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A Systematic Network Analysis Disclosing How The Digital Health Area Has Evolved in Denmark During The Last 25 Years.

Jeppe Eriksen, Signe Strandsbjerg Kloppenborg, Jorge Luis Braojos Morillas, Christian Nøhr

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Abstract

Background: The field of eHealth and Digital Health is relatively new and dynamic, making it interesting to examine how it has evolved over time. Denmark has long been seen as a frontrunner, making the development of digital health in Denmark a relevant case to scrutinize.

Objective: The aim of this study is to systematically examine how the area of Digital Health has changed over the last 25 years in Denmark.

Methods: This study's analysis is based on data from PubMed and the E-Health Observatory, which is an annual conference that focuses on the status of eHealth in a Danish context. First, a literature search was conducted, second the data was extracted and filtered by using PubMed2XL, Excel, and OpenRefine, and last, the data was analysed and visualised by using ChatGPT, Table2Net, Tableau, and Gephi. The analysis was divided into 5-year intervals to make similarities and changes across time more apparent.

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Conclusions: The results show how some tendencies change over time and how some concepts and technologies have stayed relevant over the entire period. Over the last 25 years, Electronic Health Records, Health Technology Assessment, Experiences, Implementation, Telemedicine and how to ensure a functional technical infrastructure, have been the dominating themes.

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Keywords: Digital health, eHealth, Electronic Health Record, EHR, Implementation, ChatGPT, eHealth in Denmark.

Introduction

A lot has transpired within the field of digital health over the previous 25 years, on a local, regional, national, international, and global scale. This study focuses on how Digital Health has developed in Denmark, which is often regarded as a frontrunner, making it relevant to examine in more detail. This section introduces the main actors, innovations, and technologies to describe the digital health sector in Denmark.

The case of Electronic Health Records (EHRs) is one example of how diffusion and implementation of digital healthcare technologies have evolved over the previous 25 years. In 1996 the Ministry of Health published the report titled “Handlingsplan for Eletroniske Patientjournaler” (Action Plan for Electronic Health Records), indicating a political and practical willingness to support the usage and implementation of EHR systems in Denmark. This was accomplished by providing financial support for 13 EHR pilot projects as well as a select panel of researchers tasked with evaluating these projects (the group of researchers who later became responsible for the annual Danish conference on eHealth, the E-Health Observatory). What is noteworthy in this example is the discrepancies between politicians’ and decision-makers' aspirations regarding the implementation of the EHR systems. Hence, in the early 2000s, the Minister of Interior and Health announced that all Danish hospitals would have fully implemented EHR systems by the end of 2005. As the deadline approached and the system implementation fell severely behind schedule, the criteria for full implementation were modified and the deadline was postponed to 2007. However, these estimates were still incorrect according to the group of researchers in charge of the E-Health Observatory who acquired data on the EHR implementations in Denmark, measured by the number of hospital beds equipped with an EHR system. The results are displayed in Figure 1.

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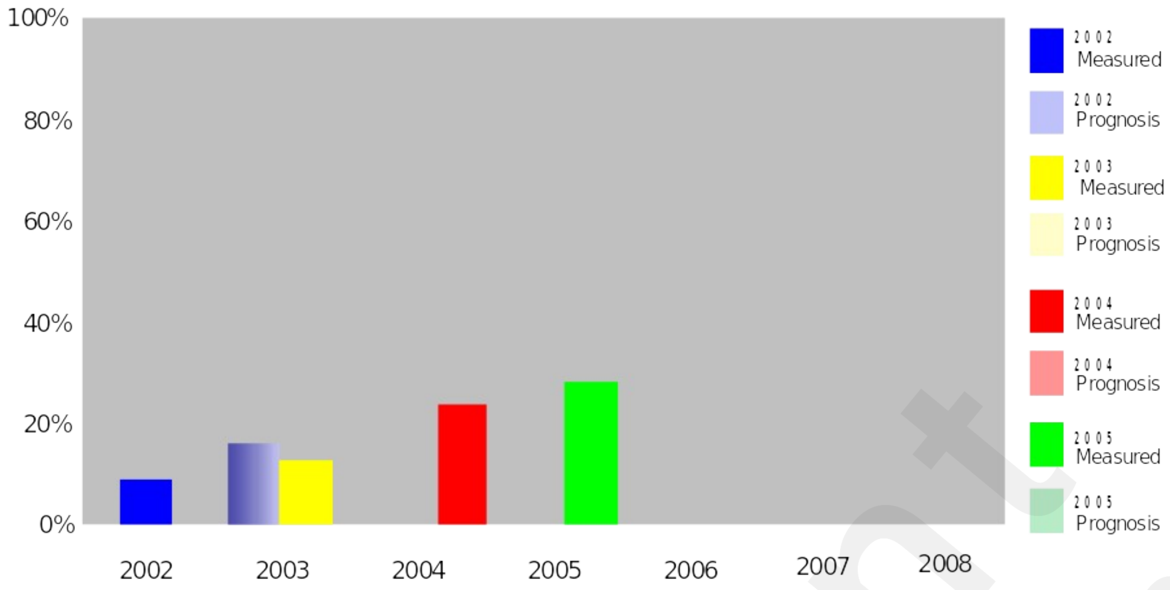

Figure 1. The proportion of hospital beds covered by an EHR system from 2002 to 2005, and the counties prognosis for the following years.

Figure 1 is based on prognoses from Danish counties who expected to reach 1100% implementation in three years. The E-Health Observatory had data on the annual EHR diffusion since 2002 and it was obvious to use these data in a technology forecasting study inspired by Everett Roger's "Diffusion of Innovation" [1] and the book by Alan L. Porter et al: "Forecasting and management of technology" [2] where they introduce the Fisher-Pry-model for technology forecast. By applying these forecasting models, it was possible to obtain an overall assessment of when the EHR systems would be fully implemented. When the actual measurements were used as input to the model it predicted that the full implementation would happen in 2016.

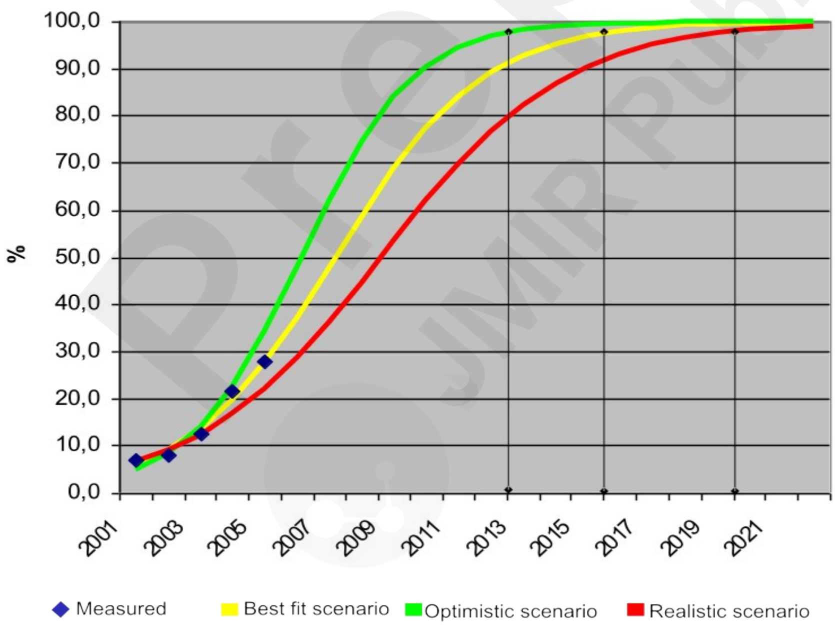

Figure 2. Model calculations for national EHR bed coverage based on five years data from 2001 to 2005.

However, as there was a strong political will to achieve a sooner implementation a more optimistic scenario was obtained as the green curve shown in Figure 2, indicating a full implementation in 2013. However, the scientific literature indicates that the implementation of EHR systems in hospitals in general takes longer time than planned [3] indicated by the red line. By presenting the model the E-Health Observatory Group had hoped for a constructive discussion on how to speed up the implementation process on a national level. However, the reactions from the political side were quite different, which resulted in an immediate stop of national funding formerly allocated to the E-Health Observatory [4,5]. Although there are no official measurements the last hospital bed was covered by an EHR system around 2019.

When the development and implementation of EHR systems started in Denmark at the beginning of the 2000's there were 13 different systems, in 2007 the number had grown to 27 systems, only four systems in 2018, three systems 2020 and finally in 2021 only two different systems. [6] There is still a debate about what an EHR system is as the regions, who are the owners of the hospitals, have bought different modules in the different regions. Hence, it might be more correct to talk about two different EHR vendors. The system in the eastern regions of Denmark is delivered by the American company Epic and in the western regions the Danish software house Systematic. The EHR systems are the backbones of the Danish hospital information systems, which is likely why recent Epic and Systematic implementations have received a lot of political and scientific attention [7,8], emphasising the systems' key role in the digital healthcare system.

MedCom has played a key role, both organisationally and practically, because they are in charge of the digital health infrastructure. MedCom has built a digitally integrated healthcare sector by implementing and disseminating standards that enable the exchange of healthcare data across sectors and providers. MedCom has also played a role in the global context, where they have participated in networks dedicated to the exchange of experience and knowledge [9,10].

Sundhed.dk, the national health portal, is another excellent example of how digital technology has had a significant impact on healthcare in Denmark. Sundhed.dk was initially created to act as a medium for sharing clinical information and knowledge. Furthermore, Sundhed.dk has enabled clinicians using various EHR systems to access alternate versions of citizens' health records, which has proven critical when treating citizens from other geographical regions outside their region of residence. Sundhed.dk has evolved into a virtual space used by both citizens and healthcare professionals (HCPs), owing to the increasing number of features and possibilities available to visitors. As a result, citizens have access to personal information such as diagnoses, lab results, immunisations, referrals, and much more, which is securely stored in dedicated databases accessible from Sundhedsjournalen (the eJournal). Sundhed.dk's central role in the Danish digital health landscape was extraordinary noticeable during the COVID-19 pandemic when test results were made available via the portal [11,12]

Det Fælles Medicinkort (FMK) (the shared medication record) is another example of how digital advancements have influenced the healthcare system. The FMK, which was implemented in 2013, provides HCPs from various institutions and organisations, as well as citizens, with a timely overview of their current medication. This means that risks, errors, and readmissions have decreased, making patient admissions more efficient, because prescription information is available as soon as they enter the hospital. Thus, FMK is typically referred to as one of the successful digital health projects that had a significant impact on clinical practice [13,14].

The implementation and application of telemedicine is another innovation made possible through the increased digitalisation of healthcare. The 1997 report "Telemedicin – en vej til et bedre sundhedsvæsen" (Telemedicine – a way to a better healthcare system) made decision-makers aware of telemedicine's possibilities. In 2012, the National Handlingsplan for Udbredelse af Telemedicin (National Actional Plan on the Diffusion of Telemedicine) was published, identifying disease areas where telemedicine could be utilised. Among these disease areas were Chronic Obstructive Pulmonary Disease (COPD) and Mental Illness, which now comprise some of the disease areas where telemedicine is applied successfully in a Danish context. In 2013, Denmark launched Det Telemedicinske Landkort (The Mapping of Telemedicine Project), which presented an overview of telemedicine projects around the country. This initiative highlighted the growing importance of telemedicine and the relevance of systematically keeping track of its spreading and development [15]. The Telecare North project, a regional and then national project to implement telemedicine for COPD patients [16] **-** if not accessible then you can find it through a Google search), and the Epital Care Model (ECM) [17]**,** a model that theoretically and in practice has demonstrated how COPD patients meaningfully can monitor and manage their health as participants in a clinical structure where contact and communication with HCPs primarily is mediated digitally [15]. Telemedicine is also used in the psychiatric field, where internet-based communication, video consultations, Virtual Reality (VR), and internet-based education have enabled the implementation of preventive interventions and treatment of conditions such as anxiety and depression [18]. Accordingly, telemedicine has become increasingly important in recent years, as virtual hospitals and home monitoring currently are among the preferred ways to mitigate the structural issues faced in a Danish context [19]; thus, it is reasonable to expect that the importance and application of telemedicine will grow in the coming years.

