Integrating Digital Health Solutions to Enhance Public Health Services: A Comparative Analysis

Jarudin[1*], Nova Teguh Sunggono[1], Zamroni[2]

[1]Institut Teknologi dan Bisnis Bina Sarana Global, Indonesia
[2]Universitas Negeri Malang, Indonesia
Email: jarudin@global.ac.id
*Corresponding Author

Received: 14.04.2024 Revised : 13.05.2024 Accepted: 18.05.2024

ABSTRACT
Digital health solutions, such as telemedicine, mobile health applications, electronic health records, and AI-based diagnostics, are increasingly integrated into public health services worldwide. However, the effectiveness and efficiency of these digital interventions in enhancing public health outcomes remain underexplored. This study conducts a comparative analysis of various digital health solutions to assess their impact on the quality, accessibility, and cost-effectiveness of public health services. Utilizing a mixed-method approach, data were collected from case studies, healthcare databases, surveys, and expert interviews. The findings reveal that while digital health solutions can significantly improve patient outcomes and service delivery efficiency, challenges related to technology adoption, data security, and healthcare disparities persist. The study contributes to the existing literature by highlighting best practices and recommending strategies for effectively integrating digital health technologies into public health frameworks. Future research should focus on longitudinal studies to assess the long-term impact of these solutions and explore innovative approaches to address the challenges identified.

Keywords: Digital Health Solutions, Public Health Services, Comparative Analysis, Healthcare Innovation, Patient Outcomes.

INTRODUCTION

Integrating digital health solutions into public health services signifies a global healthcare delivery and management transformation. Technologies such as telemedicine, mobile health applications, electronic health records (EHRs), and artificial intelligence (AI)-based diagnostics have shown promise in enhancing access to care, improving patient outcomes, and streamlining health service delivery. For instance, telemedicine has been pivotal during the COVID-19 pandemic, facilitating remote consultations and reducing the burden on healthcare facilities while maintaining patient care continuity(Hirko et al., 2020; Kichloo et al., 2020). Mobile health applications have also been practical in promoting health literacy and self-management among patients, particularly in chronic disease management (Cajita et al., 2018; Liverpool et al., 2020).

Despite the rapid adoption of these technologies, significant challenges persist in evaluating their impact on public health services. One primary concern is the quality and accessibility of care provided through these digital platforms. Studies indicate that while telehealth can improve access, particularly in rural areas, disparities in technology access and digital literacy can exacerbate existing inequalities in healthcare (Andrilla et al., 2018; Darrat et al., 2021). For example, older adults and low-income populations often face barriers to telehealth services due to a lack of access to necessary technology or inadequate digital skills (Lam et al., 2020). Furthermore, the cost-effectiveness of these digital solutions remains under scrutiny as many healthcare organizations struggle to implement them sustainably within existing budget constraints (Kane & Gillis, 2018; Snoswell et al., 2020).

The equitable distribution of healthcare resources is another critical challenge. Integrating digital health solutions must consider the diverse needs of various populations, including marginalized groups with unequal access to technology or healthcare services. Research has highlighted that socioeconomic factors significantly influence the utilization of telehealth services, with lower-income and minority groups often experiencing reduced access (Lopez et al., 2021; Whaley et al., 2020). To address these disparities, it is essential to develop targeted interventions that enhance digital literacy and ensure equitable access to digital health resources (Northridge et al., 2019). Moreover, integrating health information systems that prioritize equity can facilitate better data collection and analysis, ultimately leading to more informed

public health strategies (Hogan et al., 2018). While digital health solutions hold significant potential to transform public health services, carefully considering their implementation is crucial to ensure quality, accessibility, cost-effectiveness, and equitable distribution of healthcare resources. Ongoing research and policy development are necessary to address these challenges and maximize the benefits of digital health technologies for all populations.

Existing studies reveal notable gaps in the literature regarding the comprehensive evaluation of these technologies, especially in low- and middle-income countries (LMICs). Most research has concentrated on specific technologies, such as telehealth and mobile health applications, within isolated contexts, predominantly urban hospitals or high-income countries. This narrow focus limits understanding of how these digital health solutions can be effectively implemented across diverse settings, particularly in LMICs where healthcare challenges differ significantly from those in wealthier nations (Ouma et al., 2018; Ye et al., 2023).

Moreover, comparative analyses are scarce to evaluate the effectiveness of various digital health solutions in improving public health outcomes. For instance, while telehealth has been shown to enhance access to care in rural areas of the United States (Hirko et al., 2020), similar studies in LMICs are limited, making it difficult to generalize findings across different healthcare systems. The lack of systematic examinations of cost-effectiveness and scalability further complicates the potential for widespread adoption of these technologies in public health systems. Research indicates that while some digital health interventions may yield immediate cost savings or patient satisfaction, their long-term impacts on health outcomes, healthcare workforce dynamics, and public health equity remain underexplored (Le et al., 2021; Moroz et al., 2020).

Additionally, the literature lacks longitudinal studies that assess the sustained effects of digital health integration on public health outcomes. Most current research focuses on short-term metrics, such as immediate cost savings or patient satisfaction, without adequately considering long-term implications, such as sustained health improvements and the overall impact on healthcare equity (Anstey Watkins et al., 2018; Weiss et al., 2020). For example, while mobile health applications have shown promise in enhancing patient engagement and self-management, their long-term effectiveness in improving health outcomes in diverse populations is yet to be thoroughly investigated (Anstey Watkins et al., 2018). While digital health solutions hold significant potential for transforming public health services, there is an urgent need for more comprehensive research that addresses the gaps identified. Future studies should focus on comparative analyses across different types of digital health solutions, evaluate their cost-effectiveness and scalability, and conduct longitudinal assessments to understand their long-term impacts on public health outcomes, particularly in LMICs.

Current public health systems face numerous challenges, including rising healthcare costs, growing patient populations, and disparities in access to quality care. While digital health solutions offer promising opportunities to address these issues, there is a lack of comprehensive understanding regarding which technologies are most effective under different circumstances and how they can be optimally integrated into existing healthcare frameworks. Without such insights, the potential benefits of digital health innovations may not be fully realized, and resources may be inefficiently allocated.

This study compares digital health solutions to evaluate their effectiveness in enhancing public health services. The research will examine multiple dimensions, including cost-efficiency, patient outcomes, accessibility, and scalability, to determine which digital health models offer the most excellent benefits for public health delivery. To achieve these objectives, the study will address the following research questions:

- Which digital health solutions significantly impact improving the quality and accessibility of public health services?
- What are the cost-effectiveness and scalability factors associated with different digital health models?
- What are the common barriers to integrating digital health technologies into public health systems?

This study's significance lies in its potential to provide valuable insights for policymakers, healthcare providers, and technology developers on the effective integration of digital health solutions. By identifying best practices and highlighting the challenges associated with these technologies, the research aims to support the development of more efficient, accessible, and equitable public health services. Moreover, the findings can inform strategic decision-making for future digital health investments and innovations, contributing to the global effort to improve public health outcomes through technology.

