the clusters on disease outbreaks (n = 5493) and cross infections (n = 3875), followed by neoplasms, influenza, HIV, pregnancy, and substance abuse/obesity. The cluster on coronaviruses shows limited output, despite the two high-profile outbreaks associated with these viruses, SARS (2002–2003) and MERS (2012).

Among authors participating in different clusters, the level of collaboration appears to be quite homogeneous, although some clusters stand out from the rest for their greater collaboration index, for example the ones on genetics or influenza. At the country level, there are more notable differences, with the degree of international collaboration standing highest in the clusters on coronavirus (35.25% of the documents), tuberculosis (36.87%), and genetics (36.85%). Collaboration was also quite common in HIV, disease outbreaks, and influenza (32%–35%), whereas the rest of the clusters present a much more modest level of international collaboration (22%–29%).

Finally, the citation indicators also reveal the existence of important differences between different topic areas. Documents on mental diseases, stroke, substance abuse/obesity, and cross-infections cite an average of about 37–48 other papers and have much higher *h*-indexes than the clusters on disease outbreaks, tuberculosis, and especially coronavirus, where these values are substantially lower.

3.4.1. MeSH terms on population surveillance and public health

Table 8 presents the top 20 MeSH descriptors assigned to the documents. Together with the terms related to risk factors are others that allude to epidemiological aspects and a few associated with disease prevention and control. Annex 1 presents the full list of MeSH terms that are featured on at least 100 documents.

