

Bibliometric Analysis of the Global Research Landscape on Healthcare Resilience During Critical Events

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Abstract

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Over the past decade, natural and human-caused disasters have increased in frequency and intensity, resulting in significant human losses and the widespread deterioration of health. These critical events threaten the healthcare sector, making it challenging to operate safely and continuously. This paper aims to review and assess the international scientific landscape on healthcare resilience during critical events. The research was based on scientific documents published in high-quality scientific journals indexed in the Scopus database. The search for relevant documents was conducted by using the keywords 'critical events, healthcare, and resilience' in the titles, abstracts, and keywords of the articles. The research sample comprises 720 publications in the fields of medicine, psychology, nursing, and health. The study period covers 2000-2023 (to 1 June 2023). This study followed a logical sequence to achieve its research goal. The first stage involved searching for, collecting, and pre-processing relevant articles. Next, various bibliometric techniques were used to analyse and visualise the findings. The bibliometric analysis involved the biblioshiny and VOSviewer 1.6.16 software toolkit and Scopus analytical tools. In the third stage, the results were integrated, and directions for future research were discussed. The bibliometric analysis reveals a growing trend in research on healthcare resilience during critical events. The findings determined that the key themes in the analysed scope of scientific literature are resilience, climate change, and emerging research areas. Furthermore, the research emphasises the need for further investigation into strengthening healthcare resilience during human-caused critical events such as crime, terrorism, wars, and cyber-attacks, which have been on the rise. The theoretical implications of the paper contribute to understanding the patterns and developments in the scientific literature, while the practical implications offer guidance for conducting bibliometric analyses and insights for future research. It should be noted that the

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findings of this study are limited to data from the Scopus database; future studies should incorporate a broader range of data sources for a more comprehensive analysis.

Key words

healthcare resilience, biblioshiny, bibliometric analysis, critical events, scientific output.

Introduction

Natural (floods, earthquakes, storms, hurricanes, etc.) and human-caused (crime, terrorism, wars, cyber-attacks, etc.) disasters have been steadily rising, displaying an upward trend in frequency and intensity over the last decade. Intense urban development has resulted in the rise of the frequency and severity of climate change, extreme weather events and natural hazards (Zhang et al., 2023; Kwilinski et al., 2023; Kuzior et al., 2022). This phenomenon has been demonstrated to negatively impact vital infrastructure systems such as water and sewage treatment, transportation, and power supply (Murray and Ebi, 2012; Kwilinski et al., 2023; Pimonenko et al., 2015). Meanwhile, the rush of medical technologies makes healthcare more dependent on the energy sector (Ziabina et al., 2021; Dzwigol et al., 2023; Ziabina et al., 2023; Coban et al., 2023; Kotowicz et al., 2022; Us et al., 2021; Drożdż et al., 2021; Lyulyov et al., 2021). In this view, considering the vulnerability of the healthcare sector to interruptions in the energy system (Polcyn et al., 2022; Kharazishvili et al., 2021; Gavkalova et al., 2022), climate change, extreme weather events, and natural hazards endanger (Hussain et al., 2021; Pimonenko et al., 2017) the ability of healthcare to operate safely and continuously (Klinger et al., 2014).

It stands to reason that the energy crisis provokes disruptions in the pharmaceutical industry supply chain (Kostyrko et al., 2021; Lyulyov et al., 2021; Miśkiewicz et al., 2021; Dzwigol et al., 2023; Melnychenko et al., 2021; Kwilinski et al., 2023; Miśkiewicz, 2020). Moreover, the Russian war against Ukraine has intensified the global energy crisis and

dramatically increased energy costs. The above has created the risk of power cuts that may make it impossible to produce active pharmaceutical ingredients and medicines locally. The soaring costs of energy, labour and raw materials in other regions can also impact drugmakers as they navigate the balance between securing their supply chains and maximising profits (Kuzior et al., 2021; Miśkiewicz, 2022; Kwilinski et al., 2023; Miśkiewicz, 2018). This leads pharmaceutical companies to reassess their strategies and potentially make adjustments to maintain profitability while ensuring a reliable supply of medicines (Dukart et al., 2022).

Owing to the COVID-19 pandemic, national governments have allocated significant funds to vaccination programs, strengthening healthcare infrastructure and staffing (Smilianov et al., 2020; Lyulyov and Moskalenko, 2020). However, the global economic slowdown has disrupted their plans to maintain or increase spending in order to address non-COVID healthcare backlogs and staffing issues (EIU, 2022). According to the EIU (2022), total healthcare spending (in both the public and private sectors) is predicted to increase by 4.9% in nominal US dollar terms in 2023. However, considering inflation, spending would decline in real terms. Consequently, healthcare providers must inevitably reconsider service provision, potentially reducing non-essential services and increasing waiting lists. OECD data suggests that preventive care and pharmaceuticals were most affected by spending cuts following the global financial crisis of 2008-09, and

a similar pattern is anticipated (Kirigia et al., 2011). Despite this, recruiting and retaining healthcare personnel will prove challenging as wages also decrease in real terms.

Critical events often result in human losses and deterioration of health requiring immediate and adequate medical care. Overall, healthcare institutions and emergency services must cope with the abrupt inflow of patients during external critical events, which expose the entire system to the risk of collapse (Arefieva et al., 2021). However, the healthcare sector faces criticism due to its high cost and poor performance, with particular concerns surrounding hospital emergency departments. These departments are grappling with limited resources while experiencing a growing influx of patients. Previous research indicates that most emergency departments would struggle to cope with the demands in the event of a major disaster, and even under normal circumstances, some departments are already operating near maximum capacity (Xiao et al., 2012). In this view, the critical events prove the unpreparedness of the healthcare sector for such a burden and the slowness of the response to emergencies. Thus, there is an urgent need to strengthen healthcare resilience and encourage the health workforce as an integral part of any sustainable healthcare system (Durand-Moreau, 2022).

The abovementioned factors have shown that the healthcare sector faces different challenges resulting from critical events, whether natural, biological, or human-caused. In turn, the preliminary analysis of the scientific treatises has revealed a theoretical gap, namely the absence of comprehensive research on healthcare resilience during critical events.

The aim of this paper is to review and assess the international scope of scientific literature addressing healthcare resilience during critical events. The initial data were retrieved from the Scopus database, which is considered to be the largest multi-disciplinary database. The publications search was run using the keywords 'critical events, healthcare,

and resilience' in the titles, abstracts, and keywords of articles. Since the critical events could be defined differently (e.g. extreme events), the search of publications does not specify the type of such events. The study provides quantitative and qualitative insights into the general landscape of the theory addressing healthcare resilience to critical events to elaborate on the meaningful overview of academic interest in developing the theory of healthcare resilience during critical events. The study makes theoretical contributions by identifying directions for future research into developing healthcare resilience during critical events.

