Telemedicine Research Trends: A Bibliometric Perspective on Security and Privacy

Binnur AKIF[*], Nesrin KOLUKIRIK[**], Sinem BÜYÜKSAATÇI KİRİŞ[***]

Abstract

Aim: To explore the intersection of telemedicine, security and privacy through a comprehensive bibliometric analysis, with a focus on technological developments, thematic structures, and global research trends.

Method: This study is a bibliometric analysis examining publication trends, thematic structures, keyword patterns and authorial, institutional and County-level contributions to telemedicine security research. A total of 10,641 peer-reviewed articles were retrieved from scientific databases covering health services, telemedicine and information technology literature from 2014 to April 2026. Co-occurrence analysis and thematic mapping were used to identify foundational, specialized, driving and emerging areas of inquiry. Bibliometric tools were used to analyze scientific production, collaboration patterns, keyword structures and thematic development.

Results: The volume of research increased significantly after 2020, reflecting the growing role of telemedicine and digital health services during and after the COVID-19 pandemic. The findings show that "telemedicine," "privacy," "security," "digital health," "mHealth," and "telehealth" are among the most frequent and influential keywords in the field. The thematic map indicates that security, privacy and blockchain appear as specialized niche themes, whereas artificial intelligence, machine learning, deep learning, big data, and ethics represent emerging areas requiring stronger integration with telemedicine security and privacy research. The results also reveal broad contributions from various authors, institutions, journals, and countries, confirming the multidisciplinary and global nature of this research area.

Conclusion: Research on telemedicine security is rapidly expanding, with increasing attention to digital health infrastructures, privacy protection, cybersecurity, and patient-centered remote care. Future studies should focus on integrating security and privacy mechanisms into mainstream telemedicine applications, developing secure data-sharing frameworks, strengthening ethical and privacy-preserving AI-based telemedicine systems and addressing user acceptance differences related to sociocultural, regional, and Digital literacy. These directions can support the development of safer, more trustworthy, inclusive, and sustainable digital health systems.

Keywords: Telemedicine, security, e-health, data privacy, bibliometric analysis.

Özgün Araştırma Makalesi (Original Research Article)
Geliş / Received: 01.10.2025 **Kabul / Accepted:** 30.07.2026
DOI: https://doi.org/10.38079/igusabder.1794018
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Tele-tıp Araştırma Trendleri: Güvenlik ve Gizlilik Üzerine Bibliyometrik Bir Bakış Açısı

Öz

Amaç: Teknolojik gelişmeler, tematik yapılar ve küresel araştırma trendlerine odaklanarak, kapsamlı bir bibliyometrik analiz yoluyla tele-tıp, güvenlik ve gizlilik kesişimini incelemektir.

Yöntem: Bu çalışma; tele-tıp güvenliği araştırmalarındaki yayın eğilimlerini, tematik yapıları, anahtar kelime kalıplarını ve yazar, kurum ve ülke düzeyindeki katkıları inceleyen bir bibliyometrik analizdir. Sağlık hizmetleri, tele-tıp ve bilgi teknolojisi literatürünü kapsayan bilimsel veri tabanlarından 2014 ile Nisan 2026 tarihleri arasında yayınlanmış toplam 10.641 hakemli makale elde edilmiştir. Çalışmada; temel, uzmanlaşmış, yönlendirici ve gelişmekte olan araştırma alanlarını belirlemek için eş zamanlılık analizi ve tematik haritalama kullanmıştır. Bilimsel üretim, işbirliği kalıpları, anahtar kelime yapıları ve tematik gelişmeyi analiz etmek için bibliyometrik araçlardan yararlanılmıştır.

Bulgular: 2020'den sonra araştırma hacmi önemli ölçüde artmış olup, bu durum COVID-19 pandemisi sırasında ve sonrasında teletıp ve dijital sağlık hizmetlerinin artan rolünü yansıtmaktadır. Bulgular, "teletıp," "gizlilik," "güvenlik," "dijital sağlık," "mHealth" ve "tele sağlık" kelimelerinin alandaki en sık ve etkili anahtar kelimeler arasında olduğunu göstermektedir. Tematik harita, güvenlik, gizlilik ve blok zincirinin uzmanlaşmış niş temalar olarak ortaya çıktığını, yapay zeka, makine öğrenimi, derin öğrenme, büyük veri ve etiğin ise teletıp güvenliği ve gizlilik araştırmalarıyla daha güçlü entegrasyon gerektiren gelişmekte olan alanları temsil ettiğini göstermektedir. Sonuçlar ayrıca, çeşitli yazarların, kurumların, dergilerin ve ülkelerin geniş katkılarını ortaya koyarak, bu araştırma alanının çok disiplinli ve küresel doğasını doğrulamaktadır.

Sonuç: Tele-tıp güvenliği araştırmaları, dijital sağlık altyapılarına, gizlilik korumasına, siber güvenliğe ve hasta merkezli uzaktan bakıma artan ilgiyle birlikte hızla genişlemektedir. Gelecekteki çalışmalar; güvenlik ve gizlilik mekanizmalarını ana akım teletıp uygulamalarına entegre etmeye, güvenli veri paylaşım çerçeveleri geliştirmeye, etik ve gizliliği koruyan yapay zeka tabanlı teletıp sistemlerini güçlendirmeye ve kullanıcı kabulünde sosyokültürel, bölgesel ve dijital okuryazarlıkla ilgili farklılıkları ele almaya odaklanmalıdır. Bu yönlendirmeler, daha güvenli, daha güvenilir, kapsayıcı ve sürdürülebilir dijital sağlık sistemlerinin geliştirilmesini destekleyebilir.

Anahtar Sözcükler: Tele-tıp, güvenlik, e-sağlık, veri gizliliği, bibliyometrik analiz.

Introduction

Telemedicine refers to the delivery of healthcare services through telecommunications and electronic information technologies. It covers a set of applications that enable the remote delivery of medical services between patients and healthcare professionals. This technology offers several advantages for both patients and healthcare professionals. Rising healthcare costs and the increasing demand for high-quality care are encouraging healthcare organizations to adopt and expand telemedicine services[1].

