

## ORIGINAL RESEARCH

# Exploring the development and trends of cardiopulmonary resuscitation training: a bibliometric and visual analysis from 1995 to 2024

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## Abstract

**Background:** Cardiopulmonary resuscitation (CPR) is a critical intervention that can promptly restore circulation and save the lives of patients experiencing cardiac arrest. The significance of CPR training is widely acknowledged in both medical education and emergency care settings. Although research in this field has developed rapidly in recent years, a comprehensive overview summarizing its evolution and current landscape is lacking. To address this gap, the present study employed bibliometric methods to systematically evaluate the major research areas, current progress and potential future directions of CPR training over the past three decades. **Methods:** Literature related to CPR training published from 1995 to 2024 was retrieved from the Web of Science Core Collection database. Bibliometric visualization and quantitative analysis were performed using HistCite, VOSviewer, CiteSpace and the Bibliometrix package to examine publication trends, countries and institutions of origin, journals, authors, keywords and cited references. **Results:** A total of 5687 publications were included in the analysis. The annual number of publications was found to steadily increase, indicating growing interest and activity in the field. The United States of America was identified as the most productive country, contributing the highest number of publications. Resuscitation ranked as the leading journal in terms of both publication volume and citation count. Among individual contributors, Perkins GD was identified as the most prolific author in the area of CPR training. **Conclusions:** CPR training remains a field with considerable potential for future research, with the main focus presently lying in the development and evaluation of innovative educational and training strategies. Emerging areas such as the integration of machine learning and big data, the design of personalized training programs, and the incorporation of interdisciplinary approaches could drive the next research phase in this domain.

## Keywords

Bibliometric; Education; Cardiopulmonary resuscitation; CPR; Training

## 1. Introduction

Cardiac arrest is one of the leading causes of death globally, primarily due to its low survival rate and unpredictable nature [1]. According to a recent report by the American Heart Association, over 356,000 cases of out-of-hospital cardiac arrest (OHCA) occur annually in the United States of America, with a mortality rate approaching 90% [2]. In response to this alarming statistic, the American Heart Association issued a statement in 1995 calling for greater public awareness of cardiac arrest and resuscitation efforts [3].

Cardiopulmonary resuscitation (CPR) is an important emergency intervention that can effectively restore circulation and respiratory function in patients experiencing sudden cardiac arrest, and its success is closely associated with the level

of training and proficiency among both lay responders and healthcare providers. Evidence suggests that high-quality CPR training improves the precision of compression depth, rate and hand placement, thereby enhancing the overall effectiveness of resuscitation efforts [4]. Furthermore, a study investigating the relationship between CPR training and survival outcomes demonstrated that timely CPR performed by bystanders significantly increases the likelihood of survival following cardiac arrest [4]. Given these findings, it is essential to conduct a comprehensive investigation into the development and impact of CPR training, as such insights may inform future educational strategies and improve patient outcomes.

CPR training has evolved significantly, transitioning from traditional instructor-led sessions to more innovative training approaches. Initially, this evolution involved a shift from

conventional classroom-based instruction to video-based self-learning, which was shown to be both cost-effective and convenient, with some studies reporting superior teaching quality compared to traditional methods [5]. More recently, CPR instruction has undergone further advancements. For example, Ali *et al.* [6] reported that hybrid training, combining self-directed and instructor-led components, was more effective in enhancing CPR skills than instructor-led face-to-face instruction alone. The integration of virtual reality (VR) technology into CPR training has further expanded instructional possibilities and significantly improved learners' performance and responsiveness in OHCA scenarios [7]. The use of VR in CPR education introduces a realistic and engaging learning environment that enhances skill acquisition and trainee confidence; however, its application still requires standardized protocols and further validation [8]. In addition to immersive technologies, real-time feedback systems have emerged as essential tools in CPR training, providing immediate guidance and error correction during practice, resulting in significant improvements in both skill acquisition and overall performance quality compared to traditional CPR training methods [9, 10]. Despite these advancements, disparities in access to CPR training persist. Residents in rural areas often have fewer opportunities to receive formal training than those in urban settings, which may contribute to lower cardiac arrest survival rates in these populations [11]. To mitigate this issue, various organizations and institutions have undertaken efforts to expand remote training programs and develop online learning resources, thereby improving the accessibility and reach of CPR training initiatives [12].

The research in the field of CPR training presents considerable potential for continued development, and a systematic analysis of the current status, key research areas and emerging trends is essential to gain meaningful insights into its progression. Bibliometric analysis offers a valuable approach for both qualitative and quantitative evaluation of scientific publications. By applying this method, researchers can efficiently examine the evolution of research themes, identify core areas of interest, and uncover emerging directions within a given field. Despite its applicability, bibliometric studies specifically focused on CPR training remain limited. To address this gap, the present study adopts a bibliometric approach to systematically analyze literature on CPR training to obtain a comprehensive evaluation of research developments in the thirty-year period from the issuance of the American Heart Association's public awareness statement in 1995 to the present and identify prevailing research hotspots, trace evolving trends, and elucidate future directions in CPR training research.

## 2. Materials and methods

### 2.1 Data source and search strategy

We conducted a retrospective quantitative analysis of the literature on CPR training published over the past 30 years (01 January 1995 to 31 December 2024). To ensure the comprehensiveness and consistency of the dataset and minimize duplication across multiple databases, we selected only the

Web of Science Core Collection (WoS) as the data source. The following search strategy was applied: TS = ("Cardiopulmonary Resuscitation" OR "cardio-pulmonary resuscitation" OR "cardiopulmonary resuscitation" OR "CPR" OR "Heart and Lung Revival" OR "Heart-Lung Revival") AND ("education" OR "teach\*" OR "train\*"). The search was limited to articles published in English language. To ensure data consistency and avoid variations due to database updates, all search operations were conducted on a single day, 29 March 2025.