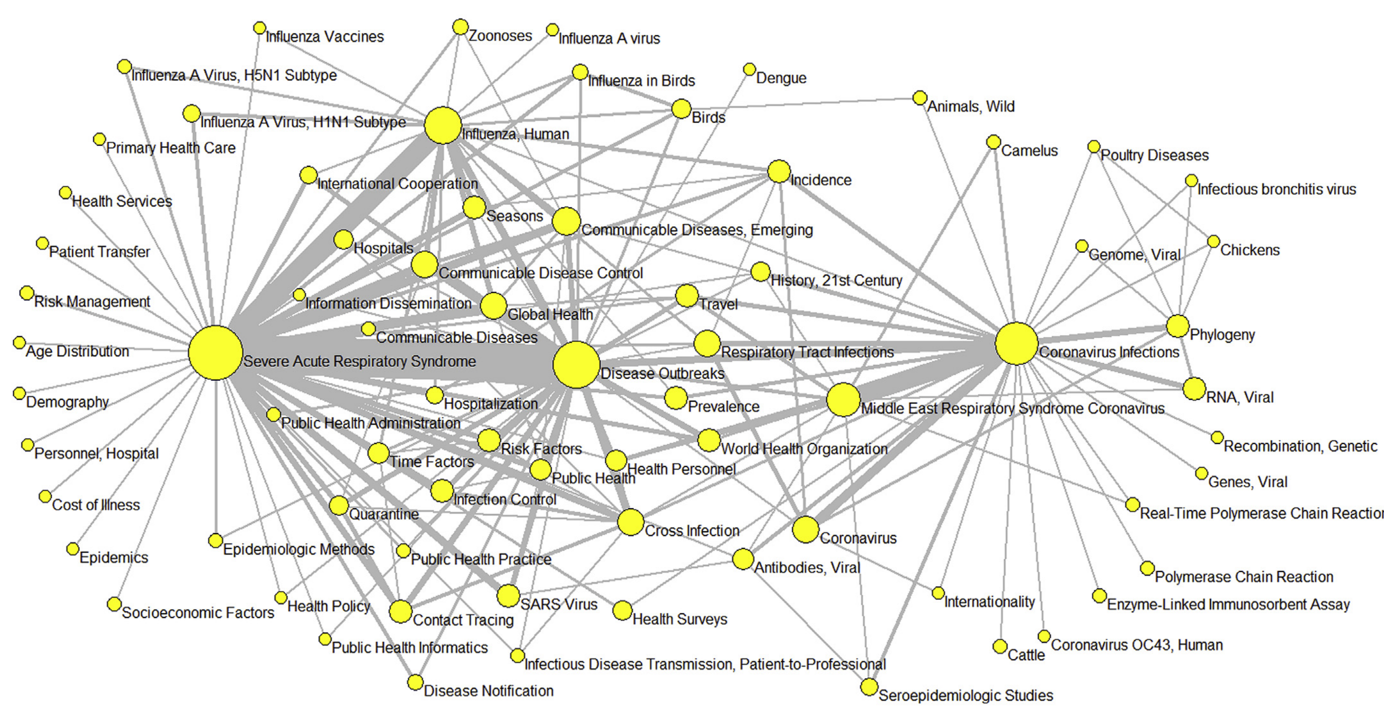

Figure 3. Network of MeSH descriptors linked to publications on coronavirus in the literature on population surveillance.

Table 7. Bibliometric indicators on scientific output, collaboration, and citation in the clusters under the area of population surveillance.

Cluster	N docs	Authors' collab. index	±SD	Int. collab. (% docs)	N citations	Citations/ doc	±SD	*H*-index
Disease outbreaks	5493	6.52	±5.05	32.28	139923	25.47	±74.49	137
Cross infections	3875	7.05	±6.91	22.069	144490	37.29	±114.71	143
Neoplasms	3265	7.08	±5.54	21.911	114099	34.95	±136.08	136
Influenza	2899	7.8	±7.15	31.772	74007	25.53	±71.82	105
HIV	2869	6.64	±4.82	34.586	78998	27.53	±61.19	113
Pregnancy	2462	6.4	±5.84	29.192	65900	26.77	±64.73	104
Substance abuse/obesity	2338	5.67	±4.39	22.938	91561	39.16	±112.56	127
Genetics	2148	9.17	±6.97	36.852	63352	29.49	±76.02	103
Cardiovascular and coronary diseases*	1113	6.84	±4.55	25.361	38614	34.69	±69.04	93
Mental diseases*	795	5.45	±3.41	23.232	38474	48.39	±110.11	93
Diabetes*	687	6.95	±16.81	22.076	21480	31.27	±58.18	73
Tuberculosis	685	6.74	±4.72	36.873	17406	25.41	±63.73	58
Wounds and injuries*	637	4.94	±6.55	25.832	17255	27.09	±92.87	55
Stroke*	429	6.72	±3.76	25.472	19802	46.16	±189.85	63
Asthma*	370	6.94	±11.5	24.59	12290	33.22	±53.92	57
Coronavirus	143	6.99	±6.33	35.252	2888	20.19	±35.12	29

[*] These diseases are specific areas of the cluster "General concepts around public health and specific diseases".

3.4.2. MeSH terms on types of studies

With regard to the types of studies performed, retrospective designs were the most frequent (n = 3850, 9.82%), followed by cross-sectional studies (n = 3610, 9.21%), surveys and questionnaires (n = 3555, 9.07%), follow-up studies (n = 2785, 7.1%), cohort studies (n = 2611, 6.66%) and prospective studies (n = 2602, 6.64%). Annex 2 presents the complete list of MeSH terms related to these descriptors (>99 documents).

3.4.3. MeSH terms on population surveillance and diseases

"HIV infections" (n = 1877) and "Influenza, Human" (n = 1620) were the main MeSH descriptors related to specific diseases that were assigned to the documents. "Cross infections" (n = 1318) followed, along with numerous descriptors on NCDs. Tuberculosis was also quite relevant (n = 496), and in the most recent period (2015–2019) the descriptors related to different epidemic outbreaks like dengue (n = 310) also became more prominent. While they did not reach the quantitative importance to be specifically included in the topic clusters described, Ebola (Hemorrhagic Fever, Ebola, n = 112) and Zika (Zika Virus Infection, n = 107) also attracted research attention. Likewise, the last five years of the study period saw an increased interest in "Influenza, Human," "Breast neoplasms" and other descriptors related to tumors (see Table 9) and annex 3 for a list of the descriptors assigned to more than 99 documents.

Finally, we observed a predominance of the descriptor "humans" (n = 36,821, 93.97% of the documents) over studies on "animals" (n = 4051, 10.34%), along with some differences in the distribution of disease measures in relation to gender and age. Annex 4 shows the distribution of MeSH terms for these variables that were assigned to the documents.

