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MiniReview

Infodemiology as a Powerful Tool in Public Health: Bridging the Digital Divide for Better Well-being

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Abstract

Infodemiology, an emerging interdisciplinary field situated at the confluence of information science and epidemiology, has experienced significant growth in recent times. Playing a crucial role in epidemiological surveillance, infodemiology provides a supplementary perspective to conventional data sources. By monitoring variations in search volume over time, infodemiology researchers can discern shifts in public attention, emotions, or awareness pertaining to diverse health issues. This enables the timely detection of potential epidemics, emerging health concerns, or alterations in public consciousness, facilitating a more proactive approach to public health responses. Several tools, particularly Google Trends, are integral to the functioning of Infodemiology. Leveraging internet search intent, Google Trends can map population-wide public interest, utilizing extensive data sets across temporal and spatial dimensions to infer trends in disease prevalence. This paper presents a review of the diverse applications of Infodemiology in modern public health disease surveillance, highlighting the utility of Google Trends as a powerful tool within the Infodemiology framework. Advantages and limitations of Infodemiology are also examined. Through this review, we aim to elucidate the transformative potential of Infodemiology in bridging the digital divide for improved well-being.

Keywords: information science, public health response, emerging health issues, internet search intent, public awareness fluctuations

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1 INTRODUCTION

The increased affordability, accessibility and penetration of internet services have significantly transformed the modalities by which people procure information about health-related issues. The rapid proliferation of information and communication technology tools has led to an era of unprecedented accessibility to vast repositories of information, particularly through online communication channels and social media platforms. This access to information empowers people to make informed decisions about their health and well-being. According to the Digital 2023 global overview report, 64.4% (5.16 billion people) of the world's total population use the internet, with 4.76 billion being active social media users[1]. Between 63% and 80% of internet users, across different countries, browse the internet for health care support and knowledge[2,3]. This realization prompted the understanding that internet information can help identify risk markers and estimate disease activity within the community, giving rise to the concept of 'Infodemiology'. The term 'Infodemiology', a synthesis of informatics and epidemiology, was officially introduced by Gunther Eysenbach in 2002[4]. It refers to the science of the distribution and determinants of information in an electronic medium, specifically the internet, or in a population. Its ultimate aim is to inform public health and public policy[5]. Recently, Infodemiology gained further recognition as a critical field of study and formal practice, particularly in the context of the ongoing COVID-19 pandemic. In June 2020, the World Health Organization (WHO) held its first Infodemiology Conference to review relevant research, effective practices and define public health research needs to advance this field[6]. To date, various foundational concepts of Infodemiology have been put forth providing a framework for analyzing the dissemination and reception of health information. Eysenbach introduced the concepts of supply-based[4] and demand-based[7]. Infodemiology, contrasting their focus on the provision or uptake of information, respectively. Supply-based Infodemiology examines the quantity and quality of information available on the Web, including the number of websites, media reports, and blogs related to vaccinations, as well as the level of quality (e.g., positive or negative portrayals of vaccines)[8]. Today, the framework of supply-based Infodemiology may be more robust than its initial conceptualization, which primarily centered on what was published, particularly in terms of measuring or analyzing the quality of health information[9]. In contemporary times, supply-based Infodemiology places equal emphasis on the manner in which information is adapted, translated, published and republished. This necessitates a reflective comprehension of sociocultural dynamics influencing trust and influence. This is in addition to technical considerations such as automated responses or adaptations, communication timing and real-time monitoring.

On the contrary, demand-based Infodemiology examines patterns in people's search behaviors when seeking information on the Web, such as the increase in search activities in response to related news reports[8]. Today, methods and applications in demand-based Infodemiology have become more diverse and robust[9]. While search and click measures still provide foundational insights, the more advanced tracking of a user's complete online journey, including smartphone searches and app usage, offers numerous avenues for investigating and monitoring information-seeking behaviors. It is hypothesized that the need for novel approaches in consumer and public health informatics to evaluate information epidemiology, characterize health information, and analyze communication patterns in electronic media will persist, irrespective of supply and demand methodological advancements.

