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IT solutions for health workforce shortages: improving administrative processes and care access—a comparative study of five European countries

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Abstract
The healthcare sector faces a critical shortage of healthcare workers, creating significant challenges in healthcare delivery. The use of Information Technology (IT) solutions in healthcare presents potential remedies to reduce the negative consequences of this problem. The purpose of this study was to identify IT solutions implemented to mitigate the effects of medical shortages and improve administrative processes and care access. The study used a systematic approach integrating desk research, national expert consultations and comparative analysis to examine IT solutions in healthcare systems. Five European countries were selected for the in-depth analysis: Poland, the Netherlands, Spain, Finland, and Croatia. The impact on administrative processes, care access, and the functioning of healthcare systems was assessed. The study identified a variety of regulatory frameworks, common implementation strategies and the institutions responsible for these activities. All compared countries used telemedicine, e-prescriptions and various types of health applications. It was found that the most frequently used IT solutions were electronic health record (EHR) and e-prescription systems. However, IT training, its organization, financing and mandatory nature differed in individual countries. In addition, common barriers were identified across all countries, such as financial constraints and interoperability issues. Integrating IT solutions offers opportunities to address health workforce shortages and enhance healthcare efficiency. Tailored strategies and collaborative efforts are essential to address financial constraints and interoperability issues. Implementing best practices identified in this study can improve administrative processes and care access. Future research should prioritize longitudinal impact assessments and explore new technologies to optimize healthcare IT solutions.

Introduction

In recent years, the health workforce (HWF) has faced challenges, including heavy workload, burnout and increasing average age of healthcare workers [1]. These factors have contributed to a shortage of medical staff which poses a critical threat to quality care services [2]. The COVID-19 pandemic further intensified the need for strategies and, such as Information Technology (IT) solutions to address these challenges [3–5].

Automating tasks, streamlining data management and improving communication through IT solutions, such as artificial intelligence (AI)-based scheduling systems, machine learning algorithms, as well as telehealth platforms and integrated data exchange networks, can enable healthcare professionals to perform more efficient diagnosis, treatment and administrative processes. By adjusting staffing needs and optimizing workflows, these solutions help healthcare providers proactively manage HWF, increase retention, and improve care delivery [2, 6]. Leveraging advanced IT solutions, such as Electronic Health Record (EHR), health applications, electronic prescription, referrals, and automated virtual consultations, can alleviate the workload [2]. Nevertheless, the report 'Fighting The Health Worker Crisis: Towards A European Health Workforce Strategy' [4] shows that Europe is facing a major HWF crisis, with many countries reporting shortages. Skills gaps often stem from insufficient planning and forecasting, especially in digital competencies which are essential for integrated care [7, 8].

The novelty of this study lies in its cross-country comparative analysis of IT solutions to address HWF shortages, providing insights into current practices, common challenges, and new approaches adapted to different healthcare systems in Europe. These insights can guide decision-makers in selecting effective IT solutions to address workforce shortages and improve healthcare delivery, ensuring that solutions are aligned with the specific needs of each country's healthcare system [9]. Understanding the structural nuances and operational dynamics of these healthcare systems is imperative for evaluating the feasibility and efficacy of IT solutions aimed at mitigating HWF shortages. Among the analysed countries, healthcare systems in Finland and Spain are primarily funded through taxation, with universal coverage and non-mandatory health insurance [9, 10]. Conversely, in the Netherlands, Poland and Croatia there is a mandatory health insurance system [11–13]. The National Health Fund in Poland and the Croatian Health Insurance Fund act as the sole payer of health services [13–15]. Primary responsibilities in the

field of healthcare in Poland, Croatia, and the Netherlands (the Ministry of Health, Welfare and Sports) lie with the Ministry of Health (MoH). It developed policies and measures to promote the health and well-being of the population and ensure access to healthcare services [12–14]. Health policy in Finland is governed by the Ministry of Social Affairs and Health, which steers health and social policy jointly and prepares legislation [10]. Differently, in Spain, the Minister of Health is responsible for national planning and regulation, while 17 regional Ministries of Health have jurisdiction over regional provision of services, planning and resource allocation. High-level coordination remained the responsibility of the Inter-Territorial Council for the Spanish National Health System (SNS), which included the Spanish Minister of Health and regional Ministers of Health [11]. Comparing these systems allows for a comprehensive analysis and search for IT solutions tailored to the needs that decrease the consequences of HWF shortages [15].

