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IoT Applications in Fire Safety Management: Bibliometric Study on Resilience and Emergency Response

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Abstract - In the past few years, the Internet of Things (IoT) has been used more often in fire safety. Simple devices like smoke sensors, alarms, and connected networks are now able to detect signs of fire earlier and send alerts faster. These systems are not perfect, but they do make it easier to react before a small incident becomes serious. This paper reviews how research in this area has developed. The study looked at three main databases—Scopus, Web of Science (WoS), and IEEE Xplore. At first, the searches gave thousands of results, most of which were not directly related to fire safety. After the keywords were refined, the numbers went down to 84 in Scopus, 44 in WoS, and 52 in IEEE Xplore. These papers formed the main dataset. From the analysis, several points stand out. First, more studies are being published every year, showing a growing interest in this field. Second, much of the work is about smart detection, real-time monitoring, and automatic response systems. A smaller but important group of studies also looks at how IoT can support firefighters, improve awareness during emergencies, and help with planning resources. Overall, the findings show that IoT has clear benefits but also leaves questions. Some systems are not widely tested in real-life situations, and problems like cost, security, and reliability remain. This review helps outline what has been done so far, where the gaps are, and what directions future research might take to make IoT more useful in fire safety.

Keywords—Internet of Things, Fire Safety Management, Smart Emergency Response, Bibliometric Analysis, Smart Detection

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1. INTRODUCTION

The Internet of Things (IoT) has started to change how fire safety is managed. Simple devices such as smoke detectors, heat sensors, and communication tools can now be connected through networks. When they work together, they make it possible to spot fire hazards earlier and warn people more quickly. In many cases, this means that action can be taken before a small incident becomes a serious disaster.

Several studies explain how IoT supports faster and smarter fire responses. Mouradian *et al.* [1], for example, showed how IoT can help improve coordination during emergencies. Atul B. Kathole *et al.* [2] also found that IoT can make fire management faster and more effective. These examples show that the use of IoT in this field is not only technical but also practical, helping emergency teams do their job better.

Researchers have also looked at the wider use of IoT in fire detection and evacuation. Kostoeva *et al.* [3] and Mohammadiounotikandi *et al.* [4] described how building plans and sensors can be linked to guide people out during a fire. Pang *et al.* [5] added that when IoT is combined with Building Information Modelling (BIM), it can help create safer evacuation routes. See & Ho [6] focused on the importance of fast communication, showing that protocols like MQTT make IoT fire systems more reliable. Peng *et al.* [5] gave another example by highlighting how electrical fire risks in high-rise buildings can be monitored in real time.

The role of IoT is not only about alarms and exits. Soliman & Abu El-Magd [7] explained that data from IoT can be used in training and awareness programs. Kamel *et al.* [8] studied educational buildings and found that IoT systems made them safer for students and staff. Guo [9] looked at city-level fire management, showing that IoT could improve safety as cities grow larger.

Still, challenges remain. Altowaijri *et al.* [11] warned that IoT fire systems can raise privacy concerns if data is not handled properly. Kurda *et al.* [11] also stressed that IoT devices are often weak against cyberattacks, which can reduce trust in these systems. Without strong protection, people may be less willing to adopt these technologies on a larger scale.

In short, IoT has already made a difference in fire safety. It can detect fires earlier, improve communication, and guide safer evacuations. At the same time, problems like cost, security, and standardization need more attention. As cities become more complex, IoT is likely to play an even bigger role in protecting people and property from fire.

2. LITERATURE REVIEW

Most studies on IoT in fire safety focus on how fires are detected and monitored. Malik *et al.* [12] built a system that uses LoRa technology. It connects fire and smoke sensors to a microcontroller and can send alerts over long distances with very low power use. This makes it useful for big buildings. Kanagamalliga *et al.* [13] also showed how networks of sensors can find fires in real time and then trigger alarms or sprinklers to control them. In another case, Sacramento *et al.* [14] worked on a system for universities in Brazil. Their design combines IoT with WebGIS to provide location-based fire alerts through sensors spread across the campus.