A more recent digital technology, Patient-Reported Outcomes (PROs), also known as PROMs, are questionnaires, data, and outcomes applicable in clinical practice and as part of telemedicine interventions. PROs are developed and implemented at different levels, although AmbuFlex, who develops PROs at the regional level, and The PRO Secretariat, who is in charge of developing national PROs, are two of the key actors in this context. PROs' potential has evolved after the tools' digitalisation and application in clinical practice; thus, PROs are now used as part of algorithm-based triage systems, enabling a more sufficient use of resources; to improve the effectiveness and quality of HCP-patient consultations; and will be a focal component in current and future eHospitals, because they allow continuous monitoring of patients' disease experience and health status [20–22].

Thus, an introduction to some of the actors, innovations and digital technologies constituting Denmark's digital health sector, as well as a look back upon the last 25 years. However, to gain a more in-depth understanding of the development, we decided to conduct a systematic analysis. Accordingly, the research question addressed in this study is: "How has digital health developed over the last 25 years in Denmark?".

Methods

The methods and data sources applied in this study were chosen as they allowed us to create a systematic overview of the digital health area over time. The extraction and analysis of data consisted of several steps based on data from PubMed (DB1) and the E-Health Observatory (DB2).

Data search, extraction, cleansing and repurposing

The data search, extraction, cleansing, and repurposing were executed in eight steps. First, the authors identified relevant data sources and decided to conduct the study using data from PubMed and the E-Health Observatory. PubMed was chosen because it is the largest biomedical research database containing multiple literature sources such as MEDLINE, PubMed Central (PMC), and Bookshelf [23]. Data from the E-Health Observatory was included because this conference is where decision-makers, researchers, and practitioners meet annually to discuss the state of digital health in Denmark. As a result, a mix of data sources were chosen to present the most comprehensive overview of the development of digital health in Denmark during the last 25 years.

Second, the approach to paper search and selection was discussed and agreed upon, resulting in relevant papers being included based on title and abstract. Third, we decided which key terms to include in the search string and created a Boolean string (Textbox 1) to collect the most relevant keywords associated with digital health from 1999 to 2024 (April) in a Danish context. This step included a manual review of keywords identified in a small number of papers from various years. We submitted this search string to PubMed after it had been refined to include a considerable representation of digital health areas. The search string was not confined geographically to publications in Denmark but rather allowed for a broader expansion to minimise bias in the scope of research without constraining it. This resulted in 116,039 hits based on the categories, "Remote sensing and wearables"; "Telemedicine and health information"; "Data analytics and intelligence, predictive modelling"; "Health and wellness behaviour modification tools"; "Bioinformatics tools (-omics)"; "Medical social media"; "Digitised health record platforms"; "Patient -physician-patient portals": "DIY diagnostics, compliance, and treatments"; "Decision support systems"; and "Imaging" [24].

Textbox 1. Search string applied in PubMed.

((((((((((((((((((((("digital health") OR ("eHealth")) OR ("e-health")) OR ("electronic health")) OR ("e-sundhed")) OR ("digital sundhed")) OR ("elektronisk sundhed")) OR ("tele-health")) OR ("tele health")) OR ("tele-sundhed")) OR ("tele sundhed")) OR ("tele-medicine")) OR ("tele medicine")) OR ("tele-medicin")) OR ("tele medicin")) OR ("tele-care")) OR ("tele care")) OR ("tele-omsorg")) OR ("tele omsorg")) OR ("health technolog*")) OR ("sundhedsteknolog*")) OR ("virtual health")) OR ("virtuel sundhed")

Due to PubMed's limited ability to display multiple data tags or categories in its downloadable results, the fourth step included the conversion of all PubMed unique identifiers (PMIDs) into a CSV file (Microsoft Excel format), which would populate multiple tags and be compatible with additional data visualisation tools.

In the fifth step, inclusion and exclusion criteria were established (Table 1) to aid in the identification of relevant papers within the scope of the analysis.

Table 1. Inclusion and exclusion criteria.

Included	Excluded
eHealth	RCT studies on medicine
Technology	Studies with no digital technology
Digital health	Literature reviews
Telemedicine	HTAs of medicine
AI	Papers without an abstract
Robots	
Chatbot	
Avatars	
Health Information Technology (HIT)	

(health) Informatics	
Patient-Reported Outcome (PRO)	
Wearables	
Patient Generated Health Data (PGHD)	
Virtual health	
mHealth	
Precision medicine	
Health Technology Assessment (HTAs) on digital technologies	
Web-based health information (Use of the internet as a digital health technology)	
Discussions of HTAs	

The sixth step involved a manual screening process separated into two phases. In the first phase, all references related to the Danish context were extracted without any use of filters, yielding 3,518 results from DB1. In phase two, the manual screening processes were refined by including three additional criteria: 1) The paper had to be attached to a Danish context, which means that development, diffusion, and/or implementation involved took place in a Danish setting; 2) Danish associations, institutions, research centres, universities, and researchers were selected if they provided a result within the Danish context; 3) Articles that did not include a relevant category within digital health, although being set in a Danish context, were excluded. Following this step, DB1 contained 734 results, whereas DB2 remained as originally constructed, displaying 1,174 results.

The seventh step, after manual screening, was to set the parameters to extract the most relevant keywords per selected papers for information extraction and text summarisation for DB1 and DB2. This was created using the Large Language Model (LLM) tool ChatGPT 3.5 from OpenAI [25] with a particular prompt based on the Rapid Automatic Keyword Extraction (RAKE) algorithm principles. This algorithm extracts relevant keywords from input text using a list of stop words and phrase delimiters, taking into account co-occurrence, frequency, and significance [26]. Furthermore, LLMs, like any other language model, may have issues with accuracy and dependability due to a variety of factors, including the complexity and ambiguity of the input text, as well as the level of richness and diversity of the training data. As a result, we conducted a test comparing human keyword extraction to ChatGPT 3.5 (Table 2), which validated ChatGPT's capacity to do competent text interpretations. However, we discovered that ChatGPT occasionally struggled with complicated or technical jargon, as well as hallucinations that resulted in inaccurate responses [27]. Considering this, we manually supervised the keyword extraction process, making changes when necessary while preserving a human oversight perspective to ensure the results' relevance and validity (Table 2).

Table 2. Validation of keyword extraction - Human vs ChatGPT 3.5.

Text input example	**Human keyword extraction**	**ChatGPT 3.5 extraction**

PMID: 12371909 Abstract: At the dawn of the Information Age, the practice of evidence-based decision making (EBDM) is still hindered by many important barriers related to the decision makers, to the evidence per se or to the health system. Some of these barriers, particularly those related to the distillation, dissemination and packaging of research evidence, could be overcome by recent and ongoing developments in portable/wearable computers, internet appliances, multimedia and wireless broadband internet traffic. This article describes specific EBDM-related tools, with emphasis on internet-enabled "how to" books; and tools to improve the quality of reporting research, to formulate questions; to search for evidence; to access journals, systematic reviews and guidelines; to interact with organizations promoting EBDM; and to tailor evidence to individual cases. However, thinking that all barriers to the practice of EBDM could be solved by fancy information technology is naive. Barriers related to the generation, interpretation, integration and use of the evidence demand more complex and perhaps unfeasible solutions, as overcoming them will require substantial changes in the structure of the health system, in the politics of science and in the way in which humans think and behave.	evidence-based decision making, EBDM, portable/ wearable computers, internet appliances, multimedia, wireless broadband internet traffic, tools to improve the quality of reporting research, to formulate questions; to search for evidence; to access journals, systematic reviews, guidelines, barriers related to the generation, interpretation, integration and use of the evidence	Evidence-based decision making (EBDM), Barriers, Research evidence, Internet-enabled, Tools, Health system, Information technology, Quality of reporting research, Systematic reviews, Guidelines, Portable/wearable computers, Multimedia, Wireless broadband, internet traffic, access, journals, organizations promoting EBDM, tailor evidence, generation of evidence, interpretation of evidence

In the eighth and final step, we used OpenRefine to clean up the datasets by applying cluster methods to fix inconsistencies and merge similar values for the extracted keywords, including k-nearest neighbours distance functions such as Levenshtein and PPM, as well as key collision functions such as Fingerprint, n-Gram Fingerprint, and Metaphone 3. Keywords were also separated into single-cell values and reused for additional data visualisation analysis [28].

Data visualisation and analysis through digital methods

This study uses data visualisation and analysis tools as a digital method [29] to call attention to research and trends in the field of digital health in Denmark during the last 25 years.

We used Tableau (2023.3), an analytics software based on interactive data visualisation and analysis [30], which is not commonly used for healthcare data [31]. However, because we used data from a biomedical research database, we regarded it appropriate due to its ability to manage large datasets. In this way, the visualisations illustrated in Tableau are divided into two groups: a general visualisation of the number of digital health articles published in the last 25 years within a Danish context, based on the articles included in this study. A forecast indicator based on an additive algorithmic model (Textbox 2) has also been developed using the data from 1999 to 2023, that estimates all its components as summed to establish a forecasting model with time (2024-2028), which helps to make an approximation of forecast future values from the databases we provided [32] (Figures 4 and 6).

Textbox 2. Description of forecasting for DB1 & DB2.

DB1: Distinct count of PMID

Model			Quality Metrics					Smoothing Coefficients		
Level	Trend	Season	RMSE	MAE	MASE	MAPE	AIC	Alpha	Beta	Gamma
Additive	Additive	None	12	9	0.97	100,4%	131	0.500	0.376	0.000

DB2: Distinct count of ID

Model			Quality Metrics					Smoothing Coefficients		
Level	Trend	Season	RMSE	MAE	MASE	MAPE	AIC	Alpha	Beta	Gamma
Additive	Additive	Additive	11	9	0,39	24,2%	119	0,500	0,000	0,000

The second Tableau visualisation compares keyword performance across five-year intervals (1999-2003, 2004-

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2008, 2009-2013, 2014-2018, 2019-2024) to demonstrate the progression of papers referring to specific themes and areas within digital health (Figures 8, 9, 10, 11 and 12). In addition, a visualisation of the 25 years for the most relevant keywords is given to provide an overall view (Figure 13).

Separately, Gephi is utilised as an extra interactive visualisation programme to facilitate exploratory data and network analysis in DB1 and DB2 [33]. Due to prior repurposing work done with OpenRefine, we were able to extract two networks from the DB1 and DB2 datasets, connecting two components like keywords and authors using Table2Net [34]. This produced a network graph file that is compatible with Gephi. Once the datasets were ready, we began to build the network using ForceAtlas2 as the primary layout algorithm. The force-directed layout spatialises a network following the principle of charged particles, nodes repel one another, while edges draw their nodes towards them [35]. From here, we set up filters to define a relevant degree range of related nodes and edges, as well as attributes to establish a ranking based on occurrence count. In other words, it demonstrates a relationship between keywords (orange nodes) and authors (blue nodes) by determining which nodes are more essential than others. Additionally, the text labels reflect this attribute, as nodes with more occurrences are larger than nodes with fewer occurrences. Finally, the positions of the nodes determine how they interact with one another. This might result in a cluster of nodes, which is a set of nodes that are more densely coupled than the rest of the network. Essentially, the clustered nodes are interconnected, establishing a close-knit group inside the network. See Figure 3 for an overview of the methodological process.