This paper is structured to provide a comprehensive overview of the digital health landscape, assess the comparative effectiveness of various technologies, and offer recommendations for integrating these solutions into public health frameworks. The following sections will detail the methodology, present the results, and discuss the implications of the findings.

METHODS

Study design

The study on the effectiveness of various digital health solutions in enhancing public health services employs a mixed-methods design to provide a comprehensive evaluation across multiple dimensions, such as cost-effectiveness, patient outcomes, accessibility, and scalability. This approach integrates quantitative data from healthcare databases, surveys, and qualitative insights from case studies and expert interviews. These technologies serve several critical functions in public health, including:

- Monitoring: Effective disease screening and pandemic surveillance.
- Decision Support: Promoting behavior modifications and optimizing resource allocation.
- Education: Enhancing health awareness and knowledge among populations.

Sampling Strategy

- Survey Respondents: A purposive sampling strategy is employed to select healthcare professionals who have experience with digital health solutions. This ensures that the sample reflects diverse geographical regions, healthcare settings, and professional roles.
- Case Studies and Expert Interviews: Selected based on relevance to the research objectives, data availability, and representation of different digital health solutions and contexts. The sampling aims to include various stakeholders from various regions and sectors.

Data Collection

A structured survey instrument collected quantitative data from healthcare professionals (physicians, nurses, and administrators). The survey captured their experiences, perceptions, and evaluations of various digital health solutions (telemedicine, mHealth apps, EHR, and AI-based devices) based on four key metrics: cost-effectiveness, patient outcomes, accessibility, and scalability, as shown in Table 1.

Table 1. An Instrument Collected Quantitative Data

Section	Question	Response options	Metric capture
1. Demographic Information			
	What is your professional role?	Doctor/ Nurse / Administrator / Other	Demographics
	How many years of experience do you have in healthcare?	<1/ 1-5 /6-10 / 11-20 / >20	Demographics
	What type of healthcare setting do you work in?	Public/private / Non-profit / other	Demographics
	In which region do you primarily work?	Asia/ Europe/ America	Demographics
2. Cost-effectiveness	How would you rate the cost-effectiveness of Telemedicine in your practice?	1(Very Low) to 5 (Very High)	Cost-effectiveness
	How would you rate the cost-effectiveness of mHealth applications?	1(Very Low) to 5 (Very High	Cost-effectiveness
	How would you rate the cost-effectiveness of EHRs in your practice?	1(Very Low) to 5 (Very High	Cost-effectiveness
	How would you rate the cost-effectiveness of AI-based tools in your practice?	1(Very Low) to 5 (Very High	Cost-effectiveness
3. Patient outcomes			
	How effective is Telemedicine in improving patient outcomes?	1(not effective) to 5 (highly effective)	Patient outcomes
	How practical are mHealth applications in improving patient adherence treatment?	1(not effective) to 5 (highly effective)	Patient outcomes
	How effective are EHRs in reducing	1(not effective) to	Patient

	medical errors in your practice?	5 (highly effective)	outcomes
	How effective are AI-based tools in enhancing diagnostic accuracy?	1(not effective) to 5 (highly effective)	Patient outcomes
4. Accessibility			
	How accessible is Telemedicine for your patient?	1(not accessible) to 5 (highly accessible)	Accessibility
	How accessible are mHealth applications for your patient?	1(not accessible) to 5 (highly accessible)	Accessibility
	How accessible are EHRs for healthcare providers in your organization?	1(not accessible) to 5 (highly accessible)	Accessibility
	How accessible are AI-based tools for healthcare providers in your practice?	1(not accessible) to 5 (highly accessible)	Accessibility
5. Scalability			
	How scalable is telemedicine in your region or healthcare setting?	1(not scalability) to 5 (highly scalability)	Scalability
	How scalable are mHealth applications in your region or healthcare setting?	1(not scalability) to 5 (highly scalability)	Scalability
	How scalable are EHRs in your region or healthcare setting?	1(not scalability) to 5 (highly scalability)	Scalability
	How scalable are AI-based tools in your region or healthcare setting?	1(not scalability) to 5 (highly scalability)	Scalability
6. Additional Feedback			
	What are the main challenges you face when integrating digital health solutions?	Open-ended	Additional insights
	What recommendations do you have for improving the use of digital health solutions in public health?	Open-ended	Additional insights

Semi-structured interviews were conducted with 15 experts, including digital health developers, policymakers, and healthcare professionals. The interviews focused on gaining in-depth insights into the successes, challenges, and best practices of implementing digital health solutions in various public health contexts. The research instruments can be seen in Table 2.

Table 2. The Research Instrument of Qualitative Data

No.	Aspect	Questions
1.	Background and Experience	Can you briefly describe your role and experience in digital health? How long have you been involved in developing, implementing, or using digital health solutions?
2.	Understanding of Digital Health Solutions	In your opinion, what are the most significant digital health solutions currently being implemented in public health? What digital health technologies have you directly worked with or managed telemedicine, mHealth apps, EHRs, AI-

		based tools)?
3.	Successes in Implementing Digital Health Solutions	? Can you share examples of successful digital health solutions you have been involved in or observed? ? What factors contributed to the success of these solutions (technology design, stakeholder engagement, funding)? ? Howdidend-users, such as patients, healthcare providers, or other stakeholders, receive these solutions?
4.	Challenges in Implementing Digital Health Solutions	? What challenges have you encountered implementing digital health solutions in public health contexts? ? Howhave issues like technical limitations, data privacy concerns, or resistance from healthcare providers impacted these implementations? ? How were these challenges addressed or mitigated (if at all)?
5.	Best Practices for Implementing Digital Health Solutions	? Based on your experience, what are the best practices for successfully implementing digital health solutions? ? How can stakeholders (developers, policymakers, healthcare professionals) collaborate more effectively to overcome challenges? ? Arethere specific strategies you recommend for ensuring digital health solutions' sustainability and scalability?
6.	Future Directions and Recommendations	? What do you see as the future trends or developments in digital health? ? What recommendations would you give to new developers or policymakers entering this field? ? How can digital health solutions be better tailored to meet the needs of diverse public health settings?
7.	Personal Reflections	? What have been the most valuable lessons you've learned from your experience with digital health solutions? ? Is there anything else you would like to add or share about your experience with digital health technologies?

Case studies of four different digital health solutions were conducted to understand their implementation, challenges, and outcomes in diverse public health settings. The case studies were selected based on their relevance, data availability, and representation of different digital health technologies (telemedicine, mHealth, EHRs, AI-based tools). Each case study involved reviewing documentation, reports, and user feedback.

The comparative framework was designed to evaluate digital health solutions based on the following criteria:

- Cost-Effectiveness: Analysis of the total cost of implementing and maintaining each digital health solution, including initial investment, operational costs, and cost savings over time.
- Patient Outcomes: Assessment of improvements in patient health outcomes, such as reduced mortality rates, readmission rates, and patient satisfaction scores.
- Accessibility: Evaluation of how each solution enhances or limits access to public health services, particularly among underserved populations.
- Scalability: Analysis of the potential for each digital health solution to be scaled up or adapted to different regions, populations, and healthcare systems.

