



Global trends in smoking cessation research from 2002 to 2021: A bibliometric and visual analysis

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ARTICLE INFO

Keywords:

Smoking cessation
Bibliometric analysis
VOSviewers
Tobacco
Smoking

ABSTRACT

This study aimed to analyze the scientific outputs of smoking cessation research and explore its hotspots and frontiers from 2002 to 2021, using bibliometric methods. We use the core collection of Web of Science as a data source, and apply bibliometric methods to visually analyze articles published in smoking cessation research from 2002 to 2021, including publication year, countries/regions, journals, authors, institutions, and keywords. The VOSviewer (1.6.16) tool was used for the analysis. A total of 8797 articles related to smoking cessation research were identified. The USA was the leading contributor with 4671 publications. NICOTINE & TOBACCO RESEARCH contributed the most publications (528), with the most citations (13746) and the highest H-index (59). The most contributing institutions were the University College London and University of California San Francisco. Robert West was most productive author. We found active collaborations among both productive authors and productive institutions. There were five hot topics in smoking cessation research: (1) Public health harm from tobacco; (2) The role of e-health in smoking cessation; (3) Role of primary health care in eliminating tobacco dependence; (4) Nicotine replacement therapy and pharmacotherapy; (5) The biological and clinical understanding of addiction. Our current study showed a growing trend in smoking cessation based on the number of published articles over the last 20 years. There was active cooperation between institutions, and authors. Electronic cigarettes, mHealth, eHealth, public health and mental health are foci of new and emerging research.

1. Introduction

Tobacco use threatens human health globally, as it contributes significantly to poverty, disease, and death (Samet, 2013). Smoking causes morbidity and mortality from lung cancer, respiratory, cardiovascular, and cerebrovascular disease, in addition to several other secondary conditions (Arcavi and Benowitz, 2004; Islami et al., 2015). The burden of smoking is experienced heavily in low- and middle-income countries, which are often targets of intensive tobacco industry interference and marketing (Amul et al., 2021; Berg et al., 2018; WHO, 2011). Globally, there are wide-ranging public health efforts designed to address smoking. These efforts are supported by evidence showing that many of the adverse effects, the years of life lost, and the number of

deaths caused by smoking can be substantially decreased when people reduce or stop smoking (Collaborators, 2018; Jha and Peto, 2014; Koop and Luoto, 1982).

Public health interventions also require scientific evidence obtained through ongoing smoking cessation research. Intervention success depends on studies at various stages with eventual translation into the real-world setting. There has been considerable growth in scientific articles over time (Larsen and von Ins, 2010). Published scientific articles provide a means of creating the evidence base, disseminating knowledge learned through these stages of investigation, and allowing for public health debate. The literature on smoking cessation assists public health entities in establishing appropriate policies. Analyzing published literatures in terms of the quantity, journals, contributing authors, and

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thematic trends across geographical boundaries would provide insights to public health organizations, tobacco cessation researchers, and grant funding agencies on the research advances, challenges, and future directions in this field. Few studies have systematically analyzed the scientific literature on smoking cessation to date, and none within the past decade (Chapman and Derrick, 2012; Cohen et al., 2010; Sanson-Fisher et al., 2008).

Bibliometric analysis aims to use statistical and visual approaches to analyze multi-facet characteristics of a collection of published literature (Broadus, 1987; Okubo, 1997; van Raan et al., 2003). It has been widely used to characterize research activities and discover emerging trends in specific research fields (Guler et al., 2016). Moreover, bibliometric analysis can provide reference proposals during government policy establishment, particularly for determining funding-orientation guidance (Gauthier, 2002; Zhao et al., 2018). This analytical technique can play an important role in creating public health guidelines (Osborn et al., 2007). In this study, we use bibliometric analysis to investigate global trends in the volume, keywords, journals, locations, and authors of tobacco cessation research. Additionally, we provide visualizations of the information to help identify hotspots and emerging trends.

2. Materials and methods

Web of Science is the largest comprehensive academic information resource covering the most subjects in the world, including the most core academic journals in the field of smoking cessation (Pranckut, 2021). A comprehensive search was performed online using the Web of Science (WoS) Core Collection database. In our study, search terms were as follows: ((Title= ("smok* cessation*" or "quit* smok*" or "stop* smok*" or "give up smok*" or "tobacco*use cessation*") OR (Author Keywords= ("smok* cessation*" or "quit* smok*" or "stop* smok*" or "give up smok*" or "tobacco*use cessation*")) AND Language = English (Choi et al., 2021; Giuliatti et al., 2020; Sealock and Sharma, 2022)). The period of article publication was from January 1, 2002 to December 31, 2021. For manuscript types, only the "article" type was included.