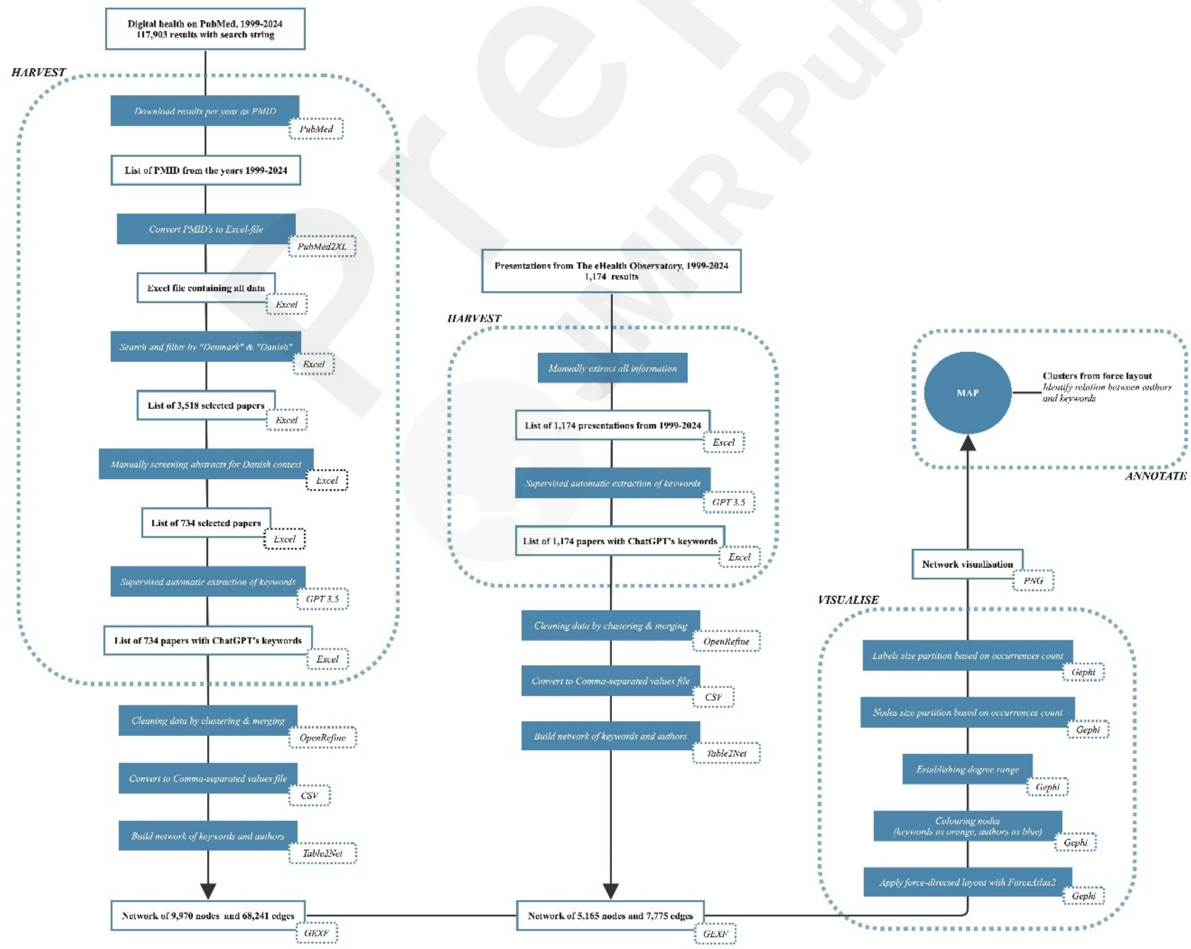

Figure 3. Overview of the methodological process for extracting networks

Results

In this section, overviews of the results from PubMed and the E-Health Observatory are first analysed and then the results are divided into 5-year intervals and analysed.

Overall results and visualisations

In this subsection, data is used to provide overall visualisations of the development of the digital health area in Denmark over the last 25 years. The results from PubMed are first presented, and then the data from the E-Health Observatory is scrutinized.

Results from PubMed

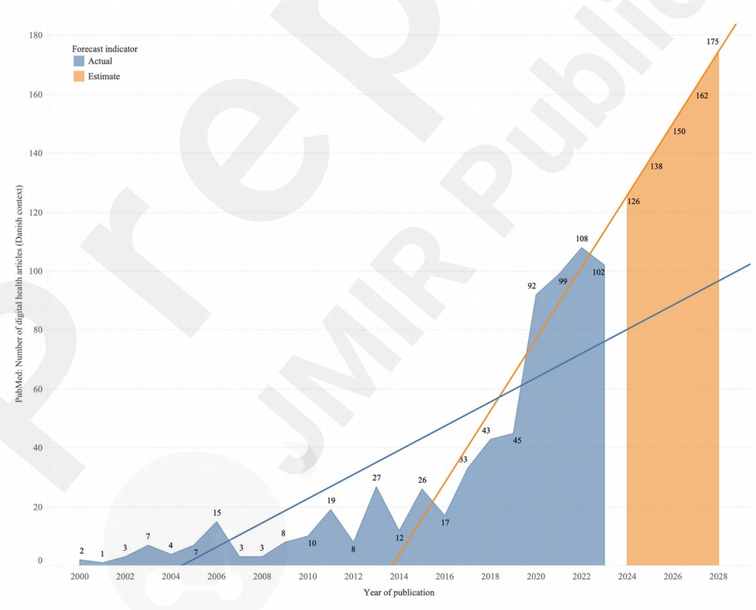

Figure 4. Overview of the included papers extracted from PubMed, 1999-2024.

Figure 4 provides an overview of the included papers extracted from PubMed. Based on the publications included in this study, the number of publications within the digital health area has increased substantially in recent years; hence, the number of included papers has increased from 17 in 2016 to 108 in 2022. An increase of 535% in papers on digital health from 2016 to 2022, which is a tendency that, based on the forecast, will continue; underscoring, how relevance of research on Digital Health becomes increasingly important in Denmark.

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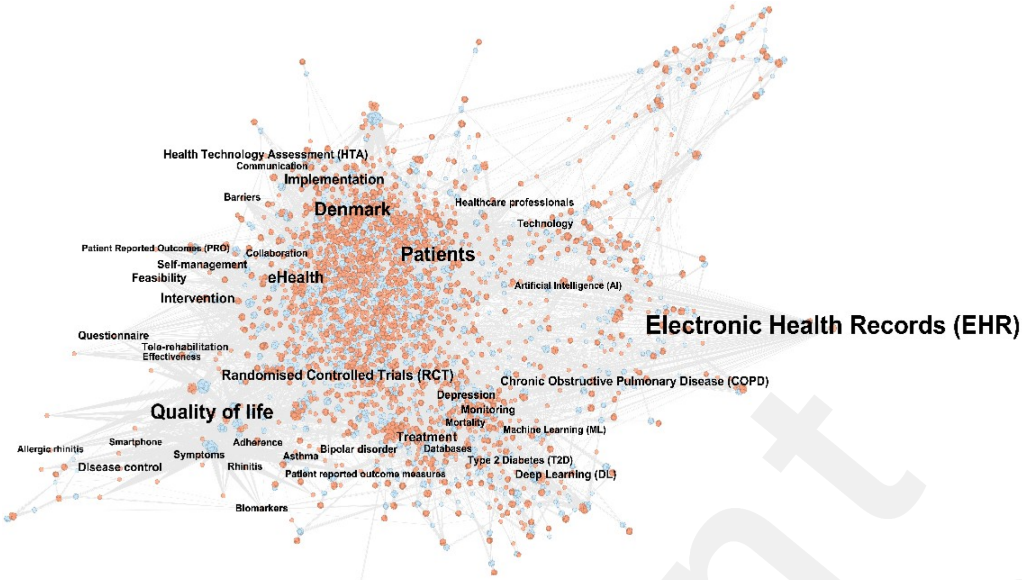

Figure 5. A network diagram of the included keywords extracted from PubMed, 1999-2024.

Figure 5 provides an overview of the most important themes in digital health in a Danish context between 1999 and 2024. There is a predominant occurrence of the term EHR; however, despite this indicating the importance of EHRs, the most significant cluster in the network relates to the terms “Denmark, patients and eHealth” as the core keywords are narrowly connected. Moreover, it is noticeable how “Quality of life”, “RCTs”, “Implementation”, and “HTA” are among the most dominating terms when in the network diagram.

Results from the E-Health Observatory

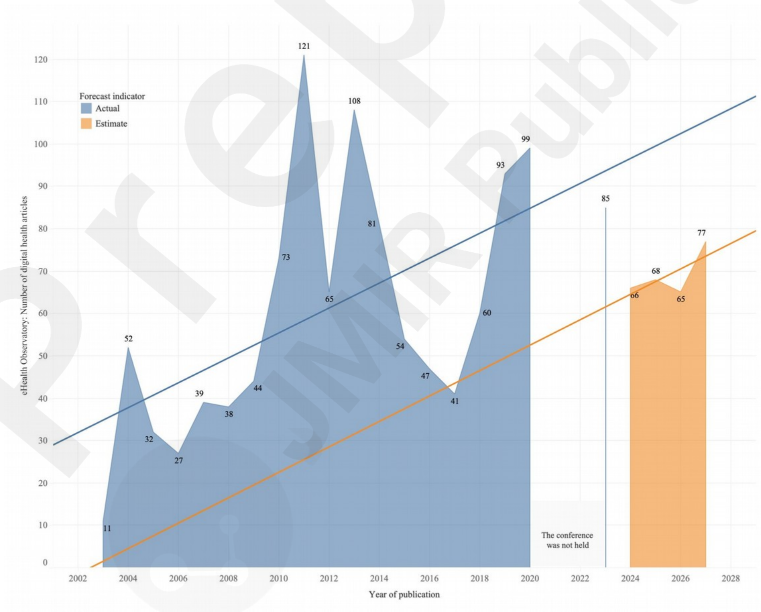

Figure 6. Overview of the included papers extracted from the E-Health Observatory, 1999-2024.

Figure 6 shows the number of contributions that the E-Health Observatory has received over the years. The number of contributions has varied over the period, which is why trends are inconsistent, except for the periods from 2006-2011 and 2017-2020, in which a more progressive growth can be identified. In contrast, the more dramatic decline lasted from 2013 to 2017. Separately, in the year 2011, the highest number of articles were presented (121).

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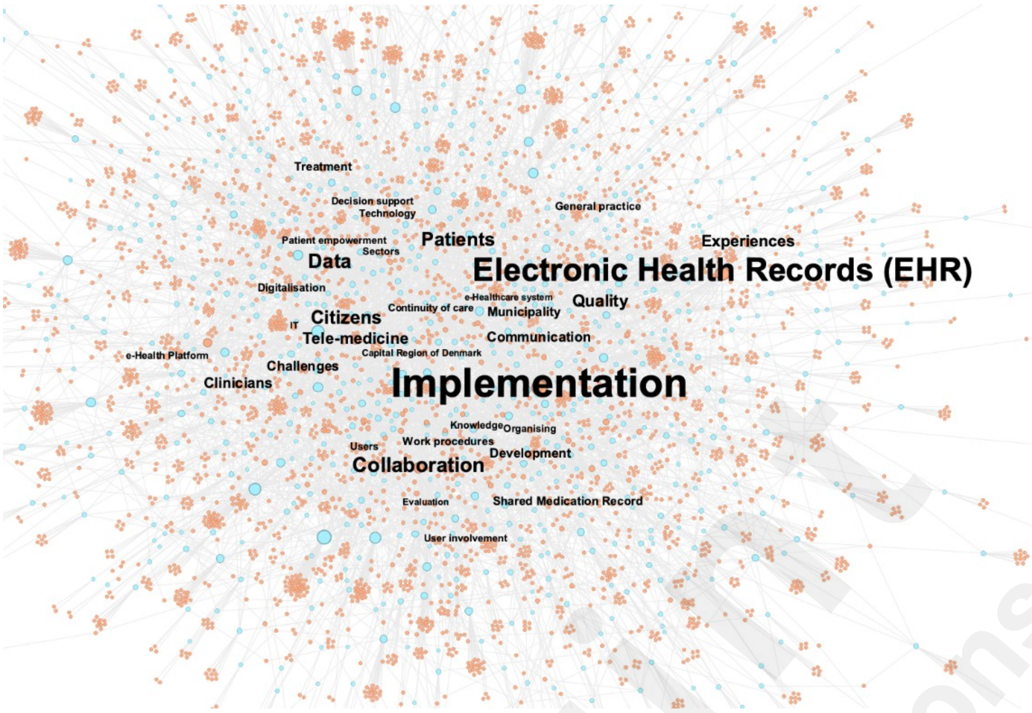

Figure 7. A network diagram of the included keywords extracted from the E-Health Observatory, 1999-2024.

In Figure 7, the most dominating keywords are “Implementation” and “EHR”, as they have relatively larger numbers of occurrences compared with the rest. Furthermore, a substantial insight into this network is the absence of large clusters, in contrast to a higher number of small clusters. The tightest of these clusters are connecting “collaboration” with “users” and “development”, and “citizens” with “telemedicine”. Additionally, although the small clusters are scattered all over the network, most of them do not have a high number of occurrences, which is why the keywords are not displayed in the graph.

Digital health in Denmark 1999-2014 - 5-year intervals

In this subsection, the results from the two databases are analysed. The analysis is divided into 5-year intervals to make changes and similarities over the period transparent.