Telemedicine has emerged as a critical approach to increasing access to healthcare, especially in remote or underserved areas. By enhancing geographic accessibility, health inequalities can be significantly reduced by providing access to basic medical services for individuals living in rural or underserved areas. To expand access to telemedicine for underserved patients, healthcare providers must develop strategies that promote engagement and ensure equitable access to essential telemedicine services. Additionally, addressing challenges such as digital literacy, provision of necessary equipment and

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communication tools, as well as regulatory and legal barriers, is essential to ensure equitable and inclusive access to telemedicine for all individuals[2].

According to United Nations data, 76% of hospitals use telemedicine technologies to connect with patients. Among the medical specialties, teleradiology (39.5%), emergency medicine (38.9%), pathology (30.4%) and psychiatry (27.8%) demonstrate the highest levels of telemedicine adoption. In addition, telemedicine is widely applied in cardiology, dermatology, oncology, and both pre- and post-surgical care. Globally, the purposes of telemedicine use vary by region. In Japan, healthcare providers use telemedicine as a complementary tool to face-to-face meetings. In South Korea, it is used for post-examination follow-ups. Across the European Union, telemedicine is widely utilized to monitor patients with chronic diseases. In the United States, telemedicine is broadly integrated into hospitals and clinics, including prescription determination and treatment decision-making[3].

Despite offering such great conveniences and benefits, telemedicine still faces various technological, regulatory, and financial barriers. The primary barriers for patients include adaptation to new technology, lack of face-to-face interaction, communication difficulties, and security concerns. Significant barriers from the perspective of healthcare providers include inadequate infrastructure, high costs, and legal uncertainties. These barriers can be categorized into two main categories: internal and external barriers. Internal barriers are directly related to patients' personal perceptions, experiences, and technological skills[4-6]. External barriers arise from broader issues, such as technological infrastructure, financial planning, data security, and regulatory framework[4,6-8]. Among these, data security remains the most pressing concern.

The secure sharing of patient information is a major requirement in telemedicine. Traditional centralized systems typically store data in a central cloud infrastructure. These data include highly sensitive medical images and health records. Numerous studies have highlighted that patient data collection and processing may lead to significant privacy and security risks[9]. Data privacy in telemedicine refers to the protection of sensitive patient information exchanged during remote healthcare services. This encompasses ensuring confidentiality, integrity and secure transmission of medical data. Confidentiality ensures that patient information is only accessible to authorized individuals, such as healthcare providers, and prevents unauthorized access or sharing[10,11]. Data integrity protects medical data from unauthorized modifications, which could lead to misdiagnosis or incorrect treatment[11]. Secure data transmission involves the transmission of large volumes of sensitive data over public networks[12]. To address these, improvements in IT security together with enhanced measures for data privacy and cybersecurity, are essential for maintaining trust, ensuring effective healthcare delivery, and protecting against evolving cybersecurity threats. A multi-layered security strategy encompassing IoT devices, communication networks, and hospital information systems has been proposed[13-15]. The proposed strategy includes key components such as authentication, access control and Data Loss Prevention (DLP) solutions.

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Authentication is the process of verifying the identity of a user, device, or system to ensure they are who they claim to be[16,17]. It establishes trust between the user and the system and ensures that only legitimate users or devices can access the telemedicine system[18]. Passwords, tokens, and biometric features (e.g., fingerprints, facial recognition)[17], advanced methods such as single sign-on (SSO)[19] or cryptographic protocols (e.g., elliptic curve cryptography)[20] are some techniques to verify a patient's or doctor's identity. Access control determines what authenticated users are allowed to do within the system[16,17]. It enforces rules about who can access specific resources and what actions they can perform[21]. Role-based access control and consent-driven data sharing frameworks enhance privacy by allowing patients to control who accesses their data[22]. Blockchain-based systems and encryption protocols, such as Attribute-Based Encryption (ABE), provide fine-grained access control, ensuring that only authorized users can access sensitive data[23]. Granting specific privileges to authenticated users by cryptographic tokens (e.g., Security Access Tokens) is another restricting mechanism[24].

Cybersecurity in telemedicine refers to the measures and practices implemented to protect sensitive medical data, ensure the secure operation of telemedicine platforms, and safeguard patient privacy in a digital healthcare environment. Telemedicine relies heavily on interconnected technologies, including the Internet of Medical Things (IoMT), cloud computing, and artificial intelligence, to facilitate remote consultations, diagnostics, and treatment services. This reliance introduces significant cybersecurity challenges, including data breaches, ransomware attacks, insider threats, and vulnerabilities in medical devices, which can disrupt healthcare services and compromise patient safety[25-27]. Breaches can lead to identity theft, unauthorized access, and misuse of personal health information[28].

In recent years, the intersection of telemedicine and cybersecurity has attracted increasing scholarly attention, driven by the rapid digitalization of healthcare and the escalating challenges of data privacy and system integrity. Against this backdrop, this study conducts a bibliometric analysis to systematically examine research at the intersection of telemedicine and security. By identifying key research trends, influential contributors, and thematic developments, the study aims to provide a comprehensive perspective on how telemedicine technologies have evolved and where future research opportunities lie.

This study is structured into four main sections. Following the introduction, the methodology section explains the bibliometric analysis approach. The results and discussion section presents key findings, including publication trends, prominent authors and institutions, thematic developments, and keyword patterns. Finally, the conclusion summarizes the main insights and outlines potential directions for future research.

Material and Methods

Bibliometric analysis, which emerged as an alternative to meta-analysis and systematic literature reviews, has become a widely used method for examining scientific literature[29].

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This analysis is used as a descriptive method to organize, measure, and evaluate the impact and contributions of research on a particular topic within a certain period of time. Additionally, it evaluates the performance of authors, institutions, and countries by using different metrics[30]. Techniques such as co-word analysis, theme mapping, and citation analysis are commonly employed in bibliometric analysis to identify new trends and/or areas of declining interest. Because of these aspects, bibliometric analysis stands out as a powerful tool for identifying both existing patterns in data and potential future research trends[31].