We searched the WoS database licensed by the China Medical University on March 9, 2022 and downloaded the full records and cited references of the retrieved 8797 articles in plain text format. This was performed on a single day to avoid daily updating bias since the database remains constantly open. The search utilized public databases, and thus ethical approval was not required (deemed as non-human subject research).

The VOSviewer (1.6.16) software was used to perform data mining, mapping, and clustering of the retrieved publications (Zhai et al., 2017). VOSviewer uses the VOS (stands for "visualization of similarities") mapping technique which produces better structured co-occurrence network maps than another popular multidimensional scaling technique for bibliometrics. Specifically, when constructing a co-occurrence network maps, VOSviewer takes as input a similarity matrix which is created uses a similarity measure known as the association strength (van Eck and Waltman, 2010). It calculates the similarity s_{ij} of two items i and j by $s_{ij} = c_{ij} / (w_i w_j)$ where c_{ij} denotes the number of co-occurrences of items i and j and where w_i and w_j denote the total number of occurrences of items i and j (Eck and Waltman). Once the similarity matrix is created, VOSviewer maps all the items in a two-dimensional map such that items with a high similarity will be located close to each other, while items with a low similarity will be located far from each other. VOSviewer (Leiden University, Leiden, Netherlands) creates maps based on bibliographic data and allows users to visualize and explore the maps (van Eck and Waltman, 2010). First, we used the VOSviewer to extract bibliometric index data including publishing source, publishing institution, author, number of citations, H-index, and keywords. The H-index reflects both citation number and citation impact of publications (Bertoli-Barsotti and Lando, 2017; Bornmann and Daniel, 2009). We used Microsoft Excel 2016 to analyze the top 10 countries, journals, institutions, authors separately; as well as the number of annual

publications, the total number of citations, the H-index, the journal's impact factor (IF). We obtained each journal's 2020 IF, reflecting the mean number of citations to articles published in that journal (Hasaballah, 2020). Then we used VOSviewer to conduct co-occurrence analysis of authors, institutions, and keywords and build visualization maps. The research framework of smoking cessation was shown in Supplement Fig. 1.

3. Result

3.1. Analysis of publication trend and Country distribution

The total number of publications by year is demonstrated in Fig. 1. A total of 8797 publications on "smoking cessation" were published between 2002 and 2021. Overall, the number of publications increased from 190 in 2002 to 598 in 2021. The highest number of publications was in 2019 (638).

The publications came from authors representing 115 countries/regions. The United States had the largest number of publications (4671, 53.1 %), followed by England (1104, 12.5 %), Australia (632, 7.2 %), Canada (590, 6.7 %) and the Netherlands (432, 4.9 %). Fig. 2 shows the number of publications by top 10 countries/regions over time.

3.2. The distribution of journals

A total of 1415 unique journals published research on smoking cessation. The top 10 journals (based on total publication count) published 27 % of the articles (2391, 27.2 %; see Table 1). NICOTINE & TOBACCO RESEARCH (528 publications, IF2020: 4.244, 13,746 citations) published the most publications on smoking cessation, followed by ADDICTIVE BEHAVIORS (393 publications, IF2020: 3.913, 8106 citations) and ADDICTION (341 publications, IF2020: 6.526, 11611 citations).

3.3. The distribution of institutions

Table 2 presents the top 10 contributive institutions by publication counts. The University College London published the most publications (England, 310 publications, 10,069 citations), followed by the University of California San Francisco (USA; 264 publications, 8285 citations) and Brown University (USA; 257 publications, 9514 citations). The Harvard University was ranked highest for the number of citations (10226).

The minimum number of articles published by institutions was set as 25. According to this threshold, 166 productive institutions were included in the network analysis (Supplement table 1). As shown in Fig. 3, the co-authorship network of institutions was divided into 6 clusters. There were active collaborations among the institutions, especially among the institutions in the same cluster.

3.4. The distribution of authors

The ten most productive authors contributed 855 publications (9.7 %) on smoking cessation research. Robert West from University College London, England, contributed the most articles with 184 publications, followed by Ron Borland from the University of Melbourne, Australia, with 88 publications, and Timothy B Baker from the University of Wisconsin System, USA, with 83 publications (Table 3). The author's average appearing year (AAY) indicates that Jamie Brown (AAY:2017) and Billie Bonevski (AAY:2017) have been active in recent years.

The minimum number of articles published by authors was set as 15. With this threshold, we included 227 productive authors in the author network analysis. As shown in Fig. 4, the largest co-authorship network of authors, which consisted of 213 out of 227 productive authors, was divided into 12 clusters (Supplement table 2). It shows active collaborations among these authors, especially those within the same cluster.