Development 1999-2003

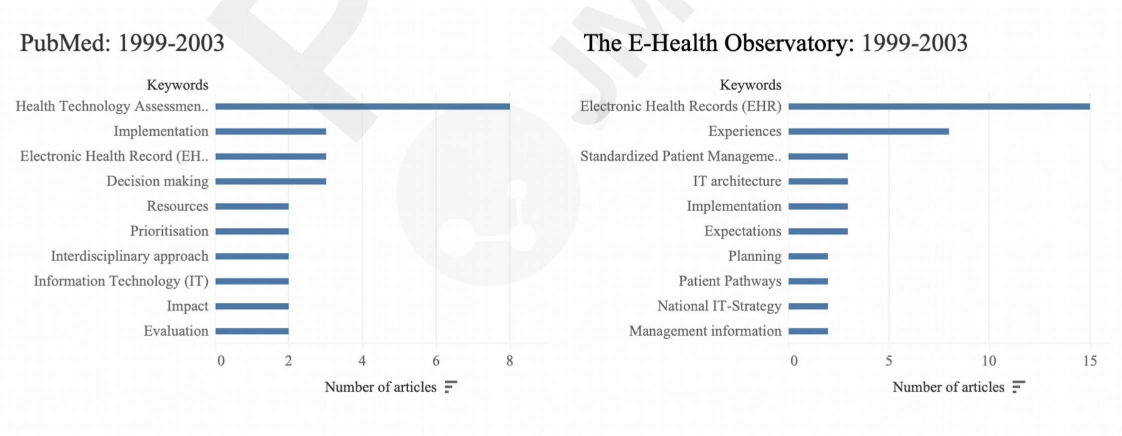

Figure 8. 5-year intervals overview of the included keywords extracted, 1999-2003.

From 1999 to 2003, "Health Technology Assessment (HTA)" emerged as one of the most prominent keywords (Figure 8), indicating a significant focus on assessing the effectiveness and impact of health technologies, which aligns with the increased emphasis on evidence-based praxis and decision-making in this period [36,37]. Similar to the results displayed in the network diagrams (Figures 5 and 7), EHRs is the technology receiving the most attention from researchers. The prevalence of phrases like "Decision making", “Implementation”, "Prioritisation", “Resources”, “Impact” and

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“Evaluation”, indicates the purposes of digital technologies, why they are implemented and how important it is to examine the effect of these digital technologies when used in clinical practice. The terms "Experiences" and “Expectations”, indicate that the application and acceptance of digital technologies are related to users’ expectations and experiences, as explained in the Technology Acceptance Models (TAMs) [38]. However, these terms may also reflect the importance of the inclusion of user experience and perspectives when evaluating digital health technologies. The terms "Standardised Patient Management", “IT architecture”, “Patient Pathways” and “Planning”, reflect the importance of standards and standardised procedures in digital healthcare, to promote uniformity and consistency in patient care and practices. Moreover, the results indicate that focus on how data and digital technologies can be used to support “Decision-making” was considered right from the beginning of the eHealth era.

Development 2004-2008

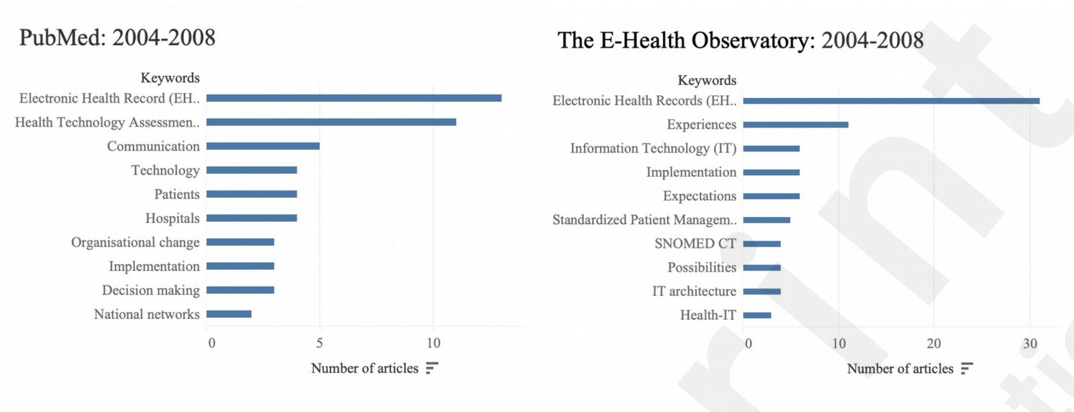

Figure 9. 5-year intervals overview of the included keywords extracted, 2004-2008.

From 2004 to 2008, the dominance of EHRs and HTAs persists, which are accompanied by the terms “Implementation”, “Experiences” and “Expectations”, verifying the continued focus on these matters. The emergence of the keywords "Communication" and "Organisational change" might demonstrate a rising awareness of the importance of good communication channels and adaptability when new technologies are transforming healthcare organizations. The appearance of "SNOMED CT" and the reappearance of “IT architecture” and “Standardized Patient Management” underscores how standards and terminologies are necessary to facilitate interoperability and semantic consistency; subsequently, allowing effective and accurate sharing of information [39]. The popularity of the term "Health-IT" instead of the broader term information technology (IT) confirms the independence and importance of the Digital Health area. On an organizational level the term “Hospitals” indicates that hospitals in this period remain the most important actors within digital health. Additionally, there is continued awareness on how data and digital technologies can be used to support “Decision-making”.

Development 2009-2013

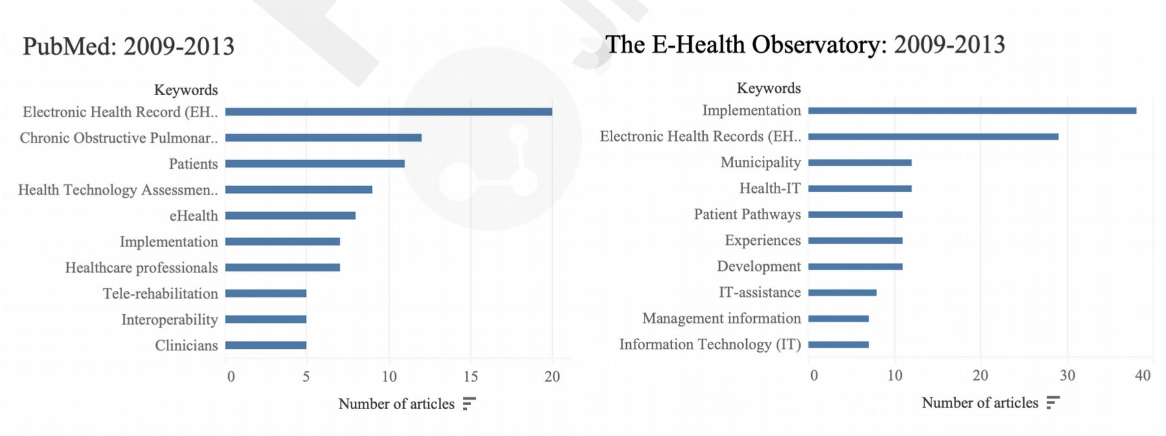

Figure 10. 5-year intervals overview of the included keywords extracted, 2009-2013.

In this period, EHRs remain the most examined technology, whereas the application of HTA and awareness of issues pertaining to the technical infrastructure stays relevant reflected by the terms “Interoperability” and “IT assistance”. From 2009 to 2013, the focus on "Implementation" was significant, which might indicate the increased use of digital technologies and the obstacles and complexities associated with the transition. The keywords "Chronic Obstructive Pulmonary Disease (COPD)" and "Telerehabilitation" appear for the first time, showing how telemedicine started to gain ground in a Danish context. The term “eHealth” is now also part of the overviews, which is not that shocking; however, it is noticeable that it took around 10 years from the coining of the concept [40] until it appeared as a common term in the included material. Interestingly, the term "Municipality" is relatively popular in this period, showing how the local governments are key actors in the digital healthcare system. The keyword "Development" might imply a broader concern for design aspects and system refinement, underscoring the relevance of questions like, how are we designing systems?; do the designs facilitate the needs of the users?; and, who benefits from these designs? In this context, it is noticeable that the term “Management information” is among the top ten keywords, showing how digital health technologies also facilitate the needs of the management level. The reappearance of "Patient Pathways" demonstrates how the lack of coherence experienced by patients is a continuous problem that might be solved through the implementation and use of digital solutions.

Development 2014-2018

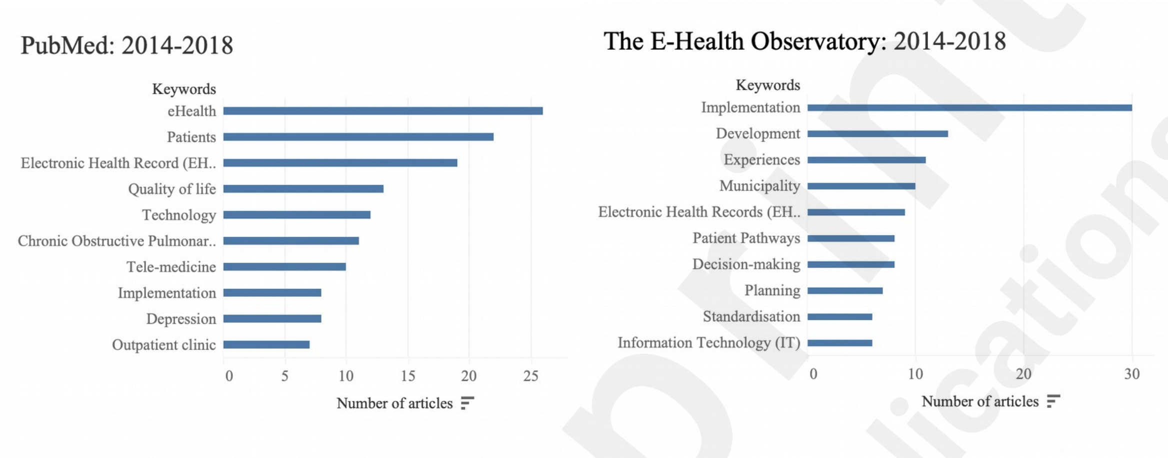

Figure 11. 5-year intervals overview of the included keywords extracted, 2014-2018.

In the next period, from 2014 to 2018, the term "eHealth" is now an integrated term in academia. This period also highlights the importance of patient-centred care, as the keywords "Patients" and "Quality of life (QoL)" appear frequently. “Telemedicine", “Outpatient clinic”, “Depression” and “COPD”, which are disease areas that most likely appear due to their connection to telemedicine, show how telemedicine and home treatment to a greater extent are applied in a Danish context and resemble the increased focus on patients with chronic diseases. Studies on EHRs and implementation are still dominating and focus on digital health in a “Municipality” context and “Patient pathways” remain relevant, whereas the increased focus on "Development" confirms the importance of the design of the technologies, which may reflect how development and implementation have become increasingly integrated processes. The technical focus is less profound in this period; however, the term "Standardisation" indicates that the technical structure of the digital healthcare system is part of a continuous debate. Furthermore, "Planning" and Decision-making" indicates a joint effort to streamline processes and use data to make informed clinical and administrative decisions.

Development 2019-2024

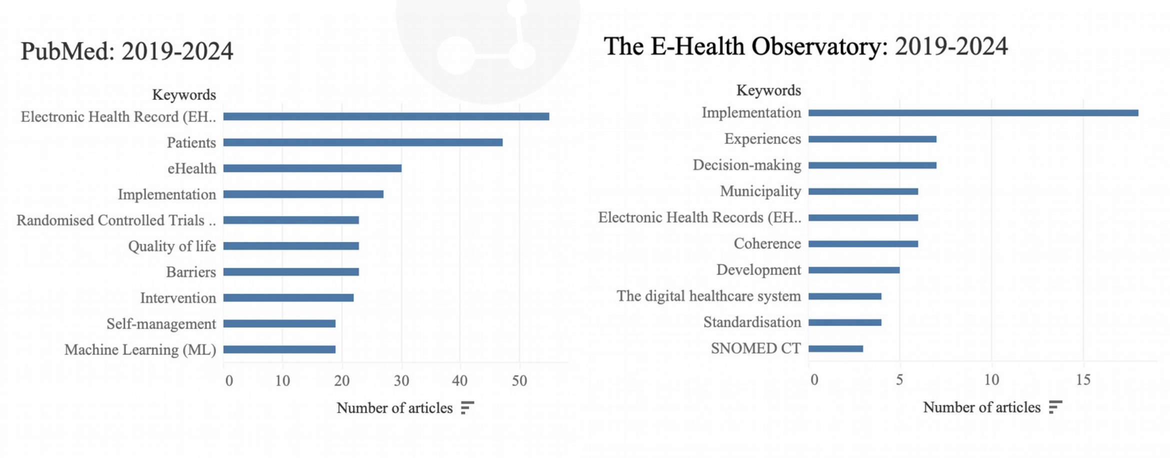

Figure 12. 5-year intervals overview of the included keywords extracted, 2019-2024.