Table 8. Top 20 descriptors related to public health in the scientific output on population surveillance (2000–2019).

MeSH descriptors	2000–2004 (N = 6277)		2005–2009 (N = 8965)		2010–2014 (N = 11,992)		2015–2019 (N = 11,950)		Total (N = 39,184)	
	n	%	n	%	n	%	n	%	n	%
Risk Factors	1576	25.11	1918	21.39	2530	21.10	2498	20.90	8522	21.75
Incidence	1199	19.10	1412	15.75	1794	14.96	1876	15.70	6281	16.03
Prevalence	1068	17.01	1510	16.84	1853	15.45	1704	14.26	6135	15.66
Disease Outbreaks	461	7.34	861	9.60	920	7.67	877	7.34	3119	7.96
Risk Assessment	342	5.45	664	7.41	710	5.92	776	6.49	2492	6.36
Registries	425	6.77	464	5.18	615	5.13	827	6.92	2331	5.95
Sex Distribution	634	10.10	496	5.53	485	4.04	319	2.67	1934	4.94
Sex Factors	218	3.47	343	3.83	470	3.92	328	2.74	1359	3.47
Hospitalization	203	3.23	214	2.39	401	3.34	447	3.74	1265	3.23
Comorbidity	186	2.96	192	2.14	343	2.86	500	4.18	1221	3.12
Health Surveys	192	3.06	275	3.07	453	3.78	267	2.23	1187	3.03
Public Health	182	2.90	300	3.35	359	2.99	334	2.79	1175	3.00
Treatment Outcome	150	2.39	265	2.96	343	2.86	390	3.26	1148	2.93
Sensitivity and Specificity	265	4.22	321	3.58	297	2.48	213	1.78	1096	2.80
Survival Rate	127	2.02	191	2.13	305	2.54	360	3.01	983	2.51
Severity of Illness Index	238	3.79	297	3.31	234	1.95	203	1.70	972	2.48
Cause of Death	185	2.95	183	2.04	304	2.54	295	2.47	967	2.47
Vaccination	109	1.74	137	1.53	249	2.08	438	3.67	933	2.38
Disease Notification	194	3.09	251	2.80	257	2.14	226	1.89	928	2.37
Health Status	182	2.90	212	2.36	277	2.31	142	1.19	813	2.07

Table 9. Top descriptors related to diseases (>1% of the documents) in scientific output on population surveillance (2000–2019).

MeSH descriptors	2000–2004 (N = 6277)		2005–2009 (N = 8965)		2010–2014 (N = 11,992)		2015–2019 (N = 11,950)		Total (N = 39,184)	
	n	%	n	%	n		n	%	n	%
HIV Infections	283	4.51	415	4.63	595	4.96	584	4.89	1877	4.79
Influenza, Human	91	1.45	283	3.16	685	5.71	561	4.69	1620	4.13
Cross Infection	285	4.54	464	5.18	361	3.01	208	1.74	1318	3.36
Breast Neoplasms	128	2.04	159	1.77	167	1.39	367	3.07	821	2.10
Neoplasms	115	1.83	161	1.80	227	1.89	280	2.34	783	2.00
Obesity	102	1.62	224	2.50	259	2.16	196	1.64	781	1.99
Cardiovascular Diseases	75	1.19	163	1.82	270	2.25	251	2.10	759	1.94
Neoplasm Staging	69	1.10	115	1.28	176	1.47	378	3.16	738	1.88
Wounds and Injuries	126	2.01	172	1.92	195	1.63	144	1.21	637	1.63
Communicable Diseases	96	1.53	146	1.63	195	1.63	183	1.53	620	1.58
Colorectal Neoplasms	79	1.26	126	1.41	166	1.38	206	1.72	577	1.47
Chronic Disease	87	1.39	147	1.64	177	1.48	139	1.16	550	1.40
Tuberculosis	81	1.29	106	1.18	142	1.18	167	1.40	496	1.27
Hypertension	81	1.29	130	1.45	148	1.23	134	1.12	493	1.26
Occupational Diseases	125	1.99	102	1.14	149	1.24	77	0.64	453	1.16
Stroke	59	0.94	84	0.94	154	1.28	132	1.10	429	1.09
Staphylococcal Infections	88	1.40	142	1.58	128	1.07	68	0.57	426	1.09
Prostatic Neoplasms	23	0.37	82	0.91	162	1.35	153	1.28	420	1.07
Respiratory Tract Infections	99	1.58	83	0.93	98	0.82	135	1.13	415	1.06
Streptococcus pneumoniae	112	1.78	116	1.29	91	0.76	95	0.79	414	1.06
Communicable Diseases, Emerging	43	0.69	125	1.39	111	0.93	121	1.01	400	1.02
Zoonoses	32	0.51	125	1.39	148	1.23	94	0.79	399	1.02
Pneumococcal Infections	98	1.56	104	1.16	102	0.85	92	0.77	396	1.01

