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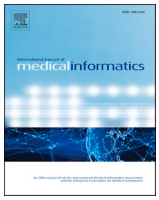

Impact of the COVID-19 pandemic on mHealth adoption: Identification of the main barriers through an international comparative analysis

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ABSTRACT

Background: The COVID-19 pandemic greatly challenged health systems worldwide. The adoption and application of mHealth technology emerged as a critical response. However, the permanent implementation and use of such technology faces several barriers, which vary by each country's innovation level and specific health policies. This study provides a detailed analysis of the transformations in mHealth service implementation within the context of the COVID-19 pandemic.

Objectives: The study analyses the changes to mHealth service implementation during the COVID-19 pandemic. It seeks to identify the main uses of technology in mHealth, to assess their level of adoption, and to address any barriers found. It also aims to compare different countries to understand how factors such as geographical location and public health policies affect mHealth status worldwide.

Methods: The survey tool was a revised version of the World Health Organization (WHO) 2015 Global Survey on eHealth, which had been updated to reflect the latest advances and policy priorities. The 2022 Survey on Digital Health in the WHO European Region was conducted by the WHO between April and October 2022 to gather information from the Member States of that region.

Results: This study shows that across the countries analysed, significant variations occurred in mHealth service adoption during the pandemic. Teleconsultation, access to patient information, and appointment reminders were the most implemented services, highlighting the importance of remote care during health crises. Regional differences were identified regarding barriers such as privacy and security and patient digital literacy, underscoring the need to address such shortcomings. These conclusions have important implications for stakeholders in the digital health sector and emphasise the need for collaboration to address the identified challenges.

1. Background

Technological advances, particularly the introduction of mobile health (mHealth), have led to a paradigmatic shift in traditional healthcare models, optimizing the healthcare system by expanding its reach through telehealth and its various tools for patient care [1]. mHealth, which uses mobile devices, patient monitoring tools, and wireless technologies, empowers both patients and healthcare providers. The World Health Organization (WHO) defines mHealth as "the use of mobile wireless technologies for public health, […] which refers to the cost-effective and secure use of information and communication technologies in support of health and health-related fields"[2]. This transformative approach offers real-time access to health services, fosters patient involvement, improves care coordination, and enables the provision of remote care, a vital component for addressing the demands of the modern health landscape [3].

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The outbreak of the COVID-19 pandemic introduced unique challenges into health systems worldwide. Even though telehealth services already existed, the pandemic brought significant changes that sped up the digital transformation and intensified the implementation and use of such services, thus triggering varied mHealth service responses[4]. These changes were driven by the need to adapt to the crisis and to ease the pressure on traditional healthcare methods. Moreover, since social distancing was one of the key strategies for morbidity and mortality mitigation during the COVID-19 pandemic[5], telehealth emerged as an attractive tool, not only for observing social distancing, but also for coping with the increased demand for remote health services[6,7].

In the midst of the COVID-19 pandemic, the positive impact of mHealth, especially within the telehealth context, was evident[8]. However, it remains unclear how the pandemic affected the adoption and implementation of other mHealth services. The allocation of resources and priority to different mHealth initiatives during the crisis may have given rise to variations in development and implementation, with some services garnering more attention and resources than others due to their immediate relevance to the pandemic response.

Moreover, the integration of mHealth tools into health systems has taken various paths depending on the country. McCool et al. note that the COVID-19 pandemic sped up the adoption of these technologies by many high-income countries, where the robustness of the infrastructures and health resources have enabled a relatively smooth implementation. However, in low- and middle-income countries, the adoption of mHealth tools may have been marked by delays and challenges due to the frequent lack of necessary infrastructure in both technology and healthcare facilities. Consequently, the benefits of mHealth in those regions have taken longer to materialise and, in some cases, mHealth is still in the early stages of application, years after the start of the pandemic [9].