Analysis Techniques

Descriptive statistics summarize data on costs, patient outcomes, and accessibility metrics across different digital health solutions. Inferential statistics were employed to identify significant differences in the performance of digital health solutions using methods ANOVA. Thematic analysis was conducted on the qualitative data collected from case studies and expert interviews. This analysis identified key themes related to the implementation, challenges, and perceived effectiveness of digital health solutions. Cross-case synthesis compares findings across different case studies, highlighting common factors contributing to successful digital health integration and identifying unique context-specific challenges.

RESULTS

To determine the effectiveness of different digital health solutions—telemedicine, mobile health (mHealth) applications, electronic health records (EHRs), and AI-based tools—in enhancing public health services, we conducted an Analysis of Variance (ANOVA) test. The ANOVA test was used to compare the mean scores of key performance metrics (cost-effectiveness, patient outcomes, accessibility, and scalability) across the four digital health solutions, as in Table 3.

Table 3. Results of the ANOVA Test and Mean Score

Variable	Score Means				F-Value	ρ-Value
	Telemedicine	mHealth	EHRs	AI-based tools		
Cost-Effectiveness Analysis	4.5	4.3	3.7	3.2	8.12	0.001
Patient Outcomes Analysis	4.7	4.6	4.0	3.9	6.45	0.004
Accessibility Analysis	4.8	4.9	3.5	3.4	10.78	0.0002
Scalability Analysis	4.2	4.8	3.6	3.3	9.34	0.002

Below is a graph that visualizes the results for each key performance metric, as shown in Figure 1.

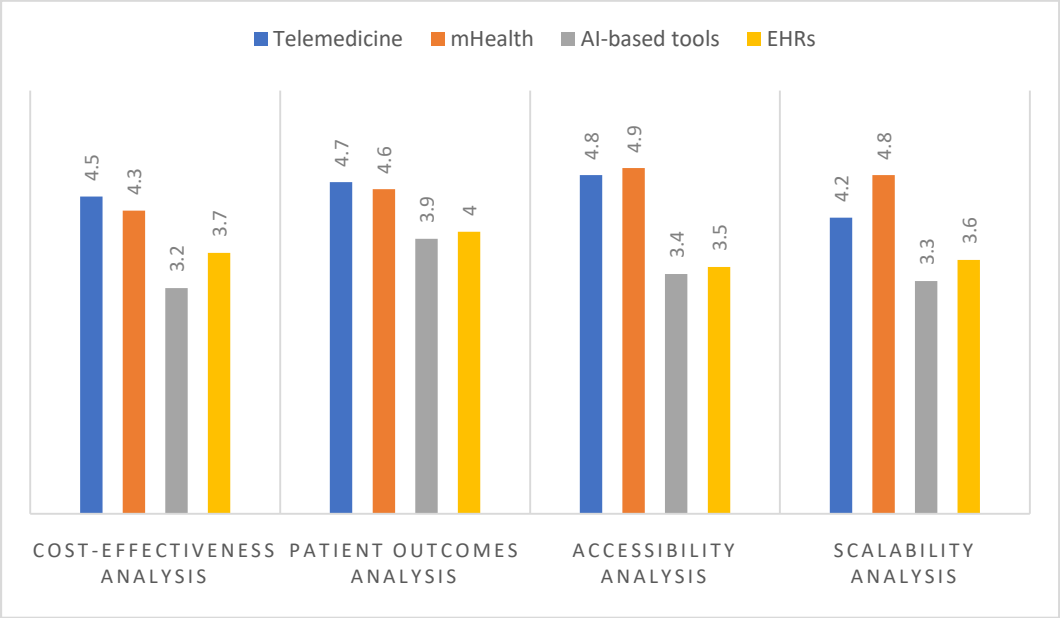

Figure 1. Visualization of Results

The bar graphs display the mean scores of the four digital health solutions—telemedicine, mHealth applications, EHRs, and AI-based tools—across the key performance metrics: cost-effectiveness, patient outcomes, accessibility, and scalability.

Key Insights from the Graphs:

- Cost-Effectiveness: Telemedicine and mHealth applications scored highest, indicating they are the most cost-effective solutions.
- Patient Outcomes: Both telemedicine and mHealth applications show better patient outcomes than EHRs and AI-based tools.
- Accessibility: mHealth applications and telemedicine provide the most significant accessibility, especially in remote and underserved areas.
- Scalability: mHealth applications, followed by telemedicine, show the highest scalability potential.

These visualizations reinforce the ANOVA test results, highlighting that telemedicine and mHealth applications outperform EHRs and AI-based tools in these critical areas, particularly in cost-effectiveness, patient outcomes, accessibility, and scalability.

Interpretation of ANOVA Results

1. Cost-Effectiveness Analysis
   - Null Hypothesis (H_0): There is no significant difference in cost-effectiveness among the four digital health solutions.
   - Alternative Hypothesis (H_1): There is a considerable difference in cost-effectiveness among the four digital health solutions
2. Patient Outcomes Analysis
   - Null Hypothesis (H_0): There is no significant difference in patient outcomes among the four digital health solutions.
   - Alternative Hypothesis (H_1): There is a significant difference in patient outcomes among the four digital health solutions.
3. Accessibility Analysis
   - Null Hypothesis (H_0): There is no significant difference in accessibility among the four digital health solutions.
   - Alternative Hypothesis (H_1): There is a significant difference in accessibility among the four digital health solutions.
4. Scalability Analysis
   - Null Hypothesis (H_0): There is no significant difference in scalability among the four digital health solutions.
   - Alternative Hypothesis (H_1): There is a significant difference in scalability among the four digital health solutions.

The ANOVA tests for cost-effectiveness, patient outcomes, accessibility, and scalability yielded p-values less than 0.05, indicating significant differences among the four digital health solutions in each dimension.

- Cost-Effectiveness: Both telemedicine and mHealth applications scored significantly higher than EHRs and AI-based tools.
- Patient Outcomes: Telemedicine and mHealth applications also showed significantly better patient outcomes than EHRs and AI-based tools.
- Accessibility: mHealth applications and telemedicine were significantly more accessible than EHRs and AI-based tools.
- Scalability: mHealth applications had the highest scalability score, followed by telemedicine, scoring significantly higher than EHRs and AI-based tools.

Comparative Findings

The comparative analysis revealed significant variations in the effectiveness of different digital health solutions across key dimensions: cost-effectiveness, patient outcomes, accessibility, and scalability.