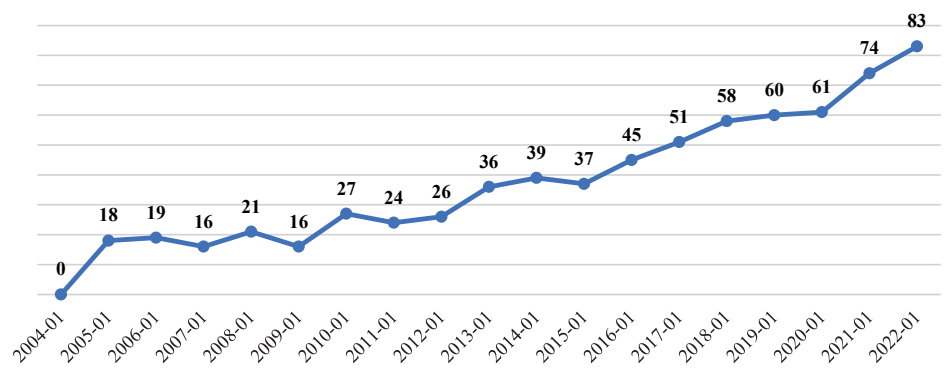
The structure of this paper is as follows: the introduction presents the research problem and the necessity of analysing the scope of scientific literature addressing healthcare resilience during critical events; the literature review section displays the preliminary findings of the scientific literature analysis on the investigated topic; the methodology section provides the material and methods involved in this study for achieving the research aim; the research results section refers to the results of bibliometric analysis; and the concluding section discusses the related conclusions and suggests directions for further research.

1. Literature review

The analysis of web research shows that web searches for 'resilience' in healthcare by global netizens increased by 4.2 times in January 2023 when compared to January 2005 (Figure 1). At the same time, netizens were mostly interested in searching for information on stress resilience, resilience health, mental resilience, emotional resilience, resilience care, building resilience, coping, etc. Considering the general web search requests over the last five years (2018-2023), the summary shows that the topics of climate resilience, stress resilience, mental resilience, business resilience, emotional

resilience, community resilience, cyber resilience, and disaster resilience are gaining popularity in the global web environment (Google Trends, 2023).

Figure 1. The dynamics of web searches for ‘resilience’ in healthcare (January 2005-2023)



Source: developed by the authors using the Google Trends web tool

According to the Google Books Ngram Viewer data (2023), the term ‘resilience’ in English literature came into use at the beginning of the 17th century. ‘Resilience’ originates from the Latin verb ‘resilire’, which means to “rebound or recoil” (Zhong et al., 2014). It refers to the inherent processes and capacities that empower the subject (individuals, technical or natural systems) to successfully overcome, withstand, adapt to, and recover from profound crises (Southwick et al., 2014). It encompasses the ability to bounce back, restore functionality, and thrive in the face of adversity. Resilience involves a dynamic interplay between various factors, including psychological, social, and organisational elements, and it plays a crucial role in fostering robustness and sustainability in the face of challenges and disruptions (Talubo et al., 2022; Pasquinelli and Sjöholm, 2015).

A review of the scientific literature shows that the term ‘resilience’ is used in various disciplines (Kuzior et al., 2021; Chen et al., 2022; Abazo, 2021; Dong et al., 2022; Dzwigol, 2020; Guan et al., 2022; Kharazishvili et al., 2022). Werner and Smith (1977) investigated resilience from a psychological point of view, having explored resilience and recovery in

adolescence and adulthood under the influence of perinatal stress and the quality of the family atmosphere. In an ecological context, resilience is acknowledged as the capacity to persist and endure in the face of change (Holling, 1973). In turn, Adger (2000) considered the concept of social resilience to refer to the capacity of collectives or societies to effectively deal with external pressures and disruptions stemming from alterations in the realms of society, politics, and the environment. Wiig et al. (2022) pointed out that from the organisational perspective, resilience is presented as the capacity to adapt and embrace change as a base for high-quality levels. Based on the above, it could be stated that resilience pertains to the subject’s flexibility, adaptation, improvisation, response, and adjustment to different critical events (Aase et al., 2020).

The international scope of literature presents several recent studies investigating critical events in healthcare (Woloshynowych et al., 2005; Kirigia et al., 2011; Yazdani et al., 2022; Lloyd-Smith, 2020). Achour et al. (2014) revealed three significant challenges encountered by healthcare facilities. Firstly, there is an inherent vulnerability of infrastructure

to natural hazards, which puts healthcare facilities at risk. Secondly, alternative energy sources and supplies for healthcare utilities often exhibit low levels of performance, hindering their ability to ensure uninterrupted services during disruptions. Lastly, there is a lack of adequate consideration of healthcare utility supplies in resilience codes and legislations, which undermines their ability to effectively prepare for and respond to critical events. Cimellaro et al. (2010) have introduced a comprehensive model that seeks to quantitatively assess the resilience of hospital systems in the context of disasters. The model defines resilience as the system's capacity to sustain functionality and effectively recover from losses resulting from extreme events. On the other hand, Kunzler et al. (2020) focused on the resilience of healthcare professionals. The findings showed that resilience training for healthcare professionals has the potential to enhance their resilience and potentially decrease symptoms of depression and stress immediately after completion of the training.

Individuals, communities, or states are not exempt from the influence of critical events or associated losses (Pimonenko and Cebula, 2015; Sokolovska et al., 2020; Su et al., 2023; Tambovceva et al., 2020; Wang et al., 2023; Szczepańska-Woszczyna et al., 2022; Stępień et al., 2023). These can include natural hazards, outbreaks of infectious disease, acts of terrorism, social unrest, or financial crises (Cutter et al., 2013; Kwilinski et al., 2020; Kharazishvili et al., 2020; Kianpour et al., 2021; Kuzior et al., 2022). With temperatures increasing worldwide, more people require emergency medical assistance for various health issues caused by climate change (Humphrey and Dresser, 2023). These include heat exhaustion and heat stroke due to extreme heat, respiratory problems caused by air pollution leading to asthma, and the spread of infectious diseases resulting from flooding and changes in ecosystems, which prompt the relocation of ticks, mosquitoes, and other

pests. News headlines frequently highlight the physical and emotional trauma experienced due to climate-related disasters such as hurricanes, wildfires, tornadoes, and floods.

The consequences of such events can be far-reaching, affecting nations and communities (Chen et al., 2023; Kwilinski et al., 2022; Moskalenko et al., 2022; Nawawi et al., 2022; Panchenko et al., 2021; Pimonenko et al., 2020; Vaničková et al., 2020). As a result, communities and nations as a whole are confronted with challenging decisions encompassing fiscal, social, cultural, and environmental considerations (Cutter et al., 2013; Rui et al., 2019; Wang et al., 2022; Moskalenko et al., 2022; Chen et al., 2021). These decisions aim to safeguard fundamental security and enhance the overall quality of life in the face of hazards, intentional attacks, and disasters.