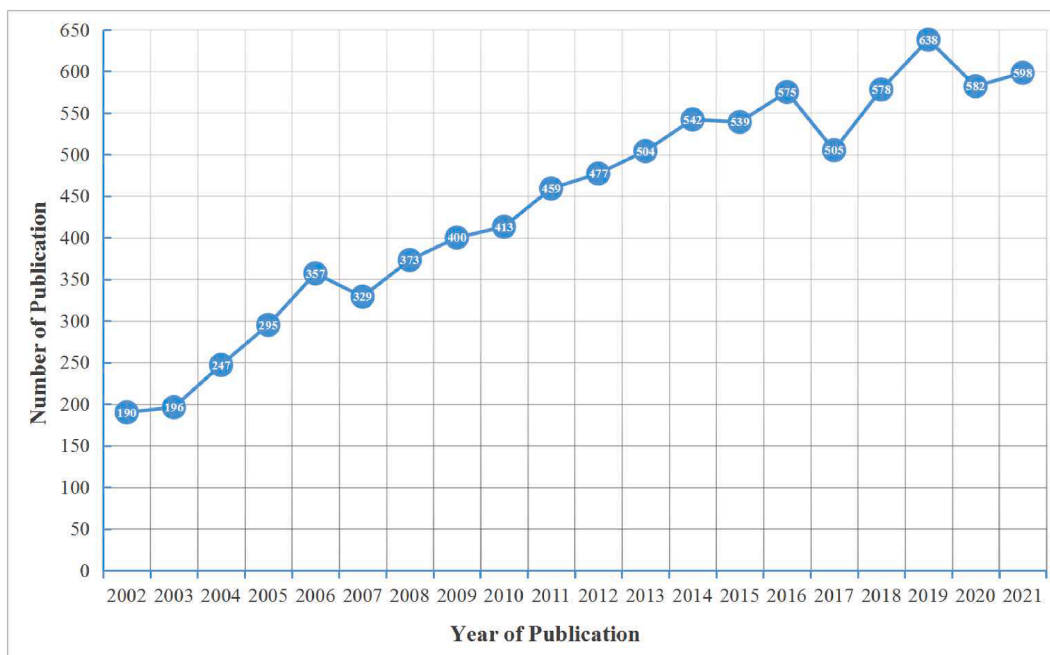


Fig. 1. The annual number of publications in smoking cessation research from 2002 to 2021.

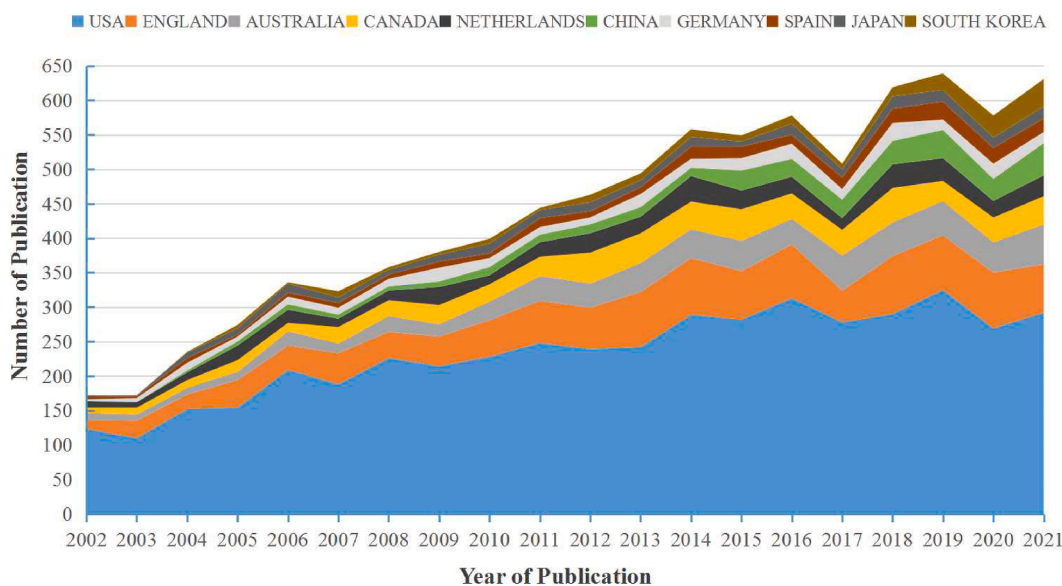


Fig. 2. The top 10 countries/regions of the total number of publications from 2002 to 2021.

Table 1

The top 10 journals in smoking cessation research from 2002 to 2021 based on the total number of publications.

Rank	Journal Title	Country	IF (2020)	Count	Citations	H-index
1	NICOTINE&TOBACCO RESEARCH	England	4.244	528	13,746	59
2	ADDICTIVE BEHAVIORS	England	3.913	393	8106	41
3	ADDICTION	England	6.526	341	11,611	57
4	BMC PUBLIC HEALTH	England	3.295	238	3465	29
5	INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH	Sweden	3.390	208	1928	20
6	PREVENTIVE MEDICINE	England	4.018	186	5134	42
7	DRUG AND ALCOHOL DEPENDENCE	Sweden	4.492	173	4501	35
8	TOBACCO CONTROL	England	7.552	114	4082	37
9	JOURNAL OF MEDICAL INTERNET RESEARCH	Canada	5.428	105	3276	36
10	BMJ OPEN	England	2.692	95	851	14

Table 2
The top 10 most active institutions in smoking cessation research from 2002 to 2021.