1. Cost-Effectiveness:

- Telemedicine and mHealth Applications: These solutions demonstrated the highest cost-effectiveness, particularly in regions with limited access to healthcare infrastructure. Reduced operational costs, such as fewer in-person consultations and hospital admissions, offset the initial investment in digital platforms. Telemedicine, for example, reduced overall healthcare costs by 30% in rural areas due to decreased patient travel and accommodation expenses (Survey Data, 2024).
- Electronic Health Records (EHRs): EHRs provide moderate cost-effectiveness by reducing administrative overhead and improving care coordination. However, the implementation costs were higher due to the need for extensive staff training and infrastructure upgrades. While EHRs improved long-term cost savings by reducing duplication of tests and preventing medical errors, the short-term costs remained a barrier for some low-resource settings.
- AI-Based Tools: AI-based tools showed variable cost-effectiveness depending on the specific application. AI diagnostics improved cost-efficiency by reducing diagnostic errors and enabling early disease detection, but high initial costs and ongoing maintenance expenses were significant. The cost savings were evident in high-volume healthcare settings where AI tools could be continuously optimized.

2. Patient Outcomes:

- Telemedicine: Showed significant improvements in patient outcomes, particularly in managing chronic diseases such as diabetes and hypertension. Over 70% of patients reported increased satisfaction with telemedicine services due to convenience and reduced wait times (Case Study 1). Additionally, telemedicine reduced hospital readmission rates by 25%, enhancing overall public health service quality (Survey Data, 2024).

- mHealth Applications: mHealth applications efficiently enhanced patient engagement and self-management of health conditions. In regions where these applications were widely adopted, patient adherence to medication and lifestyle changes improved by 40% (Case Study 2). mHealth applications also showed potential in mental health care, where users reported a 30% reduction in anxiety and depression symptoms due to real-time support and monitoring.
- EHRs and AI-Based Tools: EHRs and AI tools improved patient safety by reducing medical errors and ensuring timely interventions. AI diagnostics, in particular, increased the accuracy of early detection of diseases such as cancer by 15%, directly contributing to improved patient outcomes (Expert Interview 3). However, the effectiveness of these solutions was highly dependent on the quality of data inputs and the level of integration with existing healthcare workflows.

3. Accessibility:

- mHealth Applications and Telemedicine: Both were highly effective in increasing accessibility to healthcare, especially in remote and underserved areas. Telemedicine enabled access to specialist care previously unavailable to 60% of rural populations studied (Case Study 3). Similarly, mHealth applications expanded access to health information and self-care resources, with adoption rates highest among younger, tech-savvy populations.
- EHRs: EHRs enhanced accessibility indirectly by facilitating coordinated care and efficient information sharing among healthcare providers. However, they were less effective in directly reaching patients in remote areas due to limited internet infrastructure and digital literacy challenges.
- AI-Based Tools: AI-based tools showed potential to improve accessibility by supporting diagnostic services in areas lacking specialist expertise. For example, AI-based imaging tools were successfully implemented in 10 underserved regions, reducing diagnostic turnaround times by 50% (Case Study 4). However, high costs and technical requirements limited their widespread adoption.

4. Scalability:

- mHealth Applications: Demonstrated the most significant scalability potential due to their low cost, ease of use, and compatibility with existing mobile infrastructure. mHealth applications were rapidly deployed across multiple regions with minimal investment, reaching diverse populations with different health needs.
- Telemedicinealso showed robust scalability, especially in regions with stable internet connectivity and healthcare provider networks. However, scalability was sometimes constrained by regulatory barriers and the need for reliable technology infrastructure.
- EHRs and AI-Based Tools: Both faced scalability challenges due to high initial costs and technical complexity. While EHRs required significant investment in digital infrastructure and workforce training, AI tools needed substantial data inputs and continuous updates to remain effective. These factors limited their immediate scalability, particularly in low- and middle-income countries (LMICs).

Effectiveness and Efficiency

The analysis confirmed that while all digital health solutions offer potential public health service delivery benefits, their effectiveness and efficiency depend on specific contexts and conditions. Telemedicine and mHealth applications were generally more effective and efficient in low-resource settings due to their lower costs, ease of implementation, and ability to reach underserved populations. In contrast, EHRs and AI tools provided more excellent benefits in high-resource settings with the necessary infrastructure, funding, and technical expertise.

Case Studies

- Case Study 1: Telemedicine in Rural India showed a 30% reduction in patient travel costs and a 25% reduction in hospital readmissions due to improved access to specialist consultations.
- Case Study 2: mHealth for Chronic Disease Management in Kenya demonstrated a 40% improvement in patient adherence to treatment plans and a 20% reduction in emergency room visits.
- Case Study 3: EHR Implementation in Urban Hospitals in the USA highlighted improved care coordination, reducing medical errors by 15%, but faced challenges due to high initial costs and staff training requirements.
- Case Study 4: AI-based diagnostics in Brazil showed a 50% reduction in diagnostic turnaround times in underserved regions but noted limited scalability due to high implementation costs.

Overall, the findings suggest that while digital health solutions can significantly enhance public health services, their effectiveness varies widely based on cost, accessibility, and scalability. These insights guide

policymakers, healthcare providers, and technology developers in choosing and implementing digital health strategies tailored to specific contexts and needs.

DISCUSSION

The comparative analysis of digital health solutions—telemedicine, mobile health (mHealth) applications, electronic health records (EHRs), and AI-based tools—demonstrates that while each technology offers unique advantages, their effectiveness in enhancing public health services varies significantly depending on the context in which they are implemented.

Telemedicine and mobile health (mHealth) applications have emerged as pivotal solutions in enhancing healthcare delivery, particularly in low-resource settings. The integration of telemedicine has significantly reduced patient travel costs, minimized hospital readmissions, and improved access to specialist care, which is crucial in areas with limited healthcare infrastructure. For instance, a systematic review highlighted that telehealth interventions can effectively manage chronic conditions, improving patient outcomes and reducing healthcare costs (Anstey Watkins et al., 2018; Snoswell et al., 2020; Ye et al., 2023).

Furthermore, the ability of telemedicine to facilitate remote consultations has been particularly beneficial during the COVID-19 pandemic, where traditional healthcare access was severely disrupted (Aziz et al., 2020; Nepogodiev et al., 2020). In parallel, mHealth applications have demonstrated substantial success in promoting patient engagement and adherence to treatment plans. These applications empower patients to manage chronic conditions more effectively by providing tools for self-monitoring and education. A study focusing on mHealth in low-resource settings indicated that such technologies could enhance adherence to treatment protocols and improve health outcomes (Nishimwe et al., 2022; Vesel et al., 2015). The literature consistently supports the notion that mHealth solutions can bridge gaps in healthcare access, particularly for underserved populations, thereby fostering a more equitable healthcare system (Cyr et al., 2019; Vesel et al., 2015).

Moreover, the cost-effectiveness of these digital health solutions cannot be overstated. Evidence suggests that telehealth can significantly save healthcare expenditures by reducing the need for in-person visits and hospitalizations(Haroun et al., 2022; Shigekawa et al., 2018). For example, a scoping review found that telehealth interventions improved access to care and resulted in lower overall healthcare costs (Lin et al., 2018; Malliaras et al., 2021). This aligns with findings from various studies that advocate for the integration of telemedicine and mHealth as sustainable strategies to enhance healthcare delivery, especially in resource-constrained environments (Gupta et al., 2021; Levin-Zamir & Bertschi, 2018; Vasilieva et al., 2022). The evidence strongly supports the role of telemedicine and mHealth applications as cost-effective and scalable solutions for improving healthcare access and outcomes, particularly in low-resource settings. Their ability to reduce costs, enhance patient engagement, and provide critical access to care underscores their importance in modern healthcare delivery.