Some researchers have used artificial intelligence to make detection more accurate. Dwivedi *et al.* [15] created a system for construction sites that uses smartphones with vision-based deep learning. It can spot sparks and other risks on site. Davrazos *et al.* [16] developed “Predictive Vigilance,” which applies machine learning to smoke detection. Their goal was to reduce false alarms and make the system more dependable. Bhardwaj and Joshi [17] suggested using the CSA-IoT Matter protocol with machine learning. They argued this approach helps systems respond faster and with fewer errors.

Beyond detection, IoT is also used for evacuation and emergency response. Pachipala *et al.* [18] designed an alert system with flame, gas, and temperature sensors to guide safe evacuation. Gustiyana *et al.* [19] looked at IoT standards for Fire Alarm Control Panels (FACP). They recommended using MQTT protocols with backup connections to keep systems working during an emergency.

Communication technology has also been studied. Chen *et al.* [20] argued that 5G and edge computing could speed up fire monitoring and responses. Patel *et al.* [21] pointed out that using IoT in smart cities faces challenges like compatibility and scalability, which slow down adoption. This study by Zhang *et al.* [22] developed and tested a real-

time IoT emergency alert system that can quickly detect fires, accidents, gas leaks, and medical cases. The results show it is fast, accurate, and reliable, making it useful for safer cities and industries.

Table 1 gives a summary of these applications, covering detection, prevention, suppression, response, and also issues related to data and security.

Table 1. Type of IoT Applications in Fire Safety Management

Authors	Type of IoT applications in fire safety management				
	Fire Detection & Monitoring	Fire Prevention	Fire Suppression	Emergency Response	Data Management & Security
[23]	✓	✓	✓	✓	✓
[24]	✓	✓	✓	✓	
[25]	✓	✓	✓	✓	
[26]	✓	✓	✓	✓	✓
[27]	✓	✓	✓	✓	
[28]					✓
[21]	✓			✓	✓
[29]	✓	✓		✓	✓
[12]	✓			✓	✓
[13]	✓	✓	✓	✓	
[14]	✓	✓		✓	✓
[30]	✓			✓	✓
[18]	✓	✓		✓	
[19]	✓	✓		✓	✓
[16]	✓			✓	✓
[17]	✓			✓	✓

From the review, it is clear that IoT has a lot to offer. It supports early fire detection, prevention, and faster emergency responses. It can also be combined with other new tools like artificial intelligence or blockchain to make systems stronger. But some barriers are still there. High costs, lack of standards, and data security risks are common problems. More research is needed to improve system compatibility, lower costs, and build trust in IoT fire systems. Only then can these technologies be applied more widely and reliably in real-world fire safety.

3. RESEARCH METHODOLOGY

This paper used bibliometric analysis to study how IoT is being used in fire safety. Bibliometric methods are useful for showing patterns in published research. They can highlight which topics are common, which studies are most cited, and which countries are active in the field. In this case, the method helped identify how IoT supports fire detection, prevention, and emergency response.

Three databases were chosen: Scopus, Web of Science (WoS), and IEEE Xplore. These were picked because they cover many peer-reviewed journals, conference papers, and technical reports. They are also known for indexing strong studies in engineering, technology, and computer science. The search was done in stages. The time frame was set as 2014 to June 2025 for Scopus, 2016 to June 2025 for WoS, and 2018 to June 2025 for IEEE Xplore. This range was chosen so that both older and newer works could be included.

The first search used broad keywords: ("Internet of Things" OR "IoT") AND ("fire" OR "fire safety"). This gave 2,600 results in Scopus, 149,950 in WoS, and 174,990 in IEEE Xplore. Many of these papers were not really about fire safety but were linked to other fields like smart cities or healthcare. To focus better, a second search used stricter keywords: ("Internet of Things" AND "IoT") AND ("fire" AND "fire safety"). After this, the results dropped to 84 in Scopus, 44 in WoS, and 52 in IEEE Xplore. Extra steps were taken to refine the dataset. Duplicates were removed. If

both a conference and journal version of the same work existed, only the journal version was kept. Non-English papers were also excluded.

In the end, the final dataset had 180 papers: 84 from Scopus, 44 from WoS, and 52 from IEEE Xplore (0 duplicates removed, 180 unique records retained). These papers were then studied using bibliometric tools. The focus was on publication trends, countries and institutions involved, citation counts, and keyword patterns. To go deeper, a co-occurrence keyword analysis was done with VosViewer. This software can create maps that show how authors, keywords, and institutions are linked. With this, the study was able to identify clusters of research, networks of collaboration, and the main themes that shape this field. By following these steps, the review stayed systematic and reliable. It also gave a clear picture of what has been studied so far and what gaps are still open for future research.