A total of 6515 English-language publications were initially retrieved. After applying the inclusion criteria, we retained all research articles and review articles, and selectively included 123 proceedings papers and 28 early access articles, resulting in a total of 5364 eligible publications. These records were exported in plain text format, including metadata such as citation counts, titles, authors, institutional affiliations, countries, keywords, journal names, publication years and references. The exported data were then imported into CiteSpace for further processing, including removal of duplicate entries.

### 2.2 Statistical analysis

This study employed four bibliometric tools for data analysis: HistCite (version 12.03.17, Thomson Reuters, New York, NY, USA), VOSviewer (version 1.6.20, Nees Jan van Eck and Ludo Waltman, Leiden, Netherlands), CiteSpace (version 6.4.R1), and the Bibliometrix Package (version 4.1.4) based on the R programming language.

HistCite [13] was used to calculate key bibliometric indicators, including the total number of publications, total global citation score (TGCS), and total local citation score (TLCS) for each publication year. It also identified leading countries, top institutions, core journals and influential authors in the field, and enabled the identification of key citation pathways among representative references.

VOSviewer was used to construct and visualize co-citation networks, particularly those illustrating collaborations and temporal trends among countries, institutions and authors [14]. In the visual outputs, node size indicates the number of publications, and link thickness reflects the strength of collaboration or co-citation, and node color corresponds to different clusters or time periods.

CiteSpace supported visual analyses of the knowledge structure and emerging trends in CPR training research [15]. Cluster analysis was applied to author names, keywords and references to identify major research themes. The robustness of cluster structures was evaluated using modularity (Q) and mean silhouette scores, where  $Q > 0.3$  indicates a well-defined structure and a silhouette score  $> 0.5$  suggests high internal consistency. CiteSpace was also used to detect citation and keyword bursts, which reflect sudden increases in attention to specific topics, and to assess betweenness centrality, a measure of a node's bridging role between clusters. Nodes with high centrality values were marked with a purple ring, whose thickness corresponded to the magnitude of centrality.

The Bibliometrix Package, a widely used tool for bibliometric analysis in the R environment [16], was used to perform thematic evolution analysis for categorization of CPR training

research into distinct developmental stages over time, thereby highlighting shifts in thematic focus and research priorities.

### 3. Results

#### 3.1 Analysis of publication outputs

A total of 5364 publications related to CPR training were retrieved from the Web of Science Core Collection (WoSCC), comprising 4894 original research articles (91.23%) and 470 review articles (8.77%). The annual publication output is illustrated in Fig. 1A. From 1995 to 2024, the number of publications increased steadily from 52 to 529 per year, corresponding to an average annual growth rate of 8.74%. For analytical clarity, the 30-year period was divided into three stages based on publication volume: the initial stage (1995–2006), the second stage (2007–2015), and the third stage (2016–2024). During the initial stage, the annual number of publications remained consistently low, with fewer than 100 articles published each year. In 2007, the number of publications surpassed 100 for the first time, marking the onset of more rapid publication growth. This upward trend continued, and publication output stabilized at a high level after 2016. Notably, 2024 recorded the highest number of publications in the field, exceeding the cumulative total published before 2003.

As of the final retrieval date, the 5364 articles had received a total of 130,675 citations, excluding self-citations, which amounted to 99,439. The average citation count per article was 24.36. Given the early developmental stage of the field, publications before 2004 had lower TGCS and TLCS. However, from 2005 onward, TGCS remained relatively stable, suggesting that CPR training research has entered a phase of relative maturity (Fig. 1B).

#### 3.2 Analysis of countries

From 1995 to the end of 2024, a total of 127 countries published research articles related to CPR training. The global distribution of publication output is illustrated in Fig. 2A. The top 10 most productive countries accounted for approximately 83% of the total publications in this field (Table 1). Among them, the United States of America was the leading contributor, with 1890 publications, significantly surpassing all other countries. The United Kingdom ranked second with 459 publications, followed by Canada (423 publications) and Australia (318 publications). In regards to citation metrics, the United States of America also recorded the highest number of citations (66,012), followed by Canada (14,787) and the United Kingdom (14,472) (Table 1). Notably, Canada had the highest average number of citations per publication (34.96), followed closely by the United States of America (34.93) and the United Kingdom (31.53).

Country collaboration analysis, an important form of co-authorship evaluation, reflects the level of international cooperation and helps identify countries with strong influence in the field. Visualization of international collaborations using VOSviewer (Fig. 2B) revealed that cross-country partnerships are relatively extensive, with the United States of America maintaining collaborative ties with nearly all other countries

involved in CPR training research. Temporal trends in international collaboration (Fig. 2C) show that since 2014, publication output has notably increased in the United States of America, the United Kingdom and Australia. Furthermore, countries such as China and Spain have exhibited a marked rise in CPR training research output since 2020, indicating growing global engagement in this field.