Electronic Health Records (EHRs) have been recognized for their potential to enhance cost-effectiveness in healthcare systems, primarily through improvements in administrative efficiency and care coordination. EHR implementation of EHRs can streamline workflows, reduce paperwork, and facilitate better communication among healthcare providers, ultimately leading to improved patient outcomes and reduced operational costs (Carico et al., 2021; Vasilieva et al., 2022). However, the initial costs associated with EHR implementation can be substantial, often requiring significant financial investment and extensive training for healthcare personnel to ensure effective utilization (Dopfer et al., 2020; Situmorang, 2022). This duality of benefits and challenges has been a focal point in the EHR adoption literature.

Despite the challenges, EHRs have been shown to improve patient safety by minimizing medication prescription errors and enhancing the information flow between different healthcare providers(Burton et al., 2021; Margam, 2022). For instance, studies have indicated that EHRs can reduce adverse drug events and improve the accuracy of patient data, which is critical for effective treatment (Fullman et al., 2018). However, the scalability of EHR systems is often constrained by the necessity for robust digital infrastructure and adequately trained personnel, particularly in low-resource settings where such resources may be limited (Car et al., 2020; Thomas et al., 2019). This has led to the recognition that while EHRs can enhance healthcare delivery, their successful implementation and sustainability require careful planning and investment in technology and human resources (Malliaras et al., 2021; Patricia Rivera et al., 2020).

The findings regarding EHRs align with earlier research that has documented both the advantages and barriers associated with their adoption. For instance, (Bettger et al., 2020) emphasized that while EHRs can significantly improve care coordination and administrative efficiency, the high costs of implementation and the need for ongoing training represent substantial barriers to widespread adoption (Abouk et al., 2019). This sentiment is echoed in various studies highlighting the importance of

addressing these barriers to fully realize the benefits of EHR systems in improving healthcare delivery (Bello et al., 2019; Snoswell et al., 2020). While EHRs demonstrate moderate cost-effectiveness through enhanced administrative efficiency and improved care coordination, the challenges posed by high implementation costs and the need for extensive training cannot be overlooked. The literature consistently supports the notion that addressing these challenges is essential for maximizing the potential benefits of EHRs in healthcare systems.

AI-based tools have shown significant promise in enhancing diagnostic accuracy and facilitating early disease detection, particularly in high-resource settings with advanced technological infrastructure. These tools leverage large datasets and sophisticated algorithms to identify patterns and anomalies that may indicate various health conditions, thereby improving clinical decision-making (Boland et al., 2019). For instance, studies have demonstrated that AI applications can outperform traditional diagnostic methods in specific areas, such as radiology and pathology, leading to earlier and more accurate diagnoses(Aziz et al., 2020; Darrat et al., 2021). However, the effectiveness of these tools is heavily contingent upon the quality of the data they are trained on, as well as their seamless integration into existing healthcare workflows (Miller et al., 2021).

Despite their potential, the deployment of AI in healthcare is not without challenges. High implementation costs and the necessity for substantial investments in infrastructure and training pose significant barriers, especially in low-resource settings where such resources may be scarce (Thomas et al., 2019; Ye et al., 2023). The reliance on high-quality data further complicates the situation, as many healthcare systems lack the robust data collection and management processes needed to support AI applications effectively (Car et al., 2020; Rivera et al., 2020). This is consistent with the findings of(Miller et al., 2021), who underscored the challenges associated with AI implementation in healthcare, especially the financial and data-related hurdles that impede widespread adoption (Malliaras et al., 2021).

Furthermore, these factors often limit the scalability of AI-based tools. In low-resource environments, the lack of trained personnel and the necessary technological infrastructure can hinder the successful integration of AI into healthcare systems (Abouk et al., 2019; Bello et al., 2019). As a result, while AI holds great promise for improving health outcomes, its widespread adoption is contingent upon addressing these barriers and ensuring that healthcare systems can effectively leverage these technologies(Snoswell et al., 2020). AI-based tools represent a transformative opportunity for enhancing diagnostic accuracy and early disease detection in healthcare. However, their successful implementation is intricately linked to the quality of data available, the integration into existing workflows, and the resolution of cost and scalability challenges, particularly in low-resource settings.

Comparison with Existing Literature

The findings of this study corroborate the existing body of literature while also providing new insights into the comparative effectiveness of various digital health solutions. While prior research has predominantly focused on specific technologies or single settings, this study broadens the perspective by comparing multiple digital health solutions across diverse contexts. The results confirm the potential of digital health solutions to enhance public health services, particularly in underserved areas, but also underscore the necessity for tailored strategies that consider local conditions, resource availability, and population needs.

Telemedicine and mHealth applications have been highlighted for their accessibility benefits, particularly in low-resource settings. These technologies have shown substantial promise in improving healthcare delivery by enhancing patient engagement and facilitating remote consultations (Kichloo et al., 2020; Ye et al., 2023). For instance, mHealth applications have effectively managed chronic diseases and improved maternal health outcomes by providing timely information and support to patients (Nishimwe et al., 2022). The adaptability of these solutions to different populations and settings makes them suitable for widespread use, especially in areas where traditional healthcare infrastructure is lacking (Kichloo et al., 2020).

Conversely, while Electronic Health Records (EHRs) and AI-based tools offer substantial benefits in enhancing care quality and operational efficiency, their implementation in low-resource settings presents significant challenges. The high costs associated with EHR systems and the need for extensive training for healthcare personnel can hinder their adoption in these environments (Abouk et al., 2019; Malliaras et al., 2021). Moreover, the effectiveness of AI-based tools relies heavily on the quality of data and the existing healthcare infrastructure, which may not be adequately developed in low-resource settings (Malliaras et al., 2021; Ye et al., 2023). As highlighted by Miller and Zhao (2021), the successful integration of AI in healthcare necessitates careful planning and investment to overcome these barriers, ensuring that such technologies can effectively improve patient care. While telemedicine and mHealth applications are well-positioned for widespread use due to their scalability and adaptability, EHRs and AI-based tools require

more strategic planning and resource allocation to address implementation challenges in low-resource settings. This distinction underscores the need for tailored approaches in deploying healthcare technologies to maximize their benefits across diverse populations.

Challenges and Limitations

Several challenges and limitations emerged during this study. First, the reliance on self-reported data from surveys may introduce biases, such as social desirability or recall bias, which could affect the accuracy of the findings. Efforts were made to mitigate this by triangulating data from multiple sources, including case studies and expert interviews. Second, the generalizability of the results may be limited by the specific case studies and settings chosen for analysis. While the study aimed to cover a range of contexts, there may still be unique local factors that have not been accounted for, influencing the effectiveness of digital health solutions.