The bibliometric analysis presented in this study aims to investigate the relationship between telemedicine and security while also identifying future research opportunities in this domain. A comprehensive search was conducted in the Topic section of the Web of Science (WoS) Core Collection database and Title/Abstract section of the PubMed database to achieve this objective. The following keywords were used to construct the search query: ("telemedicine" OR "telehealth" OR "tele-medicine" OR "tele-health" OR "mHealth" OR "m-health" OR "eHealth" OR "e-health" OR "digital health" OR "remote patient monitoring" OR "teleconsultation" OR "telemonitoring") AND ("security" OR "cybersecurity" OR "cyber security" OR "data privacy" OR "data protection" OR "information security" OR "privacy" OR "confidentiality" OR "authentication" OR "encryption" OR "blockchain") AND ("health" OR "healthcare" OR "clinical" OR "patient" OR "medical").

Figure 1 presents the systematic stages of the search process.

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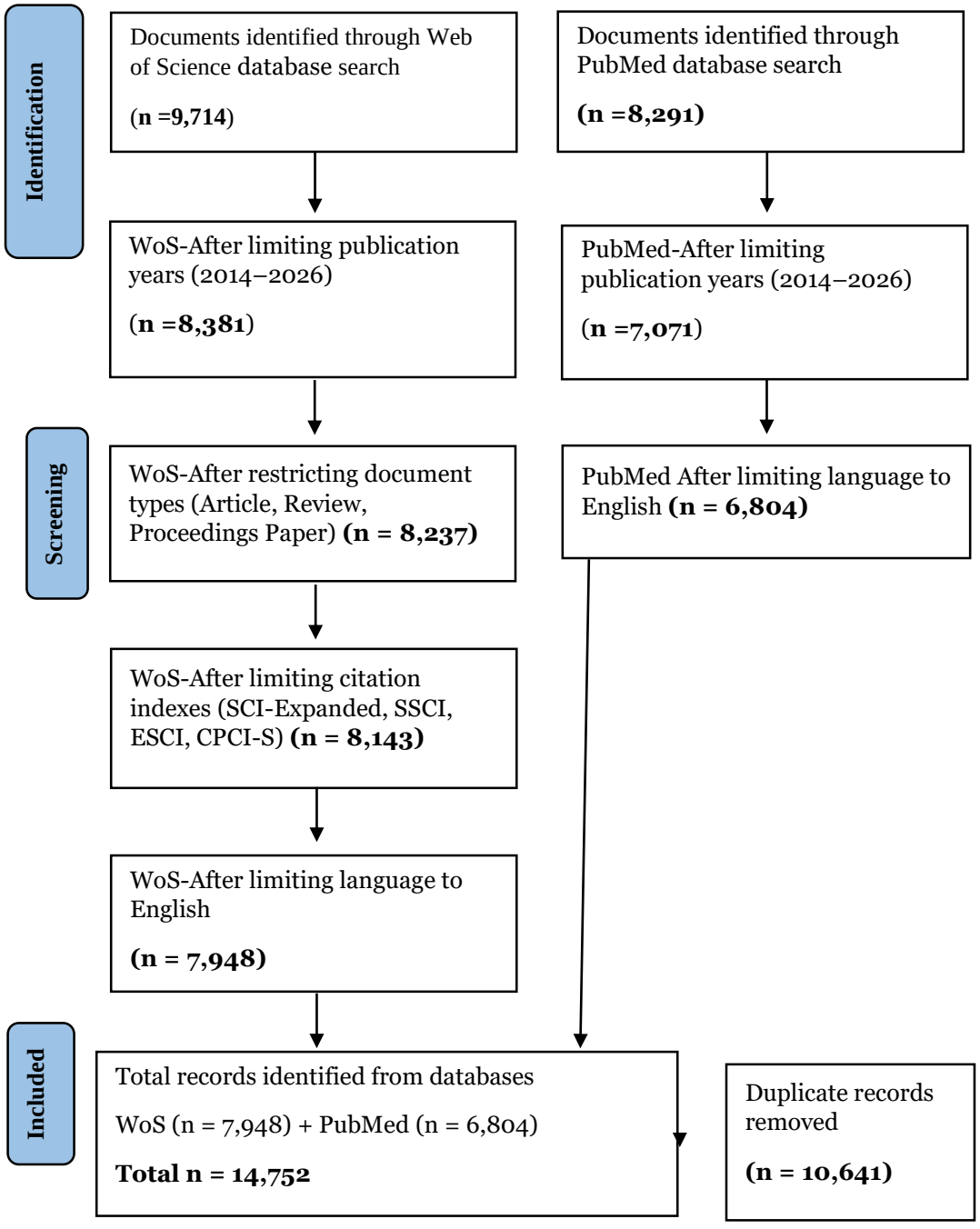
Figure 1. PRISMA diagram.



Results

The bibliometric data were analyzed using Biblioshiny, a web-based interface of the Bibliometrix R package[32]. Biblioshiny was used to perform descriptive bibliometric analyses, including annual scientific production, most relevant sources, institutional

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productivity, country-level scientific production, corresponding author country analysis, keyword frequency analysis, word cloud visualization, and thematic mapping. The use of Biblioshiny enabled systematic visualization and interpretation of publication trends, collaboration patterns, and thematic structures within the dataset.

Data Analysis

Table 1 summarizes the key descriptive metrics related to the final selected dataset. The basic information for the dataset reveals that 10,641 publications/documents (e.g., articles, conference papers) published between 2014 and 2026 appeared in 3,594 different sources. The annual growth rate of publications on the topic was calculated as 72.91%, indicating a rapidly expanding body of literature. Although this value appears relatively high, it should be interpreted cautiously. The high growth rate is largely attributable to the very low number of publications in the early years of the dataset and the substantial increase in publication output after 2020, when telemedicine and digital health research expanded rapidly during and after the COVID-19 pandemic. Therefore, this value does not necessarily indicate a stable year-by-year increase across the entire period but rather reflects the overall expansion of the field from a low initial baseline. The average age of the documents is 4.15, suggesting that the topic is highly recent and continues to attract increasing scholarly attention.

A total of 15,856 author-provided keywords were identified, reflecting a high level of conceptual diversity and a wide range of research perspectives. However, information regarding the total number of references in the dataset was unavailable.

