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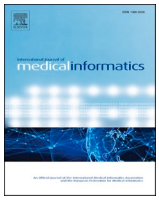

Electronic health records and data exchange in the WHO European region: A subregional analysis of achievements, challenges, and prospects

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ABSTRACT

Electronic health record (EHR) systems are powerful tools that enhance healthcare quality. They improve efficiency, enable data exchange, and ensure authorized access to patient information. In 2022, the World Health Organization Regional Office for Europe (WHO EURO) conducted a survey to assess the digital health capabilities of the 53 Member States. This article provides a sub-regional analysis of the status of EHR systems and major barriers to their implementation, their readiness for information sharing, and the access and re-use of EHR data.

Generally, EHR implementation and national data exchange are at an advanced stage in the region, though achievements and challenges vary across subregions. While more Member States in the Eastern, Western, and Southern Europe subregions reported having centralized national EHR systems, the situation is more diverse in Northern Europe and the Asian subregions, where both centralized and decentralized EHR systems are in use. Significant barriers to EHR implementation, including funding, technical capacity, competing priorities, and lack of interoperability standards are frequently cited, while others like demand, knowledge or acceptance challenges are not reported as significant. Significant barriers were reported the most by the Central Asia subregion, while barriers had least significance in Western Europe. Five out of the six subregions reported a wide adoption of national strategies and have dedicated agencies to ensure interoperability and secure data exchange. However, only 29 Member States have established legal requirements for healthcare providers to adopt EHR systems that conform to national standards for both clinical terminology and electronic messaging, with this being most notable in Western, Eastern, and Northern Europe, and the lowest percentage of Member States in Central Asia. All Member States of the six sub regions have passed privacy and data protection legislation. The use of EHR data is widely regulated, with only five remaining Member States of WHO Europe to develop EHR legislation distributed across subregions (Southern Europe, Western and Central Asia).

Looking ahead, Member States are encouraged to define national legislation governing EHR systems and their use, while ensuring the interconnectivity of the local and regional EHR systems. Sustainable funding should be allocated to the development and maintenance of these systems. Efforts should also focus on creating comprehensive roadmaps for the full implementation of health data standards, addressing interoperability at local and regional levels, and developing quality management systems for testing and certification. Additionally, monitoring and evaluation should be conducted to assess whether EHRs are contributing to national health objectives. Finally, engaging patients and intersectoral partners will be key to developing a more patient-centered approach, ensuring that EHR systems meet patient needs and expectations.

1. Introduction

The use of Electronic Health Records (EHR) systems is a fundamental component of health information systems (HIS), which encompass the use of electronic tools and systems to manage health information. EHRs are real-time digital systems that typically store patients' medical

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histories, diagnoses, treatments, medications, allergies, immunizations, referrals, radiology images, and laboratory results. These systems have the potential to improve healthcare quality while ensuring the protection of patient information [1]. Their adoption seeks to enhance efficiency, minimize errors, facilitate data exchange, and ensure authorized access to the information.

EHR system implementation and approaches vary by country. Top-down approaches establish a national EHR under central authority, while decentralized systems use regional/local EHRs (bottom-up). A national health information exchange platform can link regional systems (middle-out) [2]. Top-down and middle-out strategies enable national data exchange, but their implementation, coverage, and challenges differ. Experiences with national and local EHR systems have already been documented [3–6]. Additionally, patient portals, encompassing a suite of applications and online services, enable patients to manage their clinical and administrative information. These platforms facilitate communication with healthcare professionals, grant access to medical records, control data permissions, schedule appointments, and process payments. Furthermore, patient portals can serve as a gateway to different regional or national health services [7].

The achievement of EHR interoperability at national level facilitates information-sharing with care providers, enabling Member States to achieve accurate and timely care. Moreover, the secondary use of EHR data can boost research, public health policies, evidence-based care guidelines, and epidemiological surveillance [8]. Nevertheless, the implementation of these systems in the complex healthcare environment is challenging. For example, data format variations across systems hinder data exchange, care coordination, and information sharing. Moreover, the adoption of these technologies faces obstacles such as lack of trust, security and privacy concerns, high cost and governance regulations, conflicting policies, or low stakeholder commitment [2,9]. National interoperability strategies and digital health regulation can address these challenges and enable the integration of digital health systems.