But, alongside a country's income level, the literature points to other potential barriers (direct and/or derived from the previous barrier) to the adoption of mHealth. Data privacy and security are primary concerns, thus underscoring the need for secure patient information storage systems[10]. The security of health data collected by mHealth systems is a concern for patients due to data breaches and unclear privacy policies, which erode user trust. Additionally, the vulnerability of mHealth systems to hacking or malware attacks can expose sensitive information [11,12]. Moreover, the important barrier of patient digital literacy accentuates the digital divide because many people lack the skills to be able to use these tools effectively[13,14]. Cultural attitudes towards technology also play a role in acceptance, influenced by traditional beliefs that may affect people's willingness to adopt telehealth options [15]. In addition, the lack of access to smart mobile devices is a significant issue [16]. Not everyone can access smartphones or other devices necessary for mHealth solutions, which can exacerbate health inequalities[17]. Furthermore, different perceptions of the usefulness of mHealth tools among various populations highlight the importance of educational and awareness-raising campaigns to foster acceptance[18]. These challenges reduce the effectiveness of mHealth interventions by limiting their adoption, implementation, and acceptance by both healthcare providers and patients[19]. Addressing these challenges is essential to ensuring equitable access to health services, especially in settings where resources are limited.

This study offers an exhaustive analysis of the changes in mHealth service implementation during the COVID-19 pandemic. Based on data from the 2022 Global Survey on eHealth, the aim is to identify the main uses of technology in the mHealth field, to assess their level of adoption, and to address any barriers found. In addition, an international comparative analysis across the different Member States will be performed in order to ascertain how each Member State's geographical location and public health policy (priorities) model affect the mHealth situation.

2. Method

This is a survey-based cross-sectional study. The WHO Regional Office for Europe conducted a survey to assess digital health adoption and diffusion across its Member States. Data were gathered via an online survey tool based on the WHO 2015 Global Survey on eHealth, which had been modified and updated to ensure its relevance and alignment with the latest advances and priorities in digital health. The survey was officially launched by the WHO Regional Office for Europe in April 2022 and remained open to responses until October 2022.

The main format of the survey was digital. It was available in Russian and English. Coordinators for each Member State were invited to take part, which involved identifying national digital health experts and ensuring that the information gathered was enriched by their input.

All 53 Member States of the WHO European Region (Table 1) actively participated in the 2022 survey. The survey gathered information about the WHO Member States' digital healthcare transformation. However, for the purposes of this paper, only those questions directly related to the main objectives of the study were included.

2.1. Study variables

To learn about the changes in mHealth service implementation during the COVID-19 pandemic, the survey considered seven different services based on mobile technology use, on which respondents were asked to identify the stage they were at during the pandemic (Table 2).

Meanwhile, and in accordance with the specialized literature, a total of five barriers to mHealth integration were suggested. As shown in Table 2, the suggested barriers are different in nature, and they relate to the lack of effectiveness and trustworthiness of technology, privacy and security of patient information, patient digital literacy, and patients' lack of access to smart mobile devices. The variables were measured using a 5-point Likert scale, where 1 is "Not a barrier" and 5 is "A barrier.".

Member States were grouped into six different subregions, four in Europe and two in Asia (Table 1), in order to identify the impact of their geographical location on the level of mHealth service implementation.

Lastly, to establish each Member State's income per capita level and public health policy objectives, the following macroeconomic indicators were included in the database: the HDI [20] and public spending on health as a percentage of gross domestic product (GDP) for 2022. Created by the United Nations Development Programme, the HDI is an indicator of human well-being. This indicator is a compound measure of well-being based on a population's life expectancy, educational level, and gross national income (GNI) per capita[21]. Its value ranges from 0 to 1, establishing four groups of countries with low, medium, high, and very high indices. Regarding public spending on health as a percentage of GDP per capita, it shows the percentage of GDP per capita that a country allocates to public spending on health. The values range from 0.6 % for Venezuela to 14.10 % for the United States [22] | *Datosmacro.*

Table 1
Member States by subregion.

Subregion	Member States	Number
Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan	5
Eastern Europe	Belarus, Bulgaria, Czechia, Hungary, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia, Ukraine	10
Northern Europe	Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Norway, Sweden, United Kingdom	10
Southern Europe	Albania, Andorra, Bosnia and Herzegovina, Croatia, Greece, Italy, Malta, Montenegro, North Macedonia, Portugal, San Marino, Serbia, Slovenia, Spain	14
Western Asia	Armenia, Azerbaijan, Cyprus, Georgia, Israel, Türkiye	6
Western Europe	Austria, Belgium, France, Germany, Luxembourg, Monaco, Netherlands, Switzerland	8

Table 2
Study variables.