There are 43,604 authors' contributions to the dataset. Only 494 documents were written by a single author, whereas the vast majority were co-authored by multiple researchers. The average number of co-authors per document was 5.94, and the international collaboration rate was 30.52%, highlighting the strong global academic engagement in this research area. The average number of citations per document was 13.93, indicating a considerable level of academic interest and impact.

Table 1. Main Information About the Data.

DESCRIPTION	**RESULTS**
Timespan	From 2014 to April 2026
Sources (Journals, Books, etc.)	3,594
Documents	10,641
Annual Growth Rate (%)	72.91
Document Average Age	4.15
Average citations per doc.	13.93

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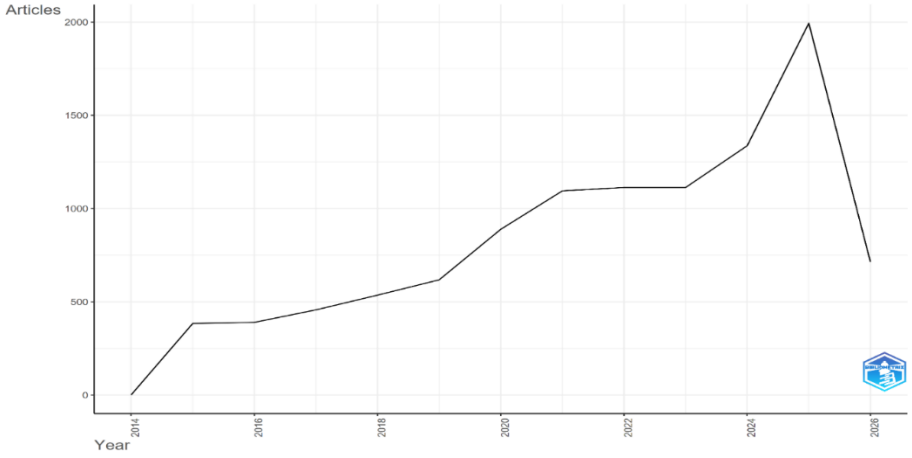
Authors	
Authors	43,604
Authors of single-authored docs.	494
Authors Collaboration	
Co-Authors per Doc	5.94
International co-authorships (%)	30.52

Annual Scientific Production

Figure 2 shows the scientific productivity in the field from 2014 to first week of April 2026. The graph shows that publication activity remained relatively limited until 2018, followed by a sharp increase after 2019. This pattern indicates that the topic gained considerable academic attention, particularly in the post-pandemic period.

Figure 2. Distribution of Scientific Publications Over Time



The publication trend can be evaluated in three main periods:

1st Period (2014-2018) – Low and Fluctuating Publication Activity: The number of publications remains quite low during this period. Although minor fluctuations were observed, the overall level of scientific production was limited. This suggests that the intersection of telemedicine and data security had not yet become a major research focus during the early years of the dataset.

2nd Period (2019-2021) – Gradual Increase: A noticeable increase in publication output began around 2019 and became more pronounced in 2020 and 2021. This growth can be associated with the rapid expansion of telemedicine and digital health services during the COVID-19 pandemic. The pandemic accelerated the adoption of remote

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healthcare delivery systems, which in turn increased scholarly attention to issues such as data privacy, cybersecurity, secure communication, patient information protection, and digital health infrastructure.

3rd Period (2022-2026) – High Publication Volume with Fluctuations: From 2022 onward, the number of publications remained at a considerably high level compared with the earlier years. The figure shows fluctuations across these years, with publication counts reaching peak levels around 2024 and remaining strong in 2025. The decline observed in 2026 should be interpreted cautiously, as the dataset includes publications only until April 2026. Therefore, the lower value for 2026 does not necessarily indicate a real decrease in academic interest, but rather reflects the incomplete coverage of the publication year.

Most Relevant Sources

Table 2 presents the top ten sources in the field. The most prominent source is "Journal of Medical Internet Research" with 416 articles. This journal is one of the leading digital health journals. The journal focuses on areas such as digital health interventions (apps, wearables, platforms), telehealth and telemedicine, mHealth (mobile health), and eHealth systems. Given that the current bibliometric analysis explores telemedicine, the prominence of this journal is highly meaningful.

"Digital Health" ranks second with 300 publications. This journal covers a broad range of digital health technologies and interventions, making it a relevant resource for research at the intersection of telemedicine and emerging digital health solutions.

Table 2. Top 10 Most Relevant Resources

#	*Name of Journal*	*Number of Publications*	*Journal Impact Factor (Reference Year)*
1	Journal of Medical Internet Research	416	6.0 (JCR 2025 Release)
2	Digital Health	300	3.3 (JCR 2024 Release)
3	JMIR mHealth and uHealth	265	6.2 (JCR 2025 Release)
4	JMIR Formative Research	181	2.1 (JCR 2025 Release)
5	Studies in Health Technology and Informatics	156	N/A
6	IEEE Access	154	3.6 (JCR 2024 Release)
7	BMC Health Services Research	143	3.0 (JCR 2024 Release)
8	Journal of Medical Systems	114	5.7 (JCR 2024 Release)

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#	*Name of Journal*	*Number of Publications*	*Journal Impact Factor (Reference Year)*
9	Frontiers in Digital Health	98	3.8 (JCR 2025 Release)
10	Scientific Reports	97	3.9 (JCR 2024 Release)

* JCR: Journal Citation Reports

Most Relevant Institutions

Table 3 presents the top 10 institutions based on the number of publications. The University of Toronto leads with 368 publications, followed by the University of Washington (322 publications) and Imperial College London (315 publications). The listed institutions come from diverse geographical regions, including the United States, Canada, the United Kingdom, Australia and Saudi Arabia, reflecting the global interest in the topic.

