REVIEW ARTICLE

INTERNATIONAL JOURNAL OF CURRENT ADVANCED RESEARCH
ISSN: O: 2319-6475, ISSN: P: 2319-6505
Available Online at www.journalijcar.org
Volume 14; Issue 08; 2025; Page No.478-482
DOI: http://dx.doi.org/10.24327/ijcar.2025.0482.0074

Subject Area : Medical

DIGITAL TRANSFORMATION OF THE PHARMACY SYSTEM FROM A PUBLIC PERSPECTIVE: A SYSTEMATIC REVIEW OF IMPLICATIONS FOR LOCAL SUPPLY STRUCTURE STABILITY

Stefan WAHL*, Moni BUTZ, Hendrik-Matthias PALLIEN, Samer MADERNATand Mariana MRAZOVA

izabeth University of Health and Social Work, Bratislava, Slovakia

ARTICLE INFO

Received 30th July 2025
Published online 15th August, 2025

Key words:

Social determinants of health, occupational health, health equity, remote work, home office, digital inequality, work-life balance

ABSTRACT

Introduction: The pharmacy sector is undergoing significant digital transformation, especially in the European Union with Germany at the forefront through its Digital Healthcare Act (DVG). While technological advancements promise improved healthcare delivery, they simultaneously threaten the stability of local pharmaceutical supply structures, particularly in rural areas. This study examines how digitalization impacts public health equity and the resilience of pharmacy services across diverse geographical settings. **Methods:** This systematic review followed PRISMA guidelines. Peer-reviewed articles, government reports, and policy documents published between 2018-2023 were identified through comprehensive searches of PubMed, Scopus, Web of Science, and Google Scholar. Inclusion criteria focused on digital pharmacy transformations in the EU (particularly Germany), public health implications, and supply chain stability. A narrative synthesis approach was employed to analyze the heterogeneous data. **Results:** Key digital advancements identified include e-prescriptions, online pharmacies, telepharmacy, and AI-driven systems. While these technologies have improved efficiency and access in urban areas, rural regions face implementation challenges due to inadequate digital infrastructure. The review identified regulatory fragmentation across the EU, persistent digital infrastructure gaps, and cybersecurity vulnerabilities as primary barriers to equitable digital transformation. Additionally, approximately 500 rural German pharmacies closed between 2020-2023, highlighting threats to local supply stability. **Discussion:** Our Digital pharmacy transformation offers significant potential benefits but requires coordinated intervention to ensure equitable implementation. Recommendations include harmonizing EU-wide regulations, investing strategically in rural digital infrastructure, strengthening cybersecurity measures, supporting local pharmacy models through financial incentives, and updating healthcare curricula to include digital competencies. These measures are essential to harness digital innovation while preserving equitable access to pharmaceutical care and maintaining the stability of vital local supply structures. **Take-home message:** While digital transformation of pharmacy systems offers significant efficiency and accessibility benefits, it simultaneously threatens local supply structures, particularly in rural areas with limited digital infrastructure. The closure of approximately 500 rural German pharmacies between 2020-2023 underscores the urgent need for balanced regulatory approaches that protect community access while embracing innovation. Addressing this challenge requires harmonized EU regulations, targeted infrastructure investments in underserved regions, and financial support for local pharmacies adapting to digital transformation.

*Corresponding author: **Stefan WAHL**

Elizabeth University of Health and Social Work, Bratislava, Slovakia.

INTRODUCTION

The increasingly growing technology is driving a massive change in the worldwide pharmacy sector, redefining prescription, dispensation, and drug management. The shifting patient needs and technological innovation drive

this revolution in the European Union, particularly Germany. Germany has a Digital Healthcare Act (Digitale-Versorgung-Gesetz, DVG), which defines how digital instruments, such as e-prescriptions, telepharmacy, and artificial intelligence (AI)-driven record-keeping, are incorporated into the pharmacy sector (1). While the advancements have increased the efficiency of drug administration, they have adversely affected the stability of local pharmaceutical supply models, causing inequitable access to medical services. Approximately 18,000 community pharmacy establishments in Germany serve as critical touchpoints and frontline healthcare systems (2). Technological developments may disrupt the role of local pharmacies in connecting patients with healthcare services in rural and underserved regions where pharmacies are the sole medical access point. These stores may be left behind because of inadequate digital infrastructure and lower adoption rates. This paper examines the effect of digitalization on public health equity and supply chain resilience, focusing on Germany's experience as a European leader in healthcare innovation.