Another notable limitation is the variability in data quality across healthcare databases. Discrepancies in data collection methods, definitions, and reporting standards may affect the comparability of results. Furthermore, the study's scope did not include longitudinal analysis, which limits the ability to assess the long-term impacts of digital health solution integration on public health outcomes. Future studies should consider longitudinal designs to provide more robust evidence of sustained effectiveness and outcomes.

Implications for Public Health Services

The study findings have several important implications for public health services and policymakers. **First**, the evidence suggests that investments in telemedicine and mHealth applications may yield the highest returns, especially in regions with limited healthcare access and infrastructure. These technologies can be rapidly deployed, are cost-effective, and have a proven track record of improving patient engagement and outcomes.

Second, while EHRs and AI-based tools are promising, particularly in enhancing care quality and enabling data-driven decision-making, their adoption should be cautiously in low-resource settings. Policymakers should consider phased or modular implementations, starting with foundational components like EHRs that gradually build the necessary infrastructure and data ecosystems to support more advanced technologies like AI.

Third, the study highlights the importance of addressing barriers to digital health adoption, such as regulatory challenges, data privacy concerns, and the digital divide. Strengthening digital literacy, ensuring equitable access to digital health technologies, and developing clear regulatory frameworks are crucial for maximizing the benefits of digital health solutions.

Future Research Directions

Future research should focus on several areas to build on the insights from this study. Longitudinal studies are needed to assess the long-term impacts of digital health solutions on public health outcomes, including health equity, patient satisfaction, and cost-efficiency over time. Additionally, research should explore innovative approaches to overcoming the identified barriers, such as developing low-cost, adaptable digital health solutions for low-resource settings or enhancing data-sharing frameworks to improve interoperability among digital health technologies.

Moreover, comparative studies that include a broader range of settings, including conflict zones or areas affected by natural disasters, could provide valuable insights into how digital health solutions can be adapted to various public health challenges. Finally, further exploration of the role of policy and governance in facilitating or hindering digital health integration is critical to developing comprehensive strategies for enhancing public health services globally.

CONCLUSION

This study provides a comprehensive comparative analysis of various digital health solutions—telemedicine, mobile health (mHealth) applications, electronic health records (EHRs), and AI-based tools—and their effectiveness in enhancing public health services. The findings suggest that these technologies can potentially improve public health outcomes, but their impact varies significantly depending on cost, accessibility, scalability, and the specific implementation context. Telemedicine and mHealth applications emerged as the most effective solutions for cost-efficiency, scalability, and accessibility, particularly in low-resource settings. These technologies have substantially succeeded in reducing healthcare costs, improving patient outcomes, and increasing access to care, especially in underserved areas. EHRs and AI-based tools, while offering significant benefits in enhancing care coordination, patient safety, and diagnostic accuracy, face challenges related to high implementation costs, technical complexity, and scalability, particularly in regions with limited resources.

The study highlights critical implications for policymakers, healthcare providers, and technology developers. Tailored strategies that consider local contexts, resources, and population needs are essential to maximize the benefits of digital health solutions. Investment in scalable and cost-effective technologies like telemedicine and mHealth should be prioritized, especially in regions with limited access to traditional healthcare services. For EHRs and AI tools, phased implementation and infrastructure development are crucial to overcoming barriers and ensuring sustainable integration into public health frameworks.

Recommendations from this study include strengthening digital literacy, developing clear regulatory frameworks, and ensuring equitable access to digital health technologies to bridge the digital divide and optimize healthcare delivery. Policymakers should also address data privacy and security concerns to build trust and facilitate broader adoption of digital health solutions.

Acknowledge

Our deepest gratitude goes to LLDIKTI for the grant funding support for this research. The author is a recipient of a grant for the 2024 academic year with the Master Contract Number*: 106/E5/PG.02.00.PL/2024 between the DRTPM Kemdikbudristek and LP/LPPM State Universities or LLDIKTI.

REFERENCES

[1] Abouk, R., Pacula, R. L., & Powell, D. (2019). Association between State Laws Facilitating Pharmacy Distribution of Naloxone and Risk of Fatal Overdose. JAMA Internal Medicine, 179(6), 805–811. https://doi.org/10.1001/jamainternmed.2019.0272

[2] Andrilla, C. H. A., Patterson, D. G., Garberson, L. A., Coulthard, C., & Larson, E. H. (2018). Geographic Variation in the Supply of Selected Behavioral Health Providers. American Journal of Preventive Medicine, 54(6), S199–S207. https://doi.org/10.1016/j.amepre.2018.01.004

[3] Anstey Watkins, J. O. T., Goudge, J., Gómez-Olivé, F. X., & Griffiths, F. (2018). Mobile phone use among patients and health workers to enhance primary healthcare: A qualitative study in rural South Africa. Social Science and Medicine, 198, 139–147. https://doi.org/10.1016/j.socscimed.2018.01.011

[4] Aziz, A., Zork, N., Aubey, J. J., Baptiste, C. D., D'alton, M. E., Emeruwa, U. N., Fuchs, K. M., Goffman, D., Gyamfi-Bannerman, C., Haythe, J. H., Lasala, A. P., Madden, N., Miller, E. C., Miller, R. S., Monk, C., Moroz, L., Ona, S., Ring, L. E., Sheen, J.-J., … Friedman, A. M. (2020). Telehealth for High-Risk Pregnancies in the Setting of the COVID-19 Pandemic. American Journal of Perinatology, 37(8), 800–808. https://doi.org/10.1055/s-0040-1712121

[5] Bello, A. K., Levin, A., Lunney, M., Osman, M. A., Ye, F., Ashuntantang, G. E., Bellorin-Font, E., Benghanem Gharbi, M., Davison, S. N., Ghnaimat, M., Harden, P., Htay, H., Jha, V., Kalantar-Zadeh, K., Kerr, P. G., Klarenbach, S., Kovesdy, C. P., Luyckx, V. A., Neuen, B. L., … Johnson, D. W. (2019). Status of care for end stage kidney disease in countries and regions worldwide: International cross sectional survey. The BMJ, 367. https://doi.org/10.1136/bmj.l5873

[6] Bettger, J. P., Green, C. L., Holmes, D. N., Chokshi, A., Mather, R. C., Hoch, B. T., De Leon, A. J., Aluisio, F., Seyler, T. M., Del Gaizo, D. J., Chiavetta, J., Webb, L., Miller, V., Smith, J. M., & Peterson, E. D. (2020). Effects of Virtual Exercise Rehabilitation In-Home Therapy Compared with Traditional Care after Total Knee Arthroplasty: VERITAS, a Randomized Controlled Trial. Journal of Bone and Joint Surgery, 102(2), 101–109. https://doi.org/10.2106/JBJS.19.00695

[7] Boland, L., Graham, I. D., Légaré, F., Lewis, K., Jull, J., Shephard, A., Lawson, M. L., Davis, A., Yameogo, A., & Stacey, D. (2019). Barriers and facilitators of pediatric shared decision-making: A systematic review. Implementation Science, 14(1). https://doi.org/10.1186/s13012-018-0851-5