The main aim of this article was to explore and present a comparative overview of IT solutions implemented in selected countries to mitigate the effects of medical shortages and improve healthcare delivery. These solutions aim not only to alleviate workforce burdens but also to improve patient care, streamline administrative processes, and ensure more equitable access to healthcare services.

Methods

This article was prepared based on a systematic examination of IT solutions in healthcare systems, employing a multidimensional approach that integrates (i) desk research, (ii) national experts' consultations, and (iii) comparative analysis across selected thematic areas.

Developing a methodological framework

Given the absence of a definition of good practices for IT solutions in healthcare, based on existing literature, we can define it as: IT activities that contribute to reducing the workload and the consequences of HWF shortages. It also means accelerating the diagnostic and treatment processes using IT solutions, improving the exchange of information between the patient and the doctor, but also between health sector employees [2].

To define the scope of our analysis, we consider IT solutions that fulfil the following criteria: (i) increasing healthcare provision efficiency, (ii) reducing HWF workload, and (iii) increasing patients' access to care [9].

Two out of the four categories of digital health interventions identified by the World Health Organization [9] were included in the analysis—those targeted at patients and healthcare providers—due to their relevance in addressing medical workforce shortages. Solutions aimed at health system managers and data services were excluded, as the scope of the study focuses on frontline, practice-oriented applications and direct benefits for patients and healthcare providers, rather than systemic or infrastructural aspects. Solutions targeted at patients and healthcare providers are crucial because they play a significant role in the healthcare system. Facilitating access to medical information and remote consultations enables patients to have easier access to medical services. The use of IT technologies can enhance efficiency by automating administrative processes, electronic medical documentation, human resource planning, and supporting clinical decision-making [5–7].

Data collection and analysis

The methodological approach encompassed three key elements. Firstly, desk research involved a comprehensive literature review and analysis of existing scientific publications (PubMed, Scopus, and Google Scholar), reports, guidelines and recommendations developed by international organizations (European Commission, WHO and OECD), grey literature, as well as regulatory documents on IT solutions in healthcare across the selected countries. This literature review was initially conducted in 2023 and updated for the first time in 2024 and then in May 2025.

In the next step, the first author (K.M.) developed the data collection forms for the following countries: Poland, the Netherlands, Spain, Finland, and Croatia. The pre-completed forms were sent to the national experts for their review. National experts include ROUTE-HWF project [16] partners and are included as co-authors of this article. All experts have broad knowledge about the country's healthcare system, health policy, and challenges regarding the HWF. The experts verified and expanded the results of the desk research. These consultations were conducted to gain insights into the national context, regulatory frameworks, implementation challenges, and best practices regarding IT solutions in healthcare. This verification enabled supplementation of the obtained information for the selected countries.

Finally, a comparative analysis was conducted on the identified thematic areas, including:

- legal regulations and implementation,
- e-prescription and e-referral systems,
- health applications,
- evaluation and good practices according to the implementation of IT solutions,
- IT training programs,
- barriers in the implementation and use of IT solutions.

These thematic areas were formulated based on a review of existing literature, expert consultation within the ROUTE-HWF project, and analysis of common themes in national digital health strategies. They provided a structured framework for organizing and analysing the gathered information, facilitating a comprehensive comparative assessment of IT solutions in healthcare across the studied countries.

Results

Legal regulations and implementation of IT solutions

A comparative analysis of legal regulations governing IT solutions in healthcare in selected countries revealed various approaches. Spain introduced national and regional eHealth policies starting with the General Health Act in 1986 and the national ICT (Information and Communications Technology) strategy in 2010 [11, 17]. In the Netherlands, eHealth reforms began with the introduction of a nationwide EHR in 2005, followed by a formal legal Act on Clients Rights in Electronic Data Processing in Healthcare in 2017 [11, 12, 18]. Croatia launched its national eHealth Action Plan in 2004 followed by the Croatian National Health Development Strategy 2012–20 [14]. In Finland, key eHealth law was introduced between 2007 and 2011, including the Kanta Services launched in 2008 [10]. Poland established its regulatory framework in 2011 through the Act on Health Information Systems, supplemented by Ministerial Regulations in 2012 [13].