With reference to the literature on healthcare resilience, Wiig et al. (2022) considered healthcare resilience to be the capacity to ensure the healthcare system is able to adjust to challenges and changes at different levels while supporting high-quality care. According to the definition by the Organisation for Economic Co-operation and Development, health system resilience refers to the capacity of healthcare systems to not only anticipate and prepare for shocks and disruptions but also to mitigate their adverse impacts, recover promptly, and adapt by incorporating lessons learned to enhance efficiency and preparedness (OECD, 2023). In terms of healthcare output, resilience entails sustaining and enhancing the functioning of health system components, including governance, service delivery, resource generation, and financing. The ultimate objective is to ensure the continuity of a health system's goals, particularly in improving population health, even in the face of critical events (EOHSP, 2023). Aase et al. (2020) noted that resilient healthcare relies on the presence of adaptive capacity within the healthcare system. It entails utilising both internal and external

resources to adjust and accommodate the dynamic demands of everyday operations. Examples include adapting care processes in response to variations in demand or time constraints. By effectively addressing challenging issues, resilient healthcare systems are able to sustain high-quality services and ensure continuity of care.

The healthcare sector faces the challenge of coordinating resources during critical events while the demand for healthcare services increases (Miśkiewicz et al., 2022; Xu et al., 2023; Pimonenko et al., 2017; Kwilinski et al., 2022). Here it is noteworthy that resilience offers organisations the opportunity to allocate resources effectively by integrating considerations of both safety and productivity (Henriksen et al., 2008; Pimonenko et al., 2021; Kwilinski et al., 2020). The integrated approach allows organisations to balance the issues of safety and maximising productivity, leading to more efficient and effective operations (Petroye et al., 2020; Kwilinski et al., 2020; Lyulyov et al., 2019). Effective coordination relies on the active collaboration of individuals on the ground, such as hospital staff, to ensure adherence to established procedures. However, the behaviour and stress levels of certain staff members may have exacerbated the situation and posed challenges to the emergency response. In this view, a large stream of literature highlights the crucial impact of management on providing quality-of-care outcomes, including during critical events (Sfantou et al., 2017; Ree et al., 2021; Dzwigol-Barosz and Dzwigol, 2021; Acheampong et al., 2023; Kwilinski and Kuzior, 2020; Yevdokimov et al., 2018). Effective healthcare management is crucial in pre-hospital care in terms of utilising the available resources for timely treatment (Achour et al., 2016; Trzeciak et al., 2022; Saługa et al., 2020; Lyulyov and Shvindina, 2017; Dzwigol, 2021).

Managers of healthcare organisations should be able to promptly gather the necessary information to effectively respond

to critical events; enhance the efficient use of available resources to ensure their effective allocation and utilisation during emergencies; provide healthcare staff members who fulfil their vital roles within the rescue chain and possess the necessary skills and knowledge to respond effectively in emergencies; enhance support for the well-being of healthcare and rescue teams, including addressing their welfare, providing assistance for post-traumatic stress disorder and delivering relevant training; and improve the communication between teams and agencies both before and after a critical event to foster better coordination and collaboration, enabling a more efficient and comprehensive emergency response (Achour et al., 2016; Kwilinski et al., 2021; Prokopenko et al., 2020; Miśkiewicz, 2021; Tih et al., 2016).

Regarding the literature on healthcare resilience, Berg and Aase (2019) mentioned that anticipation, sensemaking, adaptation, and trade-offs are the cognitive and behavioural strategies defining resilience within organisations. Thus, the anticipation strategy involves the capacity of an organisation to foresee and prepare for potential shifts or risks before actualisation. Adaptation strategy entails navigating complexity by modifying actions or behaviour in challenging circumstances, displaying flexibility, and improvising as needed. To effectively adapt to novel situations or demands, it becomes essential to comprehend and make sense of ongoing events. This process is known as sensemaking, which is closely tied to the notion of trade-offs arising when choices must be made between conflicting objectives and tensions.

The abovementioned theoretical findings indicate many studies addressing healthcare resilience during critical events. Therefore, the current research is inclined to conduct a comprehensive bibliometric analysis to review and assess the international scope of scientific literature devoted to healthcare resilience during critical events.

2. Methodology

Using data from the Scopus scientific database, this study examined publications on healthcare resilience during critical events until 1 June 2023. It is worth noting that the Scopus database was chosen as the source of primary data as it is a widely recognised

and influential multi-disciplinary citation database. For instance, the Scopus database contains over 84 million documents and involves approximately 18 million researchers worldwide, affiliated with around 95,000 institutions. It is worth noting that Health Sciences is one of the primary subject areas (23%) (Elsevier, 2022).

Figure 2. Research design

DATA IDENTIFICATION AND COLLECTION <i>using the Scopus toolkit</i>	
DATA COLLECTION	DATA PREPROCESSING
determining the search terms → search in titles, abstracts, and keywords <i>Records identified from Scopus (n = 6831)</i>	adjusting the period of publication and subject areas <i>Records after filtering (n = 720)</i>
DATA ANALYSIS AND VISUALISATION <i>using Biblioshiny and VOSviewer toolkits</i>	
PERFORMANCE ANALYSIS	SCIENCE MAPPING
analysis of publication-related metrics (total number of articles, journals, authors, countries, and affiliations)	Citation analysis, co-authorship analysis, co-citation analysis, and co-word analysis

Source: developed by the authors

Therefore, utilising data from Scopus makes it possible to comprehensively assess the global research output and provide a critical overview of healthcare resilience during critical events (Dzwigol, 2022; Us et al., 2022; Szczepańska-Woszczyzna and Gatnar, 2022). This study applied bibliometrics and knowledge visualisation methods to examine the relationship between articles and keywords, presenting a comprehensive overview of emerging trends and potential research opportunities in the investigated field (Soliman et al., 2021; Dubina et al., 2020; Pimonenko et al., 2021; Letunovska et al., 2021; Us et al., 2020). The research encompassed the analysis of publication dynamics, key research trends, prolific scholars and their collaborations, and the contributions of journals, affiliations, and countries in developing the investigated topic. The primary advantage of employing bibliometric analysis is its ability

to ensure a quantitative and objective literature review, minimising the subjective biases of the authors (Vakulenko et al., 2021; Soliman et al., 2023; Ziabina and Pimonenko, 2020; Bilan et al., 2020). The bibliometric R package and VOSviewer 1.6.16 software toolkit were utilised to conduct the bibliometric analysis. In the initial stage, the analysis involved searching for, collecting, and preprocessing articles relevant to the research topic (Figure 2). Subsequently, various bibliometric techniques were employed to analyse and visualise the findings. Finally, the results were synthesised, and potential directions for future research were discussed.