Web-based data mining has had a revolutionary impact on understanding global health problems and people's behavior, offering the advantage of "large sample and high efficiency" compared to traditional epidemiological survey sources. Traditional epidemiological data collection methods, such as demographic health surveys, cohort studies, and registries, often take years or decades to allow policymakers to understand the public health impact of decisions. However, health care information generated by social media can be analyzed in real time to track and aid in health policy development. Typically, people search for relevant information online before seeing a doctor. Based on this fact, in-depth analysis of big data from these networks can aid in understanding changes in the search popularity of disease-related keywords and the health issues that concern people. This information can be used to predict fluctuations in infectious diseases and chronic non-communicable diseases.

Infodemiology, at the intersection of information science and epidemiology, has emerged as a potent tool for uncovering dynamic health patterns. It can monitor people's status updates on social networks, track symptoms and assess the effectiveness of health promotion activities. Also, Infodemiology predicts and analyzes disease outbreaks through internet search volume, discovers patterns of linkage between population health and network information changes, and establishes robust epidemiological models. Recent demonstrations have highlighted the significant role of social media and network-based (real-time) data in analyzing and forecasting certain illnesses, epidemics, and outbreaks[10-14]. This paper presents a review of the diverse applications of Infodemiology in modern public health surveillance. The paper highlights the utility of Google Trends as a powerful tool within the Infodemiology framework, utilizing vast internet search data to unveil population-level trends in disease prevalence and public interest. Additionally, it discusses the role of Infodemiology in disease surveillance, underscoring the importance of digital epidemiology methods in contemporary public health. Advantages and limitations of Infodemiology are also examined. Through this review, we aim to elucidate the transformative potential of Infodemiology in bridging the digital divide for improved well-being (Figure 1).

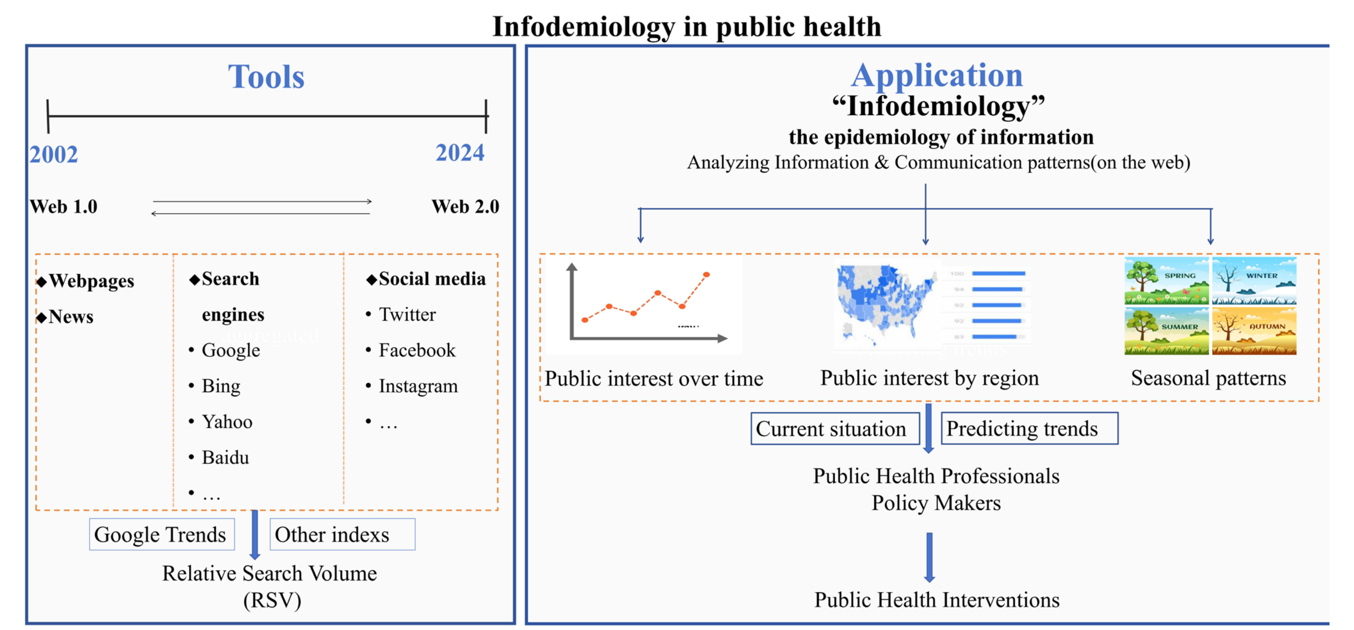

Figure 1. Infodemiology in public health.