Detailed data on legal regulations and implementation are presented in the Supplementary Files (Appendices S1 and S2).

E-prescriptions and e-referral system

The COVID-19 pandemic accelerated the adoption and refinement of e-prescription and e-referral systems [19, 20]. The initial implementations of e-prescriptions in the 2000s in the Netherlands and Croatia were followed by legislative developments in the late 2000s and early 2010s, leading to widespread adoption [12, 14]. In the Netherlands, patients must consent to the exchange of information between their family doctor and pharmacist [19]. Spain also embarked on its adoption path in the early 2000s, with full integration achieved by the 2010s (nurses are not allowed to prescribe) [18]. While Finland commenced pilots in 2010, eventually relying exclusively on e-prescriptions by 2017 [10]. In Poland, e-prescription

implementation began in 2020, with licensed healthcare professionals, such as medical doctors, dentists, and nurses [20, 21].

Finland was a pioneer in implementing e-referrals in 1990, providing primary care physicians, specialists and dentists with the opportunity to issue them [10]. The Netherlands in 2001, Spain in 2010, and Croatia in 2020 started implementing e-referral systems. Poland adopted e-referrals in 2021, authorizing doctors and dentists to issue them [13]. In all analysed countries, healthcare professionals must meet specific requirements and adhere to privacy regulations to issue e-prescriptions and e-referrals [15–17].

Health applications

Health applications across all analysed countries demonstrate a commitment to increasing healthcare access and patient engagement, revealing similarities in their types and overarching objectives. National digital patient health portals exist in Poland, Croatia and Finland, but offer varying functionalities. Patient portals are also available in the Netherlands and Spain, through regional initiatives [6]. Patient portals such as Carpeta de Salud in Spain, Croatia's eZdravlje and Finland's OmaKanta.fi provide users with access to their EHRs, fostering greater patient engagement and empowerment [22–25]. Each of analysed countries has government-funded applications that provide differentiated health-related services. In Poland, they only enable the provision of health promotion services, while in the Netherlands, they additionally offer natural disaster and crisis management services. The Spanish government's app offers public health announcements and health promotion, while the Finnish app provides access to disaster and emergency management services and feedback on healthcare services [6]. More examples of applications categorized by country and their roles are presented in Fig. 1. Detailed data on applications are presented in the Supplementary Files (Appendix S3).

Evaluation and good practices according to the implementation of IT solutions

All compared countries have national agencies responsible for assessing digital health initiatives, while regional evaluations are carried out only in Finland and Spain. A variety of effective IT solutions have been implemented in healthcare, widely recognized as good practices [20]. The SNS ensures that citizens can access healthcare and prescriptions across regions. The MoH coordinates an interoperable system, including the Individual Health Card, Digital Medical Record, and Electronic Prescription, allowing professionals to access clinical information regardless of origin [18]. Croatia, Finland, and the Netherlands have also developed systems to facilitate online registration, appointment scheduling, and access to healthcare services, enhancing patient convenience, and reducing administrative burdens [24–26]. Telemedicine has expanded significantly in all five countries, enabling remote consultations, benefiting those in remote/underserved areas. However, their evaluation was conducted only in Poland [6]. E-prescriptions have been implemented across all analysed countries, streamlining medication management, reducing errors, and promoting patient safety [6, 23, 26, 27]. In all five countries, robust EHR systems serve as platforms for storing and accessing patient information, ensuring continuity of care and efficient data sharing among providers [22, 25, 26, 28, 29]. Patient portals and applications are also widely utilized, empowering individuals to access health information, schedule appointments, and communicate with healthcare providers [21]. The evaluation of mHealth services was only carried out in Spain. Furthermore, all five countries have established national quality registries to collect and analyse data, monitoring and enhancing healthcare quality [22, 25, 27, 29–31]. Tables 1–3 showcase healthcare IT solutions across analysed countries, highlighting their roles in enhancing efficiency, alleviating workforce burdens, and improving access to care.

Figure 1. Examples of health applications categorized by country and their roles.

The assessment of IT solutions across the analysed countries was based on their observable outcomes and accordingly categorized into three groups: (1) healthcare service efficiency (e.g. reduction of duplicated tests, faster diagnostics; Table 1), (ii) alleviating HWF burden (e.g. automation of administrative tasks, improved workflow management; Table 2), and (iii) enhancing patient access to care (e.g. expansion of telemedicine and patient portals in remote areas; Table 3).