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In recent years, from 2019 to 2024, the number of articles on digital health has increased overall, and especially research on EHRs is increasing in this period, which makes sense since this is the period right after the implementation of EPIC in the eastern part of Denmark and the time interval where Systematic is implemented in two of the western regions of Denmark. Thus, also a development that might explain the continuous focus on “Implementation”. The introduction of “Randomised Controlled Trials (RCTs)” in the displays is noteworthy, which might reflect the importance of digital health technologies and their potential impact on clinical practice. As in the former periods, the term "Patient" is very naturally focal within digital health; however, the use of the term increases in this period, while the terms “Experiences” and “Decision-making” remain relevant, which might reflect how patient-centred care based on patients’ experiences and perspectives to greater extent is integrated systematically in clinical practice. At the same time, “Self-management” disclose how the current healthcare system in Denmark could be referred to as being patient-dependent, referring to the fact that digital health technologies to a larger degree are developed and used to facilitate self-management among citizens with chronic conditions [21]. Noticeable, “coherence” is among the most frequently used terms in this period, underscoring the importance of coherence across providers organisations and sectors, in patient pathways and the technical infrastructure; however, the reason that this term is among the top keywords in this period, is probably due to the explicit political focus on coherence in the digital healthcare strategy from 2018, named, “'A Coherent and Trustworthy Health Network for All” [41]. The use of the term "Machine Learning (ML)" demonstrates an increasing interest in artificial intelligence (AI) and the use of advanced technologies in the healthcare sector and clinical practice. The presence of "Standardisation" and "SNOMED CT" confirm the continued importance of standardised clinical terminologies and coding systems in facilitating interoperability and data interchange.

Discussion

In this section, the results are discussed by first examining the dominant themes over the years, and then scrutinising the development in the Danish context by revisiting Gunther Eysenbach's 10 e's coined in 2001 [40]. At the end of the section, methodological reflections and limitations are presented.

Discussion of the results

When considering the development over the entire 25 years, from 1999 to 2024, "EHR", "Patients", "Experiences", and "Implementation" are the most frequently used keywords; thus, it appears that the implementation of digital health technologies, with a particular focus on EHRs and user experiences, has been the dominant themes throughout the period. Furthermore, the overviews demonstrate how the concept and field of "eHealth" have become firmly established over the last 25 years. The results show that HTAs and RCTs are the most commonly used methods and approaches for evaluating digital health technologies. On an institutional level, the continued use of the term "municipality" demonstrates the importance of local governments in the field of digital health in Denmark. The focus over time on "Patient Pathways", "Coherence", "Decision-making", and "Quality of life" reveals some of the main purposes of digital technologies in a Danish context; thus, digital technologies are believed to improve the coherence of the healthcare system, patient experience, patient participation, and to enable the monitoring of patients' QoL, all of which are closely related to the implementation and applications of telemedicine and PROs. Figure 13 depicts an overview of the most dominant topics during the past 25 years.

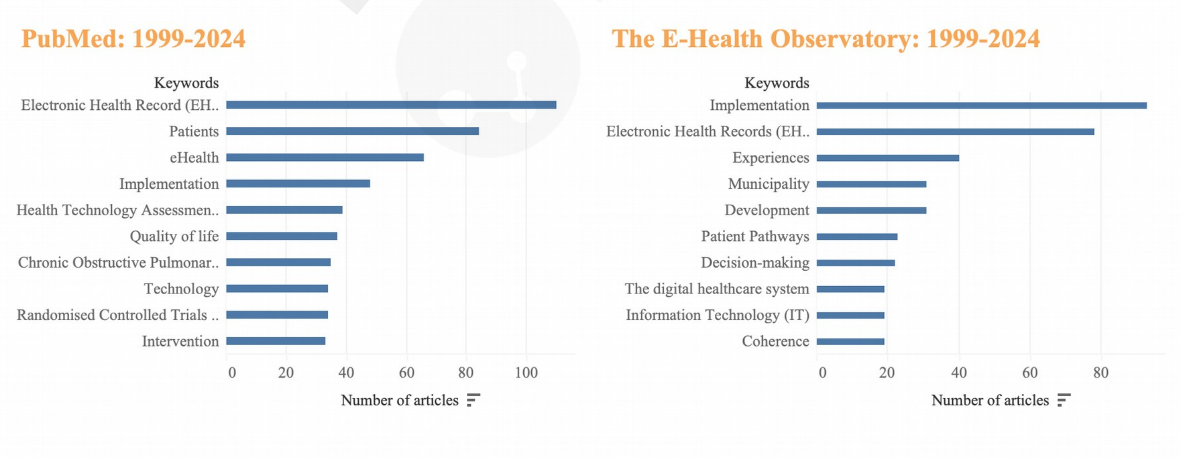

Figure 13. 5-year intervals overview of the included keywords extracted from 1999-2024.

Revisiting the 10 e's in a Danish context

In 2001, Eysenbach wrote an editorial on the main elements comprising the eHealth area, where he formulated the 10 e's referring to Efficiency, Enhancing quality of care, Evidence-based, Empowerment of consumers and patients, Encouragement of a new relationship between the patient and health professional, Education of physicians through online sources and consumers, Enabling (standardised) information exchange and communication, Extending the scope of health care, and Ethics and Equity [40]. 23 years later, it is fascinating to explore how the concepts embedded in the 10 e's have manifested in a Danish context. A development made possible by the continuing emphasis on adequate technical infrastructures, as well as the efforts and contributions of organisations such as MedCom.

Based on the keywords "HTAs", "RCTs", and "Experience", the results of this study demonstrate the importance of evidence-based and systematic approaches when implementing and evaluating digital health technologies. The relevance of "Decision-making" over the years may also reflect how digital technologies and data enable HCPs to make evidence-based decisions; however, "Decision-making" may also be linked to the Encouragement of new relations between HCPs and patients, if patients play a more significant role in deciding on the type of treatments they will receive [20]. The emphasis on Empowerment can also be linked to the rising usage of "Telemedicine," in which citizens are required to monitor their health, which aligns with the Extended scope of healthcare made possible by the digitisation of healthcare. Whether the healthcare system has become significantly more Efficient and Enhanced the quality of care is more dubious; nonetheless, it is exactly due to the effects on efficiency and quality of care that increased use of digital health technologies is perceived as one of the main ways to counter current structural and demographic challenges [42]. In Denmark, there is an awareness of the importance of Ethics and Equity in Digital Health [43]. However, there is still room for improvement in this field, as certain segments of the population face accessibility and are excluded due to language barriers, low eHealth literacy, and physical disabilities. As a result, it is critical to include citizens who are most in need of the digital healthcare systems in design and development processes.

Reflections and limitations

We have observed how the two databases can differ. For example, in the network visualisations, DB1 displays larger clusters than DB2. This can be explained from various perspectives. We argue that it entails a data interpretation representing how related keywords are and how authors utilise them, hence determining their network position. This is due to DB1 being more centralist in authors employing specific keywords within the field, whereas DB2 exhibits a more dispersed and less centralised interpretation. Based on this notion, we consider databases as distinct entities that account for diverse data points yet sharing a common context. That being stated, we believe multiple databases contribute to a more precise portrayal of the field while also reflecting a variety of outputs via digital methods. In this sense, Richard Rogers illustrates the concept of the medium as a technique to investigate to what extent the medium is influencing the findings [44]. In other words, DB1 and DB2 are different mediums for establishing an outcome, however it is up to the researcher to construct their knowledge while acknowledging that ranking is determined by the dataset. We argue that our research strategy focuses on extracting prominent keywords from an ambiguous query design, which in this context refers to multiple potential meanings, emphasising the significance of expert knowledge when interpreting data.

Finally, in the discussion of a research strategy, another aspect is the use of LLMs for information extraction and text summarisation. Some researchers have identified the benefits of using ChatGPT in the context of academic/scientific writing and scientific research in analysing massive datasets [45], but the use of this tool should be viewed as an aid to humans in augmenting intelligence and improving efficiency rather than a replacement [27]. In contrast, it has been discovered that LLMs may struggle with ambiguous input text, producing incorrect replies or experiencing hallucinations. Such situations may cause ChatGPT to produce inaccurate outcomes that appear plausible from a scientific perspective [46].

Considering this, we argue that our research strategy employs ChatGPT as an assistive tool, and we acknowledge its risks by incorporating manual screenings and tests whenever possible. This proved useful when we encountered some ChatGPT constraints during our data extraction phase. Furthermore, the basis of RAKE is backed by principles that address the ranking keywords from a specific input rather than modifying or generating new keywords from the given text. As a result, we have high confidence in the data's accuracy.

While this study is supported by two relevant sources', PubMed and the E-Health Observatory datasets, using more sources within the biomedical literature was considered in the research strategy; however, those additional data sources were not fully compatible with the scope of our study due to technical limitations from such platforms' inability to implement advanced extracting functions for large datasets.

On the other hand, given the huge number of LLMs available, we used ChatGPT due to its widespread use in healthcare literature and ease of use; nevertheless, in future research, different models should be employed to compare outcomes in keyword extraction.

Finally, because our study's main scope is limited to the Danish context, there is an opportunity in future research to replicate our study across different contexts, locations, or areas, as our work serves as a methodology and analysis for understanding not only information and communication technologies in biomedical sciences utilising large amounts of data, but also transferable to other data-driven areas.

Conclusions

In this study, we have shown how Digital Health has evolved in Denmark over the last 25 years. The results show that EHRs are the technology that has gotten the most attention throughout this period. Technical themes that have been crucial in this field over the years include adequate technical infrastructure, interoperability, and semantic standards. Other themes that have remained relevant over time include how digital technologies are developed, implemented, and evaluated, with HTAs and RCTs being common methods and approaches, where especially user experiences have been studied. The study also reveals the rising importance of Telemedicine and the treatment of citizens with chronic conditions, as evidenced by the fact that COPD and QoL were two of the primary themes throughout the period.

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Conflicts of Interest

None declared.