Variable	Description	Scope/Scale
Technology uses	Types of mHealth service	(1) Treatment adherence (2) Appointment reminders (3) Health promotion (4) Mobile teleconsultation (5) Patient monitoring (6) Access to electronic patient information (7) Surveillance
Situation	Implementation level or change during the pandemic	(1) Introduced (2) Improved (3) No change
Barriers	Effectiveness Trustworthiness Privacy and security Patient digital literacy Lack of access to smart mobile devices	Five-point Likert scale, where 1 is "Not a barrier" and 5 is an "Extremely important barrier."
Geographical subregion	Geographical subregion in which the Member State is located	(1) Central Asia (2) Eastern Europe (3) Northern Europe (4) Southern Europe (5) Western Asia (6) Western Europe
Human development index (HDI)	A compound index expressing a population's level of well-being based on life expectancy, educational level and gross national income (GNI) per capita	Low (<0.799) Medium (0.8–0.899) High (>0.9)
Public spending on health as a percentage of gross domestic product (GDP) per capita	% of GDP per capita that a Member State allocates to public spending on health	(1) Low (<3.99 %) (2) Medium (4 %-7.99 %) (3) High (>8%)
Health policy priority group	Group to which the Member State belongs, taking into account the HDI and public spending on health/GDP per capita (hierarchical cluster)	(1) High HDI, medium health spending (2) High HDI, high health spending (3) Low HDI, low health spending

com, s. f.).

In order to classify the Member States by the two aforementioned variables, a hierarchical cluster analysis was performed. This distinguished three large groups, as shown in Table 3.

2.2. Data analysis

Data analysis was performed using IBM SPSS v29. The 53 participants in the survey represent the entire countries included in the WHO European Region. Due to the small sample size and the absence of a normal distribution, a Kolmogov-Smirnov test was performed to determine the impact of COVID-19 on mHealth services. The test statistic with Lilliefors correction showed a level of significance equal to 0.00. The normality hypothesis for the variable could therefore be rejected.

In order to establish the impact of the different barriers on the level of mHealth integration, an ANOVA analysis was performed on the whole sample of Member States. In addition, and to identify whether the impacts identified at the general level would hold true when taking into account the geographical location of a Member State or its public health policy priorities, the ANOVA analysis was repeated for the previously established groups of Member States.

Table 3
Differences in the impact of COVID-19 on mHealth services.

Type of mHealth service	Introduced (n = 42)	No change (n = 29)	Improved (n = 104)
Treatment adherence	4 (9.5 %)	5 (17.2 %)	8 (7.7 %)
Appointment reminders	3 (7.1 %)	9 (31 %)	19 (18.3 %)
Health promotion	9 (21.4 %)	5 (17.2 %)	12 (11.5 %)
Mobile teleconsultation	8 (19 %)	3 (10.3 %)	21 (20.2 %)
Patient monitoring	8 (19 %)	3 (10.3 %)	11 (10.6 %)
Access to electronic patient information	6 (14.3 %)	4 (13.8 %)	22 (21.2 %)
Surveillance	4 (9.5 %)	0 (0 %)	11 (10.6 %)

3. Results

The analyses of differences in the impact of COVID-19 on mHealth services are summarised in Table 3.

To assess the impact of each barrier on the level of mHealth integration in the different Member States, an ANOVA analysis was performed (Table 4).

Of all the barriers recognised in the literature, only trustworthiness, effectiveness, and lack of access to smart mobile devices were statistically significant in explaining mHealth adoption during the COVID-19 pandemic.

Trustworthiness had a higher mean value, reaching 3.18 for the whole mHealth sample. However, the value of that variable varied depending on the status of mHealth. It was 2.93 for those that had been introduced, 3.2 for those that had improved, and 3.48 for those that had undergone no change (Appendix A).

In descending level of importance, it was followed by effectiveness, with a mean value of 2.83. As in the previous case, the mean value of the variable varied depending on the status of mHealth, that is, whether they had been introduced, had improved, or had undergone no change. In this regard, the values were 2.67, 2.76, and 3.34, respectively (Appendix A).

Lastly, the lack of access to smart mobile devices was the third barrier shown to be significant when adopting mHealth. The mean value of the variable was 2.22 and, in the same way as for the other barriers, that value varied depending on the mHealth status. Thus, the value was 2 when the mHealth had been introduced, 2.46 when it had improved, and 1.69 when it had undergone no change (Appendix A).