Table 1. IT tools enhancing healthcare provision efficiency across analysed countries[a]

Country	The Netherlands	Spain	Croatia	Poland	Finland
IT solution	**e-consultations and telemedicine:** enable remote consultations between providers and patients, improving quickness and accessibility of healthcare services delivery, especially in remote or underserved areas. **Digitized Prescription System:** improves the process of prescribing and dispensing medications, helps reduce errors, enables better control of prescribed medications, promoting patient safety. **Data analytics and artificial intelligence (AI):** used to verify diagnoses, analyse outcomes, predict patient requirements and allocate human resources to healthcare needs in the most efficient way possible.	**Historia Clínica Digital del Sistema Nacional de Salud (HCDSNS):** offers a centralized platform for accessing patient health data, facilitating care continuity and reducing unnecessary tests and/or procedures. **e-Prescription System:** improves patient safety, expedites the prescription procedure, and lowers errors. **e-Radiology:** facilitates quicker diagnosis and treatment implementation, improves diagnostic opportunities through more effective description of imaging test data.	**E-Referral System (e-uputnica):** simplifies the referral process, increases patient care efficiency, as well as decreases administrative and paperwork. **National Health Information System (NHI):** integrates various health-related data sources, providing a centralized platform for accessing and managing health information, thereby improving healthcare provision efficiency. **Telemedicine Services:** enable patients in remote locations to get healthcare services, including monitoring chronic illnesses and conducting remote consultations.	**The Internet Patient Account (IKP):** it allows patients to register online, access prescriptions and information on services rendered, reducing the involvement of medical staff in administrative activities. **Telemedicine Services:** enable remote consultations between patients and healthcare professionals, improving accessibility to care, particularly for those in underserved and remote areas. **Hospital Information Systems (HIS) and Primary Care Information System:** streamlines administrative processes and supports the management of patient data.	**KanTa (Kansallinen Terveysarkisto):** allows healthcare workers to access and share patient information, improving care coordination and reducing duplication of tests. **Digital Prescriptions (e-Resepti):** streamline the medication process, improves medication management, reduces errors, and enhances patient safety. contributing to increased efficiency in healthcare provision. **Omaolo Symptom Checkers:** supports self-care and helps people to contact public healthcare professionals.

a: *Source*: Authors own work.

Table 2. IT tools alleviating health workforce burden in the analysed countries[a]

Country	The Netherlands	Spain	Croatia	Poland	Finland
IT solution	**Landelijke Elektronische Uitwisseling van Patiëntgegevens (LSP):** enables healthcare providers to access patient health information, ensuring better care coordination, and reduces duplication of tests or other medical procedures. **Electronic Health Records (Zorginfrastructuur** formerly known as **EPD):** facilitates the exchange of patient health information healthcare providers. Medical specialists are only permitted to share data for patients who have given their consent. **Patient Portals and Self-Service Tools:** enable remote consultations between patients and various healthcare providers, as well as among medical workers, which may contribute to faster diagnosis and treatment implementation.	**Telemedicine and E-Consultations:** enable remote consultations between various healthcare providers, as well as medical professionals and patients. **Interoperability among Autonomous Communities:** allows for the exchange of patient data between healthcare providers, reducing mistakes, duplicated services and the administrative burden on healthcare staff.	**Electronic Health Records (EHRs):** digitized patient information, enabling healthcare providers to access patient data more efficiently, reducing the administrative burden on medical professionals. **Healthcare Data Exchange Networks:** enable the safe exchange of patient data between health care providers, facilitate the coordination of care, and relieve the burden on medical staff by limiting the need to perform unnecessary tests and procedures.	**e-Zwolnienia L4 (e-Sick Leave Certificates):** sick leave certificates issued electronically by doctors, which are remotely transferred to the employer and Social Security (ZUS), thus streamlining the process and reducing the administrative burden on healthcare workers. **e-Recepta (e-Prescription):** enables healthcare providers to issue and manage prescriptions electronically, enhancing drugs management process, reducing errors, and therefore promoting patient safety. **Integrated Electronic Health Records (EHR) and e-Health system (P1):** a platform for storing, processing and sharing digital resources of patients' health events. They contain solutions that may improve the processes of planning and implementing health care services, streamlining the provision of services, thus reducing the administrative workload for healthcare professionals.	**Telemedicine and Remote Consultations:** allow patients to consult with medical workers remotely, lowering the workload on healthcare professionals. **Digital Prescriptions (e-Resepti):** streamline and improve medication management process, reduces errors, and enhances patient safety. **Health Data Interoperability:** enables different healthcare providers to exchange and read shared electronic/digitized patient data.

a: *Source*: Authors own work.