Rank	Institution	Country	Count	Citations	H-index
1	University College London	England	310	10,069	54
2	University Calif San Francisco	USA	264	8285	53
3	Brown University	USA	257	9514	56
4	Harvard University	USA	252	10,226	61
5	University of Minnesota	USA	249	7766	47
6	University of Pennsylvania	USA	188	6096	44
7	University of Texas System	USA	165	3253	45
8	University of Toronto	Canada	163	7816	40
9	University Wisconsin	USA	159	7760	42
10	University of Nottingham	England	158	3756	32

3.5. The co-occurrence analysis of keywords

Co-occurrence analysis of different keywords in the scientific literature can be used to assess the correlation between the keywords, reveal the research structure and identify hot topics in the specific field during this period (Liang et al., 2017). In recent years, this technique has been widely used in biological research, drawing increasing attention among medical researchers. We have performed co-occurrence analysis of high-frequency keywords and identified the research hotspots among smoking cessation studies. We identified 96 keywords with a minimum of 30 occurrences (Supplement table 3). These keywords in the publication on smoking cessation research were analyzed using the co-occurrence network analysis tool in VOSviewer and a co-occurrence network map was generated. The map consists of five clusters (shown in 5 colors in Fig. 5). Cluster 1 was the largest, consisting of 26 keywords. Tobacco control, chronic obstructive pulmonary disease, lung neoplasms, public health, and neoplasms appeared most frequently.

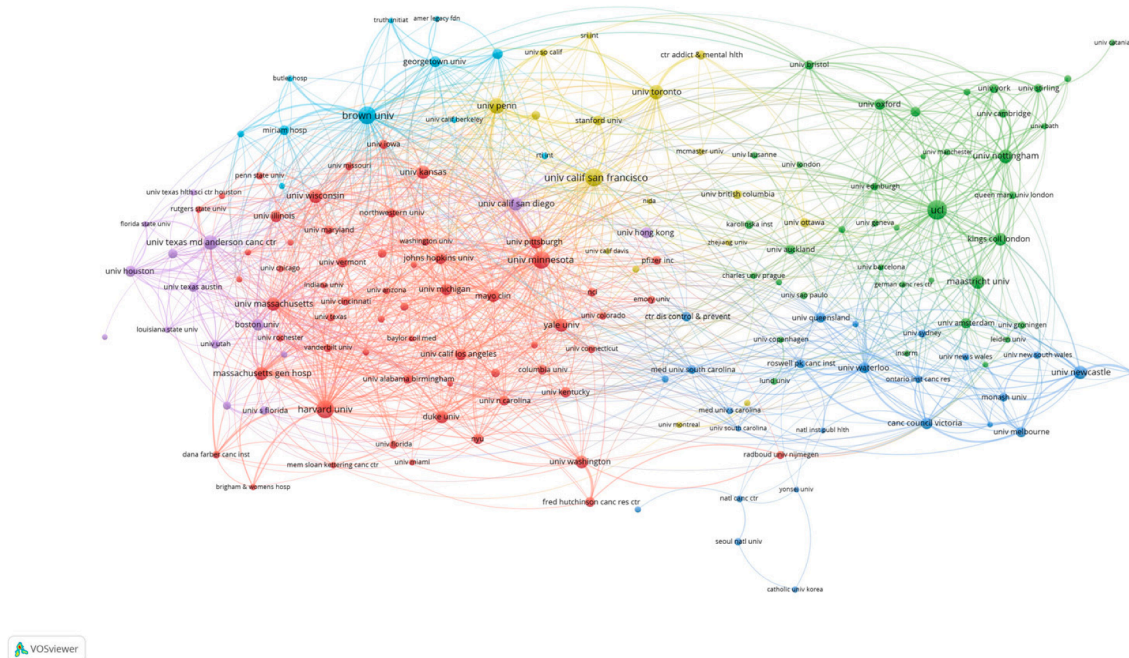


Fig. 3. The Co-authorship network map of leading research institutions in smoking cessation research.

Table 3
The top 20 most active authors in smoking cessation research from 2002 to 2021.