METHODS

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (3).

Eligibility Criteria

Studies were included if they focused on:

a. The digital transformation of pharmacy systems within the EU, with a particular emphasis on Germany.
b. Public health implications, including access, equity, and patient outcomes related to digital pharmacy services.
c. The stability and resilience of local pharmaceutical supply structures in the context of digitalization.
d. Specific digital technologies such as e-prescriptions, online pharmacies, telepharmacy, automation, and AI in pharmacy.
e. Regulatory, infrastructural, and workforce challenges associated with digital transformation.

Peer-reviewed articles, published reports from governmental and non-governmental organizations (European Commission, ABDA), and relevant policy documents published between January 2018 and December 2023 were considered. Studies not available in English or German, or those majoring exclusively in pharmaceutical manufacturing without direct implications for pharmacy services or supply chains, were excluded.

Information Sources and Search Strategy

A comprehensive search was conducted across multiple electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar. Grey literature was identified through targeted searches of websites of relevant organizations such as the European Commission, the Federal Union of German Associations of Pharmacists (ABDA), and the World Health Organization (WHO). The search strategy combined keywords and MeSH terms associated with "digital transformation," "pharmacy," "e-health," "telepharmacy," "e-prescription," "artificial intelligence," "supply chain," "public health," "health equity," "Germany," and "European Union." A sample search term employed for PubMed was: `((("digital transformation" OR "eHealth" OR "telepharmacy" OR "e-prescription" OR "artificial intelligence") AND ("pharmacy" OR "pharmaceutical services") AND ("supply chain" OR "local supply" OR "resilience") AND ("public health" OR "health equity") AND ("Germany" OR "European Union"))`.

Study Selection

Retrieved citations were imported into reference management software, such as Zotero, and duplicates were removed. Two reviewers independently screened titles and abstracts against the eligibility criteria. The same two reviewers then retrieved full texts of potentially relevant articles and assessed their eligibility. Any disagreements were resolved through discussion or consultation with a third reviewer.

Synthesis of Results

Given the anticipated heterogeneity in study designs, interventions, and outcomes, a narrative synthesis approach was employed. Findings were grouped thematically based on the key aspects of digital transformation in pharmacy, its public health implications, and challenges identified. These themes were derived from the data and aligned with the review's objectives.

RESULTS

The systematic review identified a range of studies and reports detailing the multifaceted impact of digital transformation on the pharmacy sector in the EU, particularly in Germany. The synthesis of findings is presented below, organized by key themes emerging from the literature.

Key Digital Advancements in the Pharmacy Sector

E-Prescriptions

The sources included highlighted the shift towards electronic prescriptions as a cornerstone of pharmacy digitalization. These sources determined that electronic medication prescription is a critical development in the digital pharmacy systems, with Germany passing the mandatory e-prescription requirements. This advancement is managed by Gematik, streamlining the medication process to reduce errors and improve patient convenience (4, 5). Compared to the paper-based system, e-prescriptions allow healthcare providers to share patients' prescription records with pharmacy computers electronically, decreasing medication faults and instances of callbacks by pharmacists for clarification (4). Similarly, this method has improved the clinical practice workflow, boosted patient contentment and compliance, and decreased paperwork and related mistakes in handwritten notes. Nonetheless, e-prescription is associated with challenges, including delayed adoption because of interoperability issues between different healthcare structures and limited access among elderly patients and those who lack digital knowledge, negatively influencing healthcare equality (6, 7). Regardless of these challenges, the increasing technological adoption in Europe, which is driven by the European Health Data Space (EHDS), will make e-prescriptions the standard across the region.