In its Global Strategy on Digital Health 2020–2025, the World Health Organization (WHO) committed to developing global minimum standards for electronic health records, as part of advocating for people-centered health systems that are enabled by digital health [10]. The WHO Regional Office for Europe (EURO) prioritized in its European Programme of Work (EPW) 2020–2025 digital health as an accelerator towards universal health coverage [11]. The Regional Digital Health Action Plan for the WHO European Region 2023–2030 outlines challenges and opportunities for digital health in the region, and it urges Member States to promote the digitalization of their health systems through a structured framework and four clear strategic priorities [12]. The action plan's four priorities are evidence-based norm setting and technical guidance, strengthening country-level governance capacities, building networks and fostering dialogue, and horizon-scanning and landscape analysis to identify patient-centered and scalable digital solutions [12].

Accordingly, and in line with the strategic priorities of the regional digital health action plan [12], in 2022, WHO EURO conducted a survey to evaluate status of digital health in the 53 Member States. Respondent Member States, clustered in several subregions, provided information on several digital health pillars, including EHRs. This survey builds on previous evaluations, like the 2015 WHO eHealth survey [13], and served as a foundation for several WHO Europe publications providing a regional (and subregional) overview analyses (2023) [14] and country profiles (2024) [15].

This article offers an in-depth subregional analysis of the 2022 survey results, highlighting achievements, challenges, and prospects for EHRs and national data exchange capabilities. Its insights could support better decision-making, policy design, and targeted actions for each WHO EURO subregion. Before addressing each subregion, a brief regional overview is provided, while the full WHO report can be consulted for comprehensive insights into the regional evaluation.

2. Material and methods

2.1. Implementation of the 2022 survey and data collection

WHO EURO developed a survey to assess the progress and adoption of digital health among its Member States. The survey is an updated version of the 2015 WHO Global Observatory on eHealth [13]. It was launched in April 2022 and accepted responses until October of the same year. An expert coordinator linked to the national Ministry of health or relevant institutions was nominated per country to act as the central point for each consulted expert in their country. This coordinator recruited a committee of national experts who collaborated to complete the survey. Each coordinator was also entrusted with convening and collaborating with relevant government bodies for each survey section, such as Public Health, Telecommunications, Statistics, or IT offices, agencies or administrative bodies.

Therefore, responses were submitted following a centralized approach by the nominated expert coordinator. The survey was available in both digital and paper formats, with instructions and questions provided in English and Russian. All 53 Member States of WHO Europe participated in the survey, an increase from 46 participants in 2015 [16].

The survey asked questions related to the digital transformation in healthcare across WHO European Member States. These aspects were divided into 12 chapters and four of which are addressed in this article, which evaluated (a) regulatory frameworks for digital health, (b) implementation of EHR systems, (c) standards and interoperability for data exchange, and (d) access to, sharing, and reuse of EHR data. Definitions for key digital health concepts were introduced in the survey to homogenize them. These definitions can be consulted in the supplemental appendix.

2.2. Data processing

For the Member States covered by WHO Europe, the geographic subregions are determined by the definitions set by the United Nations Statistics Division, and these definitions are consistent across all United Nations publications and databases [17]. Table 1 introduces the six subregions covered by WHO Europe as defined by the United Nations.

3. Results

3.1. EHR systems and data exchange: Survey results and analysis at subregional level across the WHO European regional Office

Survey questions related to EHR systems covered policies, regulation, implementation, and challenges across four chapters. This analysis focuses on: (a) EHR systems and regulation (16 questions, 92 % response rate), (b) standards and interoperability for data exchange (24 questions, 86 % response rate), and (c) access and re-use of EHR data (14 questions, 90 % response rate). The survey identified three routes for implementing national data-sharing in EHR systems among Member States: national EHR systems (NEHR), interconnected local EHR systems, and EHRs with exchange capabilities linked to patient portals. Fifty-two Member States respondents were able to clearly define the scope and limitations of EHR capabilities in their countries. National data-sharing capabilities were reported by 45 (87 %) of these respondents. However, the implementation to achieve these capabilities varies across subregions. 35 Member States reported having a NEHR system, an increase of eight Member States since 2015, and the remaining ten Member States had interconnected local EHR systems and/or to patient portals (see Fig. 1). Out of the 35 Member States with NEHR systems, 33 reported the year of introduction. The earliest NEHR was introduced in 1992, while two were implemented as recently as 2022 (see Fig. 2).