4. Discussion

4.1. Scientific production on population surveillance

The two-fold increase in scientific literature on population surveillance over the study period reflects the increasing interest in the field. The evolution of the number of documents published on population surveillance in the first five years of the 2000s shows a similar tendency as that observed in Soteriades and Falagas's study on the fields of preventive/occupational and environmental medicine, epidemiology, and public health, that is, the scientific output is stable until the second half of the decade [41], when it begins to grow dramatically. This pattern is also apparent in Yao et al.'s study on global health care sciences and services research [42].

The peaks observed coincide with important public health events that motivated temporary spikes in research interest, especially the H1N1 pandemic flu in 2009–2010 [34,37]. In the most recent study period (2015–2019), scientific output also increased in response to the outbreaks of Ebola in both West Africa in 2013–2014 [43] and in the Democratic Republic of the Congo and Uganda in 2018 [36], Zika in the Americas and Southeast Asia in 2015–2016 [44], measles in the Democratic Republic of the Congo in 2019, and dengue in the Asian Pacific and Latin America in 2019.

Research production was highly concentrated in developed countries, though North America published more than Europe (36% versus 32% of worldwide production). In contrast, in other areas of biomedical research, the distribution of research publications is more balanced, for example in pneumonia (42% in North America versus 41% in Europe) [45]. The participation of Africa (5.6%) and Latin America and the Caribbean (4.3%) is far from ideal, not just because a large portion of epidemic outbreaks with a global projection originate in these regions [46], but because their countries bear a disproportionate disease burden for both infectious diseases and NCDs, even though the latter are traditionally associated with high-income countries [36, 47]. This low level of scientific output reflects the limited public health surveillance systems with a very pronounced disparity among low- and middle-income countries in general [48, 49] as well as in the BRIC countries (Brazil, Russia, India, and China) specifically [50, 51]. To address this situation, initiatives have been developed for community-based surveillance, which involve community members who help to identify and report health events for public health surveillance. However, these programs are insufficient for ensuring an effective global public health surveillance system. In their review, Guerra et al. [52] analyzed 79 community-based surveillance systems developed since 1958 in 42 countries, finding that these systems cover very specific geographic areas, are focused on a single area of interest, and have had a limited duration.

At the country level, the leadership of the USA is clear in that its scientific output is far greater than that of any other country; this is not the case for other areas of study, where countries' contributions are more balanced [53, 54]. This leadership responds to the pioneering character of the USA and its initiatives in research and conceptual and model development in the field of population surveillance. In that sense, the CDC has been a central actor, participating intensely in research activities, the generation of health statistics data, and the development of surveillance systems since its creation [6, 51, 55, 56, 57]. This leadership also responds to the high levels of public and philanthropic financing in the USA for research projects to identify emerging or other communicable diseases; assess health-related risk behaviors and chronic health conditions; develop preventive services; or control epidemic outbreaks using diagnostic tools, drug therapies, or vaccines [32, 34]. Indeed, CDC financing has been well above that of other bodies like the European Commission in some areas like Ebola research between 1997 and 2015 [56]. Other factors have also come into play, for instance the terrorist threat since the September 11th attacks, which gave a strong impetus to research in areas closely linked to surveillance like bioterrorism [28].