Rank	Author	Country	Institution	Count	Citations	AAY
1	Robert West	England	University College London	184	6538	2013
2	Ron Borland	Australia	University of Melbourne	88	2343	2014
3	Timothy B Baker	USA	University of Wisconsin System	83	2999	2015
4	Jasjit S Ahluwalia	USA	Brown University	82	2659	2009
5	David W Wetter	USA	University of Utah	73	1857	2014
6	Michael J Zvolensky	USA	University of Texas System	70	1309	2016
7	Megan E Piper	USA	University of Wisconsin System	69	2453	2013
8	Nancy A Rigott	USA	Massachusetts General Hospital	69	3124	2016
9	Paul Aveyard	England	University of Birmingham	69	2044	2015
10	Tim Coleman	England	University of Nottingham	68	999	2015
11	Ann McNeill	England	King's College London	65	2051	2014
12	Jamie Brown	England	University College London	63	1891	2017
13	Hein De Vries	Netherlands	Maastricht University	60	1349	2014
14	Billie Bonevski	Australia	University of Newcastle	59	598	2017
15	Saul Shiffman	USA	University of Pittsburgh	58	3328	2009
16	Raymond Niaura	USA	New York University	57	2888	2008
17	Michael C Fiore	USA	University of Wisconsin System	56	2229	2014
18	Paul M Cinciripini	USA	University of Texas	54	1545	2014
19	Andy Mcewen	England	King's College London	52	1308	2013
20	Kenneth Michael Cummings	USA	Medical University of South Carolina	50	1579	2014

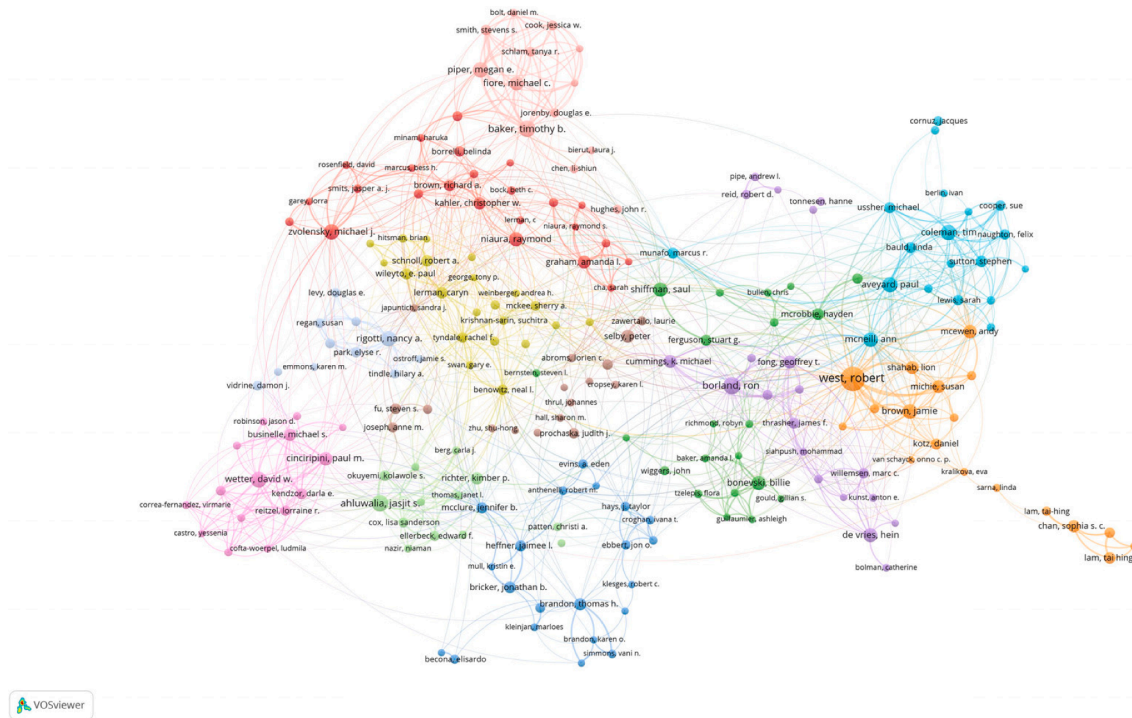


Fig. 4. The Co-authorship network map of leading research authors in smoking cessation research.