In order to establish whether a Member State's geographical subregion and public health policy priorities had any impact, the analysis was repeated, segmenting the sample by the different groups identified in accordance with the previous criteria.

Taking into account the Member States' geographical location, a total of six geographical subregions in Europe and Asia were established. As shown in Table 1, there was a major imbalance in terms of the size of the different groups. Also, the population size and structure of some Member States differed considerably, as did their cultures and, above all, their economic and sociopolitical models. Indeed, that circumstance affected significance when performing the ANOVA analysis (Table 5).

Regarding public health policy priorities, the different Member States were classified according to two criteria: the HDI and public spending on health as a percentage of GDP per capita. For the Member States in this sample, the HDI values ranged from 0.961 for Norway and Iceland to 0.7 for Tajikistan. It is important to note that the interval scale used in HDI measurement was adjusted to reflect the socioeconomic diversity of the Member States analysed. While the original scale

Table 4
ANOVA for barriers to Health mHealth integration.

Barriers to mHealth integration	Mean	SD	*P*
Privacy and security	3.49	1.18	0.418
Trustworthiness	3.18	0.997	0.067
Effectiveness	2.83	1.19	0.037
Patient digital literacy	3.30	0.90	0.134
Lack of access to smart mobile devices	2.22	1.08	**<0.01**

Table 5
ANOVA for barriers to mHealth integration by subregion.

Barriers to mHealth integration	Southern Europe			Central Asia			Eastern Europe			Northern Europe			Western Asia			Western Europe		
	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P
Privacy and security	3.37	1.27	0.689	4.17	0.937	0.943	4.00	8.16	0.912	3.37	1.14	0.868	3.72	1.02	0.391	3.13	1.13	0.021
Trustworthiness	3.16	1.04	0.285	3.67	0.492	0.393	3.39	1.03	0.670	3.00	0.874	0.543	3.16	1.10	0.163	3.10	1.06	0.733
Effectiveness	2.73	1.20	0.632	4.00	1.42	0.477	2.96	1.22	0.477	2.83	1.17	0.216	2.96	1.24	0.474	2.83	1.14	0.510
Patient digital literacy	3.16	0.986	0.211	3.67	0.778	0.201	3.35	0.832	0.877	3.49	0.818	0.317	2.20	0.837	0.273	3.03	0.80	0.033
Lack of access to smart mobile devices	**2.18**	1.04	0.087	2.25	1.68	0.161	2.43	1.12	0.884	**2.31**	0.932	0.011	2.40	1.19	0.302	1.83	0.950	0.634

proposed by the WHO classifies Member States into the HDI categories of low (0.350–0.549), medium (0.555–0.699), high (0.7–0.799) and very high (0.8–1), the variable in this study classified Member States into the following HDI categories: low (<0.8), medium (0.8–0.899) and high (>0.9), as detailed in Table 2.

Regarding public spending on health as a percentage of GDP per capita, the percentages ranged from the highest at around 11 % for Germany and France to 2 % for Azerbaijan and Kyrgyzstan [22] | *Datosmacro.com*, s. f.). For this variable, the interval scale used the established three Member States groupings according to their level of public spending on health as a percentage of GDP per capita: low (<3.99 % of GDP per capita), medium (between 4 % and 7.99 %), and high (>8%).

A hierarchical cluster analysis enabled us to establish three well-differentiated groups. The first comprised 19 Member States with a medium level of spending and a high HDI, the second comprised eight Member States with a high level of spending and a high HDI, and the third comprised 13 Member States with a low level of spending and a low HDI.

As shown in Table 6, and unlike the previous case, this clustering generated more homogeneous groups in terms of not only the size of the groups, but also the public health concerns that the different Member States within them had, even though those concerns may have been related to different situations.

Table 7 shows the results of the ANOVA analysis of the impact of the different barriers for the three groups, considering the degree of mHealth implementation.

The first group comprised those countries with a medium level of public spending on health and a high HDI. According to the analysis performed, the barriers that impacted on the mHealth situation were effectiveness and lack of access to smart mobile devices. The mean values for the two barriers were 2.78 and 2.17, respectively.