The implementation of national and local portals varies across

Table 1
Population, GDP and health expenditure data disaggregated by WHO Europe subregions.

Subregion	Member States	Population (2023) (Million)	GDP (PPP) (current international $) (2023) (Trillion)	Current health expenditure (% of GDP) (2021)	Current health expenditure per capita, PPP (current international $) (2021)
Central Asia (n = 5)	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan	80.07	1.24*	6.14	680.0
Eastern Europe (n = 10)	Belarus, Bulgaria, Czechia, Hungary, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia, Ukraine	280.55	11.64	7.58	2,302.0
Northern Europe (n = 10)	Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Norway, Sweden, United Kingdom	107.71	7.16	9.56	5,661.2
Southern Europe (n = 14)	Albania, Andorra, Bosnia and Herzegovina, Croatia, Greece, Italy, Malta, Montenegro, North Macedonia, Portugal, San Marino, Serbia, Slovenia, Spain	149.67	7.66**	9.34	3,367.7
Western Asia (n = 6)	Armenia, Azerbaijan, Cyprus, Georgia, Israel, Türkiye	112.99	4.74	7.89	2,221.8
Western Europe (n = 8)	Austria, Belgium, France, Germany, Luxembourg, Monaco, Netherlands (Kingdom of the), Switzerland	201.04	13.85***	10.10	7,526.2
All countries (n = 53)		932.04	46.29	8.44	3,626.5

Data was obtained from the World Bank.
Sources: World Bank Database (https://data.worldbank.org/) [accessed 29 October 2024].
* The figure for Central Asia does not include Turkmenistan due to missing data.
** The figure for Southern Europe does not include San Marino due to missing data.
*** The figure for Western Europe does not include Monaco due to missing data.

subregions, but responses are homogeneous regarding their key goals: empowering patients to access their health records and using these platforms as information hubs to enable care providers to access health data (see Fig. 1).

National interoperability strategies and dedicated national agencies responsible for setting national standards remain underdeveloped in many Member States. The subregional analysis in this article will explore the most commonly adopted standards and the progress in developing interoperability policies across different subregions. Additionally, it will tackle the current state of personally identifiable data protection, the safeguarding of patient data within EHR systems, and patient access to these records. This analysis will also assess the secondary use of EHR data for decision-making (see Fig. 3).

The following subsections highlight subregional specificities in national and regional EHR implementation, interoperability strategies and agencies, the use of international clinical standards, and the protection of personally identified data.

3.2. Central Asia subregion

The Central Asia subregion, part of the WHO Europe Region, consists of five Member States (Table 1), all of which reported to have achieved, at some level, national data exchange capabilities for their EHRs. Three Member States reported having NEHR systems, one Member State reported having interconnected regional EHRs and one Member State reported having EHRs interconnected through patient portals. All Member States of the Central Asia subregion also reported to have implemented regional EHR systems. The sharing of EHR records throughout care providers has already been regulated by Member States. The first NEHR system was reported to have been implemented in 2011 and the most recent in 2020. Member States of the Central Asia subregion reported that the lack of infrastructure (equipment and connectivity), insufficient human resources and technical capacity are the most significant barriers for successfully developing EHR systems.

Efforts have been made to set the foundation for interoperability in Central Asia. For example, four of the Central-Asian Member States reported having a national organization or agency responsible for setting national standards. However, four out of five Member States have yet to adopt a national interoperability strategy for secure information sharing, legally regulate the adoption of standardized software to healthcare providers and establish programs that nationally assess EHR interoperability on a regular basis. Only one member state reported having adopted a legal requirement for EHR compliance. The most common international clinical standards are ICD (n = 4) and DICOM (n = 3). However, one Member State does not report any.

All five Member States report implementing regulations that protect personally identifiable data, and four Member States have regulated the exchange and use of data stored in EHRs. Furthermore, two Member States have regulated the access to EHR systems by public health authorities and the creation of local or national databases, routinely imported into these databases. Finally, two Member States have developed national patient portal platforms.

