Original research article

LEVERAGING DIGITAL HEALTH TECHNOLOGIES: ADMINISTRATIVE STRATEGIES FOR ENHANCING PUBLIC HEALTH OUTCOMES IN UNDERSERVED COMMUNITIES

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Abstract: *Integrating digital health technologies in public health systems has shown potential to enhance healthcare delivery, particularly in underserved communities. However, the differential impact of varying regional infrastructure and policies remains less explored.* **Objectives:** *This study investigates the impact of digital health technologies on improving public health outcomes in underserved communities.* **Methods:** *A mixed-methods study was conducted across three major cities in Punjab (Lahore, Faisalabad, and Multan), targeting underserved urban and rural populations. Three hundred healthcare administrators, policymakers, and digital health professionals from public and private healthcare settings participated. Data collection involved structured surveys, in-depth interviews, and focus groups. The geographical analysis assessed the variation in digital health adoption across different cities, factoring in urbanization levels and local infrastructure availability. The statistical analysis of the study variables was done using the SPSS 26 software, where multivariate regression analysis was conducted, and geographical mapping of health outcomes was also done.* **Results:** *Studies performed on the feedback revealed critical regional differences. In Lahore, which has an excellent urban setting and governmental policies covering telemedicine, the increase was 65% (p < 0. 01), while in Faisalabad and Multan, where internet facilities are not very strong and facing problems regarding funding, the increase was 50 and 45%, respectively. Reducing chronic disease management hospital readmissions was found to be 35% in Lahore and Faisalabad and 28% in Multan, signifying that digital health infrastructures influence patient outcomes. The administrative strategies, including policy changes, provider training, and other related programs, were found to have made quite a significant contribution, the contribution of which was estimated to be around 70%, the result being the coefficient of changes in the success of the implementation of the digital health notion (r = 0. 74, p < 0. 001).* **Conclusion:** *Lahore is also the beneficiary of digital health adoption, while the rural areas in Faisalabad and Multan need more investment in infrastructure and digital health literacy programs to realize comparable benefits.*

Keywords: Digital Health Technologies, Public Health Administration, Punjab, Underserved Communities, Health Outcomes, Geographical Analysis, Healthcare Access.

Introduction

Therefore, introducing digital health technologies can be seen as holding opportunities for furthering work in this area and improving public health, especially for LICs. Integrating the use of various technologies in the provision of health care services is commonly referred to as digital health, and it involves telemedicine, mHealth, electronic health record systems (EHR), wearable gadgets, and health information technology (IT) (1). Such tools have the potential to reduce this gap, which, so far, has been an unchanged challenge for both urban and rural patient-oriented care worldwide and even in developing areas such as Punjab in Pakistan (2). Adopting digital health technologies into public health systems is acknowledged as one of the essential actions to enhance health equity, reduce health disparities, and improve the population's health (3). An example is telemedicine, which enables patients to receive health care services without being physically present. This consideration reduces healthcare accessibility by distance or lack of proper means of transport (4). In the same way, mHealth platforms provide patients with health-related information, health status, and communication with

healthcare providers, defining patient engagement and patient-centered care (5). EHRs also have the essential function of sharing patient details across different levels of care, reducing cross-checking of results, reducing mistakes, and enhancing the flow of care, especially in health facilities with multiple services (6).

One of the core challenges is the inadequate general and advanced utility, including constant internet connections, health care units, and more in the rural areas (7). Punjab represents a kind of mixed situation; urban Punjab in Lahore appears to have much better infrastructural support than rural Punjab in cities like Faisalabad and Multan. These factors have led to an imbalance in the deployment of digital health solutions, which has seen health outcomes differ between regions (8). They can also enhance these transitions through effective administrative management, where evidence demonstrates that strategic governance improves digital health outcomes by ensuring equity and adaptability to relevant systems (9). Governmental policy, as the enabler of the deployment of the technologies, is crucial for establishing the enabling conditions of digital health. Telemedicine is a promising approach that must be

supported by policies addressing existing obstacles. Such policy measures include expanding reimbursement for telemedicine services, providing government subsidies for coverage of Internet connectivity and the digital divide in rural regions, and changing the continuing education and training of healthcare providers and patients (10).

This study investigates the impact of digital health technologies on improving public health outcomes in underserved communities. The study aims to create a framework for integrating these technologies into community health systems to enhance healthcare access, reduce health disparities, and promote equity.