The second group comprised those countries with a high level of public spending on health and a high HDI. The results obtained from the ANOVA analysis showed that the barriers that impacted on the mHealth situation were patient digital literacy, with a mean value of 3.25, and privacy and security, with a mean value of 3.00.

Lastly, the third group comprised those countries with a low level of spending on public health and a low HDI. The data obtained from the analysis suggest that trustworthiness and lack of access to smart mobile devices were the barriers determining the mHealth situation. The mean values for the two barriers were 3.38 and 2.37, respectively.

4. Discussion

The aim of this study was to exhaustively analyse the changes in implementation of mHealth services during the COVID-19 pandemic, with special attention paid to the identification of potential barriers to mHealth integration and to comparing the results across the subregions of Europe and central and western Asia. Recognizing the dynamic mHealth implementation during the pandemic enables us to better understand the health systems' ability to adapt in times of crisis and offers a roadmap for future improvements. In addition, the identification of potential barriers and regional disparities underscores the need for specific intervention to guarantee equitable access to health services,

Table 6
Groups of Member States by public health policy priorities.

Group	Member States
Group 1	Austria, Croatia, Cyprus, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Norway, Portugal, Romania, San Marino, Spain
Group 2	Belgium, Denmark, France, Germany, Netherlands, Slovenia, Sweden, United Kingdom
Group 3	Albania, Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Macedonia, Russia, Serbia, Tajikistan, Türkiye, Ukraine

Table 7
ANOVA for barriers to mHealth integration by subgroup.

	GROUP 1			GROUP 2			GROUP 3		
Barriers	**Mean**	**SD**	**P**	**Mean**	**SD**	**P**	**Mean**	**SD**	**P**
Privacy and security	3.43	1.147	0.587	3.00	1.111	0.031	3.83	1.171	0.618
Trustworthiness	3.13	0.984	0.351	3.25	0.500	0.823	3.38	0.974	0.091
Effectiveness	2.78	1.196	0.055	2.74	1.172	0.661	2.95	1.224	0.226
Patient digital literacy	3.16	0.865	0.444	3.26	0.886	0.075	3.51	0.948	0.116
Lack of access to smart mobile devices	2.17	0.971	0.003	2.06	1.056	0.264	2.37	1.222	0.089

especially in settings with limited resources.

An important finding from our study was the clear differences between the surveyed Member States in how the various mHealth services were adopted. The least-frequently introduced service was appointment reminders. Curiously, it was also the service that had either undergone no change or had improved in the surveyed Member States. Meanwhile, and as expected, mobile teleconsultation was the mHealth service that was most frequently introduced, thus highlighting the importance of remote healthcare provision during a health crisis. The generalised adoption of that service probably helped reduce in-person contact, a key consideration during the pandemic. The considerable improvement in mobile teleconsultation and access to mHealth with digitalised information for patients suggest the effectiveness of such services in addressing the challenges posed by the pandemic, such as social distancing and remote patient care. These results show the potential of smart mobile devices to transform the provision of health services[23], and they are consistent with the perspective presented in studies such as in Bouabida et al.[24]or in the previously mentioned study by Hollander & Carr[6], which deem telehealth to be an effective and cost-effective approach for health systems seeking to improve access to care and to maintain quality of care and information security. However, those studies acknowledge certain challenges, such as the absence of in-person human contact and concerns about data confidentiality and security.

The least-introduced service was appointment reminders, and it was often suspended during the pandemic. That lack of priority could be attributed to an urgent need to reallocate resources, focusing mainly on preventive mHealth to control the spread of the disease. Thus, secondary prevention mHealth, such as appointment reminders, were temporarily relegated to second place[8,25,26]. Such resource reallocation corresponded with the health systems' adherence to COVID-19 protocols, which emphasised the prevention of infection, early detection of the virus, and the identification of effective treatment protocols[27,28]. These findings would demonstrate the adaptability and responsiveness of health systems during a global health crisis. The emphasis on mobile teleconsultation and the lack of priority given to appointment reminders suggest that mHealth services played a key role in maintaining access to healthcare and minimising the risks associated with in-person visits, thus ultimately improving patient care during the pandemic.