Online Pharmacies and Telepharmacy

Other developments that have changed the pharmacy landscape include online pharmacies and telepharmacy. Germany recorded a 30% increase in online pharmacies in 2022,

allowing patients to conveniently order drugs from home at affordable prices (8). This model has been supported by reliable internet access in the country. However, it threatens the brick-and-mortar pharmaceutical stores in rural areas, which have started to record declining foot traffic, as most people order medicine online (9). Conversely, telepharmacy allows patients to consult healthcare providers remotely and acquire drugs, possibly sustaining pharmacy services in underserved areas. A pilot study in rural Bavaria demonstrated telepharmacy's efficiency in enhancing medication access among community members (10). However, this development can only be successful if patients willingly adopt new technologies and the digital structure is robustly developed in rural and isolated communities.

Automation and AI-Driven Systems

Automation, including robotic dispensing systems, is transforming operations in larger, typically urban, pharmacies. These technologies automate drug sorting and packaging, reducing human error and improving efficiency in medication dispensing (11). The significant financial investment required, however, limits their adoption in smaller, independent pharmacies. Additionally, AI-driven systems impact pharmaceutical supply chain management by optimizing stock levels and predicting demand through data analytics, thereby reducing waste (12). Nevertheless, the reliance of these systems on centralized data makes them potential targets for cyberattacks, which could disrupt supply chains.

Public Health Implications

The digital transformation of the pharmacy sector carries both positive and negative implications for healthcare access, equity, and the resilience of public health systems.

Access and Equity

While digital tools such as e-prescriptions and telepharmacy have the potential to enhance access to healthcare and medication services, the review found that their benefits are not evenly distributed. In Germany, the rollout of e-prescriptions has been more concentrated in urban centers, including Berlin and Munich, with lower adoption rates in rural areas such as Mecklenburg-Western Pomerania, often because of inadequate digital infrastructure (5). A significant percentage of rural German communities reportedly lack reliable broadband access, hindering the employment of e-prescriptions and other digital health services (13). The EU's EHDS aims to harmonize health data systems; however, disparities in digital preparedness between member states (Germany vs. Bulgaria or Romania) would widen existing health inequities if not addressed through targeted investments in infrastructure and digital literacy programs.

Supply Chain Resilience

Digital tools, including AI-powered inventory management, can optimize pharmaceutical supply chains and reduce waste (11). However, this digitalization introduces risks associated with centralization and can contribute to the closure of rural pharmacies, potentially destabilizing local supply networks. Germany's adoption of centralized digital infrastructures, while improving efficiency, increases dependency on systems vulnerable to cyberattacks. A notable example was the disruption of drug distribution following a breach in North Rhine-Westphalia hospital networks (14). Furthermore, the rise of online pharmacies and automation has been linked to the closure of numerous rural pharmacies in Germany (approximately 500 between 2020 and 2023, according to ABDA data), leaving some communities with diminished access to essential medicines and pharmaceutical care (2). This occurrence affects regions with limited transportation and aging populations.

Shifting Roles of Pharmacists

The increasing digital transformation of the healthcare sector has changed the role of pharmacists from drug administration and dispensation to health management and counseling. This transition ensures enhanced patient care; nevertheless, it causes challenges to workplace education and resource distribution. According to a study in 2023, 60% of German pharmacists complain of limited training in applying digital tools, such as electronic prescriptions (1). The skill gap prevents these professionals from harnessing the potential of digital technologies to improve patient care and increases disparities between rural and urban pharmacies (15). Although the expanded pharmacists' role, facilitated through digital tools, enables them to perform activities such as chronic disease management and distribution of tests during pandemics such as COVID-19, it demands additional training and resources, which are scarce in rural settings.