Table 3. Top 10 Most Relevant Institutions

#	*Name of Institution*	*Number of Publications*
1	University of Toronto	368
2	University of Washington	322
3	Imperial College London	315
4	University of California San Francisco	163
5	University of Oxford	154
6	Icahn School of Medicine at Mount Sinai	153
7	University of Queensland	145
8	King Saud University	141
9	University of British Columbia	132
10	Harvard Medical School	125

Production Over Time

To evaluate authors' productivity, it is important to consider the time span of their scholarly contributions. Long-term involvement reflects specialization and may indicate higher quality of publication. Figure 3 shows the annual publication activity of top authors using dots, where larger dots represent more publications and darker shading

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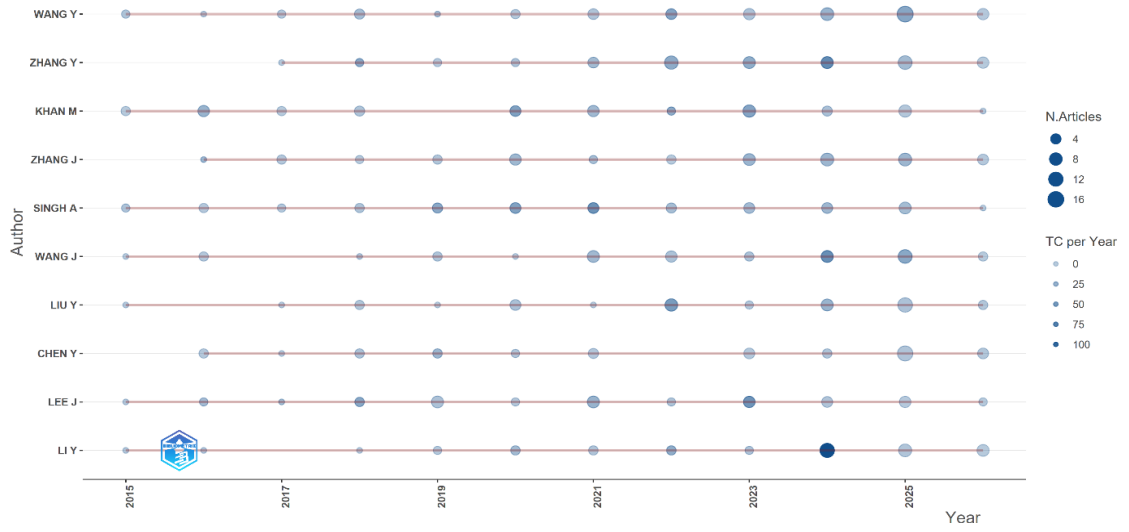
indicates higher citation impact per year. Wang Y. emerged as the most prolific author, with notably large dots in 2023 and 2024, suggesting both sustained contribution and recent peak productivity. Zhang Y., Khan M. and Zhang J. have maintained consistent presence across multiple years, indicating long-term engagement with the field. Singh A., Wang J. and Liu Y. show more concentrated activity, particularly after 2019. Li Y. stands out with an exceptionally high citation impact in 2024, represented by the darkest dot in the figure, despite a relatively moderate publication count. The prevalence of activity after 2019 across most authors suggests that the field attracted intensified scholarly attention in the post-pandemic period, reflecting the growing global emphasis on telemedicine and digital health security.

Figure 3. Productivity of the authors over time.



Corresponding Author's Countries

This analysis categorizes corresponding authors based on the type of collaboration. Multi-Country Publications (MCPs) refer to publications produced through international co-authorship, while Single-Country Publications (SCPs) represent studies authored by researchers from the same country, indicating national collaboration. Figure 4 illustrates the MCP-SCP analysis. The United States ranks first in total publication output, with the majority of its publications classified as SCPs, indicating a strong domestic research base. India and China follow the USA and are similarly dominated by national collaborations (SCP). The United Kingdom, Australia, Germany, and Canada also make notable contributions, although their publication volumes are lower than those of the three leading countries. SCPs constitute the larger share of publications in most countries, suggesting that national-level collaboration remains dominant in this research field. However, the presence of internationally co-authored papers highlights the global relevance of telemedicine, digital health and data security research.

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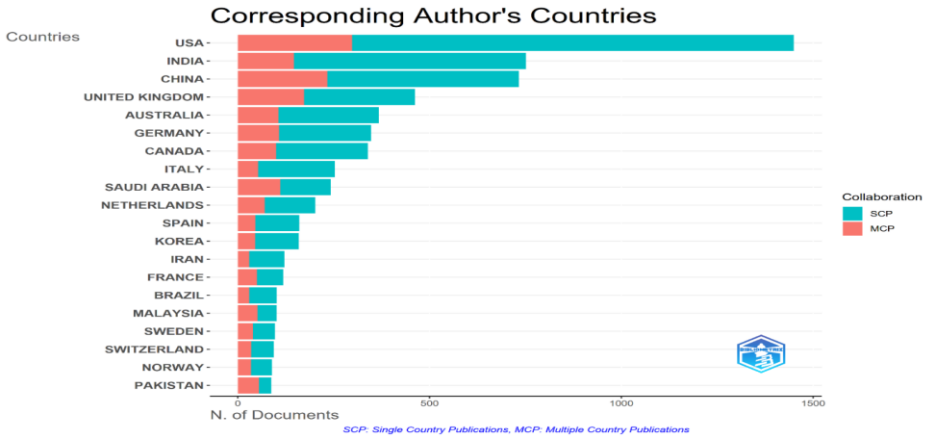
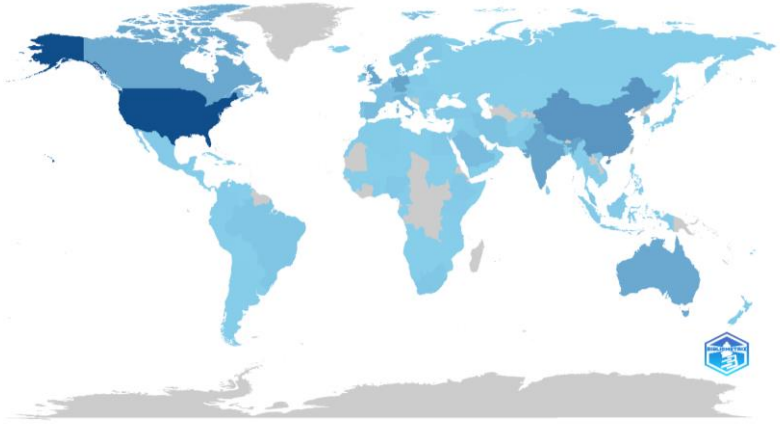
Figure 4. Corresponding author's countries.