4. RESULTS AND DISCUSSIONS

Based on the analysis through VosViewer, there are a few important findings captured. Figure 1 shows on the trend of publication based on the year basis. The analysis shows that interest in IoT for fire safety has grown slowly at first and then much faster in recent years. Between 2014 and 2018, there were very few publications. This suggests that the area was still new and only a handful of researchers were looking into it. Both Scopus and IEEE Xplore had one or two papers per year. WoS had almost nothing during this period. From 2019, the numbers started to rise. By 2020, Scopus and IEEE Xplore showed a clear jump. The peak came in 2024 with 20 papers in Scopus and 18 in IEEE Xplore. WoS also showed some growth, though the numbers were smaller compared to the other two databases. One reason could be that WoS indexes fewer conference papers, while Scopus and IEEE cover them more widely. In 2025, the number of publications dropped sharply. This might be because the data for that year is incomplete, as the search was done mid-year. Another reason could be that research is spreading into related areas, such as smart city safety or disaster management more broadly. Shifts in funding and policy might also explain the fall. Overall, the results suggest that IoT in fire safety became an active research field mainly after 2019, driven by better sensors, faster networks, and stricter safety rules.

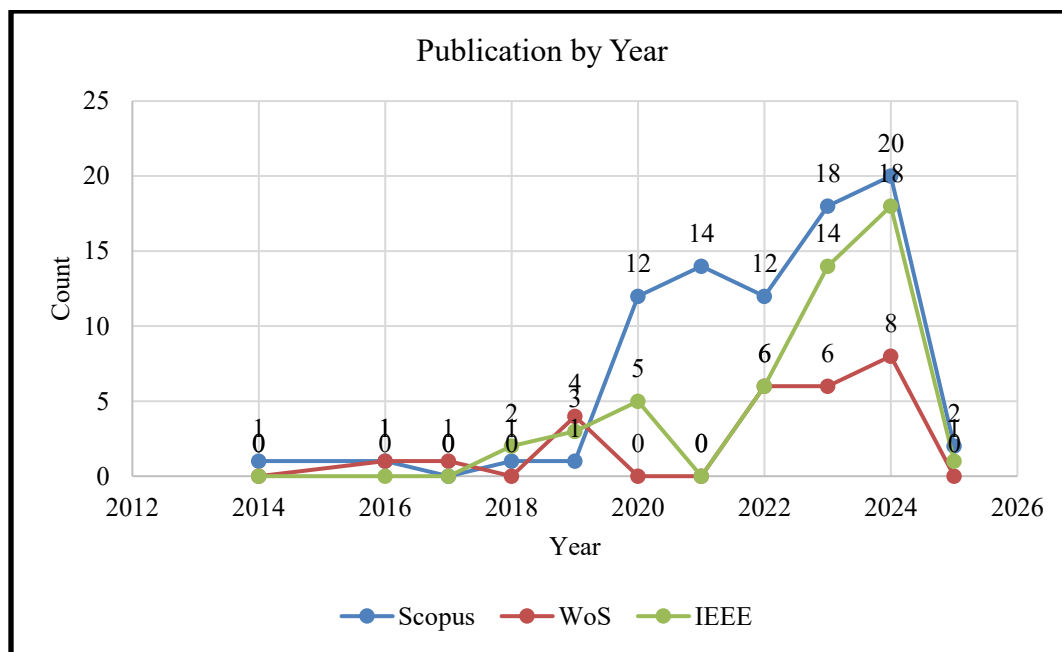


Figure 1. Publication by Year for Scopus, WoS and IEEE

The treemap in Figure 2 shows the most common research themes. The largest blocks are “Internet of Things,” “Fire Safety,” and “Fire Detection.” This tells us that most work is about detection systems. Other keywords such as “IoT devices,” “Wireless networks,” and “Cloud computing” highlight how researchers use connected systems to make detection faster and more reliable. Temperature and gas sensors also appear strongly, which means that multiple sensor types are often combined to improve accuracy. Other important terms stand out as well. Words like “Firefighters,”

“Fire protection,” and “Fire extinguishing” show that IoT is not only for alarms but also for supporting emergency teams. The presence of “Machine learning” and “System architecture” suggests that artificial intelligence and smart design are being added to make systems more adaptable. Together, the treemap points to IoT as a mix of hardware, software, and communication that connects safety systems in new ways.