3.3. Western Asia subregion

The Western Asia subregion covers six Member States of the WHO European region (Table 1). Four out of six Member States reported to have achieved some level of national data exchange capabilities. While half of the subregion's Member States reported having NEHR systems (developed between 2015 and 2019), only one Member State reported relying on interconnected regional EHR and another Member State reported using patient portals to exchange data. All six Member States reported having developed regional EHR systems. The most significant barriers for EHR system implementation are the lack of technical capacity, human resources, competing health funding priorities and lack of information standards to guarantee interoperability.

Member States of the Western Asia subregion have made substantial strides to enhance interoperability and standardize health data exchange. Five Member States have already adopted interoperability strategies to standardize secure data exchange. Also, five Member States reported having a national agency responsible for setting national standards. Although all Western Asian states have adopted international terminology standards, only half of the Member States legally require care providers to use software complying with these standards. The most common standards used are DICOM, ICD and HL7, each adopted by five Member States.

All six Western Asian Member States have legally protected personally identifiable data and have regulated the exchange and data use EHR

Subregion	Member States with NEHR (n)	Member States with local or regional EHR (n)	Member states with patient portals (n)	National-level exchange capabilities through interconnected regional EHRs and/or interconnected through patient portals (n)
Central Asia (n=5)	3	5	2	5
Western Asia (n=6)	3	6	4	5
Eastern Europe (n=10)	7	6	6	7
Northern Europe (n=10)	5	8	9	8
Southern Europe (n=13/14)	11	8	11	12
Western Europe (n=8)	6	3	6	8
All Member States	35	36	38	45

Fig. 1. Availability of National Electronic Health Records (NEHR), local or regional Electronic Health Records (EHRs), and patient portals across various regions. The figure also illustrates whether these local or regional systems or portals are interconnected at the national level. The color gradient in the heatmap represents the percentage of availability, with non-responding countries considered as a "no" in the calculation.

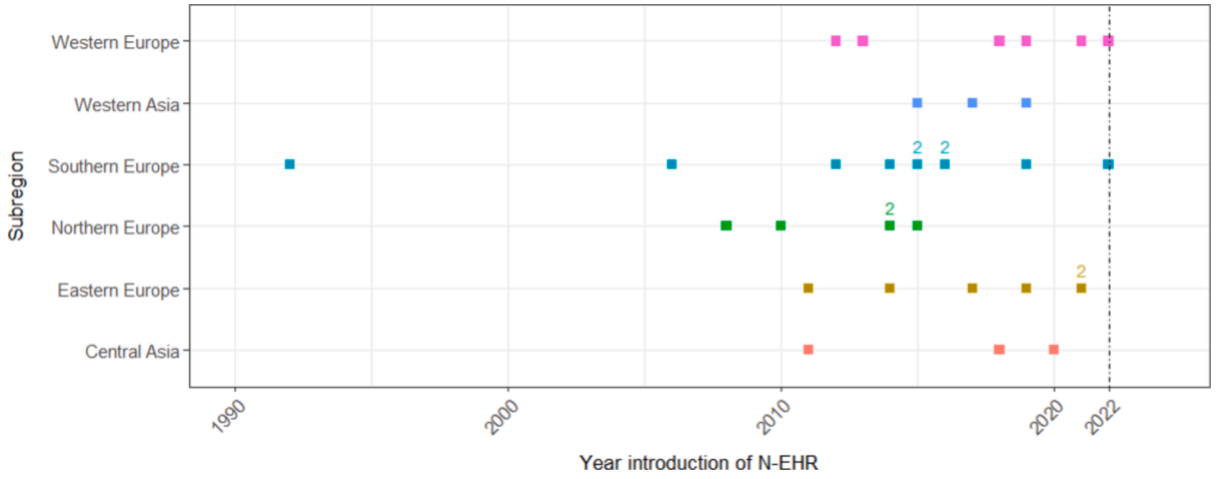

Fig. 2. The figure shows the years when each NEHR system was introduced, displayed by the six subregions of the WHO Regional Office for Europe. Data range from 1992 to 2022, when the survey was completed. A number over a data point is shown when more than 1 EHR was developed for a year in a subregion. There are 2 NEHR systems whose years were not reported, 1 in Eastern Europe and 1 in Southern Europe.