Abbreviations

AI: Artificial Intelligence
COPD: Chronic obstructive pulmonary disease
EHR: Electronic Health Record
FMK: Shared Medication Record (Fælles Medicinkort)
JMIR: Journal of Medical Internet Research
LLM: Large Language Model
ML: Machine Learning
PROs: Patient-Reported Outcomes
PROMs: Patient-Reported Outcome Measures
RCT: Randomized controlled trial
QoL: Quality of Life

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Figures

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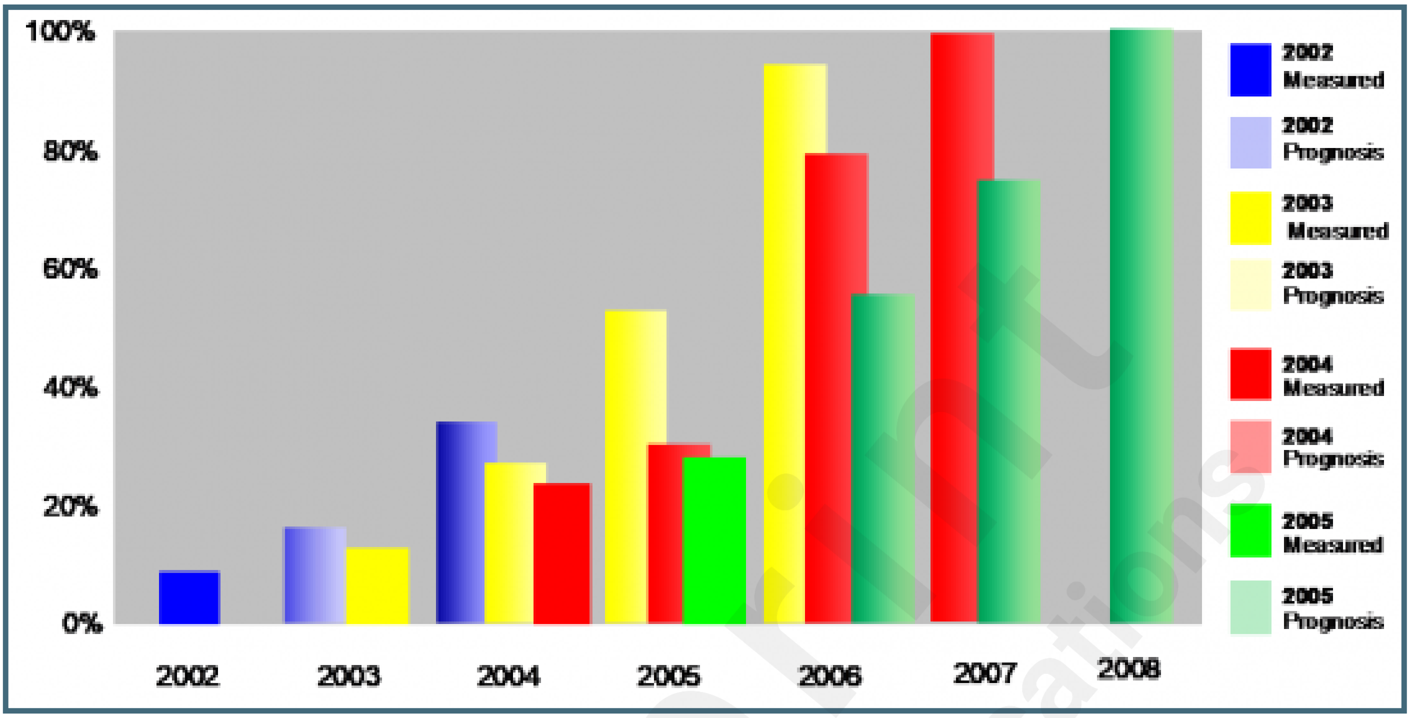
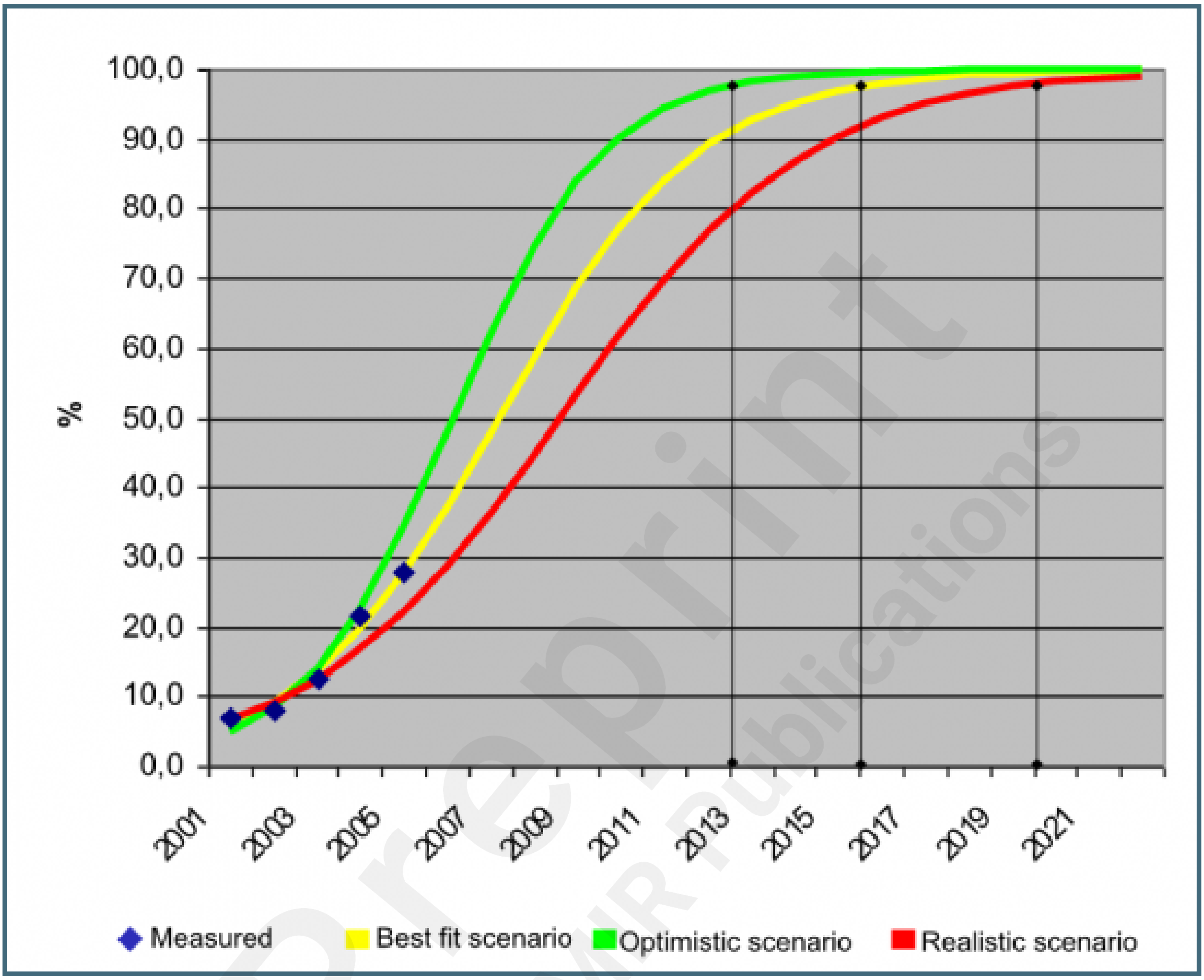
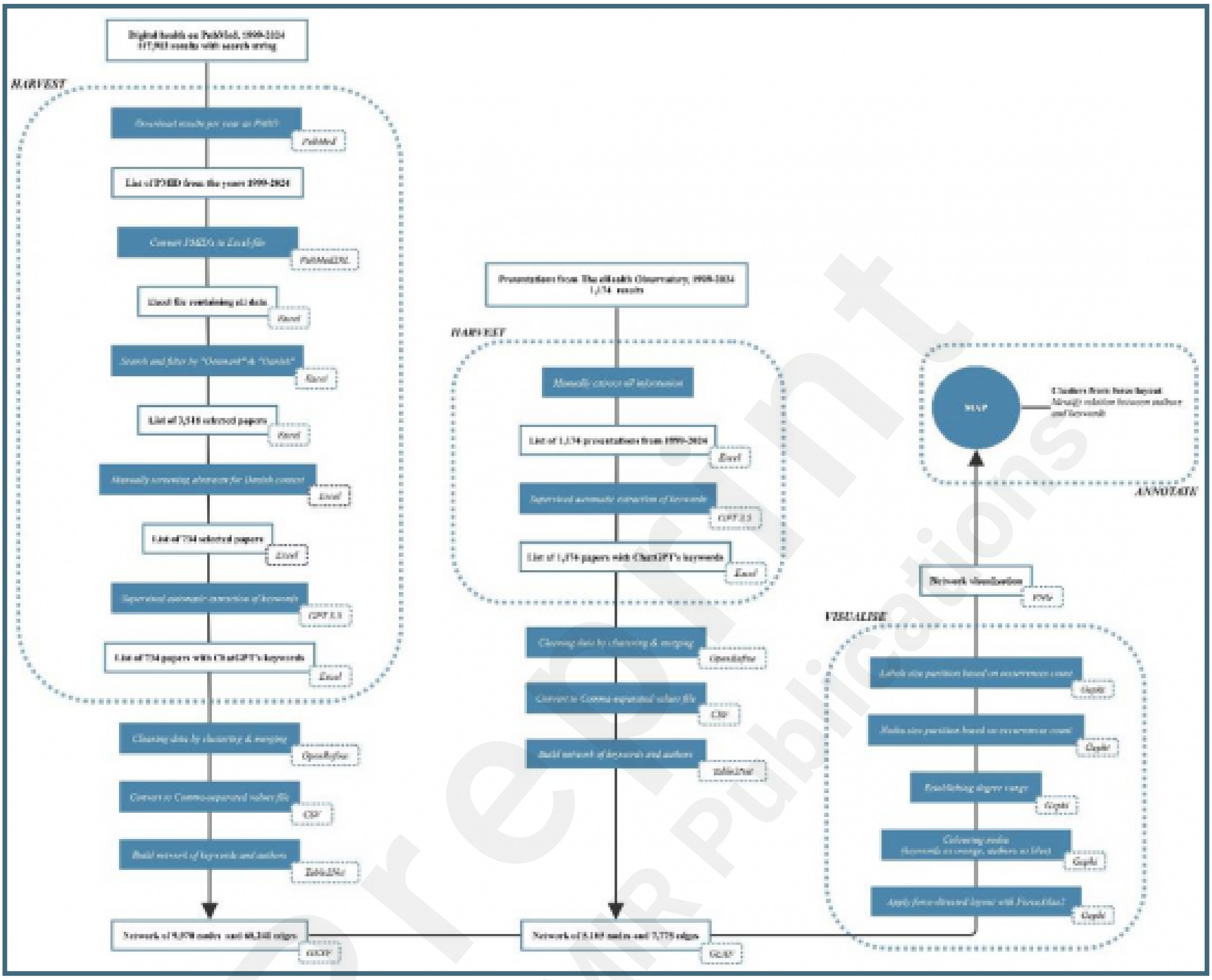
The proportion of hospital beds covered by an EHR system from 2002 to 2005, and the counties prognosis for the following years.



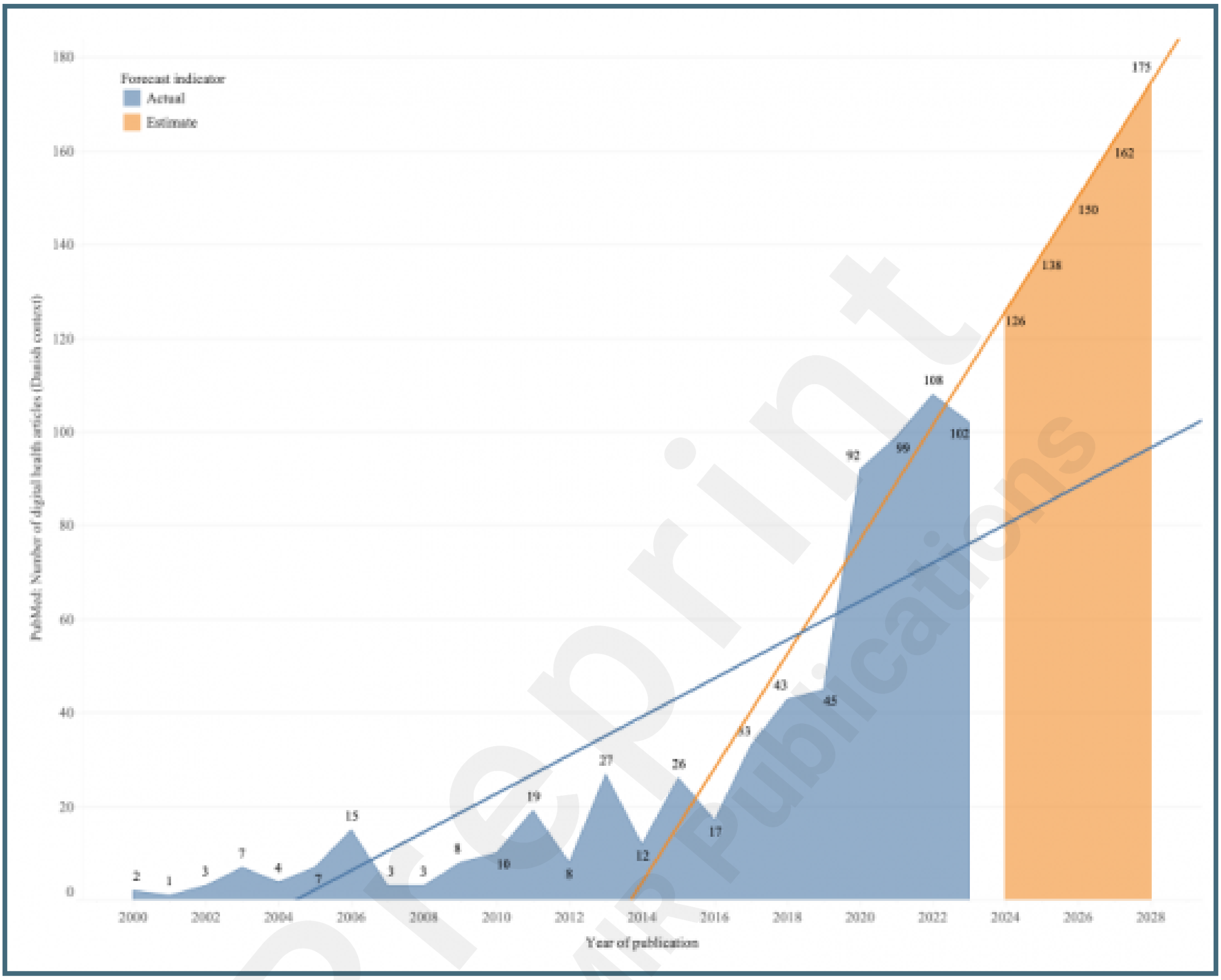
Model calculations for national EHR bed coverage based on five years data from 2001 to 2005.