#### 3.3 Analysis of institutes and authors

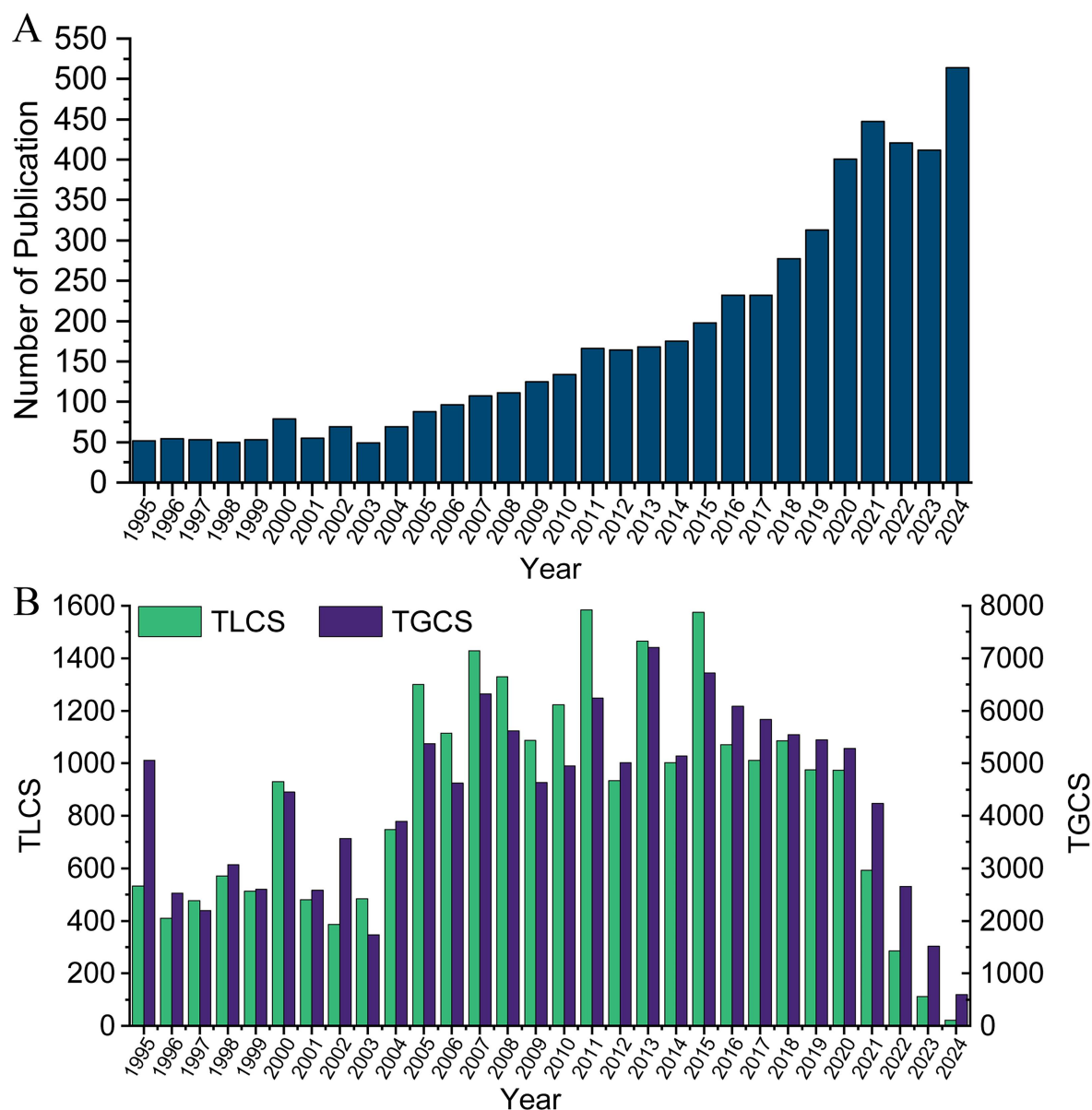
A total of 6596 institutions and 23,121 authors have contributed to research publications on CPR training. The top 10 most productive institutions are shown in Fig. 3A. Notably, nine of the top ten institutions are based in the United States of America, highlighting the country's dominant position in the field. The University of Pennsylvania ranked first in research output with 222 publications, followed by Harvard University (164 publications), the University of Washington (159 publications), and the University of Washington Seattle (159 publications). Collaboration among institutions was relatively close. The University of Washington emerged as a central node in the inter-institutional collaboration network, maintaining strong cooperative relationships with several other institutions, as illustrated in Fig. 3B.

Regarding author productivity, the top four contributors were Nadkarni, Vinay M. from the University of Pennsylvania (80 publications), Perkins, Gavin D. from the University of Warwick (61 publications), Cheng, Alice Yu-Chin from the University of Calgary (58 publications), and Greif, Robert from the University of Bern (56 publications). Analysis of author collaborations indicated that the overall degree of cooperation remains limited, with most collaborations occurring within individual institutions rather than across institutions (Fig. 3C). Herlitz, Johan from the Karolinska Institute, recognized as one of the early pioneers in CPR training research, has maintained continuous contributions to the field for nearly three decades, as shown in the timeline distribution (Fig. 3D).

#### 3.4 Analysis of journals and co-cited journals

Journal co-citation analysis is a widely used approach to explore the structure and development of a research field, as it not only reflects the intellectual framework of the discipline but also reveals the interrelationships among journals within the domain. Using VOSviewer software, we constructed a co-citation network of journals, with a minimum citation threshold set at 250, which resulted in 75 journals meeting the inclusion criteria. In the visualization, node size represents the relative activity and publication volume of each journal. As shown in Fig. 4, the network is divided into four distinct clusters, each represented by a unique color, indicating journal groupings based on co-citation patterns. In the field of CPR training, the journal *Resuscitation* was identified as the most frequently co-cited source, followed by *Circulation* and *The Journal of the American Medical Association*. Notably, *Resuscitation* serves as the official journal of the European Resuscitation Council, while *Circulation* is published by the American Heart Association, highlighting their authoritative roles in the field.