Despite China's emergence in the last five-year period studied, its scientific contribution is far from having the relevance it does in other disciplines or areas of knowledge [31, 58, 59]. In one review, Huff et al. [51] analyzed the development of global infectious disease surveillance systems from 1900 to 2016, finding that Iran, India, and China were the countries with the fewest biosurveillance systems per capita and speculating whether this could be related to the major outbreaks of infectious disease in China. Feng et al. [50] had already called for greater Chinese investments in pathogen-based surveillance for preparation and response to infectious disease outbreaks. While such a need has clearly become evident in the case of China, where the COVID-19 pandemic eventually originated, it is also true more broadly that a greater degree of global participation in research initiatives on public health surveillance should be fostered.

With regard to the areas of knowledge, although public, environmental, and occupational health and infectious diseases are the two main disciplines linked to population surveillance, the outstanding presence of other disciplines like immunology, microbiology, veterinary science, pharmacology & pharmacy, and genetics highlights the importance of multidisciplinary approaches to research on communicable and vector-borne diseases. The study of natural reservoirs or transmission vectors to develop prevention and control programs is just as important as knowledge on the mechanisms of human-to-human transmission, pathogenesis, development of vaccinations that limit transmission, and drug treatments that enable an adequate therapeutic approach to the infections [32].

Regarding the most productive journals publishing the research, just 2 of the top 15 specialize in surveillance (Eurosurveillance and Communicable Diseases Intelligence). And unlike the patterns observed in other fields [45, 60], a substantial proportion of the most productive journals are not in the first quartile or among the top 1% for impact, which suggests that the field of population surveillance still has to gain ground before it is fully recognized and established as an area of knowledge. For this to happen, specialized journals should be advertised and recognized by the community, and better dissemination of studies published in journals of high impact and visibility [61, 62].

4.2. Topics

The great diversity in topic areas addressed is one of the defining features of literature on population surveillance, as signaled by theoretical studies that have described the formation process and the characteristics of this area of knowledge [6, 13, 20]. The clusters we identified respond largely to two broad groups of studies: those on NCDs and those on communicable diseases and cross-infections.

4.2.1. Non-communicable diseases

The presence of common NCDs at the center of the topic cluster network and among the MeSH terms assigned most frequently to the documents is logical in light of their high incidence and prevalence. This finding supports the postulates of the epidemiological transition theory, which aims to explain the increased relevance of research on chronic compared to infectious diseases as a result of the improved living conditions of the population, the development of public health, and the increase in life expectancy, among other factors [63].

All the NCDs within the top 10 causes of mortality worldwide (ischemic heart disease, stroke, dementia, cancers, diabetes, and road injury) have a very visible presence in the subfields of population surveillance that we identified [64]. The only exception is chronic obstructive pulmonary disease (COPD), the third cause of global mortality, which is not included in any of the clusters and has only a modest presence in the body of research analyzed (120 documents). This probably reflects the relevance of limiting the risk factors rather than establishing the incidence of the disease, especially the most important one, smoking, which is present in the network [65].

In general, diseases amenable to control programs are more present in the networks, whether this control takes the form of preventive policies to reduce the incidence of risk factors (diet, alcohol intake, smoking, physical activity) [66]; or whose early diagnosis is essential for increasing the effectiveness of treatment [67]. In that sense, wounds and injuries, together with stroke, are the most prominent among the NCDs because tackling their risk factors is crucial to reducing the associated mortality and morbidity. For example, awareness campaigns can change norms around driving while under the influence of alcohol and drugs [68], and dietary habits and healthy lifestyles can reduce the impact of stroke [69]. With regard to cancer, most research focuses on breast neoplasms, colorectal neoplasms, and prostatic neoplasms, probably because their early detection greatly affects their prognosis. In breast cancer, for instance, population-based screening in women aged 50 to 75, and even in women aged as young as 40, significantly decreases the mortality rate. Different scientific societies in the area have also pointed to the interest in preventing colorectal cancer by means of periodic colonoscopies in people aged over 50 years [70, 71].