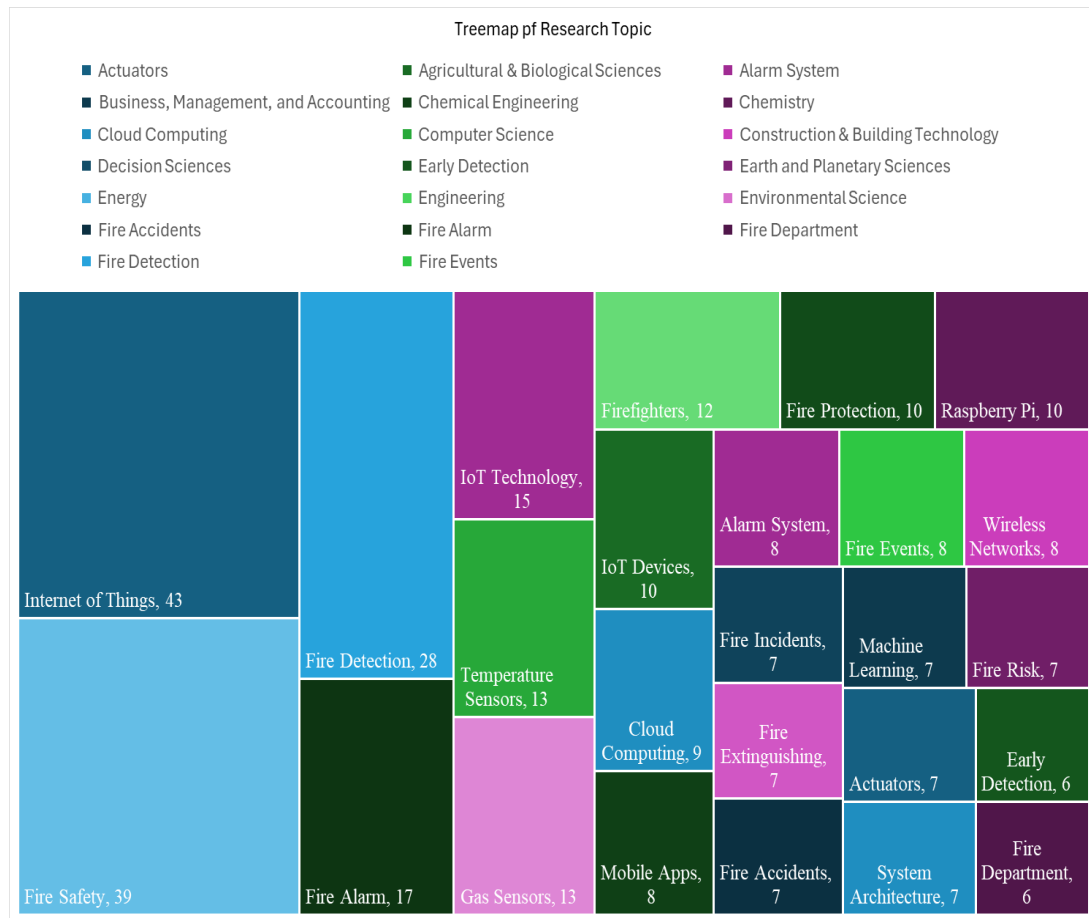


Figure 2. Treemap of the Research Topic

Figure 3, which shows the keyword network from VosViewer, gives a similar picture. The strongest link is between “IoT,” “Fire safety,” and “Fire protection.” Other close terms include “fire detectors,” “smoke detectors,” and “alarm systems.” These show that detection is still the main focus. But there are also clusters around “automation,” “microcontrollers,” and “embedded systems,” which indicate hardware-based approaches. At the same time, terms like “artificial intelligence” and “Industry 4.0” point to integration with larger digital systems. This mix of keywords suggests that the field is expanding. It is not just about early warning anymore. Researchers are also working on automatic suppression, predictive models, and real-time data sharing. Safety management is becoming a whole cycle, from prevention to recovery, supported by IoT.