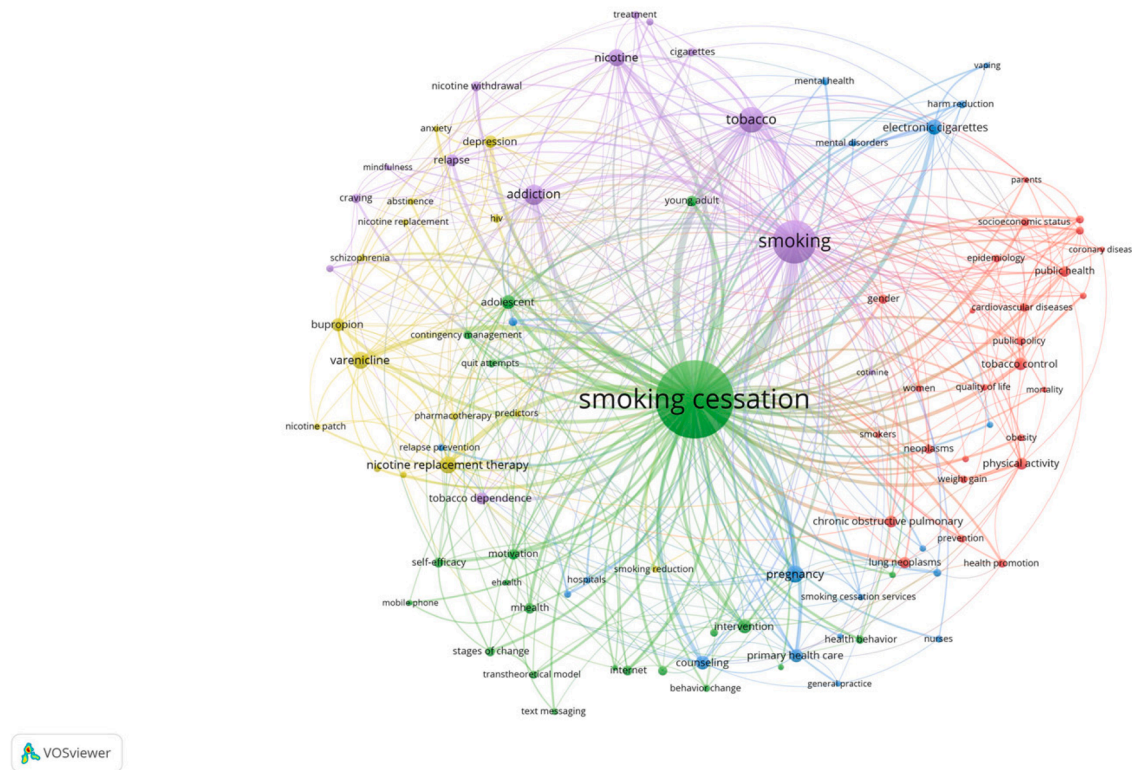


Fig. 5. The Co-occurrence network map of keywords in smoking cessation research.

The average appearing year (AAY) was defined in VOSviewer to estimate the novelty of a keyword (Zhao et al., 2018). Based on the different AAY of keywords, VOSviewer marked it with the different colors (Fig. 6). In this overlay visualization map (Fig. 6), the color bar indicates the AAY value range, and those nearest to the color red

represent keywords that have emerged more recently (i.e., the keywords in purple appeared earlier than those in yellow and red). Bupropion (AAY:2010), adolescent (AAY:2010), and transtheoretical model (AAY:2009) are shown in purple, indicating a decrease in attention to them. We found that electronic cigarettes (AAY:2018), mHealth