In total, articles on CPR training have been published across



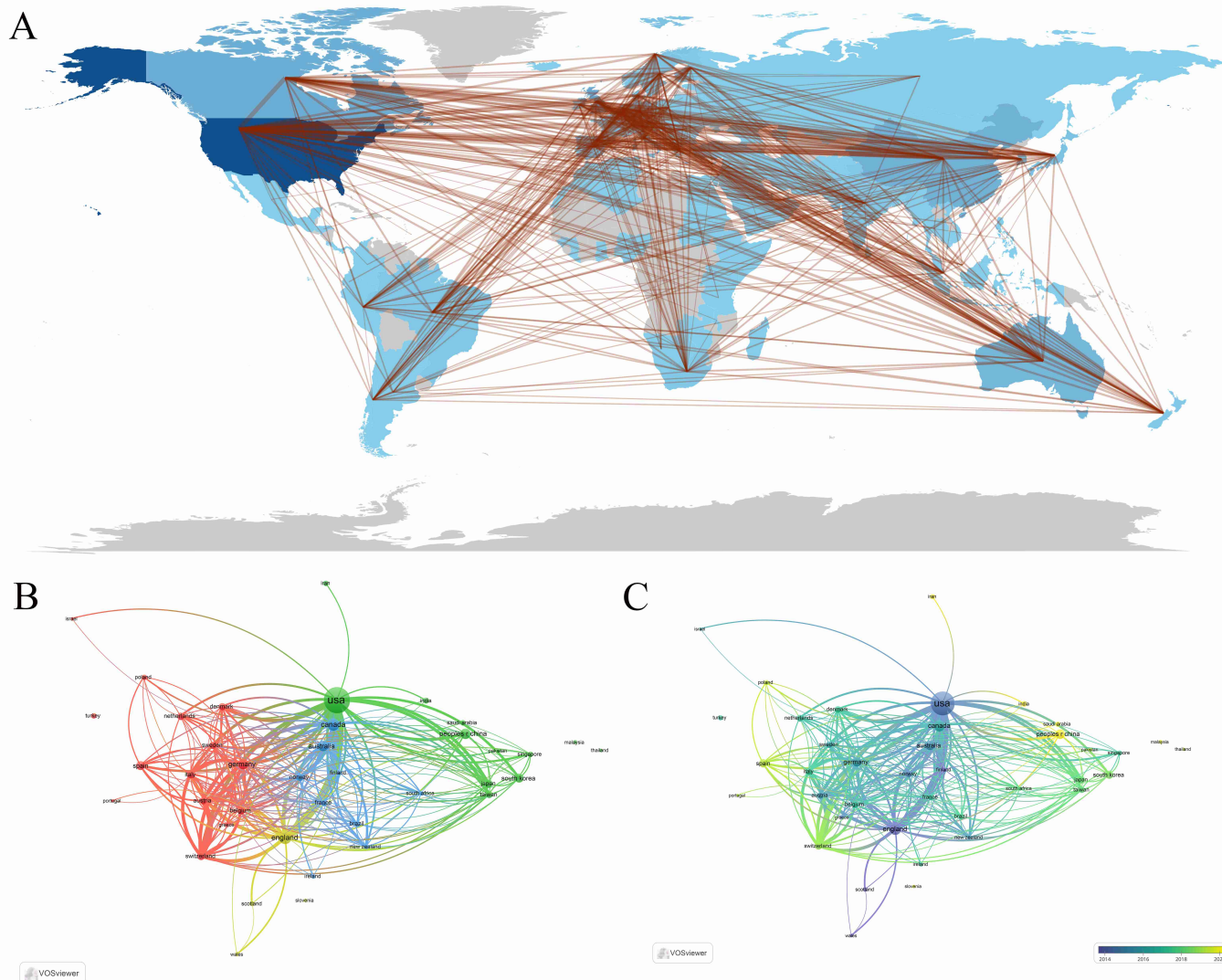
**FIGURE 1. Overall distribution of publication output on CPR training.** (A) Global annual output trends. (B) TLCS and TGCS in annual publications. TLCS: total local citation score; TGCS: total global citation score.

**TABLE 1. The top 10 productive countries concerning CPR training research.**

Rank	Country/Regions	Publications n (%)	TLCS	TGCS	Average citation	Centrality
1	USA	1890 (35.23%)	60,547	66,012	34.93	0.36
2	England	459 (8.55%)	13,836	14,472	31.53	0.14
3	Canada	423 (7.88%)	14,088	14,787	34.96	0.08
4	Australia	318 (5.92%)	7076	7473	24.34	0.12
5	Germany	307 (5.72%)	8580	8920	26.08	0.08
6	China	275 (5.12%)	2738	2892	10.52	0.00
7	South Korea	220 (4.10%)	3118	3332	15.15	0.01
8	Spain	218 (4.06%)	2938	3237	14.85	0.21
9	Japan	173 (3.23%)	4708	4875	28.18	0.07
10	Italy	173 (3.23%)	5093	5424	31.35	0.04

TLCS: total local citation score; TGCS: total global citation score.





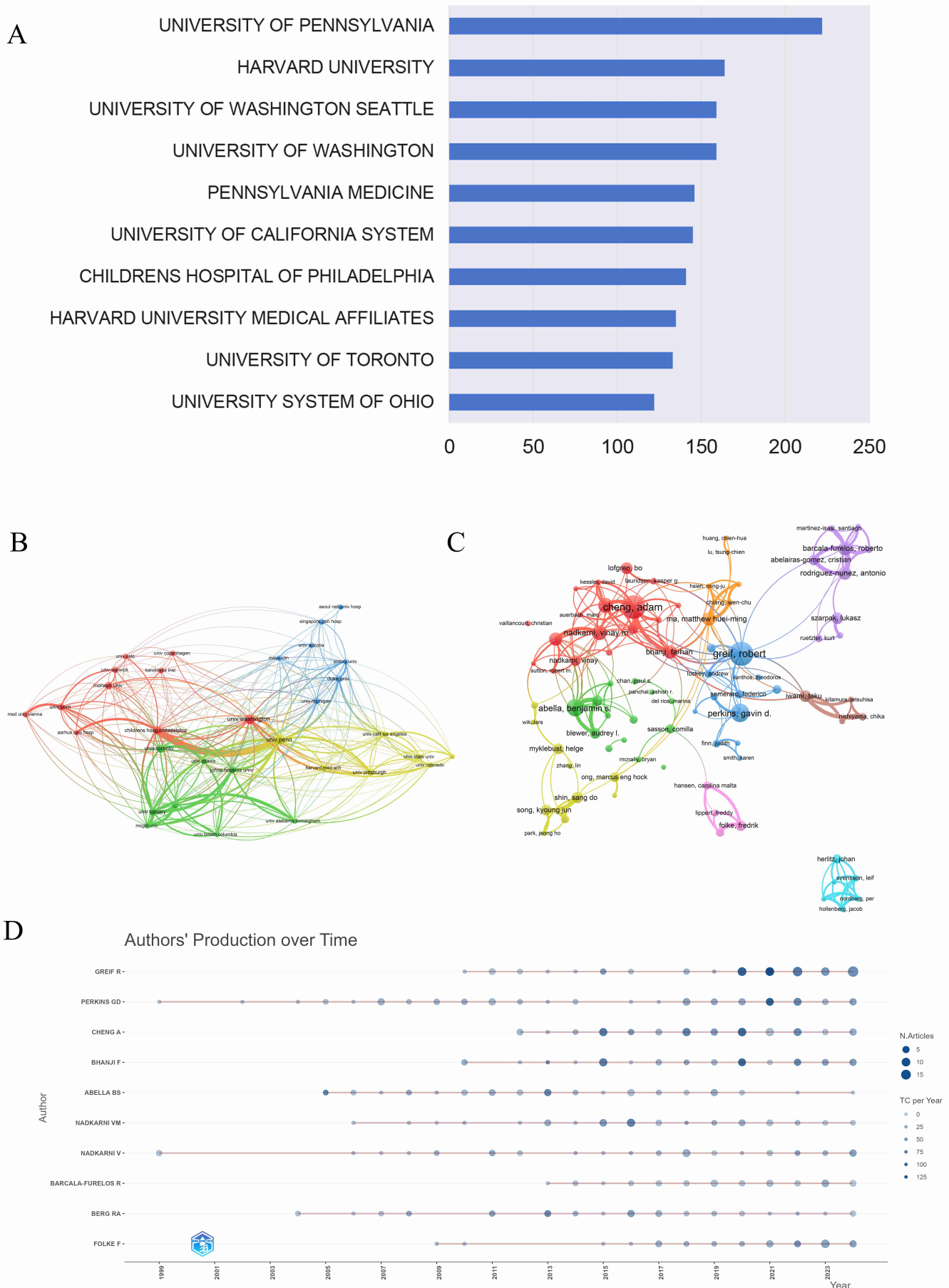
**FIGURE 2. Leading countries in CPR training.** (A) Geographical distribution of global output. (B) Visual cluster analysis of cooperation among countries. (C) Timeline visualization of cooperation among countries.