This study also shows few differences between the different subregions: privacy and security and patient digital literacy were barriers to mHealth in Eastern European Member States, whereas the lack of access to smart mobile devices was the only acknowledged barrier in Northern and Southern Europe. This finding would highlight the imperative need to make strategic investments and get political backing in order to maximise their impact in Eastern European Member States[29]. It is crucial for governments to implement regulatory strategies focusing on the fundamental priorities of healthcare in order to take full advantage of the potential of mHealth to improve people's health[30].

Regarding the lack of access to smart mobile devices, it was odd to find that Member States located in Northern Europe considered it a bigger barrier than those in Southern Europe. The COVID-19 pandemic has uncovered the impact of social determinants of health on access to telemedicine, revealing the disparities in broadband Internet availability, digital skills, and language barriers, all of which exacerbate healthcare inequalities [31,32]. This scenario takes on particular relevance in mHealth, where the lack of access to smart mobile devices can worsen these disparities. Furthermore, the pandemic exposed the need for digital health solutions, such as mobile and wearable devices, to support mental health[33], though the cost of such devices may be a barrier for some populations. The expansion of online digital medicine, which includes mHealth, has been put forward as a solution to optimise healthcare and to improve access to it[34].

Besides access to the Internet and to smart mobile devices, the importance of digital skills should also be mentioned, especially for older people. Mobile teleconsultation has been shown to be efficient and has endured in the post-COVID-19 pandemic era, so health policies must address the need for digital skills to enable people to use it. For older populations, and as found in an earlier study on eHealth, it is crucial to pay attention to the promotion of digital health skills among patients and caregivers [35].

Economic inequality among the countries of Eastern Europe has significantly impacted their populations' digital literacy and educational development[36]. This further exacerbates the disparities in access to the Internet and in digital skills, with a particular focus on the third level of digital divides (tangible and beneficial outcomes of Internet use) among which eHealth is found [37]. These findings would demonstrate the importance of directing attention towards older people, those at a lower educational level[38,39], and also to vulnerable populations that may encounter additional barriers when accessing and attempting to understand digital health information[40]. Within this context, a promising, cross-cutting tool for inclusive and equitable digital health promotion for countries and their residents is to establish international mobile telemedicine policies. As a previous study for Latin America has shown[41], the establishment of international telemedicine practices does not only drive improvements in health service provision and quality in the destination country. Indeed, international telemedicine also has positive spillover effects on a country and its health system through efficiency or quality improvements.

This study would contribute to the broader debate on the role of mobile technology in healthcare and its potential to address public health challenges, not only during pandemics, but also in the post-pandemic era, thus shaping the future of healthcare provision. According to our findings, if attention were given to digital skills and the possibilities of international mobile telemedicine, these aspects should be seriously considered in mHealth promotion policies.

5. Limitations

Our study encountered several limitations that warrant consideration. Firstly, despite the findings of our study, it is important to remember that our conclusions are based on a single methodological design. This means they should be corroborated with other types of designs to avoid potential interpretive and methodological biases. In this regard, intragroup variability could be crucial for understanding the differences within each group. Additionally, we recommend that future studies include mixed and/or qualitative methodologies with various key stakeholders to achieve a better understanding of the results. This approach could reveal new perspectives and provide greater depth to the findings.

Secondly, missing data, especially from specific survey questions,

posed a significant obstacle. This issue could potentially restrict the depth and reliability of interpretations and cross-comparisons drawn from the collected data. While some potential solutions have been explored by those conducting the survey, such as mandating respondents to provide definitive answers in future surveys, it is important to acknowledge that instances of incomplete or inaccurate information may persist even with mandatory responses. Therefore, further research is needed to explore additional strategies aimed at enhancing data completeness and accuracy in future surveys.

Thirdly, this study was conducted during an ongoing public health crisis, reflecting a specific point in time during the pandemic. Survey responses may not encompass the full range of experiences or perspectives that could have emerged before or after the survey period. The evolution of the pandemic, including changes in policies, public perceptions, and medical practices, could have influenced the collected data, limiting the generalizability of findings to different periods. Hence, it is crucial to continue researching to capture the dynamics of public health emergencies and ensure that the findings remain relevant and informative over time.

And finally, the limitation arising from the absence of a direct comparison with the WHO 2015 survey. The lack of such comparative data might have limited our ability to provide comprehensive insights into the changes and developments in the implementation of mHealth services during the COVID-19 pandemic. It might have also hindered our capacity to assess the full extent of the impact and progress made during the pandemic, potentially leaving some aspects of our analysis incomplete. As a result, our study may not fully capture the evolving landscape of mHealth services as effectively as a direct comparison with the WHO 2015 survey might have. Given the dynamic nature of the continuous evolutions of digital health, addressing this can be challenging.