Table 3. IT tools enhancing patient access to care in the analysed countries[a]

Country	The Netherlands	Spain	Croatia	Poland	Finland
IT solution	**Telemedicine and E-Consultations:** improve patient access to care through remote consultations, particularly beneficial for those in remote or underserved areas. **Health Information Exchange (HIE):** allows for easier sharing of patient health information among different healthcare workers and facilities. **Patient Portals and Self-Service Tools:** enable patients to easily communicate with healthcare workers and therefore better and faster access to care. They also allow to access health information, manage appointments and diagnostic tests.	**Tarjeta Sanitaria Individual (TSI**, The Individual Health Card): provides patients with access to their medical records—history of visits and tests, enables electronic purchase of medicines and arranging appointments. Thanks to TSI, patients can play a more active role in managing their health. **Health Information Exchange (HIE):** ensures the interchange of patient information among different healthcare providers and systems, thereby improving patients' access to care. **Telemedicine and E-Consultations:** enable patients to have remotely conducted, faster and more accessible consultations with healthcare professionals. **e-Radiology:** increases diagnostic possibilities through faster description of imaging test results, facilitates timely and better access to specialized health care.	**Telemedicine Services:** increase and accelerate patients' access to health care services through access to health information and specialist consultations. They enable better monitoring of chronic diseases and delivery of healthcare services to patients in underserved and remote areas.	**The Internet Patient Account (IKP):** allows patients to register online for preventive services and therefore improves patient access to care. **Telemedicine Services:** increase patient access to care, particularly for those in remote areas, by enabling remote consultations with healthcare professionals. **Hybrid cardiac rehabilitation:** enables patients to use services under a rehabilitation contract with the National Health Fund or as a comprehensive service as part of coordinated care 'KOS-Zawał'.	**Personal Health Records (MyKanta):** promote self-management and patient engagement, thereby increasing patients' access to care. **Health Village My Path:** supports referral based digital care pathways, digital social service pathways, remote receptions and self-care programs. **Omaolo Symptom Checkers:** facilitates self-care and helps people to contact public health care professionals. **Health Data Interoperability:** ensures sharing of patient data across different systems and providers, contributing to increased access to care. **Telemedicine and Remote Consultations:** enables patients to have remote, faster and more accessible consultations with healthcare professionals.

a: *Source*: Authors own work.

To ensure clarity regarding outcomes, measurable indicators were incorporated into the analysis. These include the timeliness of health data and the linkage of health datasets, which ensure real-time access to essential information, crucial for efficient healthcare delivery, especially in systems like EHRs and telemedicine. The concept of digital health readiness, which evaluates a system's ability to leverage data readiness and technology readiness, supports measurement of health system's capacity to utilize analytics and technology to improve outcomes. The reduction of waiting times, often associated with improved scheduling and patient management, is a key outcome facilitated by digital solutions that streamline processes and reduce delays in care delivery [32].

Economic evaluations of digital health tools have been conducted in several countries, including Poland, Spain, Finland and the Netherlands. In Poland, telemedical programs for heart failure patients were proven cost-effective [33], while in Finland, Spain and the Netherlands, cost-utility and cost-benefit analysis confirmed the financial viability of select e-health solutions [34–36]. Although a national e-health strategy exists in Croatia, economic evaluations of IT-based healthcare interventions remain lacking. The widespread implementation and active use of e-prescriptions in all five countries was recognized as a major contributor to efficiency, patient safety and medication error reduction [37].