200 different journals. The top 10 journals by publication volume are presented in Table 2. Resuscitation (published by Elsevier) is the leading journal, with 849 articles and 34,141 citations, followed by Resuscitation Plus (published by Elsevier, with 124 articles and 603 citations), American Journal of Emergency Medicine (published by W.B. Saunders Co-Elsevier Inc, with 89 articles and 1168 citations), BMJ Open (published by British Medical Journal Publishing Group, with 70 articles and 729 citations), and Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine (published by Springer Nature, with 68 articles and 1083 citations). Among the top 10 journals, Critical Care Medicine has the highest impact factor (IF) of 7.7. The average IF across the top 10 journals is 3.23, with three journals exceeding an IF of 3.0. These results reflect both the academic influence and the diversity of publishing platforms supporting research on CPR training.

### 3.5 Analysis of keywords

Keyword co-occurrence analysis can be used to identify research hotspots in a discipline effectively and is an impor-

tant auxiliary tool for guiding scientific inquiry. From the 5364 publications related to CPR training, a total of 10,949 keywords were extracted. Using a full counting strategy, we generated a co-occurrence map based on bibliographic data. Among these keywords, 7332 appeared only once, accounting for 66.9% of the total. To enhance analytical accuracy, we applied a thesaurus for data cleaning and refinement and set the minimum keyword occurrence threshold to 121. As a result, 54 keywords met the inclusion criteria and were grouped into five distinct clusters (Fig. 5A). The keyword “cardiopulmonary resuscitation” appeared most frequently, with 1997 occurrences. Other prominent keywords included “hospital cardiac arrest” (940 times), “cardiac arrest” (639 times), and “education” (419 times). The keyword density map offers a comprehensive view of the field’s overall structure and focal areas (Fig. 5B). In this visualization, brighter regions represent higher keyword frequencies, while dimmer regions indicate less frequently occurring terms. The density distribution confirms that “cardiopulmonary resuscitation” remains the central focus of research, followed closely by “cardiac arrest” and “education”, highlighting the ongoing emphasis on both clinical



**FIGURE 3. Visualization of active institutes and authors analysis.** (A) The top 10 productive institutions in CPR training research. (B) Cluster analysis of cooperation among institutions. (C) Cluster analysis of cooperation among authors. (D) Timeline distribution of the top 10 most productive authors.