Subregion	national agencies responsible for setting standards (n)	adopt a national interoperability strategy for secure information sharing (n)	legally require care providers to use software complying with these standards (n)	legislations to protect personally identifiable data (n)	Legislation regulating the extraction of EHR data for public authority databases (n)
Central Asia (n=5)	4	1	1	5	4
Western Asia (n=6)	5	5	3	6	6
Eastern Europe (n=10)	7	7	7	10	8
Northern Europe (n=10)	9	6	7	10	10
Southern Europe (n=13/14)	4	3	6	13	12
Western Europe (n=8)	8	8	7	8	8
All Member States	37	30	31	52	48

Fig. 3. Availability of national agencies dedicated to setting standards, national interoperability strategies, legal requirements mandating care providers to use software that complies with these standards, legislation to protect personally identifiable data, and legislation regulating the extraction of EHR data for public authority databases. The colour gradient in the heatmap represents the percentage of availability, with non-responding members states considered as a "no" in the calculation.

data by public health authorities. Four Member States have developed patient portals, three of which are connected at national level. These portals are often used to facilitate data access to care providers and patients. Moreover, four Member States reported having national databases and registries being routinely updated with EHR data.

3.4. Eastern Europe

The Eastern Europe subregion consists of ten Member States as presented in Table 1. Seven out of ten Eastern European Member States reported having a NEHR (developed between 2011 and 2021), while remaining Member States reported having a non-connected regional EHR. Eight Member States have already had legislation governing data exchange through EHRs. When asked about challenges towards EHR implementation, the most significant barriers reported were lack of funding, not enough evidence of cost-effectiveness, and missing information standards to ensure interoperability.

Eastern European Member States have demonstrated efforts in relation to interoperability. Seven of the ten Member States developed national interoperability strategies for secure exchange of health information, as well as designated national agencies for setting national standards. The most common standards are ICD (n = 8), DICOM (n = 7), and LOINC (n = 4). However, four Member States reported that international clinical terminologies are not consistent across digital systems and care providers. Care providers are legally required to follow national information standards in seven Member States. The same Member States also require software developers to follow the national specifications.

Legislation protecting personally identifiable data has been enacted in all ten Eastern European Member States, with eight Member States having also regulated the exchange and use of data stored in EHRs. Furthermore, four Member States have reported existing legislations regulating access to these data by public authorities. Only two Member States have reported regularly updating national registries through EHR data. Patients in six Member States can access their data through patient portals, with five of these portals integrated at the national level. Additionally, these portals are reported to serve as an information hub for all health actors.

3.5. Northern Europe

The Northern Europe subregion consists of 10 Member States (Table 1). Five Member States of this subregion have NEHR systems, and three have interconnected local EHR systems, enabling eight Member States to exchange data nationally. The first NEHR system was developed in 2008, with the most recent in 2015. Uniquely one Member State has only regional non-connected EHR systems, and one does not report any. All Member States of the northern European sub-region have legislation regulating exchange of information from EHR. The subregion's main challenges to EHR implementation were competing health

policy priorities and insufficient funding for digital services.

In the Northern Europe subregion, substantial efforts have been made in advancing interoperability and setting standards for secure health information exchange. Six out of ten Member States have developed national interoperability strategies for secure health information exchange, and nine Member States have reported designated national agencies for standards and interoperability. This subregion has adopted the most information standards, particularly ICD and HL7 (n = 10), DICOM and LOINC (n = 9), and SNOMED CT (n = 8). Seven Member States have legally required care providers and software developers to follow national standards.

All ten Northern Europe Member States possess legislation protecting personally identifiable data and regulating exchange and use of data in EHR systems. Additionally, eight Member States have legislations governing the access to these data by public authorities, and seven Member States regularly update national databases and registries using EHR data. Patients can access their records via patient portals in nine Member States, which also serve as information hubs for all health actors.

3.6. Southern Europe

The Southern Europe subregion consists of 14 Member States (Table 1). Southern European Member States have made significant progress by adopting centralized EHR systems. Eleven Member States in this subregion reported having NEHR systems. One Member State relies on interconnected regional EHRs, another uses regional EHRs that are not nationally connected, and one Member State did not provide a response. The main barriers to EHR implementation in Southern Europe include the absence of national policies promoting EHR adoption, a lack of legislation or regulations governing EHR programs, and insufficient trained human resources or technical support for EHR initiatives.