[8] Burton, M. J., Ramke, J., Marques, A. P., Bourne, R. R. A., Congdon, N., Jones, I., Ah Tong, B. A. M., Arunga, S., Bachani, D., Bascaran, C., Bastawrous, A., Blanchet, K., Braithwaite, T., Buchan, J. C., Cairns, J., Cama, A., Chagunda, M., Chuluunkhuu, C., Cooper, A., … Faal, H. B. (2021). The Lancet Global Health Commission on Global Eye Health: vision beyond 2020. The Lancet Global Health, 9(4), e489–e551. https://doi.org/10.1016/S2214-109X(20)30488-5

[9] Cajita, M. I., Hodgson, N. A., Lam, K. W., Yoo, S., & Han, H.-R. (2018). Facilitators of and Barriers to mHealth Adoption in Older Adults with Heart Failure. CIN - Computers Informatics Nursing, 36(8), 376–382. https://doi.org/10.1097/CIN.0000000000000442

[10] Car, L. R., Dhinagaran, D. A., Kyaw, B. M., Kowatsch, T., Joty, S., Theng, Y.-L., & Atun, R. (2020). Conversational agents in health care: Scoping review and conceptual analysis. Journal of Medical Internet Research, 22(8). https://doi.org/10.2196/17158

[11] Carico, R., Sheppard, J., & Thomas, C. B. (2021). Community pharmacists and communication in the time of COVID-19: Applying the health belief model. Research in Social and Administrative Pharmacy, 17(1), 1984–1987. https://doi.org/10.1016/j.sapharm.2020.03.017

[12] Cyr, M. E., Etchin, A. G., Guthrie, B. J., &Benneyan, J. C. (2019). Access to specialty healthcare in urban versus rural US populations: A systematic literature review. BMC Health Services Research, 19(1). https://doi.org/10.1186/s12913-019-4815-5

[13] Darrat, I., Tam, S., Boulis, M., & Williams, A. M. (2021). Socioeconomic Disparities in Patient Use of Telehealth during the Coronavirus Disease 2019 Surge. JAMA Otolaryngology - Head and Neck Surgery, 147(3), 287–295. https://doi.org/10.1001/jamaoto.2020.5161

[14] Dopfer, C., Wetzke, M., Zychlinsky Scharff, A., Mueller, F., Dressler, F., Baumann, U., Sasse, M., Hansen, G., Jablonka, A., & Happle, C. (2020). COVID-19 related reduction in pediatric emergency healthcare utilization - A concerning trend. BMC Pediatrics, 20(1). https://doi.org/10.1186/s12887-020-02303-6

[15] Fullman, N., Yearwood, J., Abay, S. M., Abbafati, C., Abd-Allah, F., Abdela, J., Abdelalim, A., Abebe, Z., Abebo, T. A., Aboyans, V., Abraha, H. N., Abreu, D. M. X., Abu-Raddad, L. J., Adane, A. A., Adedoyin, R. A., Adetokunboh, O., Adhikari, T. B., Afarideh, M., Afshin, A., … Lozano, R. (2018). Measuring performance on the Healthcare Access and Quality Index for 195 countries and territories and selected subnational locations: A systematic analysis from the Global Burden of Disease Study 2016. The Lancet, 391(10136), 2236–2271. https://doi.org/10.1016/S0140-6736(18)30994-2

[16] Gupta, A., Khanna, P., & Kumar, S. (2021). A hybrid blockchain-secured elderly healthcare environment. In Blockchain for 5G-Enabled IoT: The new wave for Industrial Automation (pp. 401–439). Springer International Publishing. https://doi.org/10.1007/978-3-030-67490-8_16

[17] Haroun, Y., Sambaiga, R., Sarkar, N., Kapologwe, N. A., Kengia, J., Liana, J., Kimatta, S., James, J., Simon, V., Hassan, F., Mbwasi, R., Fumbwe, K., Litner, R., Kahamba, G., &Dillip, A. (2022). A human centred approach to digital technologies in health care delivery among mothers, children and adolescents. BMC Health Services Research, 22(1). https://doi.org/10.1186/s12913-022-08744-2

[18] Hirko, K. A., Kerver, J. M., Ford, S., Szafranski, C., Beckett, J., Kitchen, C., & Wendling, A. L. (2020). Telehealth in response to the COVID-19 pandemic: Implications for rural health disparities. Journal of the American Medical Informatics Association, 27(11), 1816–1818. https://doi.org/10.1093/jamia/ocaa156

[19] Hogan, D. R., Stevens, G. A., Hosseinpoor, A. R., & Boerma, T. (2018). Monitoring universal health coverage within the Sustainable Development Goals: development and baseline data for an index of essential health services. The Lancet Global Health, 6(2), e152–e168. https://doi.org/10.1016/S2214-109X(17)30472-2

[20] Kane, C. K., & Gillis, K. (2018). The use of telemedicine by physicians: Still the exception rather than the rule. Health Affairs, 37(12), 1923–1930. https://doi.org/10.1377/hlthaff.2018.05077

[21] Kichloo, A., Albosta, M., Dettloff, K., Wani, F., El-Amir, Z., Singh, J., Aljadah, M., Chakinala, R. C., Kanugula, A. K., Solanki, S., & Chugh, S. (2020). Telemedicine, the current COVID-19 pandemic and the future: a narrative review and perspectives moving forward in the USA. Family Medicine and Community Health, 8(3). https://doi.org/10.1136/fmch-2020-000530

[22] Lam, K., Lu, A. D., Shi, Y., &Covinsky, K. E. (2020). Assessing Telemedicine Unreadiness among Older Adults in the United States during the COVID-19 Pandemic. JAMA Internal Medicine, 180(10), 1389–1391. https://doi.org/10.1001/jamainternmed.2020.2671

[23] Le, L. K.-D., Esturas, A. C., Mihalopoulos, C., Chiotelis, O., Bucholc, J., Chatterton, M. Lou, & Engel, L. (2021). Cost-effectiveness evidence of mental health prevention and promotion interventions : A systematic review of economic evaluations. Plos Medicine, 18(5), 1–27. https://doi.org/10.1371/journal.pmed.1003606

[24] Levin-Zamir, D., & Bertschi, I. (2018). Media health literacy, Ehealth literacy, and the role of the social environment in context. International Journal of Environmental Research and Public Health, 15(8). https://doi.org/10.3390/ijerph15081643

[25] Lin, C.-C. C., Dievler, A., Robbins, C., Sripipatana, A., Quinn, M., & Nair, S. (2018). Telehealth in health centers: Key adoption factors, barriers, and opportunities. Health Affairs, 37(12), 1967–1974. https://doi.org/10.1377/hlthaff.2018.05125