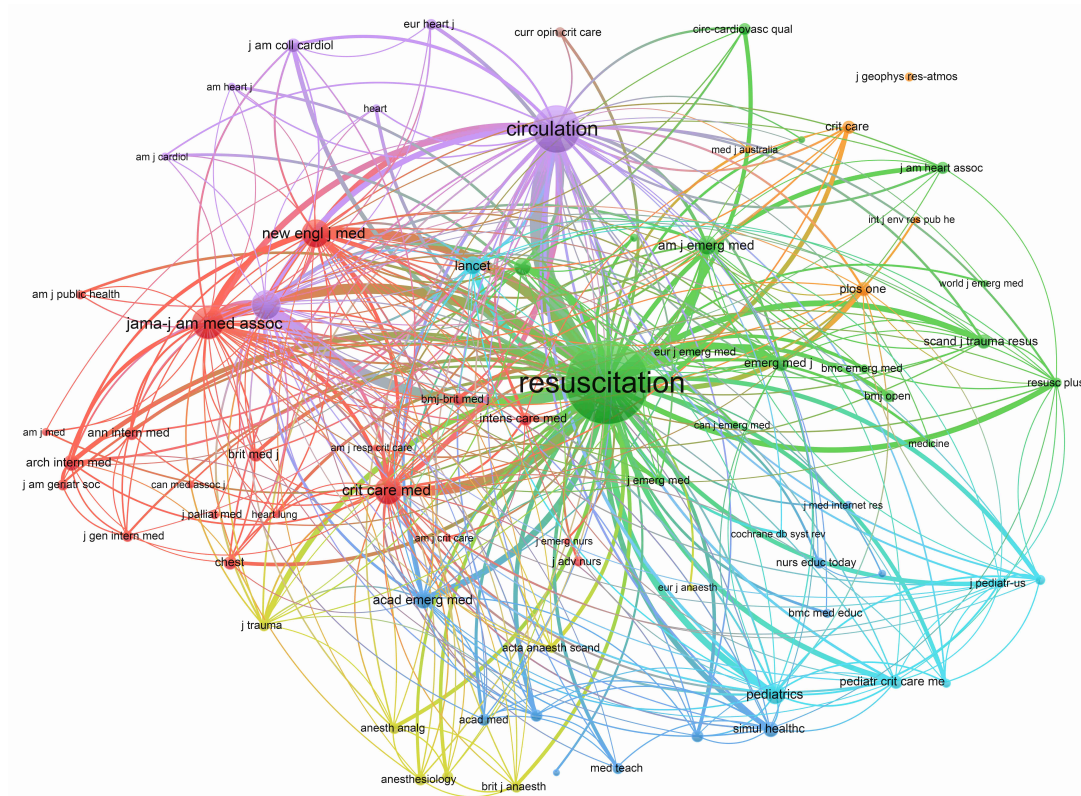


FIGURE 4. Cluster analysis of cooperation among journals.

TABLE 2. Top 10 most active journals in the CPR training field.

Rank	Sources title	Counts	TLCS	TGCS	IF (2023)	H-index*	Category quartile (2023)
1	Resuscitation	849	30,841	34,141	6.5	87	Q1
2	Resuscitation Plus	124	559	603	2.1	12	Q3/Q2
3	American Journal of Emergency Medicine	89	1147	1169	2.7	19	Q1
4	British Medical Journal Open	70	708	729	2.4	15	Q1
5	Scandinavian Journal of Trauma Resuscitation Emergency Medicine	68	1063	1083	3.0	20	Q1
6	Prehospital Emergency Care	67	1181	1199	2.1	22	Q2
7	Critical Care Medicine	64	4999	5022	7.7	41	Q1
8	Public Library of Science ONE	64	763	783	2.9	16	Q1
9	Simulation in Healthcare: Journal of the Society for Simulation in Healthcare	62	1059	1084	1.7	16	Q3
10	Pediatric Emergency Care	60	910	923	1.2	17	Q3

\*: H-index was calculated based on only the publications included in the present study.

TLCS: total local citation score; TGCS: total global citation score; IF: impact factor.

outcomes and training methodologies.

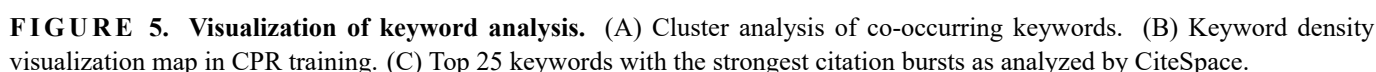
Keyword burst analysis was performed to identify terms with a sudden increase in citation frequency over time. The earliest and longest-lasting burst keyword was “ventricular fibrillation”, which emerged in 1995. The term with the highest burst intensity was “cardiopulmonary resuscitation (CPR)”, reinforcing its foundational status in the field. More recent bursts have corresponded to updated clinical practice guidelines issued by major organizations. These include keywords

such as “American Heart Association”, “association guidelines update”, and “European resuscitation”, reflecting the influence of institutional guidelines on evolving research directions (Fig. 5C).

### 3.6 Analysis of reference co-citation

Reference co-citation analysis is another key method for identifying the intellectual structure and developmental trajectory of







a research field. In this study, we constructed a visual network of co-cited references and performed cluster analysis to detect thematic groupings (Fig. 6A). The analysis yielded clusters with high reliability, as evidenced by a modularity value (Q) of 0.8462 and a silhouette score (S) of 0.9145, both indicating a well-structured and internally coherent clustering result.

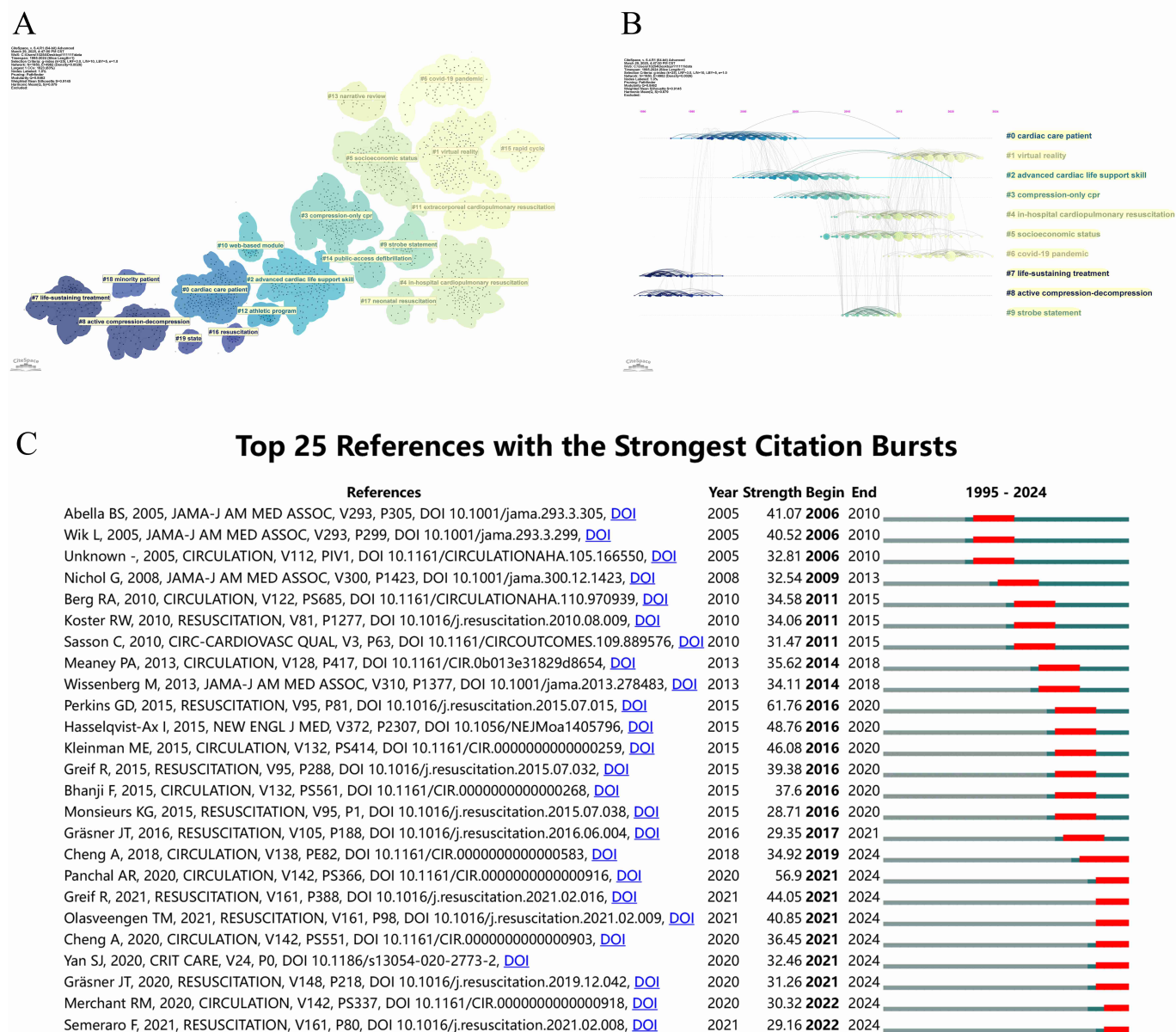
As shown in Fig. 6B, the top 10 clusters of co-cited references included themes such as “cardiac care patient”, “virtual reality” and “advanced cardiac life support skill”. Timeline visualization of these clusters revealed that early research in the field focused on topics such as “life-sustaining treatment” and “active compression-decompression”, highlighting foundational work in CPR methodology. In contrast, “virtual reality” has emerged as a current research hotspot.