Scientific Production by Country

A world map with color-coded density is presented in Figure 5 to visualize country-level scientific productivity. Dark blue (e.g., the USA) represents the highest level of research output in the field. U.S. institutions lead health informatics and telehealth research. In lighter blue, China, India, and Australia also serve as major hubs. India, in particular, is increasing its efforts with its extensive healthcare system and technology investments. The map clearly indicates that global scientific production is predominantly concentrated in a limited number of countries. However, the presence of lighter blue regions suggests considerable potential for future collaboration with researchers in those underrepresented areas. Countries such as the United Kingdom, Germany, and France could serve as valuable partners for international studies. The rising publication activity in Saudi Arabia, Iran, and the United Arab Emirates reflects the growing investments in telehealth and AI-supported health solutions, while South America, most of Africa, and parts of Southeast Asia show lower output. These underrepresented areas present opportunities for joint projects and funded research.

Figure 5. Countries' scientific production.



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Word Cloud Analysis

Word cloud analysis is a visual tool used to reflect the frequency of keyword usage. In this visualization, the most frequently used keywords appear in larger font sizes, while the less common ones are shown to be smaller. Randomly assigned colors enhance visual appeal.

Figure 6. Word cloud.

The updated keyword analysis reveals that “telemedicine” (1996 occurrences) is the most dominant term in the literature, confirming its central role in the field. This is followed by “humans” (1720 occurrences), highlighting the strong human-centered focus of telemedicine research. Other prominent terms include “privacy” (1163 occurrences), “security” (973 occurrences), and “digital health” (972 occurrences), all of which collectively indicate the growing importance of data protection and cybersecurity in digital healthcare systems.

Additionally, “mhealth” (848 occurrences), “care” (832 occurrences), “telehealth” (792 occurrences), and “health” (754 occurrences) represent key thematic areas related to healthcare delivery and mobile health technologies. The high frequency of “privacy” and “security” further emphasizes that safeguarding patient data and ensuring secure communication infrastructures are critical concerns in telemedicine applications.

Overall, the distribution of keywords demonstrates that while telemedicine remains the core research domain, there is a significant and increasing integration of digital technologies, human-centered approaches, and cybersecurity considerations within the literature.

Thematic Map

The thematic map presented in Figure 7 is a two-dimensional visualization that illustrates the centrality and level of development of key themes within the research domain. The x-axis represents the degree of centrality, indicating how strongly a theme

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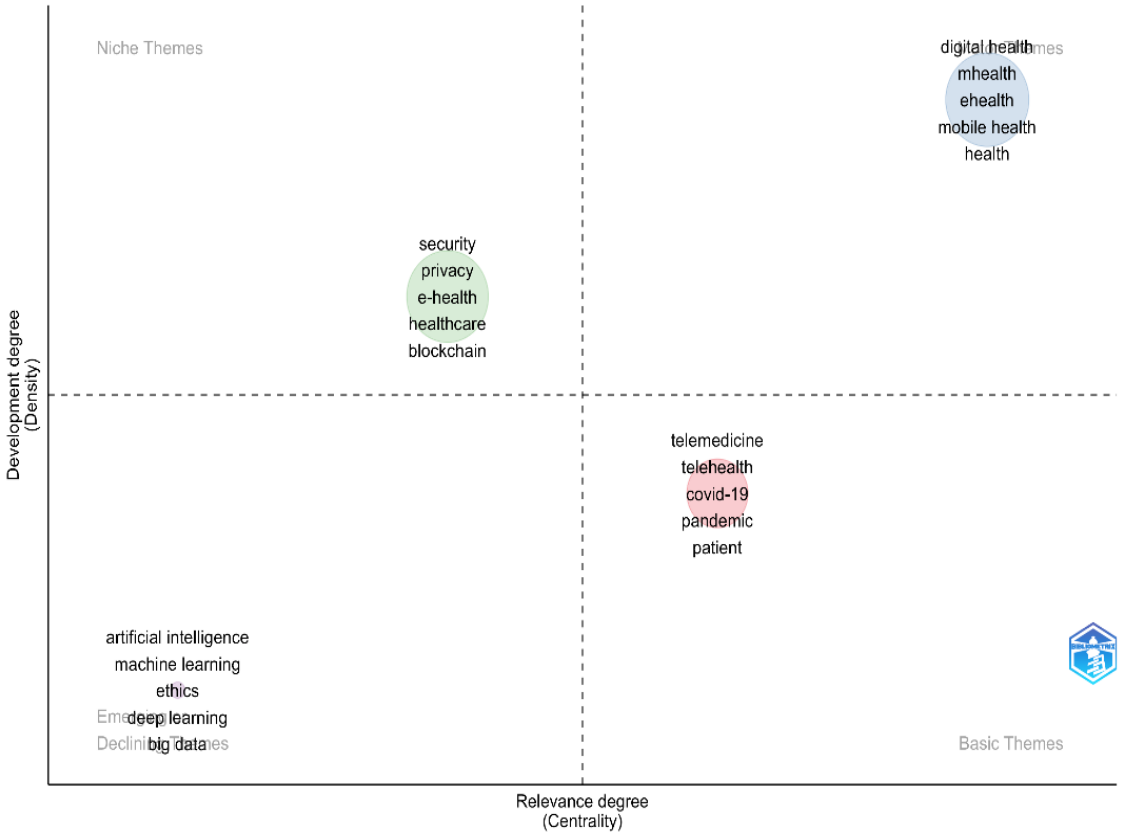
links to others, whereas the y-axis reflects the density, indicating its level of development. Themes with high density values are well-developed and are frequently explored in academic studies.

Figure 7. Thematic map.



The thematic map's upper-right quadrant, corresponding to Motor Themes, includes highly central and well-developed themes such as "digital health," "mHealth," "eHealth," "mobile health," and "health". The location of this cluster indicates that digital and mobile health technologies constitute one of the most mature and influential research streams within the telemedicine-related literature. These themes are not only strongly developed internally but also highly connected with other thematic areas, suggesting that they play a driving role in shaping the broader research field. The prominence of this cluster reflects the increasing integration of mobile platforms, electronic health systems and digital healthcare infrastructures into contemporary telemedicine practices.