2.1 Data identification and collection

The research included a comprehensive bibliometric analysis on global scholarly publications focusing on healthcare resilience in coping with critical events. The initial

dataset was obtained from the Scopus interdisciplinary database, most recently accessed on 1 June 2023. The Scopus database was chosen because it covers global scientific journals from various subject areas extensively (Falagas et al., 2008). Table 1 outlines the article search process carried out in several stages.

Table 1. Data collection steps on Scopus

N°	Query	Description	No. of papers
1	TITLE-ABS-KEY	(critical AND event*) AND healthcare AND resilience)	6831
2	PUBYEAR	1999 > PUBYEAR < 2023 (until June)	6807
3	LIMIT-TO SUBJAREA	Medicine AND Psychology AND Nurse AND Health	720

Source: developed by the authors

The search was conducted using the keywords ‘critical events’, ‘healthcare’, and ‘resilience’. Moreover, the Boolean operator ‘AND’ was applied to include all the abovementioned keywords and the combinations thereof. To ensure the inclusion of the most relevant publications, the search results were limited to specific subject fields: 1) medicine, 2) psychology, 3) nursing, and 4) health. The research encompassed publications from 2000 to 2023 (up to June 1). Notably, the initial dataset comprised 6796 publications. However, after applying filter limitations, the number of publications included in the bibliometric analysis amounted to 720 (Table 2).

Table 2. The main information about the filtered dataset

Description	Results
Documents (articles)	720
Single-authored documents	98
Average citation per document	29.48
Average age of documents	5.25
Annual growth rate (%)	119
Sources (Journals, Books, etc.)	438
Authors’ keywords	2071
Authors	3077
Authors of single-authored documents	96
Co-authors per document	4.52
International co-authorship (%)	28.89
Timespan	2000-2023 (to 1 June)

Source: developed by the authors

Following the filtering process, the analysis was conducted on a total sample of 720 articles, comprising 98 single-authored articles and 622 co-authored articles. These articles were derived from 438 different sources. The dataset involved a total of 3077 authors, with 96 authors contributing to single-authored articles. International co-authorship comprised 28.89%. On average, each article has approximately five co-authors. The average age of each document was 5.25 years, while the annual growth rate was 11.9%.

2.2 Science mapping

The intellectual structure of the analysed literature was constructed using a distance-based approach known as co-citation analysis. This method allowed for the visualisation of the collaborative relationships among scholars worldwide, thereby providing insights into the collaboration patterns within the research field. The citation analysis was conducted to detect the most influential articles and delve into the linkages among analysed articles; the co-authorship analysis identified the social interaction among authors worldwide by countries; the co-citation analysis determined the research themes most developed by the authors; and the co-word analysis included the trend analysis of research themes, as well as the analysis of the relationships among themes.

Co-word network analysis and clustering techniques allowed the researchers to define the typologies of themes related to the examined keywords. The study identified distinct themes within the research field by analysing the relationships and co-occurrences among keywords. These themes were represented in a two-dimensional diagram comprising four quadrants based on centrality and density (Corte et al., 2021).

The analysis of the two-dimensional diagram yielded the following interpretations for each quadrant:

1. the upper-right quadrant: this quadrant represents keywords with high centrality and density, indicating their significance and influence in the subject area. These keywords correspond to well-established and significant motor themes within the research field.
2. the upper-left quadrant: keywords in this quadrant exhibit high density but low centrality, suggesting niche themes with limited importance in the broader context of the subject area.
3. the lower-left quadrant: keywords in this quadrant have low centrality and density, indicating emerging or disappearing research-related themes. These keywords represent areas that are currently gaining attention or losing relevance within the research field.
4. the lower-right quadrant: this quadrant comprises keywords with high centrality but low density. These keywords represent primary themes that are fundamental to the studied scientific field. They may serve as foundational concepts or core areas of research.

To construct the thematic map visualising the key themes identified within the scientific scope of the analysed literature, the authors' keyword method was employed as the field of analysis; a total of 250 words were considered in the analysis; clusters with a frequency of at least six words were included in the thematic map; five labels were assigned to each cluster, representing the key themes within that cluster; and the label size for each cluster was set to 0.3, indicating the prominence of the labels within the map.

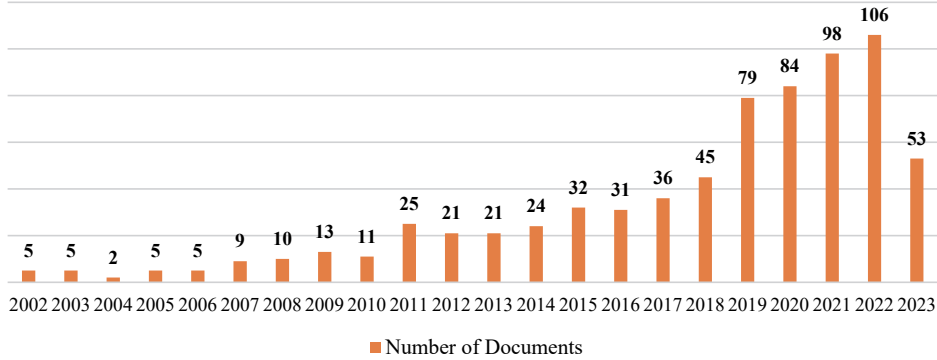
3. Research results

The popularity of investigations on healthcare resilience during critical events continues to grow. Figure 3 demonstrates that the number of documents considered increased by 21.1 times from 2002 to 2023 (up

to June 1). In turn, the analysis of annual scientific production showed no articles on the research topic before 2002 in the Scopus database. It is worth noting the first steep increase in publications analysed in 2011 (by 2.3 times). The analysis of documents published in this period shows that scholars were involved in investigations of the influence of extreme heat on public health (Bi et al., 2011), the risks of extreme weather events on health resilience (Ebi, 2011),

resilience to the impact of climate change under flood mitigation policy (Thomas et al., 2011), resilience in critical occupations (Meadows et al., 2011), etc. Furthermore, the second significant increase in the number of publications analysed was in 2019 (by 1.8 times), caused mostly by the COVID-19 pandemic. Following the formula derived by Shi et al. (2019), the average annual growth rate of publication activity was found to be 24.95 publications per year.

Figure 3. The dynamics of publication activity, 2000-2023 (to 1 June)



Source: developed by the authors

In order to identify the most influential articles in the scope of research on the issues of healthcare resilience in view of critical events, this study detected the most cited articles in the Scopus database. According to Table 3, a study on “Managing the health effects of climate change” by Costello et al. (2009) is considered to be fundamental in exploring the analysed topic (1734 citations

in Scopus). The authors elaborated on the comprehensive analysis to determine the adverse influence of the climate on health. In the study, the authors highlighted the necessity of alleviating poverty and taking climate adaptation measures. Table 3 reveals that the top five most-cited publications mainly cover the issues of stress and climate change in healthcare resilience.