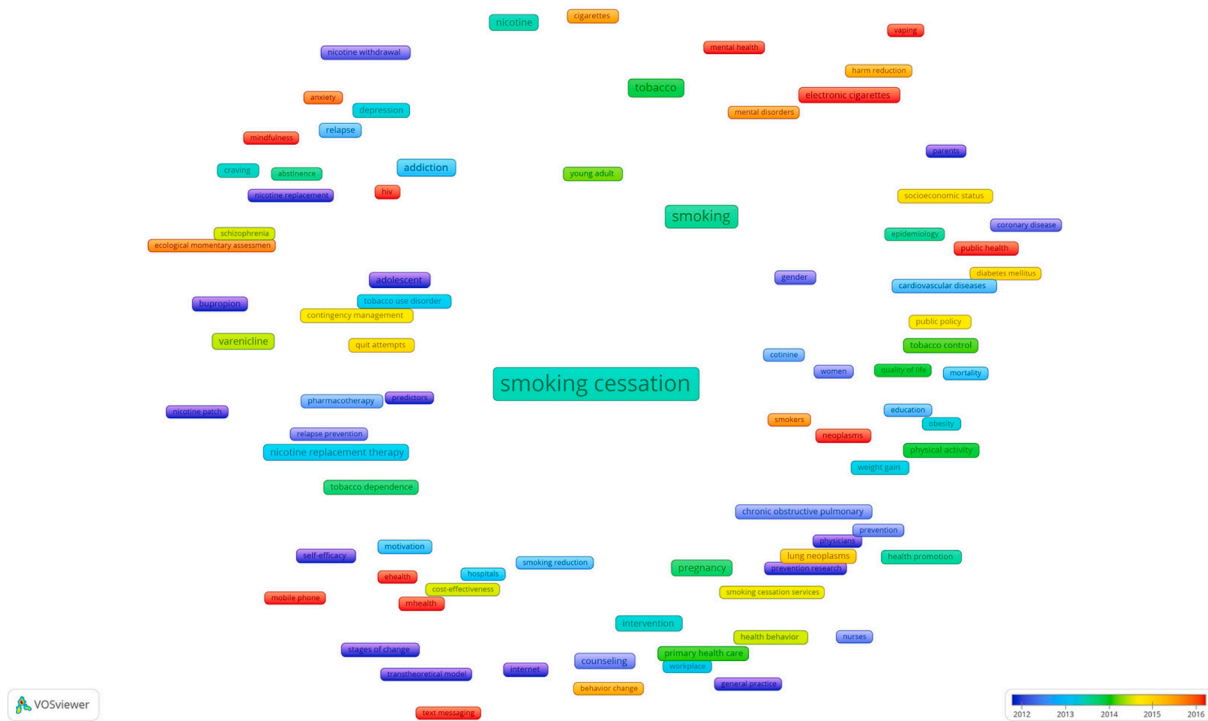


Fig. 6. The overlay visualization map of keywords in smoking cessation research.

(AAY:2018), mobile phone (AAY:2018), eHealth (AAY:2017), public health (AAY:2016), and mental health (AAY:2016) appeared in more recent years compared with others, suggesting new research hotspots in smoking cessation research (Supplement table 3).

3.6. Funding agencies.

In the past 20 years, 5883 articles (66.6 %) have been funded and 2946 articles (33.4 %) have not been funded. The top10 most active funding agencies in smoking cessation research were shown in Fig. 7. The United States Department Of Health Human Services (n = 2744; 31.1 %) has funded the most smoking cessation research followed by the National Institutes Of Health Nih Usa (n = 2663;30.2 %) and European Commission (n = 1528; 17.3 %).

4. Discussion

In this study, we utilized bibliometric analysis to analyze original research articles on smoking cessation published between 2002 and 2021. We found that the number of “Web of Science Core Collection” articles published increased from 755,655 publications in 2002 to 2,132,834 publications in 2021, a growth rate of 1.82. The growth rate of articles in the field of smoking cessation is 2.14 higher than 1.82. We found a growing number of publications for the last 20 years. While the research has arisen from over a hundred countries around the world, at least half of the published evidence comes from the United States. Also, while low- and middle-income countries are not represented in the top 10 lists for journals, institutions, and citations, they are increasing in number with efforts made to expand research productivity (Warner et al., 2014). It is interesting to note that 5 of the top 10 most active institutions are not represented as affiliations of the top 10 most active authors. This shows that the most active researchers in the field are not

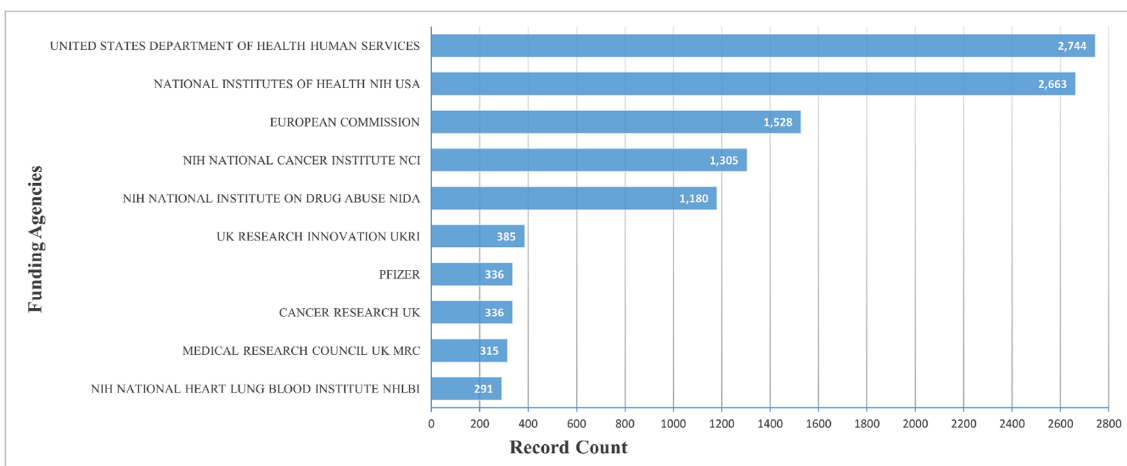


Fig. 7. The top 10 most active funding agencies in smoking cessation research from 2002 to 2021.

all in the most active teams.

Network maps show the relationships between different authors, institutions as well as publication keywords. These maps demonstrate where the most recent evidence lies in smoking cessation as well as the trends over the past two decades. The network maps highlight current and new/emerging areas of research that may lead to public health impact.