With regard to pregnancy, in addition to the relevance of preventing mother-to-child transmission of HIV, pre-term birth complications is also situated among the top 10 causes of mortality in low- and middle-income countries, with birth asphyxia and birth trauma standing out as a leading cause of death in low-income countries. These figures justify population surveillance of such conditions, especially considering that these countries also tend to have the highest birth rates [72].

4.2.2. Communicable diseases and cross-infections

The focus of scientific research on surveillance and communicable diseases has changed considerably over the years. Thus, in the study by Durando et al. [27] (which admittedly was limited to European research) disease outbreaks had a limited presence compared to sexually transmitted infections. Although the latter topic still has considerable weight in the research we analyzed, specifically with regard to HIV, "disease outbreaks" has overtaken it, in large part thanks to research on influenza. The proportional share of this topic rose from 1.4% of the total research to 4.7% in the most recent period. Research output on dengue, measles, Ebola and Zika also has much to do with this trend.

In keeping with the study by Musa et al. [35], the terms referring to early detection through surveillance systems and to the control of epidemic outbreaks stand out as the main topic areas linked to public health in relation to disease outbreaks. Specifically, respiratory tract diseases are one of the main areas of interest, especially pneumonia—whether associated with infectious diseases, community-acquired pneumonia (CAP), nosocomial infections, or bacterial cross-infections. The reasons for this interest may reside in the fact that CAP is the most important cause of mortality from infectious diseases and the third cause of death globally [45], with respiratory diseases generally receiving more attention and funding from surveillance programs [34].

Diarrheal diseases are also situated among the top 10 causes of mortality worldwide and are the second cause of death in low-income countries. This topic's presence in the cluster of disease outbreaks takes the form of viral gastroenteritis linked with rotavirus, which is particularly serious in non-vaccinated children and infants in these countries, although it can be prevented through adequate hygiene measures like handwashing and cleaning of surfaces and objects [73].

The prominence of the cluster on HIV and its related descriptors responds to the consideration of AIDS as a pandemic and as the primary issue for global health [74]. This challenge has been met with decisive investments for its control through research and surveillance programs, explaining the presence of HIV-related descriptors in our study. Of these, "HIV infections" was the most important descriptor worldwide and throughout the study period. Indeed, although HIV-related incidence, mortality and morbidity are concentrated in a few geographic regions and countries, it continues to be a global problem, and unsafe sexual behaviors—an increasingly important risk factor—put HIV at the top of the public health problems related to sexually transmitted infections, even in the most developed countries [75, 76].

Despite a WHO declaration calling it a global health emergency in 1993 and numerous programs that have aimed to reduce its incidence, tuberculosis also remains among the top 10 causes of mortality worldwide [64], having a prominent presence in the present study as a MeSH term and through a specific cluster. It especially affects developing countries and is aggravated by factors like its association with HIV and the emergence of multiple drug-resistant tuberculosis. These conundrums continue to attract researchers' attention, particularly in relation with public health surveillance, as early detection, appropriate antibiotic treatment, and infected persons' adherence to preventive measures are all essential for reducing disease transmission [77, 78].

4.3. Research gaps

The absence of clusters linked to important health events is noteworthy, as these constitute underexamined areas. Further research should be promoted and better integrated into health surveillance systems, for example in relation with environmental and air quality. Much scientific evidence already exists associating the effects of air pollution on health through different diseases, not only those affecting the respiratory tract but also cardiovascular and nervous system diseases [79]. Jia et al. [31] considered vehicle-related air pollution and noise as the main public health problem in urban settings, with poor sanitation constituting another major threat to population health.

We also found few documents linked with environmental hazards, particularly natural disasters, which have become more frequent and severe due to the climate crisis. In one, Barret et al. [80] warn that alterations in ecosystems caused by climate change may lead to an increased prevalence of vectors and reservoir hosts. This tendency, together with other factors like decreased human host resistance, may favor the spread of epidemics. Surveillance systems could contribute to this field by collecting data on diseases and casualties resulting from these events. Such information could help decision-makers determine the best interventions to respond to them [81, 82].