2 GOOGLE TRENDS AND PUBLIC INTEREST

Infodemiology relies on diverse digital data sources, such as search engines, social media platforms, health forums, and online news articles. These sources offer large-scale, real-time data on user-generated content, enabling researchers to capture and analyze information-seeking behavior. Popular social media data sources in Infodemiology include Twitter (X)[15], Facebook[16], and Instagram[17]. Queries from search engines are primarily retrieved by Google Trends[18], as well as Yandex[19], Baidu[20], Bing[21], and Yahoo[22]. Other notable sources include websites and platforms[23,24]: blogs, YouTube, forums, and online communities. According to Statista, as of July 2023, Google dominated the global search engine market, with a share of approximately 83.49%, compared to Bing (9.19%), Yahoo (2.72%), YANDEX (1.9%), Baidu (0.51%), and DuckDuckGo (0.77%)[25]. Therefore, Google represents a larger portion of the population compared to other search engine data providers, and search query analysis provides insights into public interest and information-seeking behavior.

Over time, Infodemiology has embraced sophisticated techniques, including natural language processing, machine learning, and social network analysis, to extract meaningful insights from vast and unstructured digital data. Nonetheless, Google Trends remains the most crucial tool in Infodemiology. It is a data platform based on user search behavior that provides information on the popularity of a specific keyword in cyberspace at a given time. By analyzing the popularity of search queries, researchers can identify temporal patterns, regional variations, and emerging trends related to health topics. The level of public interest, reflected in the increasing searches for specific health topics, can serve as an early indicator of health events. Tracking changes in search volume over time enables Infodemiology scientists to identify fluctuations in public attention, emotions, or awareness related to various health issues. This process aids in detecting potential epidemics, emerging health issues, or changes in public awareness, facilitating more proactive public health responses.

Google Trends has evolved into a potent and versatile tool within Infodemiology. It is both aggregated (grouped together), categorical (determines the subject of a search query), and anonymous. Providing an index known as relative search volume (RSV), Google Trends facilitates comparisons between terms, time frames, and locations. The standardization of search data by Google Trends simplifies comparisons between terms, with an RSV value of 100 indicating the highest search volume during the selected period and 0 representing the lowest. Additionally, Google Trends automatically scales RSV based on population size enabling comparisons between densely populated and under populated areas. This tool presents two query modes: "term", displayed in a given language, and "topics", illustrating groups of terms that share the same concept in any language. Further, Google Trends offers two types of related topics: "Top related topics" and "Rising related topics". The extraction of RSV from Google Trends serves to analyze the public interest. For example, a study compared the monthly RSV of Google keywords related to peripheral nerve surgery between two periods (2010-2014 vs. 2018-2022), revealing an RSV increase of more than 10 percentage points in the latter period compared to the previous period[26]. This result reflects a growing public interest in these clinical entities and surgical techniques addressing these issues.

3 IDENTIFYING ENVIRONMENTAL AND GEOGRAPHIC RISK FACTORS THROUGH INFODEMIOLOGY

Infodemiology represents a paradigm shift, employing its methods to ascertain the seasonal patterns and regional differences in disease incidence rate. An analysis of Google Trends in Poland revealed seasonal variations in public interest related to lifestyle behaviors. Specifically, the sales index of consumer goods like dairy products, meat, alcohol, and cigarettes exhibited seasonal fluctuations. There were seasonal variations in the public interest regarding terms such as "running", "diet", "dietary supplements", "nutritionists", and "weight loss"[27]. Furthermore, searches for various diseases, including osteoporosis and skin diseases, demonstrated seasonality[28,29]. Research in the United States indicated a significant seasonal pattern in search intentions related to depression, with the lowest instances in summer and the highest in spring[30]. The seasonal trends identified through Google Trends offer valuable insights for biologists to explore deeper into the mechanisms of depression. Clinicians can enhance disease diagnosis and treatment plans during high-incidence seasons. Simultaneously, respective governments, communities and other stakeholders should allocate more medical resources and optimize the healthcare system to better cater to the needs of patients. Public health workers ought to intensify educational campaigns, including media initiatives, health education programs, and community lectures, to raise public awareness about seasonal trends in depression and encourage individuals to seek professional help at an earlier stage.