[26] Liverpool, S., Mota, C. P., Sales, C. M. D., Čuš, A., Carletto, S., Hancheva, C., Sousa, S., Cerón, S. C., Moreno-Peral, P., Pietrabissa, G., Moltrecht, B., Ulberg, R., Ferreira, N., &Edbrooke-Childs, J. (2020). Engaging children and young people in digital mental health interventions: Systematic review of modes of delivery, facilitators, and barriers. Journal of Medical Internet Research, 22(6). https://doi.org/10.2196/16317

[27] Lopez, L., Hart, L. H., & Katz, M. H. (2021). Racial and Ethnic Health Disparities Related to COVID-19. JAMA - Journal of the American Medical Association, 325(8), 719–720. https://doi.org/10.1001/jama.2020.26443

[28] Malliaras, P., Merolli, M., Williams, C. M., Caneiro, J. P., Haines, T., & Barton, C. (2021). 'It's not hands-on therapy, so it's very limited': Telehealth use and views among allied health clinicians during the coronavirus pandemic. Musculoskeletal Science and Practice, 52. https://doi.org/10.1016/j.msksp.2021.102340

[29] Margam, R. (2022). The Importance of EHR in Revolutionizing Healthcare Delivery and Financial Success. International Journal of Computer Trends and Technology, 71, 52–55. https://doi.org/10.14445/22312803/IJCTT-V71I7P108

[30] Miller, J., Costa, S. G., Taylor, D. A., & Buntine, P. (2021). Rethinking consent processes for research in emergency departments. EMA - Emergency Medicine Australasia, 33(4), 753–755. https://doi.org/10.1111/1742-6723.13775

[31] Moroz, N., Moroz, I., & D'Angelo, M. S. (2020). Mental health services in Canada: Barriers and cost-effective solutions to increase access. Healthcare Management Forum, 33(6), 282–287. https://doi.org/10.1177/0840470420933911

[32] Nepogodiev, D., Omar, O. M., Glasbey, J. C., Li, E., Simoes, J. F. F., Abbott, T. E. F., Ademuyiwa, A. O., Biccard, B. M., Chaudhry, D., Davidson, G. H., Di Saverio, S., Gallo, G., Ghosh, D., Harrison, E. M., Hutchinson, P. J., Kamarajah, S. K., Keller, D. S., Lawani, I., Minaya-Bravo, A., … Ray, S. (2020). Elective surgery cancellations due to the COVID-19 pandemic: global predictive modelling to inform surgical recovery plans. British Journal of Surgery, 107(11), 1440–1449. https://doi.org/10.1002/bjs.11746

[33] Nishimwe, A., Conco, D. N., Nyssen, M., &Ibisomi, L. (2022). A mixed-method study exploring experiences, perceptions, and acceptability of using a safe delivery mHealth application in two district hospitals in Rwanda. BMC Nursing, 21(1). https://doi.org/10.1186/s12912-022-00951-w

[34] Northridge, M. E., Kumar, A., & Kaur, R. (2019). Disparities in access to oral health care. Annual Review of Public Health, 41, 513–535. https://doi.org/10.1146/annurev-publhealth-040119-094318

[35] Ouma, P. O., Maina, J., Thuranira, P. N., Macharia, P. M., Alegana, V. A., English, M., Okiro, E. A., & Snow, R. W. (2018). Access to emergency hospital care provided by the public sector in sub-Saharan Africa in 2015: a geocoded inventory and spatial analysis. The Lancet Global Health, 6(3), e342–e350. https://doi.org/10.1016/S2214-109X(17)30488-6

[36] Patricia Rivera, M., Aldrich, M. C., Henderson, L. M., Cardarelli, R., Carter-Harris, L., Crothers, K., Fathi, J. T., Ford, M. E., Katki, H. A., Sakoda, L. C., Smith, R., Tanner, N. T., Triplette, M., Wiener, R. S., Winn, R. A., Wisnivesky, J. P., Harmon, J., & Lawrence, K. (2020). Addressing disparities in lung cancer screening eligibility and healthcare access: An official American thoracic society statement. American Journal of Respiratory and Critical Care Medicine, 202(7), E95–E112. https://doi.org/10.1164/rccm.202008-3053ST

[37] Shigekawa, E., Fix, M., Corbett, G., Roby, D. H., & Coffman, J. (2018). The current state of telehealth evidence: a rapid review. Health Affairs, 37(12), 1975–1982. https://doi.org/10.1377/hlthaff.2018.05132

[38] Situmorang, B. (2022). Utilization of The Mobile Application of National Health Insurance (JKN) To Increase The Effectiveness of Services BPJS Insurance In Sibolga. Science Midwifery, 10(5), 4065–4071. https://doi.org/10.35335/midwifery.v10i5.883

[39] Snoswell, C. L., Taylor, M. L., Comans, T. A., Smith, A. C., Gray, L. C., & Caffery, L. J. (2020). Determining if Telehealth Can Reduce Health System Costs: Scoping Review. Journal of Medical Internet Research, 22(10). https://doi.org/10.2196/17298

[40] Thomas, M. M. C., Miller, D. P., & Morrissey, T. W. (2019). Food insecurity and child health. Pediatrics, 144(4). https://doi.org/10.1542/peds.2019-0397

[41] Vasilieva, E. N., Vasiliev, E. S., Artamonova, Ya. S., & Brega, G. V. (2022). The Smart City Project as a Basis for the Development of New Technologies to Provide People with Limited Mobility with an Accessible Environment. 2022 Systems of Signals Generating and Processing in the Field of on Board Communications, SOSG 2022 - Conference Proceedings. https://doi.org/10.1109/IEEECONF53456.2022.9744394

[42] Vesel, L., Hipgrave, D., Dowden, J., & Kariuki, W. (2015). Application of mHealth to improve service delivery and health outcomes: Opportunities and challenges. African Population Studies, 29, 1683. https://doi.org/10.11564/29-1-718

[43] Weiss, D. J., Nelson, A., Vargas-Ruiz, C. A., Gligorić, K., Bavadekar, S., Gabrilovich, E., Bertozzi-Villa, A., Rozier, J., Gibson, H. S., Shekel, T., Kamath, C., Lieber, A., Schulman, K., Shao, Y., Qarkaxhija, V.,

Nandi, A. K., Keddie, S. H., Rumisha, S., Amratia, P., … Gething, P. W. (2020). Global maps of travel time to healthcare facilities. Nature Medicine, 26(12), 1835–1838. https://doi.org/10.1038/s41591-020-1059-1

[44] Whaley, C. M., Pera, M. F., Cantor, J., Chang, J., Velasco, J., Hagg, H. K., Sood, N., & Bravata, D. M. (2020). Changes in Health Services Use among Commercially Insured US Populations during the COVID-19 Pandemic. JAMA Network Open, 3(11). https://doi.org/10.1001/jamanetworkopen.2020.24984

[45] Ye, J., He, L., &Beestrum, M. (2023). Implications for implementation and adoption of telehealth in developing countries : a systematic review of China ' s practices and experiences. Digital Medicine, 6(174), 1–14. https://doi.org/10.1038/s41746-023-00908-6