Methodology

This study employed a comprehensive mixed-methods approach to assess the effectiveness of digital health technologies in improving public health outcomes in underserved communities across three cities in Punjab: Lahore, Faisalabad, and Multan. Three hundred participants were selected, including healthcare managers, government policymakers, and other technology and digital health specialists from public and private organizations.

This study employed a mixed-methods approach, integrating quantitative and qualitative research designs. The quantitative component provided measurable insights into the impact of digital health technologies, while the qualitative component offered a deeper understanding of the contextual factors influencing these technologies within underserved communities.

The study targeted 300 participants drawn from Lahore, Faisalabad, and Multan. Participants included healthcare administrators, policymakers, and professionals in the digital health sector. This selection ensured a diverse representation across healthcare administration levels and geographic locations.

Convenience sampling was utilized to recruit participants from departments directly involved with public and private healthcare systems. This approach allowed the study to focus on individuals with relevant experience deploying and managing digital health technologies.

Surveys: Quantitative data was collected using self-administered questionnaires. These surveys assessed digital health technologies, including telemedicine, mobile health (mHealth), electronic health records (EHRs), patient involvement, and data openness. The aim was to quantify the effectiveness of these technologies. Interviews: Semi-structured interviews were conducted with selected participants to capture their perceptions of constraints, policy-making processes, and administrative strategies related to digital health. These interviews provided valuable insights into the challenges and opportunities for integrating digital health into local health systems.

Focus group discussions were held with healthcare professionals to explore regional differences in implementing digital health technologies. These discussions were crucial for understanding the contextual factors that influence the success of digital health interventions across different regions.

The quantitative data was analyzed using the Statistical Package for Social Sciences (SPSS) version 26. Multivariate regression analysis was employed to examine the correlation between the use of digital health technologies and health outcomes. Geographical mapping of the data was also conducted to identify regional trends in digital health adoption.

The qualitative data from interviews and focus groups was subjected to thematic analysis. This approach enabled the identification and evaluation of key themes related to administrative strategies, challenges, and enablers of digital health adoption.

The findings were analyzed in the context of the specific structural and organizational characteristics of the cities studied. Differences between urban and rural areas were also evaluated to draw actionable conclusions regarding the scaling and adapting of digital health technologies in diverse, underserved communities.

Results

The study revealed significant regional differences in the adoption and impact of digital health technologies across Lahore, Faisalabad, and Multan.

Telemedicine utilization substantially increased across all three cities, though with significant regional variation. By benefiting from more robust urban infrastructure, Lahore saw a 65% increase in telemedicine utilization ($p < 0.01$), while Faisalabad and Multan experienced 50% and 45% increases, respectively. The differences in utilization were primarily attributed to disparities in internet access, availability of digital devices, and local funding, as shown in Table 1.

Table 1: Telemedicine Utilization and Accessibility

City	Telemedicine Utilization Increase (%)	Statistical Significance (p-value)
Lahore	65%	< 0.01
Faisalabad	50%	< 0.05
Multan	45%	< 0.05

Chronic disease management through digital health technologies demonstrated a positive impact on reducing hospital readmissions. Lahore and Faisalabad showed significant reductions in hospital readmissions, as shown in Table 2.

Table 2: Chronic Disease Management and Hospital Readmissions

City	Reduction in Hospital Readmissions (%)	Statistical Significance (p-value)
Lahore	35%	< 0.01
Faisalabad	32%	< 0.01
Multan	28%	< 0.05

Patient engagement rates, a critical factor in the success of digital health interventions, varied significantly by region. Lahore saw the highest increase in patient engagement, with a 60% improvement in active patient participation in their care (p < 0.001), as shown in Table 3.

Table 3: Patient Engagement and Healthcare Utilization

City	Increase in Patient Engagement (%)	Statistical Significance (p-value)
Lahore	60%	< 0.001
Faisalabad	40%	< 0.01
Multan	35%	< 0.05

A geographical analysis using SPSS revealed significant variation in digital health technology adoption across the three cities, influenced by urbanization levels and local infrastructure availability, as shown in Table 5.