Concerning geographical risk factors, states with severe air pollution have been shown to exhibit higher levels of depression search intentions compared to states with cleaner air, aligning with previously depression[30,31]. Another study showed that individuals from diverse nations displayed varying interests in the RSV for COVID-19, with the focus of attention on the virus varying across each nation's sub-regions[32]. The interest in MitraClip, a treatment for severe functional mitral valve regurgitation, was analyzed using Google Trends data from 11 European countries. France showed the highest monthly interest growth rate, followed by Poland, Spain, and Italy, with growth rates of 40.5%, 35.9%, 37.3%, and 31.8%, respectively[33]. Disparities in public interest in a specific disease across countries may suggest variations in the prevalence of the disease, which could be linked to several factors. First, differences in socioeconomic conditions, including income level, education level, and employment status, may have an impact. Second, dietary patterns and lifestyles in different countries may influence diseases, necessitating research into aspects such as diet, food supply chains and urban planning. Third, cultural and social factors about a disease, including customs, social pressure, and aesthetic concepts may also play a role. Fourth, genetic and biological factors contribute to diseases, with genetic variation among populations in different countries playing a crucial role in disease pathogenesis. Lastly, variation in medical service systems, health education levels and disease intervention measures across different countries may also play a role. This can help identify which countries' health systems and health education campaigns may be more effective in addressing specific health problem.

4 APPLICATIONS OF INFODEMIOLOGY IN DISEASES

4.1 Infectious Diseases

Infodemiology establishes sentinel surveillance systems using digital data to monitor and detect health-related events. These systems provide a real-time overview of population health indicators and can be instrumental in early warning systems for infectious diseases and other public health crises. Previous studies have explored the concept of Infodemiology and infectious diseases. For instance, a study reported a delay of up to two weeks between the onset of the disease and the compilation of data into traditional monitoring reports[34]. This delayed reporting limits the ability of traditional monitoring systems to provide timely epidemiological information, delaying health officials' responses to potential outbreaks[35]. Ginsberg et al.[36] demonstrated the superiority of Google Trends in predicting the spread of influenza. Their study showed that Google Trends predicted the spread of influenza earlier than the Centers for Disease Control and Prevention. Eysenbach[7] reported a Pearson correlation coefficient of 0.91 between the click-through rate of keywords in Google and the influenza data for Canada's 2004/2005 flu season, with a lag of approximately one week. Zhang et al.[37] observed similar trends between weekly flu case numbers and weekly Google Trends in Brisbane and the Gold Coast, providing a prerequisite for using internet search indicators to build monitoring and early warning systems. Another study analyzed the associations between Google flu surveillance and flu-related emergency department visits in 19 United States (US) cities over seven flu seasons, aiming to measure the effectiveness of Google flu surveillance. The results indicated that at the city level, Google flu surveillance peaks were closely associated with emergency department flu-related visits[38].

To provide timely and effective responses to the next epidemic, numerous studies have utilized internet data to achieve near-real-time detection and even prediction of virus spread, such as COVID-19 pandemic, norovirus, varicella and human immunodeficiency virus (HIV). A study evaluating the association between official notifications of 64 infectious diseases and 164 internet search terms in Australia revealed a significant correlation between notifications of 17 infectious diseases and selected search terms[39]. Recently, Bragazzi et al.[40] assessed the association between Google search volume and plague outbreak in Madagascar. The authors reported a significant positive correlation between Google Trends search data and confirmed, suspected and probable cases. Ornos et al.[41] showed that HIV search volume was positively correlated with the disease prevalence and negatively correlated with GDP and the number of doctors. This result demonstrated the need to improve the quality of HIV-related health information to improve health-seeking behaviors in countries with higher HIV infection rates.

Given the extensive disease transmission and prolonged transmission period observed with COVID-19, predicting its transmission proves highly beneficial for health resource management. This is especially crucial for deploying medical equipment and personnel, as well as formulating public health preventive measures[42]. However, models estimating the number of infections, the peak time for new cases, and the epidemic pattern still exhibit significant variation. Such models strongly rely on the number of confirmed illnesses, a key limitation being that if patients exhibit mild symptoms or are asymptomatic, they may not undergo COVID-19 testing. Consequently, the number of confirmed cases may only reflect those seeking medical treatment with moderate to severe symptoms. In light of this, online search data reflects the public's interest in COVID-19, encompassing individuals with various symptom severities, including those with moderate to severe symptoms, those with mild symptoms and those without symptoms. Studies have shown that web search data tends to increase before common COVID-19 symptoms manifest[43-45]. Consequently, such data can identify new fluctuations or spikes in the early phases of an outbreak, providing real-time indications of symptoms in the population. Rabiolo et al.[45] submitted that COVID-19 epidemic projections could be enhanced by incorporating digital web search data into statistical models. In their study, the authors employed both standard COVID-19 indicators and symptom-based Google Trends queries. Google Trends can serve as a tool to track public opinion regarding vaccination initiatives. During COVID-19 vaccine programs for instance, a study carried out in the US revealed that as the vaccination rate increased, searches for vaccine-related information peaked and then declined as vaccine supply grew[46].