Citation burst analysis was conducted to identify references that experienced a sudden increase in citation frequency, indicating their impact and relevance over specific time periods.

The earliest burst was detected in 2001, corresponding to an article by Valenzuela TD *et al.* [17], published in 2000 in The New England Journal of Medicine (Fig. 6C). The strongest citation burst was associated with the article by Perkins GD *et al.* [18], published in Resuscitation in 2015. Other highly influential works showing notable bursts included those by Cheng A, Greif R, and Olasveengen TM, underscoring their significant contributions to the field of CPR training research.

## 4. Discussion

This bibliometric analysis of CPR training-related literature retrieved from WoSCC identified a total of 5364 publications, including 4894 original articles and 470 review articles. The annual number of publications increased significantly from 52 in 1995 to 529 in 2024, reflecting an average annual growth rate of 8.74% and the increasing recognition of CPR training



**FIGURE 6. Visualization of co-cited reference analysis.** (A) Cluster analysis of co-cited references. (B) Timeline distribution of reference clusters. (C) Top 25 references with the strongest citation bursts, analyzed by CiteSpace.

as a critical component of emergency medical education and preparedness. Despite the expanding research output, only three of the top 10 most active journals in the field had an impact factor (IF)  $>3$ , suggesting that publication of CPR training studies in high-impact journals remains challenging. The analysis reveals several important trends and characteristics within CPR training research. First, the consistent increase in publication volume reflects a growing global awareness of the importance of CPR training. Second, numerous governments and academic institutions have actively promoted public emergency response capabilities, which has contributed to both the expansion of the literature and an increase in international collaboration. Third, as CPR techniques have matured, research focus has progressively shifted from technological advancements toward the optimization, scalability and effectiveness of training delivery.

Representative countries and institutions have been central in advancing CPR training research. The United States of America has exhibited particularly strong academic influence, with the University of Pennsylvania emerging as the most productive institution. Dr. Nadkarni from this institution has made substantial contributions to pediatric resuscitation research, including the development of high-fidelity simulators for infant and pediatric CPR training. In 2011, his team demonstrated that low-dose, high-frequency, brief bedside CPR training could improve skill retention among pediatric hospital staff [19]. In addition to technical innovations, the University of Pennsylvania has also frequently contributed to the publication of international consensus statements on CPR science. These publications have provided a scientific foundation for training practices and informed the development of global CPR guidelines and educational programs [20]. Furthermore, the trend of collaboration in CPR training research, particularly the close cooperation between the United States of America and other countries, has significantly improved research quality and promoted the global dissemination of emergency techniques and training methods. For instance, China initially adopted American guidelines and subsequently introduced the concept of the “survival cycle” based on its own national context [21]. This framework, which emphasizes patient-centered outcomes and a broader definition of survival, imparts a distinct Eastern perspective to CPR consensus development. Such evolving collaborative dynamics indicate that CPR training research has entered a new stage characterized by internationalization and interdisciplinary integration. The increasing prevalence of cooperative studies promotes resource sharing, enhances academic exchange, and contributes to the overall advancement of the field.

Keyword analysis indicates that current research hotspots in the field of CPR training are primarily concentrated in three major domains: emergency response measures and techniques, public health dissemination, and innovations in healthcare systems and educational training methodologies. At the end of the 20th century, there was a widespread deficiency in emergency response skills, including CPR, among the general public. Eisenburger *et al.* [22] highlighted this issue in a review, noting that a very small proportion of non-professionals participated in out-of-hospital resuscitation efforts, reflecting limited public awareness and proficiency in CPR or basic life support