The upper-left quadrant, representing Niche Themes, includes terms such as "security," "privacy," "e-health," "healthcare," and "blockchain." These themes exhibit a relatively high level of internal development but lower centrality compared with the motor themes. This position suggests that security and privacy-oriented studies form a specialized and technically developed subfield within the broader telemedicine literature. In particular, the presence of "blockchain" in this quadrant indicates that blockchain-based approaches have gained scholarly attention as potential solutions for secure data sharing,

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privacy preservation, and decentralized health information management. However, the limited centrality of this cluster also suggests that these topics have not yet become fully integrated into the mainstream telemedicine research agenda.

The lower-right quadrant, corresponding to Basic Themes, contains terms such as “telemedicine,” “telehealth,” “COVID-19,” “pandemic,” and “patient.” These themes are highly relevant to the overall structure of the field, but their lower density indicates that they are relatively less developed as cohesive thematic clusters. The position of this cluster shows that telemedicine and telehealth serve as foundational concepts in the literature, particularly in relation to patient care and the rapid expansion of remote healthcare services during the COVID-19 pandemic. Although these themes are central to the field, their relatively lower development suggests that further theoretical refinement and methodological diversification are still needed, especially in patient-centered telemedicine applications.

The lower-left quadrant, which represents Emerging or Declining Themes, includes terms such as “artificial intelligence”, “machine learning”, “ethics”, “deep learning” and “big data”. These themes have both low centrality and low density, indicating that they are either newly emerging areas or topics whose influence within the field has not yet been fully consolidated. Considering the rapid development of AI-based decision support systems, predictive analytics, and data-driven healthcare applications, these themes are more likely to represent emerging research directions rather than declining topics. Their position suggests that artificial intelligence, machine learning, deep learning, big data, and ethical considerations still require stronger conceptual integration with telemedicine, privacy, and security research. Therefore, this quadrant points to important opportunities for future studies focusing on responsible AI, ethical data use, algorithmic transparency, and secure intelligent telemedicine systems.

Discussion

This study provides a bibliometric assessment of 10 641 publications published between 2014 and April 2026 at the intersection of telemedicine, digital health, privacy, and security. The results highlight a notable rise in scientific output, particularly after 2020, when the COVID-19 pandemic accelerated the adoption of remote healthcare services and increased scholarly attention to secure digital health infrastructures. This growth pattern is consistent with the broader literature, which emphasizes telemedicine as an important mechanism for improving healthcare accessibility, reducing geographical barriers, and supporting remote patient care, especially in underserved regions. However, the findings also indicate that the rapid expansion of telemedicine has been accompanied by increasing concerns regarding privacy, secure data transmission, authentication, cybersecurity, and trust.

Regional disparities in scientific production require critical attention. The dominance of countries such as the United States, China, India, and several European countries may reflect stronger digital health infrastructures, higher research funding, more advanced regulatory frameworks, and greater institutional capacity for telemedicine research. In

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contrast, lower publication activity in parts of Africa, South America, and some regions of Southeast Asia may indicate limited research visibility, weaker digital health infrastructure, lower investment capacity or underrepresentation in indexed databases. This imbalance is important because telemedicine is often considered a tool for reducing healthcare inequalities, yet research on telemedicine security appears to be concentrated in regions with stronger technological and academic capacity.

The thematic map indicates that the field is primarily driven by digital and mobile health-related themes, including “digital health”, “mHealth”, “eHealth” and “mobile health”, which appear as highly developed and central motor themes. In contrast, “telemedicine”, “telehealth”, “COVID-19”, “pandemic” and “patient” are positioned as basic themes, suggesting that they constitute the field’s foundational structure but still require further conceptual and methodological development. Security-related concepts such as “security”, “privacy” and “blockchain” appear as niche themes, indicating a specialized but relatively less integrated research stream. Meanwhile, “artificial intelligence”, “machine learning”, “deep learning”, “big data” and “ethics” are among emerging or declining themes, suggesting that these topics represent important future directions requiring stronger integration with telemedicine security and privacy research.

A critical interpretation of these thematic positions suggests that privacy and security remain niche themes not because they are marginal in practical terms, but because they have developed as technically specialized subfields within the broader telemedicine literature. Telemedicine research has historically focused on access to care, remote consultation, patient monitoring, and service delivery, especially during and after the COVID-19 pandemic. In contrast, privacy, cybersecurity, authentication, and encryption require more specialized technical, legal, and infrastructural expertise. As a result, these topics may have developed in relatively concentrated research communities rather than becoming fully integrated into mainstream telemedicine studies. This finding indicates an important gap between the operational expansion of telemedicine services and the systematic integration of security-by-design and privacy-by-design principles into telemedicine research.

The position of blockchain as a niche theme can also be interpreted critically. Although blockchain has been widely proposed as a promising solution for secure data sharing, decentralized access control, auditability, and patient-centered health data management, its integration into mainstream telemedicine research remains limited. This may be related to several factors, including scalability problems, interoperability challenges with existing health information systems, regulatory uncertainty, high implementation costs, and the technical complexity of blockchain-based architectures. In many studies, blockchain is still discussed at the conceptual or prototype level rather than being evaluated through large-scale clinical or institutional implementation. Therefore, its niche position suggests that blockchain-based telemedicine security has reached a certain level of technical development but has not yet achieved broad practical diffusion within the wider digital health ecosystem.

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The weak integration of artificial intelligence and cybersecurity research represents another important issue. AI, machine learning, deep learning, and big data appear as emerging themes, but their low centrality indicates that they are not yet strongly connected with telemedicine security and privacy research. One possible explanation is that AI-related telemedicine studies often prioritize diagnosis, prediction, clinical decision support, image analysis, or patient monitoring, whereas cybersecurity studies focus on authentication, encryption, access control, secure communication, and system resilience. This disciplinary separation may limit the development of integrated research on secure, explainable, and privacy-preserving AI-based telemedicine systems.