Table 3. Top 10 representative papers, 2000-2023 (to 1 June)

N°	Author(s)/ Year	Title	TC
1	Costello et al., 2009	Managing the health effects of climate change	1734
4	Masten, 2011	Resilience in children threatened by extreme adversity: Frameworks for research, practice, and translational synergy	557
7	Cicchetti, 2010	Resilience under conditions of extreme stress: a multilevel perspective	341
9	Keim, 2008	Building human resilience: the role of public health preparedness and response as an adaptation to climate change	267
10	Gillespie et al., 2009	Risk and resilience: genetic and environmental influences on development of the stress response	264

Note: TC – Total citations

Sources: developed by the authors

According to the Scopus database, the American scholar Kristie L. Ebi has contributed most significantly to developing a scientific treatise on healthcare resilience to critical events (Table 4). However, the publications on healthcare resilience are only 2% of the scholar's total output. On the other hand, the analysis of statistical data showed that on 1 June 2023, the most influential scholars according to the h-index were Kristie L. Ebi (74), George A. Bonanno (71), and Ann S. Masten (70). In turn, the most frequently cited scholars were Ann S. Masten (27,567 citations), George A. Bonanno (26,991 citations), and Kristie L. Ebi (25,521 citations).

In this view, it is appropriate to mention that the scientific interests of Kristie L. Ebi mainly cover heat waves, climate change, carbon, global temperature increases, the urban climate, and resilience. In turn, George A. Bonanno is primarily interested in investigating emotions, cognitive strategies, coping behaviour, and psychological

support. Helen L. Berry devotes her studies primarily to medicine, the social sciences, arts and humanities, environmental science, and nursing. David M. Dunkley investigates psychological issues, including burnout, anxiety, self-determination theory, need satisfaction, etc. In turn, Sari R. Kovats, Ann S. Masten, Geoffrey Gerard Morgan, and Caitlin S. Rublee mainly contributed to the topics of climate change, disaster, post-traumatic stress disorder, terrorist attacks, psychological resilience, mental health, etc. Luca Pietrantoni has significantly contributed to investigating environmental quality, safety climate, occupational stress, personnel, and climate change, while Gabriele Prati studies well-being.

To summarise the areas of interest of researchers, it could be concluded that studies on healthcare resilience are intertwined with various subject areas such as psychology, environmental science, social science, neuroscience, art, humanities, etc.

Table 4. The most influential scholars according to Scopus, 2000-2023 (to 1 June)

N°	Authors	NP/TP	TC	h-index	Country / Affiliation
1	Kristie L. Ebi	7/328	25,521	74	USA / University of Washington
2	George A. Bonanno	6/241	26,991	71	USA / Columbia University
3	Helen L. Berry	4/85	3683	33	Australia / Macquarie University
4	David M. Dunkley	3/42	2583	26	Canada / Université McGill
5	Sari R. Kovats	3/152	15,332	56	UK / London School of Hygiene & Tropical Medicine
6	Ann S. Masten	3/180	27,567	70	USA / University of Minnesota Twin Cities
7	Geoffrey Gerard Morgan	3/143	4563	41	Australia / The University of Sydney School of Public Health
8	Luca Pietrantoni	3/118	3043	28	Italy / Alma Mater Studiorum Università di Bologna
9	Gabriele Prati	3/135	3760	30	Italy / Alma Mater Studiorum Università di Bologna
10	Caitlin S. Rublee	3/22	143	8	USA / Medical College of Wisconsin

Note: NP – Number of papers; TC – Total citations; TP – Total papers.

Sources: developed by the authors based on Scopus data

Table 5 presents the most productive sources indexed in Scopus databases by the number of documents devoted to investigating healthcare resilience during critical events. It is worth mentioning that all journals included herein have a high impact factor (Q1-2), indicating the reliability of the journals. The largest number of documents was published in the Swiss journal ‘International Journal of Environmental Research and Public Health’, which was included in the Scopus database in 2004. Among the sources considered, this journal has the highest h-index (167).

The indicators of the CiteScore rank 2022 show that the most cited journals from 2019 to 2022 were the Dutch journal ‘Safety Science’ and the UK journal ‘Environmental

Research Letters’. The journal ‘Safety Science’ was cited 19,884 times in 1507 documents, while ‘Environmental Research Letters’ noted 33,660 citations from 3321 documents. The journal ‘Safety Science’ is highly ranked, and its papers are in the top 3% in the category of Social Sciences: Safety Research (ranked third of 103) and Medicine: Public Health, Environmental and Occupational Health (16th of 577). The papers of the UK journal ‘Environmental Research Letters’ are in the top 5% in the category of Medicine: Public Health, Environmental and Occupational Health (ranked 29th of 577) and in the top 10% in the category of Environmental Science: General Environmental Science (22nd out of 227).

Table 5. The most productive sources, 2000-2023 (to 1 June)

N°	Source / Country	NP/ TP	h-index	CiteScore 2022	SJR 2022/Q	Publisher	Years in Scopus
1	International Journal of Environ- mental Research and Public Health / Switzerland	42/ 60,669	167	5.4	0.828/2	MDPI	2004- present
2	Environmental Research Letters / UK	34/ 6992	164	10.1	2.119/1	Institute of Physics Publishing	2006- present
3	Risk Analysis / UK	23/ 5128	146	7.8	0.931/1	Wiley-Blackwell	1981- present
4	Safety Science / Netherlands	12/ 5186	140	12.4	1.429/1	Elsevier	1991- present
5	Australian Journal of Emergency Management / Australia	9/ 1161	30	0.8	0.199/2	Australian Institute for Disaster Resilience	1998- present

Notes: NP – Number of papers; TP – Total papers.

Sources: developed by the authors

The results show that 1329 affiliations were involved in investigating healthcare resilience during critical events. Table 6 shows that medicine is the dominant subject area for the 10 most relevant affiliations worldwide by the number of published documents according to the filtered Scopus dataset. Of these, four of the 10 organisations are from the USA (the University of California, Columbia University, the University of Washington, and Harvard Medical School), two from the UK (University College

London and London School of Hygiene and Tropical Medicine), two from Canada (the University of British Columbia and the University of Toronto), one from South Africa (the University of Cape Town), and one from Australia (the University of Sydney). The most prolific affiliation was the University of California; authors affiliated with that institution have published 21 documents on the studied topic. One affiliated institution published around two articles on average from 2000 to 1 June 2023.