Figure 4 highlights which countries are leading. India comes first, with 30 papers in WoS, 3 in Scopus, and 11 in IEEE Xplore. China is also active, with 9 in WoS, 3 in Scopus, and 2 in IEEE. The United States adds another strong contribution with 6 in WoS, 8 in IEEE, and 1 in Scopus. Other countries have smaller but still important roles. Saudi Arabia and the UAE link IoT fire systems with their urban development projects. In Europe, Italy, Germany, France, and Spain contribute through smart city research. Malaysia, Pakistan, Brazil, and Bangladesh show activity in developing regions, applying IoT to local safety problems. South Africa and Brazil bring in perspectives from Africa and South America. This spread shows that IoT in fire safety is not limited to one region. It is global, and it adapts to different contexts, from high-rise cities to smaller communities. In short, three points can be seen from the results. First, research activity grew sharply after 2019, with a clear peak in 2024. Second, detection remains the main focus,

but new themes such as evacuation, suppression, and cybersecurity are gaining attention. Third, contributions come from both developed and developing countries, showing that IoT in fire safety is relevant worldwide.

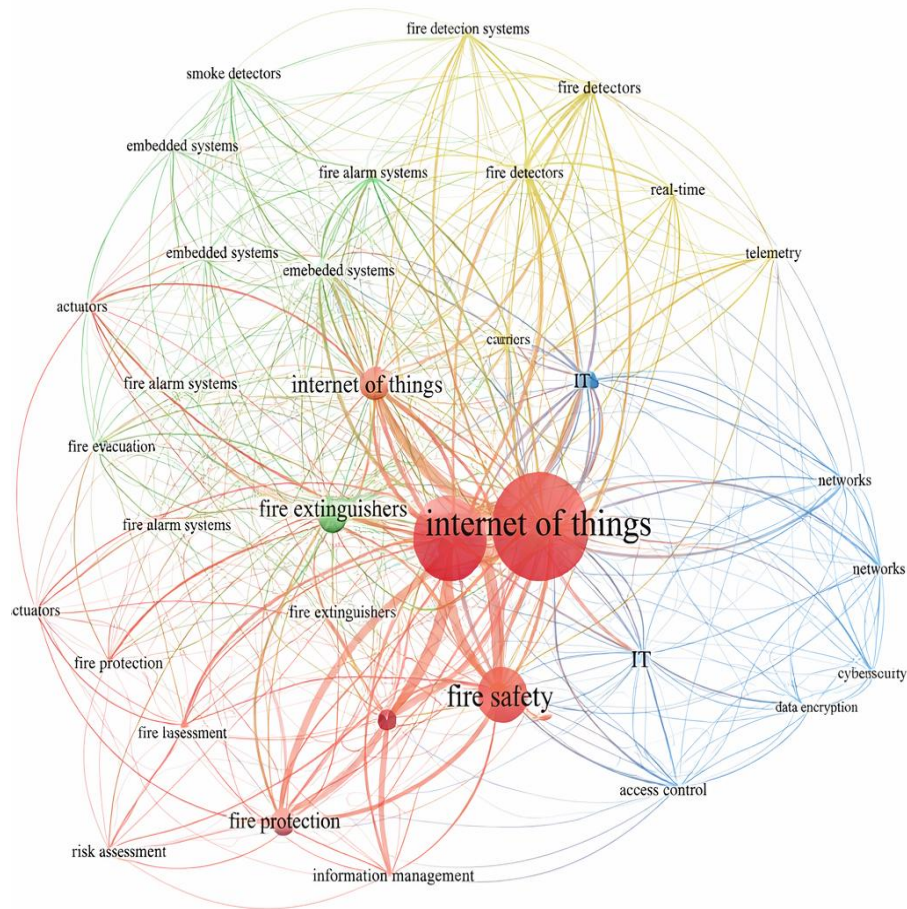


Figure 3. Keywords Used in Publication

5. CONCLUSION

This study looked at how the IoT is being used in fire safety. A bibliometric analysis was carried out to see patterns in research, such as trends, common themes, and the countries leading the field. The findings show that IoT has become an important part of fire safety in recent years. Many systems are built for early detection, real-time monitoring, and faster emergency response. By linking sensors, alarms, and smart networks, these potentially enable quicker responses and may help prevent small fires from spreading. Some studies also showed how IoT supports firefighters, improves awareness among people in danger, and helps with planning resources during emergencies. Still, not all problems are solved. Issues like cost, lack of common standards, and security risks continue to hold back wider use. Some systems are tested only in controlled environments, not in real-life conditions. Without stronger protection