Overview of the methodological process for extracting networks.



Overview of the included papers extracted from PubMed, 1999-2024.



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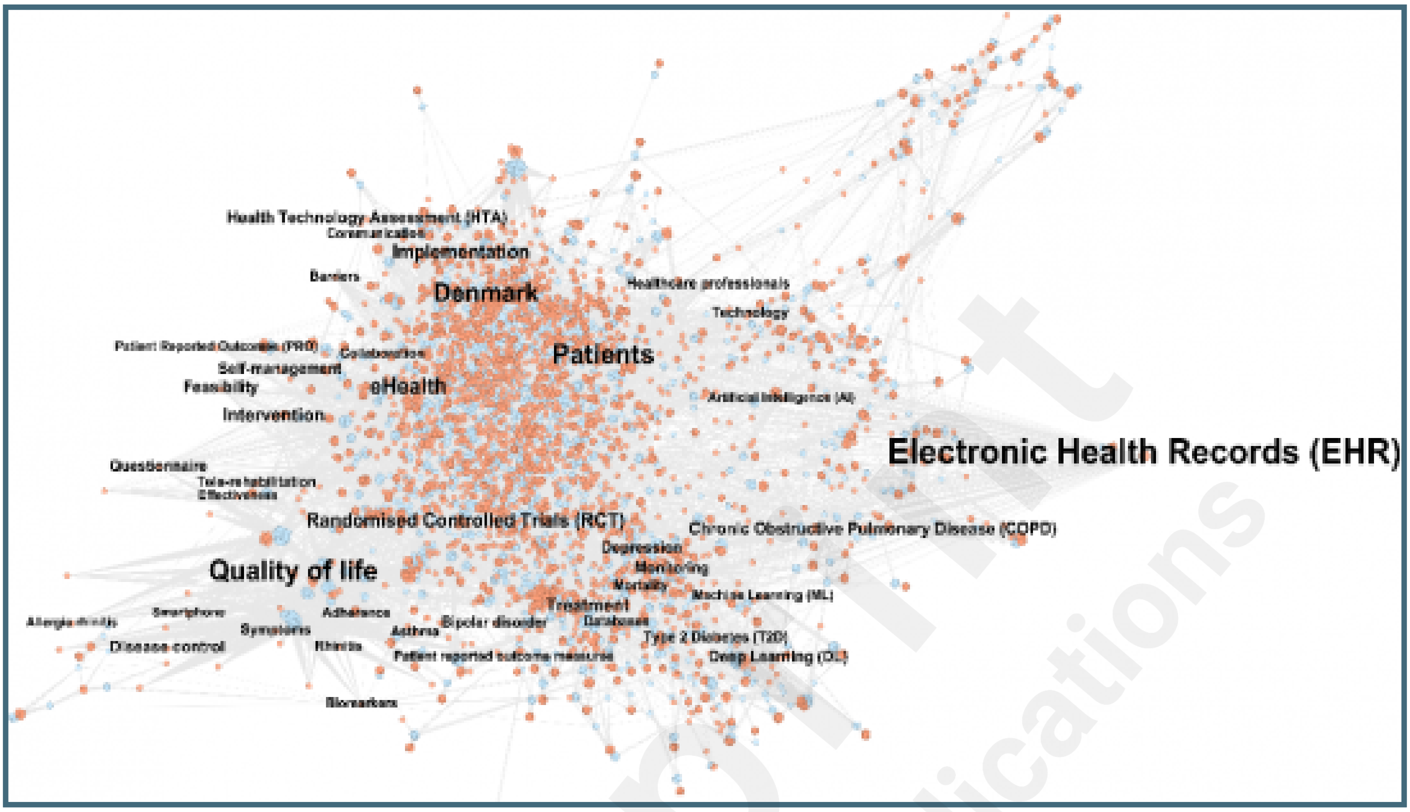
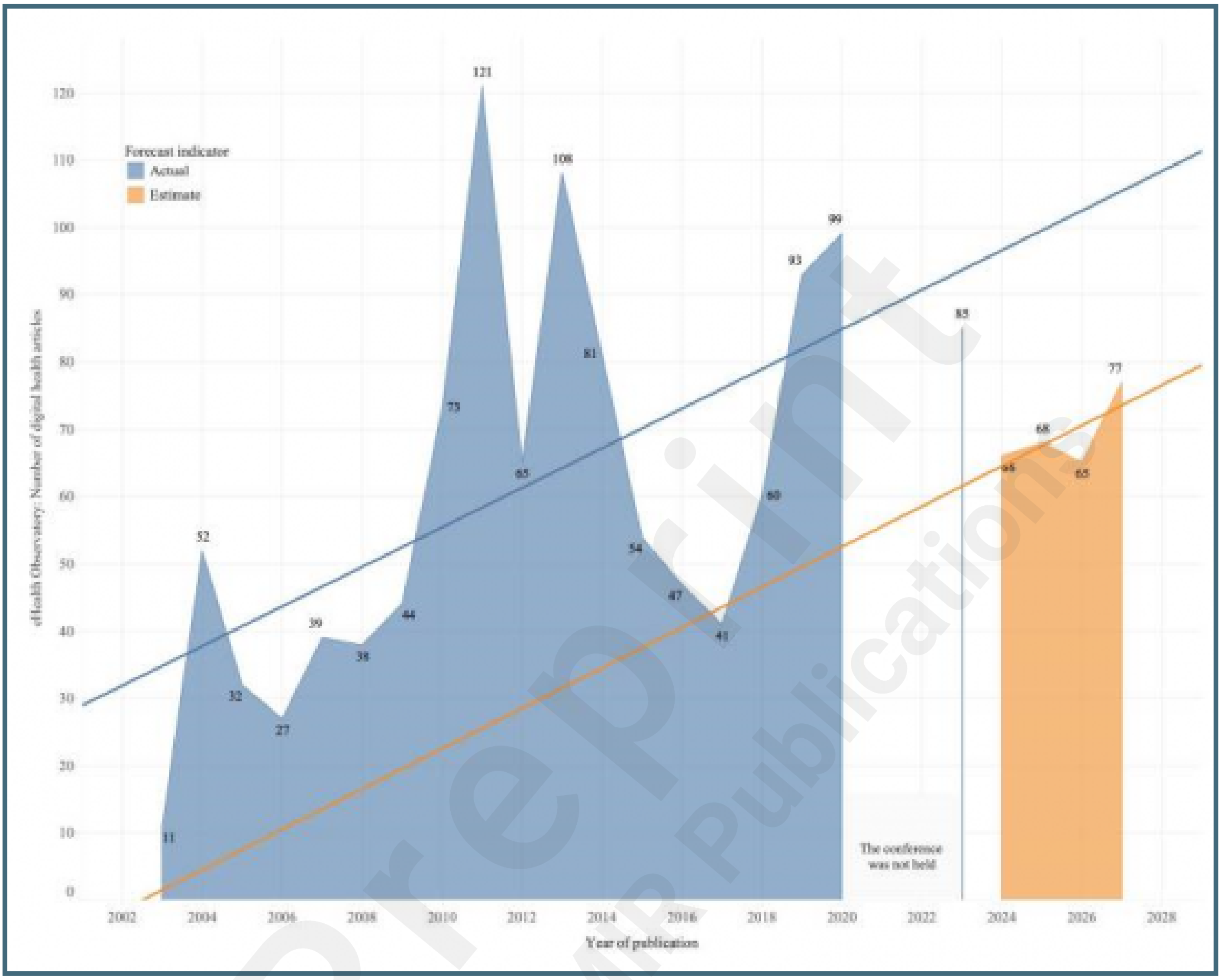
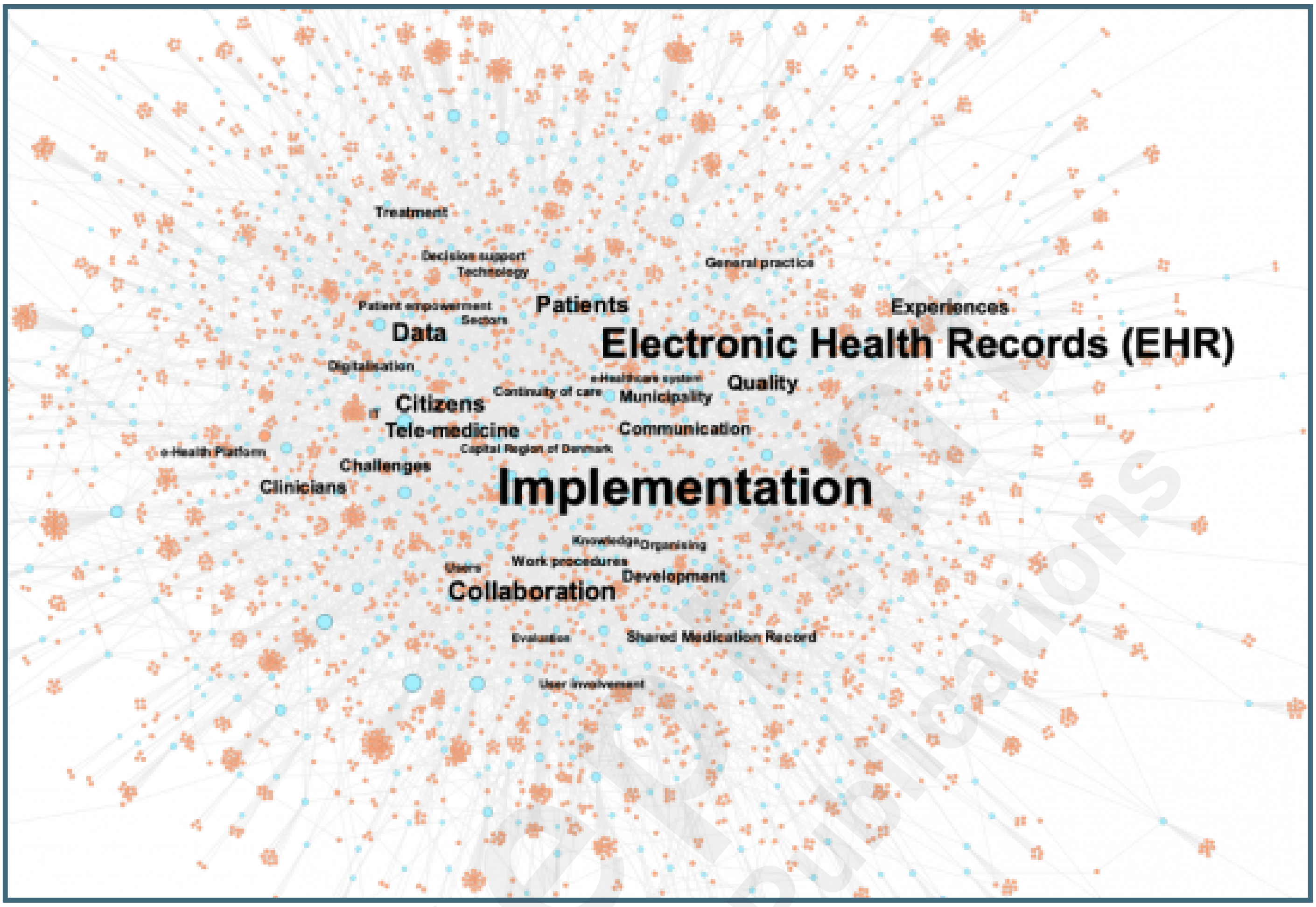
A network diagram of the included keywords extracted from PubMed, 1999-2024.