Table 4: Geographical Analysis of Digital Health Adoption

City	Urbanization Level (%)	Digital Health Adoption (%)	Infrastructure Rating (1-10)
Lahore	90%	75%	9
Faisalabad	65%	55%	6
Multan	50%	50%	5

Several administrative measures, such as policies and providers' training, helped enrich the results of applying digital health technology. These strategies, therefore, explained the 70% success of the digital health interventions (r = 0. 74 p < 0. 001). The education of different healthcare givers on how to utilize the telemedicine platforms and put policies in place in Lahore was determined as one of the reasons for its success. Conversely, Table 5 indicates that while getting equivalent results, Faisalabad and Multan needed further capital for training and development, as shown in Table 5.

Table 5: Administrative Impact on Digital Health Success

City	Administrative Strategy Success (%)	Training Program Impact (Variance, r-value)	Policy Adjustment Impact (Variance, r-value)
Lahore	80%	0.78	0.76
Faisalabad	65%	0.65	0.60
Multan	60%	0.62	0.58

Discussion

The study's implications are to provide evidence for the promising role of digital health technologies in the enhancement of public health in underprivileged communities, in general, as well as in the utilization of telemedicine, mHealth platforms, and EHRs. The studies of telemedicine use, which has risen by 65% in Lahore, 50% in Faisalabad, and 45% in Multan, suggest that telemedicine can triple healthcare access – even though it will be three times better in locations like Lahore, which have comparatively better infrastructure (11). Like previous studies, the present study has demonstrated that telemedicine reduces barriers to healthcare accessibility in urban areas since the structure is better developed to support the internet and digital devices. However, it is clear that even though the rates remain lower in terms of the rural population and people living in other less developed areas, the presence of telemedicine is pivotal in enhancing the health status of the needy or, relatively, the underserved. In a meta-analysis of studies in chronic diseases, Kruse and colleagues identified that telemedicine-enhanced patient outcomes increased in the context of regional, remote areas exclusively (13). In this regard, this finding supports our outcome, which shows that digital health interventions caused a decrease in the rate of readmitted patients by up to 35% in Lahore and Faisalabad (14). The decreases in readmission rates in the three cities are in line with the results of other studies; it is pointed out that digital health platforms can play an essential role in chronic disease management because patients and their physicians can continue to monitor their conditions and communicate with each other (15). Similar to the one conducted in the United States, another cross-sectional study also established that the application of mHealth for chronic disease resulted in a reduction of 30% in hospital readmissions (16). The results of our survey of Lahore and Faisalabad also affirm that such technologies reduce readmissions by 35%, again indicating the significance for patients. However, even a 28% reduction noticed in Multan shows what rural and less developed regions can achieve in achieving the objectives. A relatively low quality in terms of infrastructural facilities and a scarce number of health professionals undergo less impressive changes in chronic disease management within digital health interventions (17).

As shown in the case of Lahore, the enhanced patient engagement rate by 60%, 40% in Faisalabad, and 35% in Multan established digital literacy and accessibility as the determinants of success in the exploitation of digital health technologies (18,19). A discovery implies that Digital literacy via IT educational programs could well be a reason for patients' active participation, especially in the areas that are considered underserved. We see eye to eye with studies in rural Bangladesh revealing that digital literacy improved the use of mHealth platforms and, therefore, patients' health (20). Tactics such as changes in policy and provider training were identified as the main approaches that supported the

identification of the goal of digital health interventions in our study. The level of variability of 70% of the success rate of digital health implementation contributing to such strategies is an endorsement of the research done by other scholars in determining that governance and strategic planning influence the successful deployment of digital health technologies (21).

This research implies that even where innovative user-centered digital health technologies have been developed and are highly effective in improving public health outcomes, local infrastructure, digital literacy, and administrative support will determine the effectiveness and diffusion of such technologies.

Conclusion

This paper demonstrates how technologies integrated into the digital health domain promise to optimize health care in areas of low provision, especially regarding access and chronicity. Mature markets and urban areas like Lahore have experienced better success than rural areas because of better Internet infrastructure and policies. Faisalabad, Multan, and other Rawalpindi and Sialkot-like rural areas need more digital and awareness investment to get such results. These innovations should be prioritized, and the necessary resources must be called for in ways that proactively address and begin to eliminate the disparities and create access for all the populations in need of these markets' solutions.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.
Ethics approval and consent to participate.
It is approved by the department concerned. (IRBEC-LHKRI-008342/22)
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The authors declared an absence of conflict of interest.

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