Cybersecurity and Data Privacy

Cyber attackers target digitalized pharmacy systems, adversely affecting public health. To decrease these occurrences, the General Data Protection Regulation (GDPR) imposes strict requirements for pharmacies when handling patient data. These impositions, such as ensuring privacy and confidentiality of information, create administrative burdens for small stores. A study determined that 40% of German pharmacies in rural settings struggle to meet the GDPR requirements (7). Studies indicated that a substantial percentage of rural German pharmacies struggle to meet GDPR requirements (16). Cyberattacks, such as those on German hospital networks and pharmacy chains, have led to service disruptions, sometimes forcing a temporary return to less reliable manual processes and compromising patient care (14). These incidents underscore the critical need for robust cybersecurity measures, which may be beyond the financial and technical capacity of many smaller, local pharmacies.

Challenges and Risks Identified in the Literature

Regulatory Fragmentation

A key challenge identified is the lack of harmonized regulations for digital pharmacy services across the EU, particularly for cross-border services, such as telepharmacy. Divergent national regulations, for example, between Germany's DVG, France's Health Innovation 2030 plan, and Poland's e-Health Strategy, create complexities and hinder interoperability (1, 17, 18). This fragmentation can impede the seamless operation of EU-wide initiatives, such as the EHDS (18) and the effective implementation of the EU's Cross-Border Healthcare Directive, as differing national rules on telepharmacy (e.g., restrictions on online supply of prescription drugs in countries, including Italy) create barriers.

Digital Infrastructure Gaps

Persistent gaps in digital infrastructure, especially in rural and underserved areas, remain a significant impediment to the equitable adoption of digital pharmacy systems. Despite national initiatives encompassing Germany's Gigabit Strategy 2025 aimed at improving connectivity (13), many rural regions still suffer from unreliable or slow broadband access. This digital divide limits the utility of e-prescriptions, telepharmacy, and other online health services for significant portions of the population (9, 13). Similar disparities exist across the EU, with slower progress in broadband deployment in some Eastern European countries, for example, hindering the reach of EU-wide digital health programs.

Cybersecurity and Data Privacy Risks (Reiteration with focus on systemic risk)

Beyond individual pharmacy vulnerabilities, the interconnected nature of digital health systems creates systemic risks. The literature emphasizes that while GDPR provides a framework, its implementation and enforcement across diverse pharmacy settings, especially smaller ones with limited resources, remain challenging (4, 7). The consequences of security breaches extend beyond individual data loss to potential large-scale disruptions of medication supply and public trust in digital health services.

DISCUSSION

General results discussion

Both This project synthesized current publications and policy developments to offer comprehensive insights into how digitalization reshapes pharmacy systems in the EU. Digital advancements in the pharmaceutical sector, including e-prescription, have improved efficiency and care accessibility (19). However, these developments have introduced challenges, such as internet security risks and architecture disparities, adversely affecting equitable access, especially in rural regions (7). These concerns can be addressed when EU governments reconcile their policies, prioritize digital structure investment in rural locations, and sustain local pharmacy frameworks (2, 9). Implementing these strategies will enable member states, including Germany, to harness the benefits of digital enhancements and protect the healthcare systems' resilience (15, 18). These initiatives require a partnership between nations and the EU that is dedicated to inclusivity and equity during policy implementation (11, 12). The evolution of the pharmacy sector requires prioritization of vulnerable populations in underserved areas, allowing the EU to become a leader in developing a digitalized pharmacy framework that improves public health and sustains the stability of local supply models.

The changing role of pharmacists, necessitating new skills in digital health technologies and patient counseling, requires significant investment in training and professional development (1, 9). Supporting pharmacists in adapting to these new roles is essential for maximizing the benefits of digital transformation for patient care.