6. Conclusions

In conclusion, the implications of the study should have far-reaching consequences for stakeholders in the digital health ecosystem. Policymakers, healthcare providers, and technology developers should work together to address the challenges and opportunities identified in this study to ensure the ongoing evolution and success of the digital health services shaping the future of healthcare provision, especially within the context of global health crises.

Summary box

What was already known on the topic	What this study added to our knowledge
• Traditional healthcare models have undergone a significant shift with the introduction of mHealth. This shift includes leveraging mobile devices, patient monitoring tools, and wireless technologies to empower both individuals and healthcare providers. • mHealth offers real-time access to health services, fosters patient involvement, improves care coordination, and enables remote care provision, which is particularly crucial in modern health landscapes. • The outbreak of the COVID-19 pandemic accelerated the digital transformation of healthcare systems worldwide. Telehealth services experienced significant growth and adoption during the pandemic in response to the need for social distancing and increased demand for remote healthcare services. • Adoption and implementation of mHealth services varied across countries and regions, influenced by factors such as income level, infrastructure robustness, and healthcare resources. High-income countries tended to adopt mHealth technologies more rapidly than low- and middle-income countries.	• This study highlighted regional differences in the adoption of mHealth services and identified specific barriers to implementation. While privacy and security concerns were prominent barriers in Eastern European countries, access to smart mobile devices was a significant issue in Northern and Southern European nations. These insights emphasize the importance of tailored interventions to address regional disparities and barriers. • The importance of digital skills, especially among older populations, in effectively utilizing mHealth services like mobile teleconsultation is underscored. Addressing digital literacy gaps becomes crucial for ensuring equitable access to healthcare services, particularly in regions with economic inequalities and disparities in educational development. • This study highlighted the potential benefits of establishing international telemedicine policies in promoting inclusive and equitable digital health promotion. Such policies not only improve health service provision but also contribute to efficiency and quality enhancements within health systems.

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(*continued*)

Authors' contributions and statement

All authors have made substantive intellectual contributions to the published study. AJ-Z contributed to formulating the research questions, conducting the literature search, designing the study, analysing and interpreting results, and drafting the article. SCM participated in the conception and design, analysis and interpretation of data, and helped draft the manuscript. MBP participated in the design, analysis, interpretation of the data and results, and critically reviewed the manuscript. AE participated in the analysis, interpretation of the data and results, and critically reviewed the manuscript. JT-S participated in the protocol design, interpretation of results, and drafting of the article. KA participated in interpretation of the data and results and critically reviewed the manuscript. KD participated in the analysis, interpretation of the data and results, and critically reviewed the manuscript. RDS participated in the interpretation of the data and results and critically reviewed the manuscript. He is the guarantor of the article. FS-R contributed to the formulation of research questions, coordinated and participated in the study design, participated in the literature search, interpretation of results, and drafting of the article. All authors have read, revised, and approved the final manuscript.

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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.

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Appendix A. Descriptive analysis – barriers vs status.

		N	Mean	SD	SE
Effectiveness	Introduced	42	2.67	1.141	0.176
	Improved	103	2.76	1.295	0.128
	No change	29	3.34	0.721	0.134
	Total	174	2.83	1.198	0.091
Trustworthiness	Introduced	42	2.93	1.068	0.165
	Improved	103	3.20	1.023	0.101
	No change	29	3.48	0.688	0.128
	Total	174	3.18	0.997	0.076
Privacy and security	Introduced	42	3.69	1.297	0.200
	Improved	103	3.45	1.161	0.114
	No change	29	3.34	1.078	0.200
	Total	174	3.49	1.181	0.090
Patient digital literacy	Introduced	42	3.40	1.061	0.164
	Improved	103	3.35	0.776	0.076
	No change	29	3.00	1.069	0.199
	Total	174	3.30	0.909	0.069
Lack of access to smart mobile devices	Introduced	42	2.00	0.855	0.132
	Improved	103	2.46	1.170	0.115
	No change	29	1.69	0.806	0.150
	Total	174	2.22	1.085	0.082

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