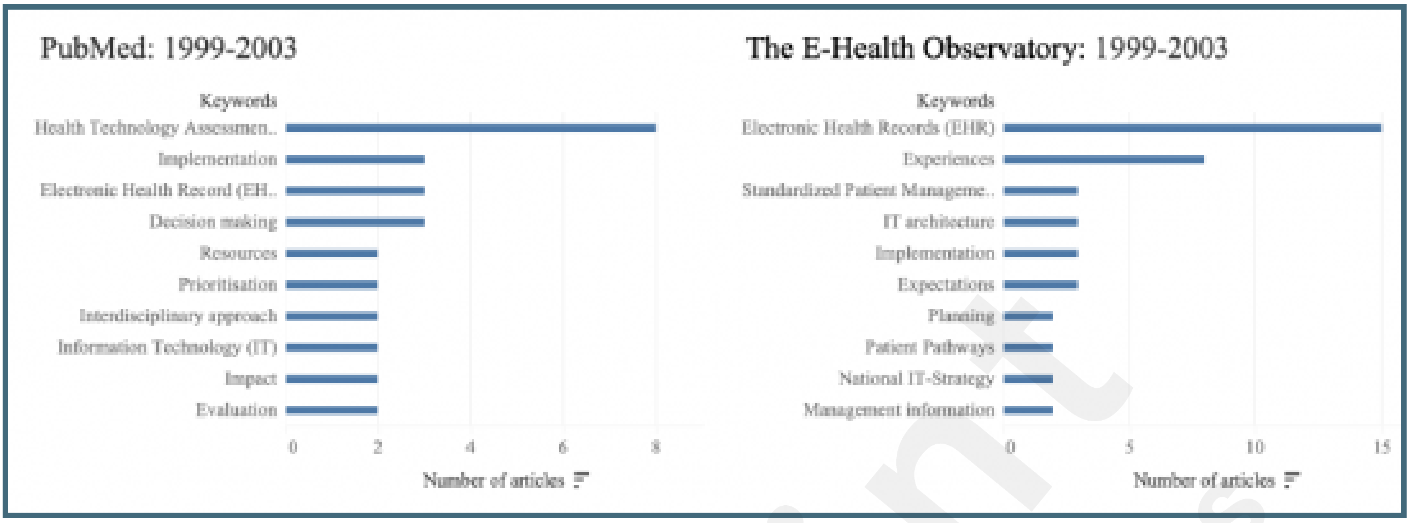
Overview of the included papers extracted from the E-Health Observatory, 1999-2024.



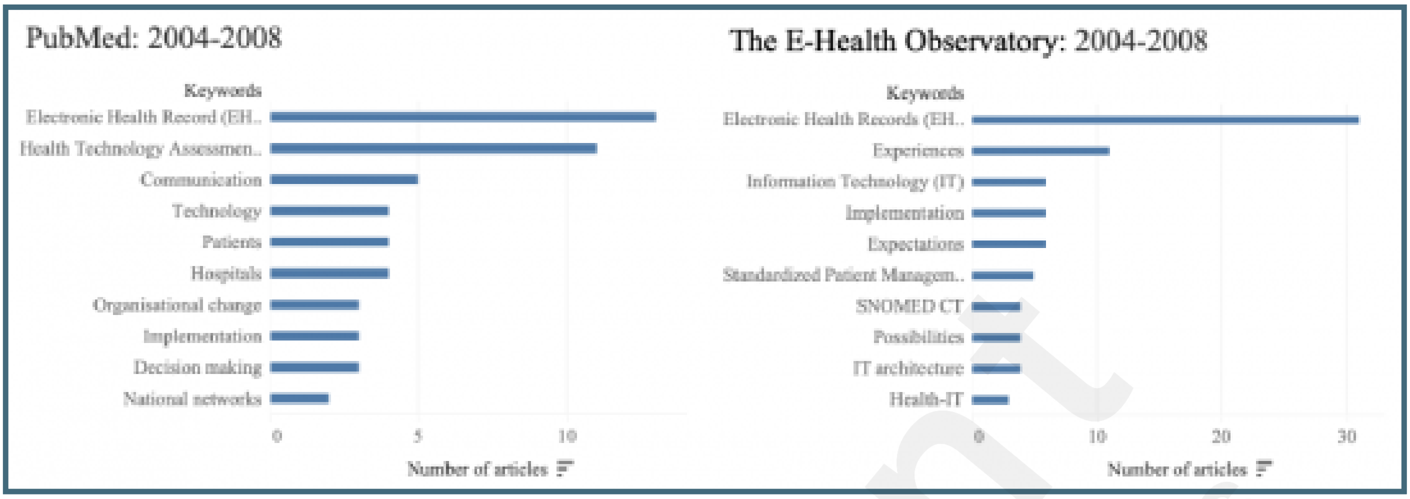
A network diagram of the included keywords extracted from the E-Health Observatory, 1999-2024.



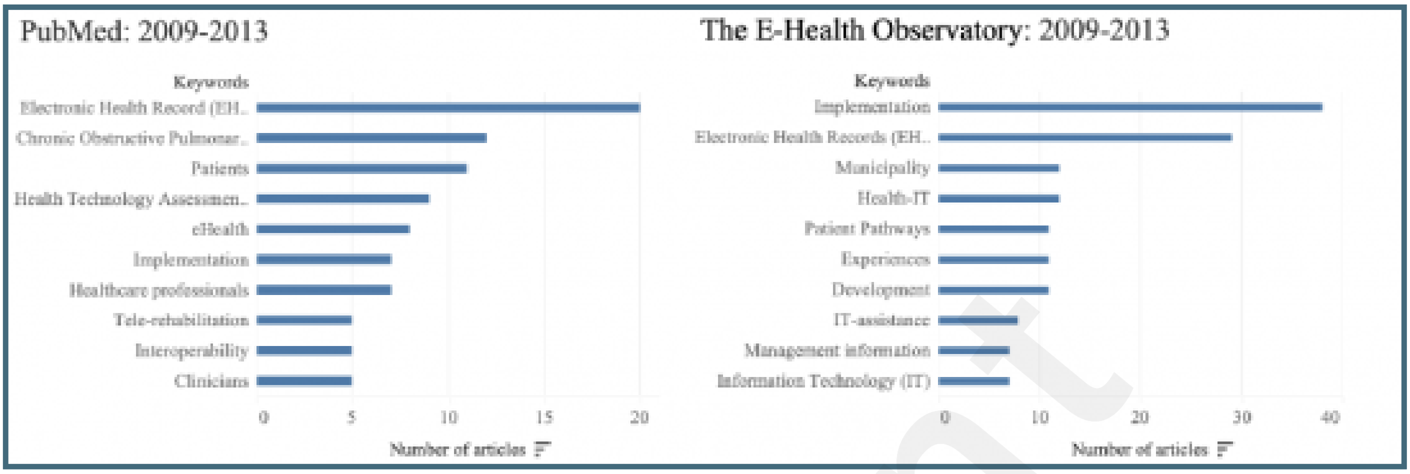
Five-year intervals overview of the included keywords extracted, 1999-2003.



Five-year intervals overview of the included keywords extracted, 2004-2008.



Five-year intervals overview of the included keywords extracted, 2009-2013.



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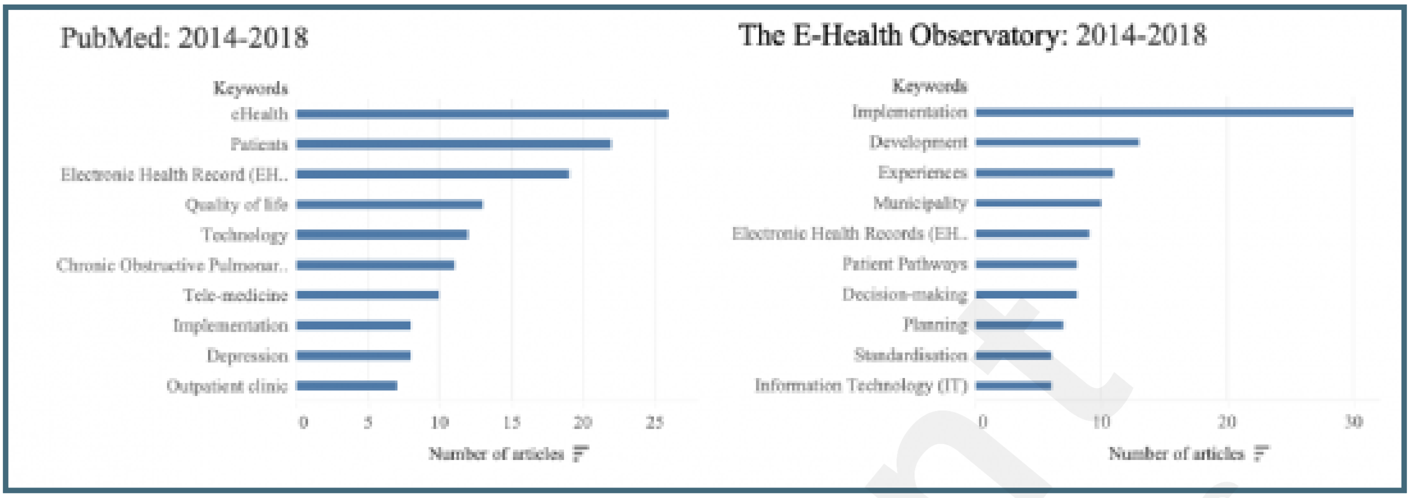
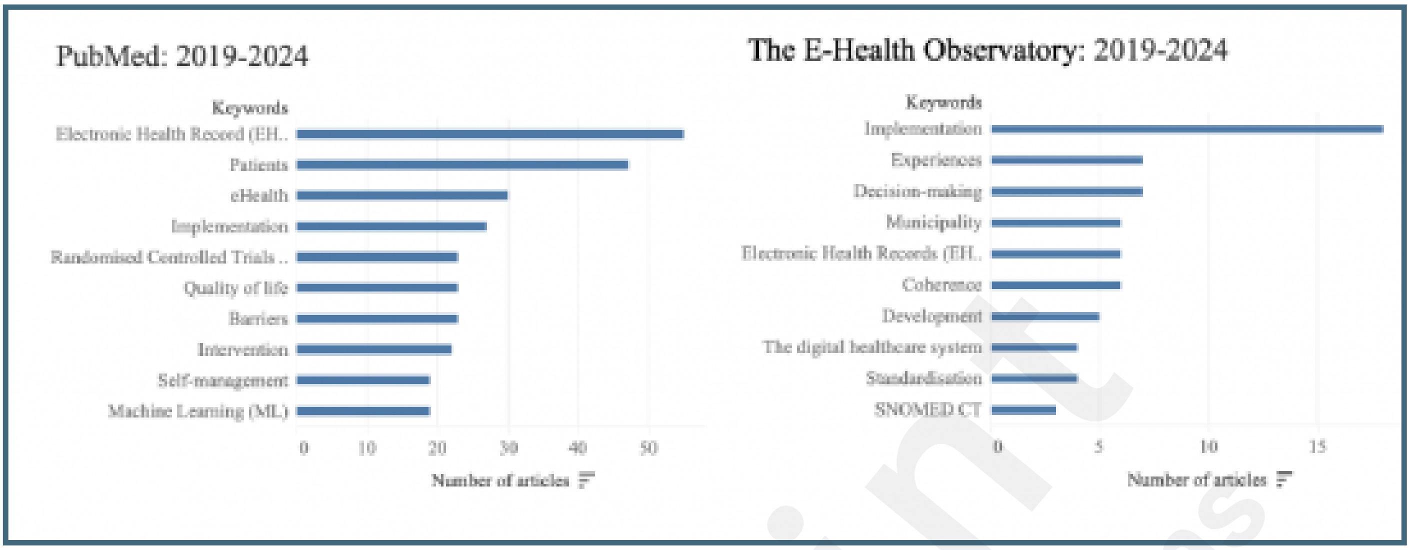
Five-year intervals overview of the included keywords extracted, 2014-2018.



Five-year intervals overview of the included keywords extracted, 2019-2024.



Five-year intervals overview of the included keywords extracted from 1999-2024.