Table 6. Most relevant affiliations, 2000-2023 (to 1 June)

N°	Affiliation	NP/TP	No. of authors	Dom. sub. area	Country
1	The University of California	21/239,238	29,109	Medicine	USA
2	University College London	19/262,690	34,805	Medicine	UK
3	Columbia University	18/236,119	34,417	Medicine	USA
4	The University of Washington	18/303,444	54,121	Medicine	USA
5	The University of British Columbia	15/232,762	46,860	Medicine	Canada
6	The University of Cape Town	14/75,768	13,869	Medicine	South Africa
7	Harvard Medical School	13/391,934	47,803	Medicine	USA
8	The University of Toronto	10/381,534	67,663	Medicine	Canada
9	The University of Sydney	11/222,196	27,975	Medicine	Australia
10	London School of Hygiene and Tropical Medicine	11/56,073	6843	Medicine	UK

Sources: developed by the authors

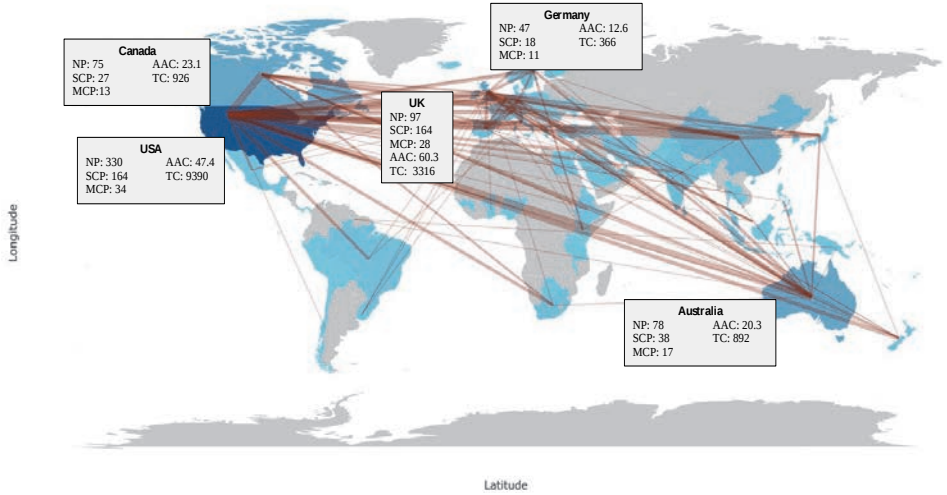
The publication of papers in different countries could indicate a country’s significance and impact in the field of healthcare resilience to a certain extent (Figure 4). The quality and quantity of research papers produced by a particular country could demonstrate the level of scientific activity and expertise in addressing healthcare resilience in view of critical events. Therefore, in the next stage, this study browsed the investigated documents by country. The findings showed that 75 countries have contributed to the investigation of healthcare resilience during critical events. In turn, the top five countries on this list are the USA (330 documents), the UK (97 documents), Australia (78 documents), Canada (75 documents), and Germany (47 documents). At the same time, the rating of the most cited country is slightly different. The most cited country was the USA (a total of 9390 citations), the UK (3316 citations), Canada (926 citations), Australia (892 citations), and Germany (366 citations). Despite the total number of citations in the USA being the largest, the indicator of average article citations shows that articles by UK scholars are the most cited

(60.3 citations per document), ahead of the USA with 47.4 citations per document.

However, it is essential to mention that publication output alone may not comprehensively assess a country’s overall importance and influence in the investigated field. Therefore, it is appropriate to consider the authors’ collaborations. Thus, the analysis of corresponding authors shows that not all countries have single or multiple country publications. Among the 75 countries included, the ones with single-country publications are Chile, Greece, the Czech Republic, Kenya, the Philippines, Slovakia, Sri Lanka, and the UAE, while those without multiple country publications are Iran, Cyprus, Denmark, Finland, Japan, Panama, Turkey, and Ukraine. On the other hand, the top five countries with the best intra- and inter-country collaborations were the USA, the UK, Australia, Canada and Germany.

Figure XX shows that the USA has the most extensive worldwide co-authorship network with 67 collaborations, followed by Australia – 49 collaborations, the UK – 43 collaborations, Germany – 37 collaborations, and Canada – 27 collaborations.

Figure 4. Scientific production by country, 2000-2022 (to 1 June)



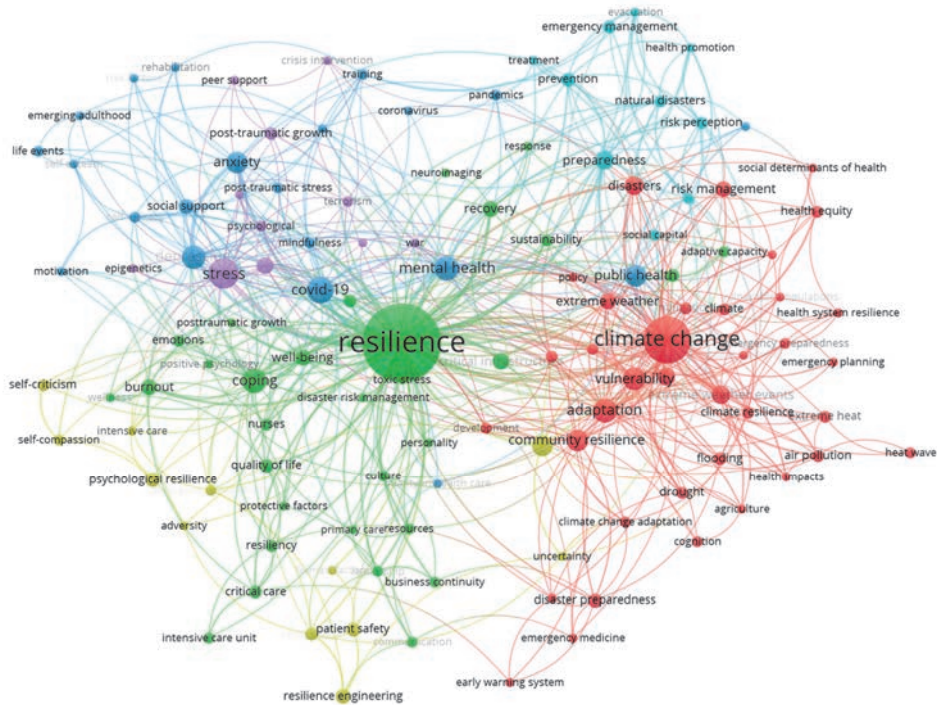
Notes: NP – Number of papers; SCP – Single country publications; MCP – Multiple country publications; AAC – Average article citations; TC – Total citations.

Source: developed by the authors

Figure 5 visualises the co-occurrence of keywords, creating a map that identifies the main scientific clusters within the scope of the investigated literature analysed from 2000 to 1 June 2023. This map identifies the relationships between different keywords, providing insights into the main themes and areas of focus within the

literature on healthcare resilience during critical events. Examining the clusters and the associations between them allows for a better understanding of key scientific areas and the interplay between different topics in the literature on healthcare resilience during critical events.