IT training programmes

Training for IT solution implementation in healthcare varies among selected countries. The digital health education plan has been implemented in the Netherlands and Spain and is under preparation in Poland [6]. IT training in Poland is not mandatory and encompasses paid and free options. Notable examples include government-sponsored initiatives like the National Program for Telemedicine Development and EHR training. Similarly, in the Netherlands, mandatory training ensures proficiency in using IT solutions, although costs and availability may vary. Government initiatives such as the National Program for IT promote standardization and implementation of IT in healthcare [29]. In Spain, mandatory IT training varies by facility and healthcare role. Governmental initiatives include the national e-Health strategy, autonomous community programs, EU funding, and collaborations with universities [18, 29]. In Croatia, training for IT solutions is encouraged but not mandatory, with some programs subsidized by the government, such as those for the e-prescription and telemedicine promotion. In Finland, the levels of compulsory training vary, and costs are often covered by employers. Governmental initiatives include Kanta services, eHealth services, digitalization programs, and funding for digital health training [10, 19]. All countries support IT training through national initiatives.

Barriers in implementing and using IT solution

The implementation and utilization of IT solutions in healthcare encounter various barriers. Common challenges include limited financial resources, which hinder investments in IT infrastructure and training [17, 38]. Interoperability issues lead to fragmented patient records and inefficient data exchange between providers. Data privacy and security compliance pose challenges, particularly in adhering to regulations such as the EU General Data Protection Regulation, requiring substantial resources and efforts to protect patient information [25, 26]. Other barriers include resistance to

technological change and gaps in the digital skills of patients and providers [18, 35, 39]. Geographical disparities in Croatia, Spain or Finland exacerbate challenges by impeding access to high-speed Internet and advanced IT infrastructure [19, 22].

Discussion

The comprehensive analysis of IT solutions in healthcare systems across Poland, the Netherlands, Spain, Finland, and Croatia yielded insights into mitigating HWF shortages and enhancing healthcare delivery. Our findings underscore the diverse approaches to regulating and implementing IT solutions in healthcare, with variations in the scope, level, and timing across the analysed countries. While some nations prioritize national regulations to ensure consistency and standardization, others opt for a more decentralized approach, allowing for regional customization. By examining specific initiatives such as Poland's significant investments in health technology to address workforce shortages [36], Spain's efforts to improve digital literacy among healthcare workers [29], the significant cost savings in the Netherlands from investments in digital care [37], Finland's scalable digital care pathways delivering tangible financial benefits [32], and the ongoing development of a digital healthcare infrastructure in Croatia [18], this study provides comprehensive insight into the effectiveness and economic impact of IT solutions in alleviating workforce shortages in healthcare by optimizing administrative processes and facilitating access to care. In Supplementary Appendices S4 and S5, we present information about the implementation of policies and strategies, digital health technologies and evaluation of digital health services in analysed countries, as well as a complete list of references and sources used for the analysis.

Primarily, IT solutions are aimed at optimizing service delivery by streamlining processes, improving coordination, and minimizing administrative burdens, thereby augmenting overall care delivery efficacy. Second, the focus was on alleviating the workload on medical personnel by automating tasks, facilitating data management, and supporting clinical decision-making, enhancing the work environment and care quality [28, 40]. Third, IT solutions prioritized enhancing accessibility to healthcare services, particularly valuable in underserved/remote areas, through telemedicine and health applications, ensuring timely care for patients [17–19]. These collective endeavours underscore a concerted effort to leverage digital innovations for enhancing healthcare delivery efficacy and optimizing patient outcomes in response to evolving needs, particularly amid the challenges posed by the COVID-19 [2, 3].

Our findings aligned with existing reports and research, emphasizing the importance of comprehensive strategies in addressing global HWF challenges [2]. This study underscored the benefits of implementing EHR and e-prescribing, highlighting collaborative endeavours to refine healthcare processes [21–23, 29]. The adoption of hospital information systems and telemedicine platforms presented promising avenues for mitigating healthcare workforce shortages by optimizing workflows and enhancing communication channels [3, 20–24, 27]. Integration of AI and data analytics has also been found to help identify trends, predict patient needs and optimize resource allocation, ultimately contributing to more efficient and effective healthcare delivery [17, 26, 38–40].

Notwithstanding these advancements, persistent challenges have been identified, such as financial constraints and interoperability hurdles [25, 30]. The study revealed resistance among certain groups of patients [18] and healthcare workers towards IT solution implementation. Some professionals expressed concerns regarding the adoption of new technologies, factors such as training needs, workflow disruptions, and perceived threats to job security [2, 7]. Addressing these barriers requires tailored strategies, investment in continuous improvement of digital literacy and infrastructure, safety and fostering a cultural shift toward embracing technological advancements in healthcare delivery [30, 38–40]. Therefore, it is necessary to improve strategic planning, and management frameworks, both integrating robust risk evaluation and mitigation strategies [30, 35, 39, 40].