Despite significant efforts in implementing EHR systems, many Southern European Member States still face challenges in establishing robust frameworks for interoperability and standardization. Only three out of 14 Member States have developed national interoperability strategies and only four Member States have national agencies designated for setting national standards. Legal requirements for care providers to align their EHR software with national standards have only been regulated by six Member States. Ten out of 14 respondents report consistent adherence to international clinical standards across care providers and information systems. Commonly adopted standards include ICD (n = 12), DICOM (n = 10), HL7 (n = 9), and IHE (n = 8).

Legislation protecting personally identifiable data exists in all responding Southern European Member States, with twelve Member States having regulations for the exchange and use of data in EHR systems. Additionally, ten Member States have reported having legislation regulating public authorities' access to EHR data, with five Member States regularly updating national databases. National patient portals have been developed in eleven Member States.

3.7. Western Europe

The Western Europe subregion consists of eight Member States (Table 1), all of which have achieved national-level information exchange. NEHR systems are the most prevalent, with six Member States using them, while two reported relying on interconnected national portals to facilitate EHR data exchange. The earliest developed NEHR was implemented in 2012, and the most recent in 2022. All eight Member States have legislation to regulate EHR data exchange. Compared to other subregions, Western European Member States reported fewer barriers to EHR implementation, with lack of funding and interoperability standards cited as significant by two Member States.

The Western Europe subregion demonstrates a strong commitment to data exchange and interoperability, with all Member States reporting having national agencies responsible for setting standards as well as developing national strategies to ensure secure data exchange among care providers. In seven Member States, care providers are legally required to use software that conforms to national standards, and four Member States also require software developers to adhere to these standards. The most adopted international standards include SNOMED-CT (n = 7), and LOINC, ICD, and HL7 (n = 6).

All eight of this subregion's Member States have reported having legislations to protect personally identifiable data and ensure the regulated exchange and use of data stored EHR systems. Legislation regulating the extraction of EHR data for public authority databases has been enacted in four Member States, with two Member States reporting regular data extraction. National patient portals have been developed in six Member States.

4. Discussion

To our knowledge, this is the first comprehensive survey seeking information from all Member States covered by the WHO EURO regarding Electronical Health Records systems and policies. Other published surveys partially covered this region. Previous surveys have evaluated the status of EHR systems and digital health in WHO Europe Member States. The 2015 WHO eHealth survey [13] assessed EHR systems and digital health in 46 WHO Europe Member States, finding that 27 had developed National EHR systems and 30 had digital health policies. A 2023 OECD report [18] showed that 14 of 20 consulted WHO Europe Member States had national EHR exchange systems. Both surveys identified challenges like standardization and integration of EHR systems.

The 2022 survey aimed to fill gaps by seeking the inputs of all 53 WHO Europe Member States, and along with this article, enables subregional analysis and understanding. With a higher number of respondents than in previous surveys, the findings offer a more comprehensive and accurate overview of the digital health landscape across the region. The subregional lens helps highlight subregional disparities, identify specific barriers and successes in EHR implementation, and support tailored policy recommendations to improve digital health governance.

The 2023 WHO Europe Digital Health report generally notes that EHR implementation and national data exchange are at an advanced stage in the region, though achievements and challenges vary across subregions [14]. Most notably, progress is highlighted through the addition of 18 new Member States able to nationally exchange information. While the number of Member States reporting having centralized national EHR systems was higher in the subregions of Eastern, Western, and Southern Europe, the situation is more diversified in Northern Europe and the Asian subregions, where both centralized and decentralized EHR systems are in use. Lack of funding, technological capability, competing priorities, and a lack of interoperability standards are among the major obstacles to EHR adoption that are commonly reported. On the other hand, demand, acceptance issues, and knowledge gaps are not reported and rated as significant barriers. The Central Asia subregion reported the greatest number of barriers rated as most significant, whilst barriers in Western Europe were rated as of the least importance. To guarantee interoperability and safe data exchange, five of the six subregions reported having widespread adoption of national strategies and dedicated agencies. However, only 29 Member States—-most notably in Western, Eastern, and Northern Europe, and with the lowest percentage of Member States in Central Asia—have established legal requirements for healthcare providers to adopt EHR systems that adhere to national standards for both clinical terminology and electronic messaging. Every member state in the six subregions has enacted laws pertaining to data protection and privacy. With only five Member States of WHO Europe left to adopt EHR legislation spread across subregions (Southern Europe, Western and Central Asia), the usage of EHR data is heavily regulated. A newly published WHO Europe report profiles each Member State for further details [15].