Figure 5. Network visualisation of keyword co-occurrences according to Scopus data, 2000-2023 (to 1 June)



Source: developed by the authors

In this study, the keyword co-occurrences network map was developed based on the results of analysing the links, total link strengths, and occurrence of the authors' keywords. Herewith, the limitation of a minimum of three keyword co-occurrences was introduced. Consequently, 171 keywords out of 2066 met this threshold, creating six clusters within the scope of the investigated literature on healthcare resilience during critical events. The clusters in the analysis were labelled based on the core keyword within each cluster that had the highest number of occurrences, links, and total link strengths. This approach could ensure that the clusters were named according to the most prominent and central keyword, which clearly represents the main theme within each cluster.

Therefore, the biggest (red) cluster depicts research on climate change, the second

(green) cluster – resilience in coping with stress, the third (blue) cluster – the influence of COVID-19 on mental health, the fourth (yellow) cluster – risks triggered by climate change, the fifth (purple) cluster – the nature of stress, and the sixth (cyan) cluster – preparedness for critical events.

The analysis of the first cluster shows that the term 'resilience' has the strongest links with 'coping' and 'climate change'. Thus, the findings show that in the view of critical events, scholars worldwide mostly investigated the issues of health system resilience regarding extreme weather events such as global warming, flooding, extreme heat, drought, etc. The first (red) cluster shows that the scholars elaborated on strengthening community resilience, looking into the social determinants of health, emergency planning and preparedness, disaster

management and preparedness, disaster risk reduction, early warning systems, emergency medicine, disaster preparedness, adaptation and mitigation to climate change, etc.

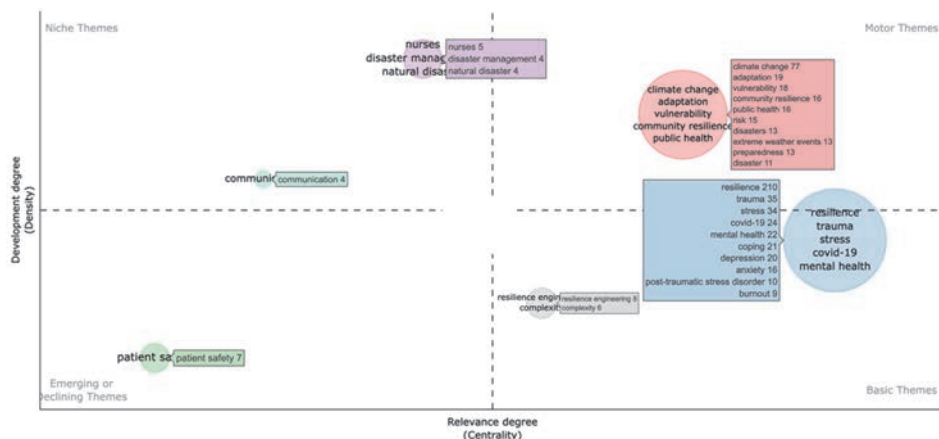
A great deal of attention is paid to investigating the psychological and mental features of healthcare resilience. The second (green) cluster shows that scholars' attention is primarily devoted to investigating burnout, emotions, leadership, positive psychology, well-being, wellness, quality of life, etc.

The unexpected spark of COVID-19 boosted the scientific interest in investigating healthcare resilience. In this view, the scholars investigated the influence of COVID-19 on public health, healthcare quality, risk factors, social support, mindfulness, training, etc. The fourth (yellow) cluster reveals the scope of studies on the risks triggered by climate change. In this view, the scholars elaborated mostly on patient safety,

psychological resilience, intensive care, etc. In turn, the fifth (purple) cluster shows studies investigating the psychological consequences of terrorism and war events. The sixth (cyan) cluster concerns preparedness for critical events such as natural disasters, health promotion, emergency management, risk perception, social capital, treatment, etc.

Figure 6 establishes a typology of the themes within the scope of the analysed literature on healthcare resilience during critical events. This study utilised the authors' keyword field to design a thematic map. By categorising and organising the keywords into distinct themes, the map visually represents the main topics in the analysed literature (basic, motor, emerging or declining, and niche themes). It allows one to look into the different thematic areas within the field of study, facilitating a better understanding of the overall landscape of the research.

Figure 6. Thematic map, 2000-2023 (to 1 June)



Source: developed by the authors

Thus, the basic themes are presented in the lower-right quadrant, which comprises keywords with high centrality but low density. Figure 6 shows that resilience is a fundamental theme in the studied scientific field. Scholars devoted specific attention to investigating resilience in the context of coping with stress, mental health, the

influence of COVID-19, depression, burnout, anxiety, etc. On the other hand, the upper-right quadrant consists of keywords with high centrality and density, indicating their significance and influence in the subject area. Therefore, the motor theme indicates that a well-established and significant research field is the issue of climate

change investigated in the view of adaptation, vulnerability, community resilience, public health, extreme weather events, disasters, etc. The niche themes presented in the upper-left quadrant with high density but low centrality indicate that papers devoted to investigating issues on communication and the influence of natural disasters on nurses are of limited importance in the broader context of the subject area. In turn, the lower-right quadrant with low centrality and density seems to indicate that studies on developing patient safety during adverse events and epidemics are an emerging research-related theme in the investigated scope of the literature.

4. Discussion and conclusions

The findings of the bibliometric analysis showed that research on healthcare resilience during critical events continues to expand. Therefore, this study employed bibliometric methods to investigate the scientific output on healthcare resilience during critical events. Bibliometrics offers a key advantage by providing a quantitative and objective analysis of the global scientific treatise, reducing the influence of the authors' inherent subjectivity. This study ensures a robust and systematic literature review by employing rigorous bibliometric analysis. Additionally, knowledge visualisation techniques were applied for a comprehensive overview of emerging trends and potential research opportunities within the investigated research field. By combining bibliometric analysis with knowledge visualisation, this study provides a holistic approach to exploring and analysing the scientific output on healthcare resilience during critical events, offering objective insights and uncovering new directions for further investigation.

The findings of performance and intellectual analysis indicated that a study by Costello et al. (2009) entitled "Managing the health effects of climate change", published

in *The Lancet*, is regarded as fundamental in exploring the analysed topic. This study has garnered 1734 citations in Scopus, reflecting its significant impact and influence in the investigated field. The authors conducted a comprehensive analysis to assess the adverse effects of climate change on health.

It should be noticed that the most frequently cited publications in the analysed field focus on the social aspect of healthcare resilience. They highlight the increasing burden of stress and the need to address the social determinants of health in the context of resilience. These oft-cited publications highlight the importance of understanding and addressing social factors in healthcare resilience during critical events.

The Swiss journal "International Journal of Environmental Research and Public Health" is the most productive source indexed in the Scopus database in terms of the number of documents dedicated to the investigation of healthcare resilience during critical events. According to the results, the investigation of healthcare resilience during critical events involved a total of 1329 affiliations. Among these affiliations, the most prolific was the University of California, with its authors publishing a total of 21 documents on the studied topic. On average, each affiliated institution published approximately two articles from 2000 to 1 June 2023, indicating a moderate level of contribution per institution in the field of healthcare resilience research.