Other areas should also receive special attention, for example, food safety surveillance, because the globalization of markets and diversification of production and supply chains can entail significant risks for the population [83]. For its part, pharmacovigilance can help to monitor adverse drug effects that were not evident in clinical trials, adverse effects from biological products, and the use of traditional medicines and medicinal plants [84]. Surveillance of risks linked to the development of the Internet, communication technologies and electronic devices also merit a closer look, given that these can generate important public health problems, for example related to addiction, illegal acquisition of drugs, or the dissemination of fake news [85].

In addition to the limited research attention to coronaviruses from the public health surveillance perspective, there was a low presence of research on other infectious diseases despite recurring epidemic outbreaks in the recent past, for example cholera in Zimbabwe in 2008–2009, Haiti in 2010, and Yemen in 2016; Chikungunya Fever (n = 62); and yellow fever, with high-profile outbreaks in Sudan in 2012 and Angola in 2016 [35,86,87,88].

There was also a certain imbalance between research in humans versus animals, even though—as evident from the current COVID-19 pandemic—the living conditions of animals may represent an important threat to human health. These results corroborate the findings of Drewe et al. [89], who found that just 25 of 99 articles on surveillance system evaluations focused on animal diseases. Likewise, Huff et al. [51] identified 180 animal surveillance systems, compared to 706 focused on humans and 105 in both humans and animals. Given the continued threat of zoonotic diseases, population surveillance research should integrate components for monitoring animal health and studying natural reservoirs and arthropod vectors. Such an endeavor would necessarily entail increased cooperation and the creation of interdisciplinary groups involving veterinarians, entomologists, and other professionals and researchers as well as public health experts [12], in the same line as the One Health approach, which emphasizes the intersection of human health, animal health, and environmental health in determining overall global health [90, 91].

4.4. Collaboration and citation

We observed a high level of international collaboration in the coronavirus cluster (35.25% of the documents), whose outbreaks prior to COVID-19 were mainly limited to Asia and the Middle East, and in the tuberculosis cluster (36.87%), whose incidence is concentrated in Asian and African countries. This measure could indicate the dependence of less developed countries on others with more advanced scientific systems for the performance of research, as reported elsewhere in the literature [92]. These reports highlight that although cooperative practices may represent a key mechanism for enabling greater participation in research activities, they should be based on common interests and a balanced participation that empowers less developed countries. This aspect is essential not only for responding to disease outbreaks that may originate in these countries but also because these so-called diseases of “affluence” are actually undeclared pandemics whose presence is increasing in low- and middle-income countries [36, 47].

In terms of the citation indicators, the clusters on disease outbreaks and tuberculosis present much lower citation values than those on mental diseases, cerebrovascular diseases, substance abuse, and cross-infections. This finding may respond to the fact that these fields are more firmly established in their own right and generally present a greater volume of scientific activity. It also helps to contextualize the similarly low citation indicators in coronavirus research and could explain the influence of other factors, like the dispersion or atomization among multiple communicable diseases attracting research attention [93, 94, 95].

4.5. Coronavirus and population surveillance research

It is undeniable that coronaviruses have received scant research attention from the perspective of population surveillance compared to other infectious diseases and related topics. However, our results—and specifically the co-occurrence map showing the research topics covered—show that some of the main problems generated by the COVID-19 pandemic have been addressed. In that sense, Dwosh et al. [96] warned that SARS can easily be spread by direct personal contact in the hospital setting and called for hospitals to be prepared to implement aggressive infection control measures in the case of having to treat such patients. Similarly, Kim et al. [97] reported a higher incidence of MERS in health professionals that did not use appropriate personal protective equipment. For their part, Sung et al. [98] also urged close attention to the environment in order to control SARS and other respiratory diseases, redesigning and reviewing hospital rooms to minimize the environmental factors associated with nosocomial infections. All this scientific evidence stands in contrast with the absence of protocols, control plans, and especially basic protective gear for health professionals in many countries, both in hospitals and in other health care institutions, in short, a lack of global preparedness to face a pandemic like the one is occurring [99].