This study has several limitations. The paper only aimed to describe

the responses gathered through this survey and therefore statistical significances between responses or correlations with demographic or national indicators were not evaluated. The primary challenge was establishing clear terminology definitions, which, though based on WHO standards, may have been interpreted differently by participating committees. Survey definitions can be found in the supplemental appendix. Some experts struggled to align their EHR approaches with the survey's questions due to variations in system functionality, access, and data exchange. Open questions allowed for more detailed input, but some responses indicated a need for clarification. Another limitation was the variation in response rates across different sections, which affected data comparability, particularly for interoperability policies. Survey responses can be subjective, particularly when rating barriers, as the data was collected centrally by expert coordinators tasked with gathering feedback from national colleagues and institutions. However, the researchers collaborated with the coordinators to verify the responses by consulting additional sources. In addition, although the survey collected information on EHR systems and policies, this may not accurately reflect the nuances of system implementation, usage, and coverage at subnational levels. Variations in local adoption and operational practices could lead to discrepancies between policy-level insights and actual on-ground realities. While this survey offers potential for further analysis of EHR development and interoperability, not all data was included in this article, such as EHR functionalities used by care providers. Future studies could explore the correlation between digital health policies, technologies, and economic or health indicators.

Looking ahead, advancements in EHR systems across WHO Europe Member States could transform healthcare by enabling coordinated patient care and supporting faster responses to health crises. As interoperability improves, subregions with new national standards may facilitate cross-border data sharing, facilitating the use of AI tools that could enhance early detection and personalized treatments. With strong privacy and interoperability frameworks, a unified EHR landscape in the WHO European region promises to elevate healthcare quality and equity across the region.

5. Summary table

- The 2022 WHO Europe Survey on Digital Health is the first comprehensive survey to cover all the Member States of the WHO European Region.
- Development of national-level information exchange capabilities varies across subregions. The most common approach is building centralized NEHR systems, while some Member states opted for a decentralized system of interconnected regional EHRs or through national patient portal platforms.
- Despite widespread adoption of international medical terminology and regulation, challenges persist, varying across subregions. These challenges include funding constraints, limited capacity/human resources, and competing priorities.
- Looking forward, further advancements in EHR systems, along with strong data exchange regulations and investments in technical capacity, are key to achieving full interoperability and maximizing the potential of digital health in the WHO Europe region.

Disclaimer

The authors affiliated with the World Health Organization (WHO) are alone responsible for the views expressed in this publication and they do not necessarily represent the decisions or policies of the WHO.

Authors' contributions

K.A, S.D, and K.D. designed the survey and collected the data. R.T., KA, K.D, A.M. and V.T. wrote the initial version of the paper. N.S, R.T and K.A contributed to the data validation, analysis and visualization. All equally participated in the discussion section and review of the paper.

CRediT authorship contribution statement

Roberto Tornero Costa: Writing – original draft, Visualization, Software, Methodology, Formal analysis, Conceptualization. **Keyrellous Adib:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Nagui Salama:** Writing – review & editing, Validation, Methodology. **Stefania Davia:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Antonio Martínez Millana:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis. **Vicente Traver:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Formal analysis. **Karapet Davtyan:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This publication has been produced with the financial assistance of the European Union. The contents of this publication can in no way be taken to reflect the views of the European Union.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijmedinf.2024.105687.