Theoretical Contribution

The theoretical contribution of this study lies in its bibliometric mapping of telemedicine security as a multidisciplinary research domain. By integrating publication trends, keyword patterns, country-level productivity, institutional contributions, and thematic mapping, the study identifies how telemedicine research has shifted from a general healthcare access topic toward a more complex field shaped by digital health, privacy, cybersecurity, mobile platforms, blockchain, and artificial intelligence. In doing so, the study contributes to the literature by clarifying the conceptual relationships among foundational, specialized, motor, and emerging themes in telemedicine security research.

Practical Contribution

The practical contribution of the study is that it provides guidance for healthcare managers, policymakers, system designers, and researchers who aim to develop safer and more sustainable telemedicine systems. The findings suggest that successful telemedicine implementation requires more than the availability of remote consultation platforms. It also requires secure data sharing frameworks, robust authentication and access control mechanisms, privacy-preserving infrastructures, cybersecurity risk management, patient-centered design, and ethical governance of AI-based tools. In particular, healthcare organizations should consider privacy and security as core design principles rather than secondary technical concerns. Policymakers should also support regulatory frameworks that balance innovation, patient protection, interoperability, and equitable access.

Future Research

It is possible to propose several promising directions for future research based on the thematic structure of the field. Although “security”, “privacy” and “blockchain” appear as niche themes, their relatively limited centrality suggests that these topics are not yet fully integrated into the broader telemedicine and digital health literature. Therefore, future studies should examine how blockchain-based systems, authentication mechanisms, access control models and encryption protocols can be implemented in real-world telemedicine platforms to improve secure data sharing, patient data verifiability, interoperability and trust. In addition, the position of “artificial intelligence”, “machine

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learning", "deep learning", "big data" and "ethics" in the Emerging or Declining Themes quadrant indicates that these areas still require stronger conceptual integration with telemedicine security research. Future studies should therefore address AI-supported telemedicine applications in relation to data privacy, cybersecurity, algorithmic transparency, accountability and ethical governance. Finally, because "telemedicine", "telehealth", "COVID-19", "pandemic" and "patient" appear as basic themes, future research should move beyond pandemic-driven adoption and focus on long-term patient-centered telemedicine services, including user trust, digital literacy, sociocultural differences and equitable access to secure digital healthcare.

In the literature, differences in telemedicine use among individuals with different sociocultural, regional, and economic backgrounds have still been investigated to a limited extent. Therefore, future research can comparatively address the cultural, social and economic and digital literacy-related factors affecting user acceptance, trust, and continued use of telemedicine services. In addition, smart contracts and security protocols may offer an important line of defense against unauthorized access, data manipulation, and weakness in patient data sharing. Future studies can investigate how these protocols can be integrated into telemedicine applications in relation to legal compliance, ethical governance, and patient privacy.

Limitations

Although this study provides a comprehensive bibliometric overview of telemedicine, security, privacy, and digital health research, several limitations should be acknowledged. First, the dataset was restricted to publications retrieved from Web of Science and PubMed. These databases were selected because PubMed offers strong coverage of biomedical and health-related literature, while Web of Science provides high-quality multidisciplinary coverage and is widely used in bibliometric studies. However, Scopus was not included in the data collection process. Given the broad multidisciplinary coverage of Scopus, its exclusion may have limited the comprehensiveness of the dataset and may have resulted in the omission of some relevant publications. Integrating three large databases may also create methodological challenges related to duplicate removal, metadata harmonization, indexing differences, and the standardization of bibliometric indicators. Nevertheless, future studies may incorporate Scopus and other databases to provide a broader representation of the literature.

Second, the analysis was limited to English-language publications. This restriction was applied to ensure consistency in data processing, keyword interpretation, and thematic analysis. However, it may have introduced language bias by excluding relevant studies published in other languages. Since telemedicine, privacy and security are globally relevant research areas, future studies may benefit from including multilingual datasets to better capture regional and non-English contributions.

Third, the findings depend on the selected search keywords and the indexing practices of the databases used. Although the search strategy was designed to cover the major terms related to telemedicine, digital health, security, privacy, cybersecurity,

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authentication, encryption and blockchain, some relevant studies may not have been retrieved if they used different terminology or were indexed differently. Therefore, the results should be interpreted within the boundaries of the search query and database indexing structure.

Finally, bibliometric analyses may be affected by inconsistencies in author names, institutional affiliations, and metadata records. In the present study, institutional names were reviewed and standardized where clear duplicate or variant forms were detected. However, variations in author initials, institutional naming conventions, spelling differences, abbreviated affiliation formats, and database indexing practices may still influence the accuracy of author- and institution-level productivity analyses. Future research may use additional data-cleaning and name-disambiguation procedures to further improve the precision of bibliometric mapping.

Conclusion

This study examined the research landscape at the intersection of telemedicine, security, privacy and digital health through a bibliometric analysis of 10,641 publications indexed in Web of Science and PubMed between 2014 and April 2026. The findings show that scholarly interest in this field has expanded considerably, especially after 2020, reflecting the rapid growth of telemedicine services and the increasing importance of secure digital health infrastructures.

The results indicate that telemedicine security research is shaped by several interconnected thematic areas. Digital health, mHealth, eHealth, and mobile health appear as central and well-developed motor themes, while telemedicine, telehealth, COVID-19, pandemic and patient-related terms constitute the foundational structure of the field. Security, privacy and blockchain emerge as specialized niche themes, suggesting that these topics are technically developed but still require stronger integration into mainstream telemedicine research. Artificial intelligence, machine learning, deep learning, big data and ethics represent emerging research directions that require further conceptual and practical development in relation to privacy, cybersecurity, and responsible digital healthcare.

Overall, the study contributes to the literature by mapping the evolution, structure and thematic orientation of telemedicine security and privacy research. It also provides practical implications for healthcare managers, policymakers, and system designers by emphasizing the need to treat privacy, cybersecurity, authentication, access control and ethical AI governance as core components of telemedicine systems. Future research should continue to integrate security and privacy mechanisms into real-world telemedicine applications, develop privacy-preserving AI-based healthcare systems, and address sociocultural, regional and digital literacy-related differences in user acceptance. Such efforts can support the development of safer, more trustworthy, inclusive and sustainable digital health systems.

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