Five clusters emerged as “hot topics” based on our bibliometric analysis (Supplement table 3). First, tobacco control, public health, public policy, and second-hand smoke related to public health and population approaches to reducing the impact of tobacco use is one cluster. These studies contribute to established evidence showing that cigarette taxes, smoke-free air laws, marketing restrictions, and comprehensive tobacco control programs play key roles in reducing smoking prevalence (Levy et al., 2018). This cluster includes chronic obstructive pulmonary disease (Chen et al., 2021; Safitri et al., 2021; Wheaton et al., 2019), lung neoplasms (Force et al., 2021; Park et al., 2020; Sheikh et al., 2021), and cardiovascular diseases (DiGiacomo et al., 2018; Duncan et al., 2019; Levin et al., 2021), and epidemiological studies support relationships between smoking and these health outcomes. Additionally, this cluster includes studies on health disparities, including access to quitting resources and cardiovascular health (Vidrine et al., 2013). As a modifiable behavior, there is continued interest in research that uncovers the benefits of smoking cessation on health. Second, electronic health (eHealth) methods are emerging areas of research, including mobile health (mHealth) and smartphone apps. Keyword associations with adolescents and young adults show how technology-based strategies are actively studied in younger populations, often exploiting text messaging, social media, and apps; though most studies still involve adults (Baskerville et al., 2018; Bendtsen et al., 2021; Blitstein-Winicki et al., 2017; Chu et al., 2021). Third, counseling, attitude, tobacco use disorder, and mental health focus on the psychological and behavioral approaches to tobacco cessation, frequently through healthcare providers and organizations. A comprehensive body of scientific evidence, which has grown stronger over time, supports the use of behavioral counseling and pharmacologic interventions for smoking cessation, with the combination of both being the most effective approach (2020). In addition, this research includes involvement of different members of healthcare teams (e.g., nurses) and referrals to evidence-based programs (e.g., Ask-Advise-Refer) (Vidrine et al., 2013). This cluster includes electronic cigarettes, where limited research has been conducted for smoking cessation (recently 3 electronic cigarettes products received FDA approval) (Das, 2019; Kalkhoran et al., 2019; Wang et al., 2021). Numerous studies have compared traditional smoking cessation therapy with electronic cigarettes as an alternative tool for smoking cessation and discussed in depth the safety of electronic cigarettes (Benowitz, 2020; DiSilvio et al., 2021; Grabovac et al., 2021; Rehan et al., 2018; Teriba et al., 2021). Fourth, nicotine replacement therapy and nicotine patch, as well as related mental health issue and relevant treatment/therapy is another cluster. This cluster includes related pharmacy, such as varenicline and bupropion, and pharmacotherapy and various psychological problems in the treatment process. Fifth, addiction to tobacco, nicotine, and alcohol, as well as tobacco dependence and nicotine withdrawal, are the focus of this cluster. This research covers the biological and clinical understanding of addiction, relationships with various concurrent psychological states and other addictions. Furthermore, the bibliometrics analysis showed that electronic cigarettes, mHealth, eHealth, public health, and mental health may represent new research hotspots in this field.

To the best of our knowledge, our study is the first bibliometric analysis on smoking cessation research of the past two decades. Our analysis included the Web of Science (WoS) Core Collection database, thus, the results are relatively comprehensive. However, there are limitations to acknowledge. First, the included studies were in English only. Some related publications in other languages have not been included.

Therefore, it is likely that our results may not be applicable to research published in other languages. Second, some authors may have the same short name and institutions have different abbreviations, which may have caused inconsistencies. However, given the large volume of data, it is likely the impact on our findings would be limited. Similarly, to address synonyms and language variations for keywords, we performed manual standardization (e.g. eHealth vs e-Health) when possible. This process may introduce additional and undesirable variability.

In conclusion, our current study showed a growing trend in smoking cessation based on the number of published articles over the last 20 years. Our study identifies productive countries/regions, institutions, authors, journals, and reveals a global network of collaborations of smoking cessation research. Graphical maps provide clusters of keywords and demonstrate trends in sub-areas of related research. This article provides insights on current status, emerging fields, and future directions in smoking cessation research, and highlights areas that may influence the field and public policy in the near future.

5. Availability of data and materials

Data can be retrieved from Web of Science using search query presented in methodology.

Funding

This work was supported by the National Key Research and Development Program of China [Grant No 2020AAA0109400], and the Foundation of Liaoning Province Education Administration [grant numbers LJKR0273].

CRediT authorship contribution statement

Yingxin Xu: Conceptualization, Methodology, Writing – original draft. **Zhengmin Gu:** Data curation, Writing – original draft. **Ye Zhang:** Visualization. **Miao He:** Investigation. **Ben S. Gerber:** Writing – review & editing. **Rajani S. Sadasivam:** Writing – review & editing. **Feifan Liu:** Writing – review & editing. **Zhongqing Wang:** Conceptualization, Writing – review & editing, Supervision.

Declaration of Competing Interest

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

Data availability

Data will be made available on request.

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