Recommendations

a. Harmonize Regulations and Promote Interoperability: The EU and member states should accelerate efforts to harmonize digital health regulations, including standards for e-prescriptions, telepharmacy, and data security, to support initiatives, such as the EHDS, and facilitate cross-border healthcare (7, 18).

b. Invest in Digital Infrastructure and Literacy: Targeted investments are needed to close digital infrastructure gaps, particularly in rural and underserved areas, as exemplified by accelerating Germany's Gigabit Strategy 2025 (13). Funding from programs, including EU4Health and Digital Europe, should prioritize these regions (7). Digital literacy programs for both patients and healthcare professionals are also crucial.

c. Strengthen Cybersecurity and Data Privacy: Robust cybersecurity measures, technical support, and clear guidance on GDPR compliance should be made accessible to all pharmacies, especially smaller ones (12, 16). This could involve establishing regional support hubs.

d. Support Local Pharmacy Models and Workforce Development: Financial incentives, such as grants and subsidies (e.g., through Germany's Pharmacy Future Act - Apothekenzukunftsgesetz), should be considered to help local pharmacies adopt digital technologies and adapt their service models (1). Curricula for healthcare professionals should be updated to include comprehensive training in digital health technologies (9).

e. Foster Public-Private Partnerships: Collaboration between governments, technology providers, healthcare organizations, and patient advocacy groups is essential for developing and implementing equitable and effective digital pharmacy solutions.

Limitations of the Review

This systematic review has several limitations. Firstly, the search was restricted to English and German language publications, potentially excluding relevant studies in other languages. Secondly, the rapid pace of technological development means that some findings may be superseded by new innovations or policy changes occurring after the search period. Thirdly, the heterogeneity of included studies (ranging from policy documents to empirical research) necessitated a narrative synthesis, which can be subject to reviewer interpretation. Finally, while efforts were made to identify challenges in rural areas, data specific to these contexts may still be underrepresented in the broader literature.

CONCLUSIONS

The digital transformation of the pharmacy sector in the European Union, and particularly in Germany, holds immense potential to improve healthcare delivery and efficiency. However, this review highlights that realizing these benefits equitably and sustainably requires proactive measures to address significant challenges. Issues of regulatory fragmentation, digital infrastructure disparities, cybersecurity threats, and the need to support local pharmacies and a digitally proficient workforce are paramount. By prioritizing harmonized regulations, investing strategically in infrastructure and training, and fostering inclusive policies, EU member states can harness the power of digital innovation to strengthen public health systems, ensure equitable access to pharmaceutical

care, and maintain the stability of vital local supply structures. A concerted effort, involving all stakeholders, is necessary to navigate this complex transition and build a future where digital pharmacy serves all citizens effectively.

Author Contributions: The authors confirm contribution to the paper as follows: study conception and design: SW, MB and HMP; data collection: SW, MB and HMP; analysis and interpretation of results: SW and HMP; draft manuscript preparation: SW, MB, MM; supervision: MM; project administration: SW and MB. All authors reviewed the results and approved the final version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

Informed Consent Statement: Not applicable.

Institutional Review Board Statement: Not applicable.