skills. The authors emphasized the importance of equipping non-professionals with essential life support competencies. In addition, Eberle *et al.* [23] found that trained rescuers often required extended time to recognize pulselessness and demonstrated low accuracy, thereby recommending enhanced initial training and periodic retraining for professional responders. In the early 21st century, research focus shifted toward the development of public health infrastructure and emergency response systems, alongside a growing emphasis on the quality of medical education and training. For instance, Capucci *et al.* [24] implemented an early defibrillation system in out-of-hospital settings, demonstrating that the widespread deployment of automated external defibrillators (AEDs) operated by non-medical volunteers substantially improved early defibrillation rates. Similarly, Wayne *et al.* [25] conducted a randomized trial which demonstrated that simulation-based education significantly improved physicians’ performance in advanced cardiac life support (ACLS) scenarios. CPR training research has increasingly emphasized the application and practical implementation of emergency techniques, and efforts to standardize educational strategies. In recent years, this foundation has been further reinforced by updated international guidelines issued by the European Resuscitation Council and the International Liaison Committee on Resuscitation, which continue to guide the evolution of training practices and research priorities in the field [20, 26]. Research in CPR training has delved deeper into the organizational and management aspects of healthcare systems. Additionally, the citation frequency of keywords such as “update” and “machine learning” continues to rise. Recently, Viderman *et al.* [27] published an article indicating that artificial intelligence can help predict outcomes such as cardiac arrest, and assist with the transportation of defibrillators via drones and the notification of dispatchers, which suggests potential innovations and transformations in medical education and training methods, as well as enhanced international communication and collaboration in the medical field. Kuyt *et al.* [28] evaluated the development of VR and augmented reality (AR) in the field of CPR in their 2021 study, finding that virtual technologies were well received by both instructors and trainees. So far, there has been a significant upward trend in the number of peer-reviewed articles and conference proceedings related to VR and AR in the CPR field.

From the citation analysis, we found that the work of Perkins *et al.* [18] exhibited the highest burst strength, indicating that it is currently a focal point in CPR training research. In their article, they introduced comprehensive technical guidelines for the initial resuscitation of adult cardiac arrest patients, including basic life support, the use of AEDs, and simple techniques for addressing choking (foreign body airway obstruction), emphasizing the critical importance of rapidly and accurately identifying cardiac arrest, as well as the need to appropriately select between AEDs and manual defibrillation under different clinical conditions [18]. In recent years, articles by Panchal *et al.* [29] have also demonstrated strong citation bursts, closely related to the topics addressed by the aforementioned work. Panchal *et al.*’s contributions provide key guidelines for adult basic and advanced life support, while also reviewing significant research advances in cardiovascular

disease and emergency medical services, particularly with regard to survival outcomes and emergency strategies for cardiac arrest patients [29]. Together, these articles offer simple and practical emergency response strategies for lay rescuers and serve as an essential reference for updating CPR and emergency cardiovascular care guidelines in clinical settings.

In addition, as global health challenges continue to evolve, new demands and shifts have emerged in CPR training research. Survival rates and quality of life for elderly individuals following in-hospital or out-of-hospital CPR remain suboptimal. Available data indicate that although survival rates among elderly patients have improved, they still do not exceed 28.5% for in-hospital CPR and 11.1% for out-of-hospital CPR [30]. The growing aging population, along with the rising prevalence of chronic diseases, underscores the increasing relevance of CPR skills in home care and community health settings, as survival rates markedly decline with advancing age. This trend highlights the need to strengthen CPR training in aging societies. Within this context, CPR training is not only a technical education in emergency response but also a vital component of broader public health education. Thus, enhancing CPR awareness and skill proficiency among the general public, particularly among elderly individuals and their family members, is essential for improving the survival outcomes of cardiac arrest patients.

The observed trends and characteristics in CPR training research indicate that the field is undergoing continuous evolution and innovation, with sustained advancements in emergency techniques and training methodologies. Research in CPR training has demonstrated profound influence, both in academic discourse and in clinical application. Through ongoing innovation and strengthened international collaboration, this field is expected to play an increasingly important role in enhancing global public health and emergency response capabilities. Looking ahead, future research may focus on several key areas. First, with the rapid development of machine learning and big data technologies, incorporating these tools into CPR training research could significantly improve the precision, efficiency, and applicability of related studies [5]. Second, the adoption of personalized training programs and remote learning is emerging as a major trend. Tailored training plans, designed to meet individual learners' specific needs and learning trajectories, are anticipated to become increasingly widespread in CPR education [7]. Third, the use of high-fidelity simulators is expected to expand further, as these technologies provide more accurate physiological feedback and better simulate real-life scenarios encountered in cardiac arrest cases [31]. Finally, CPR training is likely to become more integrated with disciplines such as psychology and behavioral science. Interdisciplinary collaboration in these areas will help trainees develop the ability to apply CPR skills more effectively under high-stress and time-sensitive conditions.

Despite the detailed analysis of CPR training research through bibliometric and visualization methods, this study has some limitations. First, due to differences in export formats, merging multiple databases from different sources is quite challenging, which may lead to potential data overlap. Therefore, we selected only the WoS database, as it offers the broadest coverage. Second, there are some potential

confounding factors in this study. Since the guidelines and recommendations referred to have relatively high citation rates, they may have introduced a degree of interference. These guidelines and expert opinions could have influenced the processes of data collection and analysis, thereby adding a certain level of uncertainty to the interpretation of the research results. Future studies may further explore how to reduce the impact of such potential confounding factors. Thirdly, the bibliometric analysis in this study relies mainly on published English-language literature and does not fully consider unpublished research or findings published in other languages, which reduces the external validity of the study and may result in the omission of certain research hotspots or emerging trends. In future research, attempts can be made to conduct multilingual validations to enhance the comprehensiveness of the analysis.

## 5. Conclusions

Through bibliometric analysis, we have identified that CPR training has substantial research potential. The number of publications related to CPR training has shown a rapid and sustained increase. Over time, the research focus in this field has gradually shifted from the dissemination of public health knowledge to the development of innovative educational and training methods. Future development trends are likely to concentrate on the integration of machine learning and big data, implementation of personalized training programs, and the advancement of interdisciplinary collaboration.

## AVAILABILITY OF DATA AND MATERIALS

The datasets supporting the conclusions of this article are included in this article.

## AUTHOR CONTRIBUTIONS

YHL, YW and ZGB—conceptualization; data curation; formal analysis; investigation; writing—original draft. YYL, JHW, HQS and ZXW—methodology; software; visualization; writing—original draft. LS and YPX—conceptualization; funding acquisition; project administration; supervision; validation. All authors contributed to editorial changes in the manuscript. All authors read and approved the manuscript.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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