and clear guidelines, trust in these systems may remain low. Future work should focus on making IoT systems more secure, easier to connect with one another, and more affordable to use. Real-world testing in schools, factories, and cities will also be important. With these improvements, IoT can become a more reliable and practical tool for protecting lives and property from fire. From the perspective of informatics and web engineering, this study contributes by mapping how IoT-driven fire safety systems depend on interoperable data platforms, real-time information sharing, and secure web-based infrastructures. The bibliometric results provide practical guidance for developers and policymakers on where innovation is needed, such as in scalable cloud architectures, open standards, and cybersecurity frameworks. These insights highlight the applied relevance of IoT-enabled fire safety not only for emergency response but also for advancing smarter, data-driven urban safety systems.

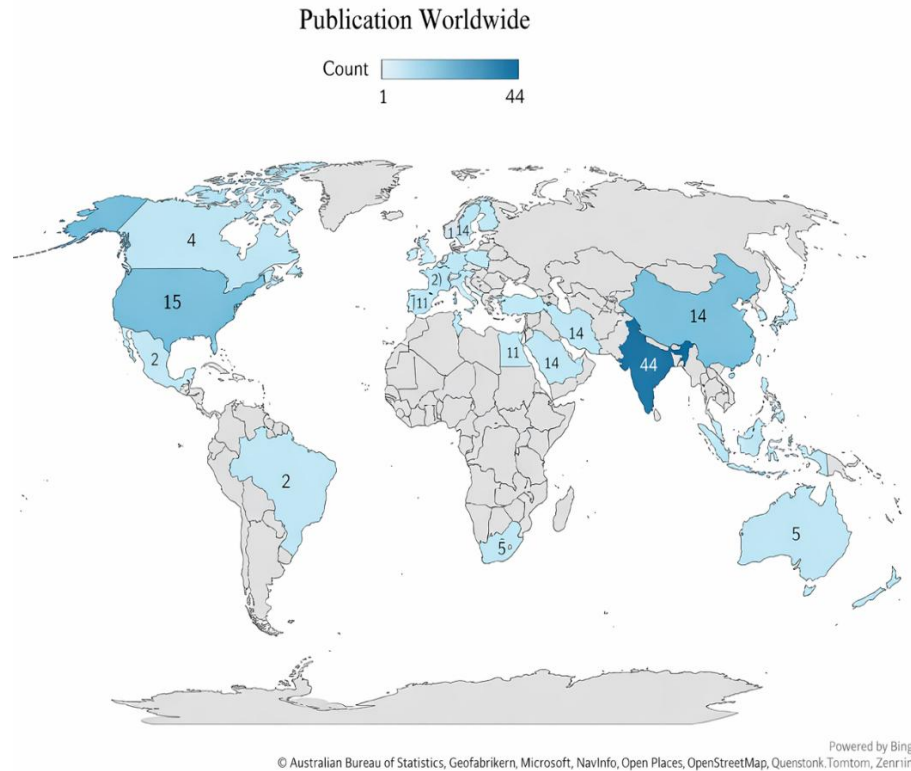


Figure 4. Publication Worldwide

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AUTHOR CONTRIBUTIONS

Nur 'Amirah Mhd Noh: Conceptualization, Data Curation, Methodology, Writing – Original Draft Preparation;
 Nor Rima Muhamad Ariff: Project Administration, Validation, Supervision;
 Ahmad Amru Mohamad Zaid: Writing – Review & Editing;
 Rabeah Md Zin: Writing – Review & Editing.

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENT

This study is a bibliometric analysis based solely on published literature and does not involve human participants, personal data, or experimental subjects. All data were obtained from publicly accessible academic databases and

analysed in accordance with ethical standards for secondary research. Therefore, formal ethical approval and informed consent were not required for this study. Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. <https://publicationethics.org/>

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are included within the article and its supplementary materials. No external datasets were generated or analysed during the current study. All relevant data are available from the corresponding author upon reasonable request.

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