4.2 Mental Health

Google Trends provides data about online queries by automatically anonymizing user information, thereby reflecting user input queries and representing actual behavior rather than user- declared preferences[47]. Given these facts, Google Trends possesses a natural advantage in predicting sensitive health topics such as anxiety, depression, mental disorders and suicide[48]. A study involving 202 countries found a correlation between the United Nations Happiness Index and country-RSVs for anxiety (r=0.39) and happiness (r=0.17)[49]. Wang et al.[30] revealed that from 2010 to 2021, Google search intentions for depression in the US increased by 67%, with an expected additional increase of 7.4% by 2025. Another study discovered a strong, albeit varying lag, relationship between the search volume for 31 terms and the suicide rate[50]. Notably, three terms, namely, "layoff" (lag-2), "anxiety disorder" (lag-3) and "generalized anxiety disorder" (lag-3) exhibited significant positive correlations with suicide rates[50].

Google Trends has the ability to examine the window of time during which search terms are most frequent. Literature show that searches for "suicide" and "depression" usually occures on weekends, especially late at night[51]. Such information indicates the necessity of providing psychological assistance calls during weekends and late-night hours. Despite numerous studies on Google search data and suicide, several potential pitfalls exist. Firstly, most searches for suicide-related terms are conducted by individuals who have experienced or considered suicide, forming the basis for using Google search data to predict suicide in the population. However, interest regarding suicide news stories, particularly following a celebrity's death, may drive search traffic. Secondly, it remains uncertain to what extent Google searches are a necessity for those contemplating suicide or experiencing poor mental health. These limitations have the potential to significantly impact the reliability of utilizing Google search activity in mental health studies.

4.3 Other Diseases

With the continuous improvement of Infodemiology theories and methods, scientific researchers have expanded their focus from infectious diseases to general diseases. Many diseases are mainly caused by occupational and environmental factors, lifestyle and behavioral exposures, such as tumors, cardiovascular diseases, and chronic obstructive pulmonary diseases (COPD). Foroughi et al.[52] identified a seasonal trend in cancer, suggesting an increasing need for information, medical services, or care for cancer, especially in October or near October. In addition, hospitalizations for six different cardiovascular diseases (cardiac dysrhythmia, stroke, myocardial infarction, coronary artery disease, heart failure, atrial fibrillation) showed moderate to strong correlations with online search data in the US[53]. A study in Singapore revealed a curved pattern in COPD search volume from 2004 to 2020, followed by a negative linear trend from 2004 to 2006 and a positive linear trend from 2007 to 2020. The COPD search volume was positively correlated with

COPD burden indicators[54].

A community's overall social capital and cohesiveness together explain a large portion of the variation in health outcomes. Leyland found that a community's overall psychological traits were a better indicator of disease risk than any one person's self-report[55]. Using a dataset of 10 million Twitter (now X) messages, a study described the correlation between community psychological characteristics and atherosclerotic heart disease mortality. The result showed that, in terms of the predicting atherosclerotic heart disease mortality, the Twitter language model was significantly better than the model combining 10 demographic, socioeconomic, and health risks (including obesity, hypertension, smoking and diabetes)[56]. This result further suggests that, data from social media platforms like Facebook and Twitter might be considered an addition to traditional monitoring methods and epidemiological research.

5 ADVANTAGES AND LIMITATIONS OF INFODEMIOLOGY

Infodemiology enables the integration of diverse data sources, including search engine queries, social media posts, and website content. This diverse data provides a more comprehensive view of health-related information and trends, offering valuable insights for public health decision-making, such as designing intervention measures and allocating resources.

Several advantages exist:

First, Infodemiology facilitates real-time monitoring of health-related information on the internet, allowing for the early detection of emerging health events and outbreaks. In essence, it complements traditional disease surveillance systems by offering early warning signals for potential disease outbreaks or health threats. This enables prompt responses, reducing morbidity and mortality rates and enhancing health-related plans and regulations for illness prevention and health promotion.