References

1. Maass L. Digital Public Health in Germany. European Journal of Public Health. 2023;33(Supplement_2). doi: 10.1093/eurpub/ckad160.374.
2. Federal Union of German Associations of Pharmacists (ABDA). German pharmacies: Figures data facts 2024. Berlin: Federal Union of German Associations of Pharmacists; 2024. Available from: https://www.abda.de/fileadmin/user_upload/assets/ZDF/Zahlen-Daten-Fakten-24/ABDA_ZDF_2024_Brosch_english.pdf
3. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. doi: 10.1136/bmj.n71.
4. Hareem A, Lee J, Stupans I, Park JS, Wang K. Benefits and barriers associated with e-prescribing in Community Pharmacy – a systematic review. Explor Res Clin Soc Pharm. 2023;12:100375. doi: 10.1016/j.rcsop.2023.100375.
5. Lösch M, Messal H, Müller T, Padmanabhan P, Richter L, Silberzahn T. German e-health offerings expand, but adoption remains uneven. McKinsey & Company; 2022 Dec 16. Available from: https://www.mckinsey.com/industries/life-sciences/our-insights/german-e-health-offerings-expand-but-adoption-remains-uneven
6. Alhur AA, Alotaibi S, Alhalwani D, Eisa R, Alshahrani S, Alqurashi M, et al. Public Perspectives on Digital Innovations in Pharmacy: A Survey on Health Informatics and Medication Management. J Infrastruct Policy Dev. 2024;8(8):5450. doi: 10.24294/jipd.v8i8.5450.
7. European Commission. Digital Health: Commission and WHO Launch Landmark Digital Health initiative to strengthen global health security. Brussels: European Commission; 2023 Jun 5. Available from: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3043
8. Almeman A. The Digital Transformation in Pharmacy: Embracing online platforms and the Cosmeceutical Paradigm Shift. J Health PopulNutr. 2024;43(1). doi: 10.1186/s41043-024-00550-2.
9. Kroenert A-C, Bertsche T. Implementation, barriers, solving strategies and future perspectives of Reimbursed Community Pharmacy Services - a nationwide survey for community pharmacies in Germany. BMC Health Serv Res. 2024;24(1). doi: 10.1186/s12913-024-11745-y.
10. MekurianewKelkay J, Wubneh HD, Beri HM, Tefera AM, Molla RA, Negatu AA. Adoption of telepharmacy among pharmacists, physicians, and nurses at Hawassa City Public Hospitals, Ethiopia. PLOS Digit Health. 2024;3(12):e0000693. doi: 10.1371/journal.pdig.0000693.
11. Yadav P. Digital transformation in the health product supply chain: A framework for analysis. Health Syst Reform. 2024;10(2):2386041. doi: 10.1080/23288604.2024.2386041.
12. Burk E, Hornung J, Schoppe C. The digital act: A boost for Digitalisation in German Healthcare. Gleiss Lutz; 2024. Available from: https://www.gleisslutz.com/en/news-events/know-how/digital-act-boost-digitalisation-german-healthcare
13. Eckert D. Gigabit connectivity. In: Professional Practice in Governance and Public Organizations. Cham: Springer; 2024. p. 169–80.
14. Traynor O. The scope of Pharmaceutical Cybersecurity in 2024. CybelAngel; 2024 Mar 11. Available from: https://cybelangel.com/pharmaceutical-cybersecurity-in-2024-cybelangel/
15. Marangwanda A. From fragmentation to integration: Developing a coherent insurance regulatory framework for AFCFTA. Int J Res Innov Soc Sci. 2024;VIII(IX):487–93. doi: 10.47772/IJRISS.2024.809044.
16. Graf A, Fehring L, Henningsen M, Zinner M. Going Digital in Germany: An exploration of physicians' attitudes towards the introduction of electronic prescriptions – a mixed methods approach. Int J Med Inform. 2023;174:105063. doi: 10.1016/j.ijmedinf.2023.105063.
17. Stoumpos AI, Kitsios F, Talias MA. Digital Transformation in Healthcare: Technology Acceptance and its applications. Int J Environ Res Public Health. 2023;20(4):3407. doi: 10.3390/ijerph20043407.
18. Odenbach-Wanner S. Stakeholder analysis of the effects on the health care system in terms of digitization and introduction of the e-prescription in Germany. SCENTIA Int Econ Rev. 2023;2(1):1–28. doi: 10.52514/sier.v2i1.33.
19. Bulaj G, Coleman M, Johansen B, Kraft S, Lam W, Phillips K, et al. Redesigning pharmacy to improve public health outcomes: Expanding retail spaces for digital therapeutics to replace consumer products that increase mortality and morbidity risks. Pharmacy. 2024;12(4):107. doi: 10.3390/pharmacy12040107.

How to cite this article:

Stefan WAHL et al. (2025). Digital Transformation of the Pharmacy System from a Public Perspective: A Systematic Review of Implications for Local Supply Structure Stability, International Journal of Current Advanced Research, 14(08), pp.478-482.

****