References

[1] L.B. Harman, C.A. Flite, K. Bond, Electronic health records: privacy, confidentiality, and security, AMA J. Ethics 14 (9) (2012) 712–719, https://doi.org/10.1001/virtualmentor.2012.14.9.stas1-1209.
[2] L.L. Fragidis, P.D. Chatzoglou, Implementation of a nationwide electronic health record (EHR): the international experience in 13 countries, Int. J. Health Care Qual. Assur. 31 (2) (2018) 116–130.
[3] Monitoring the implementation of digital health: an overview of selected national and international methodologies. Copenhagen: WHO Regional Office for Europe; 2022. Licence: CC BY-NC-SA 3.0 IGO.
[4] L.L. Fragidis, P.D. Chatzoglou, Development of Nationwide Electronic Health Record (NEHR): an international survey, Health Policy and Technology 6 (2) (2017) 124–133, https://doi.org/10.1016/j.hlpt.2017.04.004.
[5] S. Bonomi, The Electronic Health Record: A comparison of some European countries, In: Lecture notes in information systems and organisation, 2016, pp. 33–50. doi: 10.1007/978-3-319-28907-6_3.
[6] S. Marimon-Suñol, M. Rovira-Barberà, M. Acedo-Anta, M.A. Nozal-Baldajos, J. Guanyabens-Calvet, Historia Clínica Compartida en Cataluña, Medicina Clínica 134 (2010) 45–48, https://doi.org/10.1016/s0025-7753(10)70009-9.
[7] M. Aanestad, M. Grisot, O. Hanseth, and P. Vassilakopoulou, "Information Infrastructures for eHealth," in *Information Infrastructures within European Health Care*, M. Aanestad, M. Grisot, O. Hanseth, and P. Vassilakopoulou, Eds., Cham: Health Informatics. Springer, 2017, pp. 11–23. doi: 10.1007/978-3-319-51020-0_2.
[8] H. Atasoy, B.N. Greenwood, J.S. McCullough, The digitization of patient care: a review of the effects of electronic health records on health care quality and utilization, Annu. Rev. Public Health 40 (1) (2019) 487–500, https://doi.org/10.1146/annurev-publhealth-040218-044206.
[9] E. Negro-Calduch, N. Azzopardi-Muscat, R.S. Krishnamurthy, D. Novillo-Ortiz, Technological progress in electronic health record system optimization: systematic review of systematic literature reviews, Int. J. Med. Inf. 152 (2021) 104507, https://doi.org/10.1016/j.ijmedinf.2021.104507.
[10] Global strategy on digital health 2020-2025. Geneva: World Health Organization; 2021. Licence: CC BY-NC-SA 3.0 IGO.
[11] The European Programme of Work, 2020–2025: United Action for Better Health., Copenhagen, 2021. Accessed: May 05, 2023. [Accessed online on 10/08/2024]. Available: https://www.who.int/europe/publications/i/item/WHO-EURO-2021-1919-41670-56993.
[12] "EUR/RC72/5: Regional digital health action plan for the WHO European Region 2023–2030," Tel Aviv, 2022. Accessed: May 05, 2023. [Accessed online on 10/08/2024]. Available: https://apps.who.int/iris/handle/10665/360950.

[13] WHO Global Observatory for eHealth (2016) Atlas of eHealth country profiles: the use of eHealth in support of universal health coverage: based on the findings of the third global survey on eHealth 2015, Geneva, 2016. Accessed: November 06, 2023. [Accessed online on 10-08-2024] : https://www.who.int/publications/i/item/9789241565219.

[14] The ongoing journey to commitment and transformation: digital health in the WHO European Region, 2023, Copenhagen: WHO Regional Office for Europe; 2023. Licence: CC BY-NC-SA 3.0 IGO. [Accessed online on 10/08/2024]: https://www.who.int/europe/publications/i/item/9789289060226.

[15] "Exploring the digital health landscape in the WHO European Region: digital health country profiles. Copenhagen: WHO Regional Office for Europe"; 2024. Licence: CC BY-NC-SA 3.0 IGO. [Accessed online on 08/08/2024]: https://www.who.int/europe/publications/i/item/9789289060998.

[16] The ongoing journey to commitment and transformation: digital health in the WHO European Region, 2023, Chapter 2: The blueprint (methodology), Copenhagen: WHO Regional Office for Europe; 2023. Licence: CC BY-NC-SA 3.0 IGO.

[17] Methodology. In: Statistics division, United Nations Department of Economic and Social Affairs [website]. New York: United Nations; 2023 https://unstats.un.org/unsd/methodology/m49/.

[18] Progress on implementing and using electronic health record systems: Developments in OECD countries as of 2021, 2023. doi: 10.1787/4f4ce846-en.