In line with the results of our analysis and the WHO strategy [39], policymakers are advised to take the following policy actions: (i) continuously evaluate, refine, and widely adopt interoperable e-health infrastructures, such as EHRs and e-referral systems; (ii) invest in the development of AI-based workforce planning and the expansion of predictive analytics to forecast staffing needs; (iii) expand telemedicine and virtual care services, particularly in underserved regions; (iv) provide robust, ongoing digital literacy training for current healthcare workers and enhance curricula for medical students; and (v) implement a standardized assessment framework to assess the long-term impact of digital solutions on workforce performance and patient outcomes. These recommendations reflect international priorities for a sustainable, data-driven, and equitable digital health transition. Effective implementation requires consistent funding and coordinated efforts among healthcare providers, policymakers and technology developers.

Both our comparative analysis and other researchers confirm the potential of digital tools such as predictive analytics, virtual consultations and interoperable IT systems to streamline operations, reduce staffing burdens, and improve access and quality of care. Innovative use of predictive workforce analytics in Finland and the Netherlands, combined with extensive digital skills programmes in Spain, the development of a national e-health infrastructure in Croatia and integrated and continuously evolving virtual care models in Poland, reflects the growing shift in Europe's diverse healthcare systems towards adaptive and data-driven approaches to alleviating workforce shortages. Synergy between healthcare providers, technology developers, and policymakers is essential to the successful adoption of these solutions, ensuring that the workforce is adequately supported and patient needs are met. Health systems should prioritize the implementation and comprehensive evaluation of e-prescribing and e-referral, telemedicine platforms, and decision support tools using IT solutions, as this is still underdeveloped/unevenly implemented across many healthcare systems. In addition, governments should provide robust training programs for health professionals to ensure the smooth integration of these technologies and mitigate resistance to change. Although many of the proposed IT interventions, such as telemedicine, e-prescriptions, and AI-based forecasting tools, are not entirely novel in concept, their large-scale implementation, system-level integration, and long-term cost-effectiveness in reducing workforce shortages remain insufficiently explored in most European contexts, including Croatia, Spain and Poland. As our analyses show, although these solutions are now widespread, they were introduced at different times in different countries and are at different stages of development and uptake by healthcare providers.

Our study is not exempt from limitations. Firstly, it is predominantly based on secondary data sources, which may not offer a comprehensive perspective. Moreover, examined IT solutions in selected countries, which may not fully represent the nuanced circumstances present on a broader scale. Additionally, addressing the issue of HWF shortages involves various factors beyond IT solutions, such as health policies, remuneration, education, and other systemic factors [1, 39, 40]. While our analysis sheds light on the potential of IT solutions, it is essential to recognize that a holistic approach is necessary to address the challenges associated with HWF shortages. Additionally, future research should further examine the impact of IT solutions on HWF shortages and patient outcomes, prioritizing longitudinal studies and the development of standardized metrics to evaluate their effect on access to care, staff retention, and service efficiency.

Conclusion

Adopting, tailoring, and further developing the effective IT solutions identified in this study can significantly improve healthcare delivery

and efficiency, as well as address healthcare workforce shortages. Synergy between governments, professional associations, healthcare and IT providers is critical to the successful and safe implementation of IT solutions. Through the utilization of IT solutions, healthcare organizations can increase their ability to provide high-quality care and optimize resource utilization.

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Supplementary data

Supplementary data are available at *EURPUB* online.

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Data availability

All supplementary materials underpinning this study have been included in the supplementary file. Additional information or clarifications can be obtained from the corresponding author upon reasonable request via the email address: kamila.michalska@doctoral.uj.edu.pl.

Key points

- Comparative analysis highlights IT solutions' role in mitigating medical personnel shortages by enhancing efficiency and patient access.
- Implementation of solutions like electronic health records and telemedicine optimizes resource utilization.
- Public health policy should prioritize investment in IT infrastructure to support widespread adoption and address workforce shortages.
- Successful integration of IT solutions requires strategic planning and collaboration for sustainable effectiveness.
- It is recommended to allocate resources for the development of IT solutions strategically to areas needing healthcare workforce augmentation, enhancing delivery, and reducing disparities.

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