Also in relation to the SARS outbreak in 2003 in Taiwan, Shih et al. [100] cautioned the health care community about atypical disease presentation and the wait for laboratory results—the two major obstacles when responding to an epidemic outbreak. The authors concluded that surveillance systems should focus on early detection.

Two key elements for the initial control of outbreaks appear in the thematic network analyzed for coronaviruses: contact tracing and quarantine of infected persons. Writing about SARS, Greaves [101] deemed that the most appropriate surveillance would take the form of a clinician-based notification system, which would be swifter than laboratory-based systems. Indeed, the initial delay at the political level in notification caused by lab-based notifications was widely criticized in relation to the SARS-CoV-2 emergency in Wuhan, China, a fact that stands in contrast to the rapid dissemination of the information at a scientific level. Indeed, the genetic sequence of the virus was published just days after the declaration of a novel virus [102].

Another issue that has become particularly controversial in numerous countries since COVID-19 has spread internationally is the celebration of mass gatherings that could have contributed to the propagation of the virus. In that regard, scientific evidence indicates that the cancellation of events is the most appropriate response. For example, Li et al. [103] estimated that 71%–75% of the SARS infections in Hong Kong and

Singapore could be attributed to this kind of event. School and workplace closures, despite the difficulties in implementing due to the weight of economic or political interests, may also be critical public health measures that delay the spread of the virus [104]. Reported experiences support the need to follow the direction set out by public health professionals and surveillance systems.

The SARS-CoV outbreak of 2002–2003 occurred primarily in China, Hong Kong, Taiwan, and Singapore, with only a few cases in Europe and the USA. Likewise, MERS-CoV hit Saudi Arabia and its neighbors the hardest in 2012–2013. The fact that neither of these outbreaks greatly affected the West undoubtedly helps to explain the scant research interest reflected in the topic cluster on coronaviruses as well as the underestimation of the chance that a new coronavirus outbreak would cause the global impact that it has the SARS-CoV2 pandemic [105, 106].

4.6. Limitations

We undertook a bibliometric analysis of research generated on different diseases and public health aspects from the population surveillance perspective. For that reason, we did not consider publications that focused on other facets, like basic research or treatment approaches to the diseases described. Furthermore, we analyzed a large volume of data and centered our attention on the topics that had the biggest quantitative presence in the indexed documents. This focus should not imply that other topics were not addressed by research, as our subtopic analysis on coronavirus research and population surveillance shows. Other limitations are those inherent to any bibliometric study, like the existence of publications not included in the bibliographic sources we examined and other types of research outputs like statistics and epidemiological disease registries, mortality records, and other public health sources. Future studies may consider the analysis of the origin of the articles (academic, state, military, etc.) as well as the types of areas under surveillance (city, region, state, etc.) to shed light on the strategic stakes of surveillance.

5. Conclusion

Population surveillance research is heterogeneous, with topic clusters on disease outbreaks and cross-infections sharing research space with other clusters on NCDs. This group of diseases is responsible for a greater disease burden and is increasingly impacting low- and middle-income countries. The excessive concentration of research in North America and Europe limits capacity in population surveillance research, hampering the ability to respond to global health threats.

The COVID-19 pandemic has confined a substantial proportion of the global population in their homes and has brought many of the most advanced health systems in the world to the brink of collapse, revealing the failure of the most advanced European countries and the United States to respond rapidly and effectively to COVID-19. While the implications of this pandemic will be deep and far-reaching, their full extent is still unknown. One of the most relevant, however, must be the need to strengthen the role of public health surveillance, and share the knowledge generated from decades of epidemic and pandemic outbreaks with all stakeholders, because uncoordinated national efforts do little in the face of fast-moving and global disease outbreaks like COVID-19. Inaction and delayed or irresponsible responses from governments do not just put human health at risk, they also jeopardize geopolitical stability and the global economy and discredit and undermine the effectiveness of even the best surveillance systems.

Declarations

Author contribution statement

Gregorio González-Alcaide: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Pedro Llorente, José-Manuel Ramos-Rincón: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at https://doi.org/10.1016/j.heliyon.2020.e05141.

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