Second, Infodemiology leverages the global reach of the Internet to overcome issues of resources, time, and physical location, enabling the monitoring of health-related information in different geographic regions. This fosters a more comprehensive understanding of global health trends.

Third, by examining social mediaand other online platforms, Infodemiology provides insights into public sentiments, concerns, and perceptions related to health issues. This understanding may help craft targeted public health messages to address specific issues and improve health literacy.

Fourth, it provides data about online queries by automatically anonymizing user information. Similarly, its data represents user input queries, reflecting actual behavior rather than user-declared preferences. Therefore, it can provide readily available data on sensitive health topics such as acquired immune deficiency syndrome, mental disorders, suicide and illegal drugs.

Fifth, traditional epidemiological studies can be resource-intensive and time-consuming, whereas Infodemiology offers a cost-effective alternative by utilizing existing online data sources, reducing the need for extensive fieldwork and surveys.

Despite the advantages, Infodemiology is not without limitations:

First, there are no established methodological frameworks, resulting in a lack of standard analysis and reporting methods, such as selecting appropriate keywords, regions, periods, and categories. This inconsistency may lead to different terms having the same meaning, the same term having different meanings, and various abbreviations. For example, Google Trends data is referred to as RSV, search volume, online queries, online search traffic data, normalized click through volume, and other terms. Future studies should focus on creating specialized methodological frameworks for Google Trends studies to ensure uniformity in analysis and reporting methodologies.

Second, online data may not represent the entire population, as it may exclude individuals who cannot access the internet or participate in online discussions. Areas with low internet penetration or limited freedom of speech may yield less effective results from online queries, creating a digital divide that distorts the representativeness of certain populations.

Third, false information and rumors can quickly spread, affecting data quality. News reporting and unexpected events can also impact result effectiveness. Amid the persistent COVID-19 pandemic, we encounter substantial volumes of information daily. The WHO characterized this phenomenon as an "infodemic", denoting the widespread dissemination of inaccurate or deceptive information during a pandemic. Numerous algorithms for identifying fake news had been presented thus far, encompassing both conventional machine learning and deep learning models[57]. An ensemble multi-classifier was developed using a multilayer perceptron and trained with features derived from the aggregated outputs of binary classifiers based on deep learning for the ultimate classification process[58]. Chung et al.[59] had developed and validated a novel deep learning method to detect false information. This method was based on social and psychological theories, using deep learning and data-centric expansion to enhance false information detection. Phan et al.[60] provided a graph neural networks taxonomy-based fake news detection taxonomy. Although there had been studies using machine learning and deep learning to identify fake news, the current technology was not mature enough[57,61].

Fourth, the dynamic nature of online platforms and information dissemination poses challenges in distinguishing between transient epidemics and persistent health issues.

Fifth, the normalized nature of retrieved data prevents obtaining the exact number of queries, limiting data processing and analysis.

Sixth, while Infodemiological data can demonstrate correlations between variables, establishing causal relationships is often challenging. Validating the causal relationship between online discussions and real-world health outcomes requires additional scrutiny. Integrating Infodemiological findings with traditional epidemiological methods is complex and may necessitate collaboration across diverse fields. Understanding and addressing these limitations is essential for responsible and effective use of Infodemiology in public health research and decision-making. Researchers must carefully consider these challenges when interpreting and applying findings from Infodemiological studies.

6 CONCLUSION

In conclusion, this review underscores the transformative potential of infodemiology in enhancing our comprehension of population health. Monitoring the dissemination of health-related information online serves as an early warning system for emerging health threats, enabling swift and targeted public health interventions. Meanwhile, researchers can identify patterns of potential social, economic, or cultural factors that affect health outcomes. This deeper understanding can inform the development of more effective public health strategies and interventions tailored to specific population needs. Future researchers should innovate research methods, incorporate new data sources, conduct multimodal research, and explore new methodological methods linking infodemiology with health education, promotion, intervention, and policy.

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Authors Contribution

Pan H and Wang P designed the study. Zhao C and Musonye HA drafted the initial manuscript. All authors reviewed the drafted manuscript and approved the final version.

Conflicts of Interest

The authors declare no conflict of interest.

Abbreviation List

COPD, Chronic obstructive pulmonary disease
HIV, Human immunodeficiency virus
RSV, Relative search volume
WHO, World Health Organization

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