The findings of the analysis revealed that a total of 75 countries have contributed to the investigation of healthcare resilience during critical events. Among these countries, the top five in terms of the number of documents published are the USA (330 documents), the UK (97 documents), Australia (78 documents), Canada (75 documents), and Germany (47 documents). However, when considering citation impact, the ranking slightly differs. The USA emerged as the most cited country, with a total citation

count of 9390 followed by the UK (3316 citations), Canada (926 citations), Australia (892 citations), and Germany (366 citations). While the USA has the highest total citation count, when examining the average number of citations per document, the articles authored by UK scholars stand out with an average of 60.3 citations per document. In comparison, the USA averages 47.4 citations per document. This suggests that although the USA has the highest overall citation count, articles by UK scholars tend to receive a higher average number of citations, indicating a potentially higher impact on the field of healthcare resilience during critical events.

Analysing the countries of corresponding authors reveals that not all countries have single or multiple country publications. Among the 75 countries involved, some countries do not have publications where all authors are from the same country, while others do not have publications by authors from multiple countries. Specifically, the countries without single-country publications are Chile, Greece, Czech Republic, Kenya, Philippines, Slovakia, Sri Lanka, and UAE; while the countries without multiple country publications are Iran, Cyprus, Denmark, Finland, Japan, Panama, Turkey, and Ukraine.

On the other hand, the top five countries in terms of intra- and inter-country collaborations are the USA, UK, Australia, Canada, and Germany. These countries have demonstrated strong collaborations both within their own countries and with researchers from other countries. These collaborations signify the global engagement and knowledge exchange among researchers in healthcare resilience during critical events.

In this study, a keyword co-occurrences network map was created by analysing the links, total link strengths, and occurrences of authors' keywords. The map revealed several distinct clusters representing different research directions within the field of

healthcare resilience during critical events. The largest cluster, focused on research related to climate change, indicates a significant research direction exploring the impact of climate change on healthcare resilience. The second cluster focused on understanding and promoting resilience in individuals and communities facing stressful situations. The third cluster centred around the influence of COVID-19 on mental health, reflecting the growing research interest in exploring the mental health implications of the COVID-19 pandemic. The fourth cluster revolved around the risks triggered by climate change. This cluster constitutes research investigating the various risks and vulnerabilities associated with climate change and their impact on healthcare resilience. The fifth cluster encompasses research examining the nature, causes, and effects of stress in the context of healthcare resilience during critical events; and the sixth cluster represents research exploring measures to enhance preparedness and response capabilities in the face of critical events.

These distinct clusters in the keyword co-occurrences network map provide a visual representation of the main research directions and themes within the field of healthcare resilience during critical events, highlighting the diverse areas of focus and the interconnectedness of different research topics.

The typology of themes within the scope of the analysed literature on healthcare resilience during critical events highlights the fact that the primary themes in the field are centred around resilience. Scholars have dedicated particular attention to investigating resilience concerning coping with stress, mental health, the influence of COVID-19, depression, burnout, anxiety, and other related factors. These themes reflect the importance of understanding and promoting resilience in healthcare settings during critical events.

On the other hand, the motor theme in the field revolves around well-established

and significant research on issues related to climate change. This includes adaptation, vulnerability, community resilience, public health, extreme weather events, and disasters. The extensive research in this area underscores the recognition of climate change as a critical factor impacting healthcare resilience. In contrast, the niche themes indicate that papers focused on communication and the influence of natural disasters on nurses are of limited importance in the broader context of the subject area. While these themes may be relevant within specific contexts, they may not have gained significant prominence or influence compared to the broader themes of resilience and climate change. Furthermore, the typology suggests that developing patient safety during adverse events and epidemics is an emerging research-related theme in the investigated scope of the literature. It indicates a growing interest and focus on enhancing patient safety measures, specifically in the context of adverse events and epidemics, recognising its importance to healthcare resilience.

Overall, this typology of themes provides insights into the main focus areas within the studied scientific field of healthcare resilience during critical events, highlighting the significance of resilience, climate change, and emerging research-related themes. At the same time, the results of the keyword co-occurrences analysis indicated the need to deepen the studies on strengthening healthcare resilience during human-caused critical events (such as crime, terrorism, wars, cyber-attacks, etc.), which have been steadily rising, displaying an upward trend in frequency and intensity over the last decade.

Indeed, the healthcare sector has undergone significant technological advancements in the past decade, primarily through integrating medical devices with information technology (IT). This integration has led to the development of a critical

Health Care Information Infrastructure, which offers substantial benefits for healthcare service delivery. However, Islam et al. (2021) noted that the increased digital interconnectivity among medical and IT devices has also introduced new threats to infrastructure security. With sensitive patient healthcare information and the widespread accessibility of medical devices, the risk of cyber-attacks has escalated, potentially leading to disruptions in healthcare service delivery. Secure access control is crucial for establishing a trustworthy healthcare system and defending against cyber-attacks (Soni et al., 2023). Implementing robust access control measures can help mitigate security threats and protect the integrity and confidentiality of medical information. Consequently, there is a pressing need to strengthen the security and resilience of the Health Care Information Infrastructure.

On the other hand, the healthcare sector is not exempt from aggression and threats posed by terrorists, criminals, and rogue states. Unfortunately, these entities could target healthcare facilities and providers as part of their agendas or for various reasons. Thus, it is crucial for healthcare organisations to be aware of these risks and take appropriate security measures to ensure the safety of their staff, patients, and infrastructure. This may include implementing security protocols, conducting risk assessments, and collaborating with law enforcement agencies to prevent and respond to potential threats effectively (Granhölm et al., 2022).

This paper has theoretical and practical implications in terms of analysing and visualising the scholarly output on healthcare resilience during critical events. The theoretical implications contribute to a better understanding of the patterns, relationships, and developments in the scientific literature on healthcare resilience during critical events, offering valuable insights

for researchers and identifying potential avenues for future research. On a practical level, the study offers guidance for scholars interested in conducting bibliometric analyses on scholarly output, including the performance of academics, institutions, and academic journals. The detailed instructions provided in the article can assist researchers in conducting similar analyses in different contexts.

Furthermore, the study presents opportunities for researchers to expand their current study directions by utilising the findings and insights generated through the bibliometric analysis. The study serves as a starting point for further exploration and research in the field of healthcare resilience.

However, it is important to note that the findings of this study are limited, as they solely consider data from the Scopus database. While Scopus provides a comprehensive overview of global research output, future studies should incorporate a wider range of data sources to ensure a more comprehensive and robust analysis. Expanding the data range would enhance the validity and generalisability of the findings, leading to a more comprehensive understanding of the topic.

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