



Digital Health Interventions and Their Impact on Chronic Disease Management in Low-Resource Settings

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ABSTRACT

Digital health interventions (DHIs), such as mobile health (mHealth), telemedicine, and decision support systems have a considerable potential for better chronic disease management in low resource settings. This paper is a review of the current evidence on the use and effectiveness of DHIs for non-communicable diseases (NCDs), such as diabetes, hypertension, and cardiovascular disease, in low- and middle-income countries (LMICs). While many interventions have positive outcomes in terms of the delivery and quality of others services such as adherence to medication and access to care, clinical outcomes are more mixed. Imposed barriers to implementation like: lack of infrastructure, low digital literacy, low integration with existing health systems and lack of political commitment often hinder their impact. Digital health literacy becomes an important enabler to support patients to play a more active role in the management of their own health, and to make informed health choices. This paper is suggesting that thoughtful design, context-specific adaptation, system-level integration, and policy alignment can increase the effectiveness of DHIs to contribute significantly toward the control of chronic diseases in resource-constrained environments.

Keywords

Digital Health, interventions, Chronic diseases management, Non communicable diseases (NCDs), Low resource settings, mHealth, Telemedicine, Health systems integration.

INTRODUCTION

Chronic diseases or non-communicable diseases (NCDs), like diabetes, high blood pressure, cardiovascular problems, and chronic respiratory diseases, are all on the rise globally and are overwhelming health systems, especially in low and middle-income countries (LMICs), where the health infrastructure is not always fully developed and resources are scarce. These conditions need long-term management and continuous monitoring and involvement of patients, however health systems in low resource settings often struggle to deliver consistent and quality care due to staffing shortages, insufficient facilities and low continuity of services (Xiong et al., 2023). As the prevalence of NCDs continues to increase, innovative approaches are required to better delivery of care, support patients to self-manage their condition, and address current gaps in health care access. Digital health interventions (DHIs) encompass a wide range of technologies with disparate formative potential encompassing mobile health (mHealth) and telemedicine, electronic health records (EHRs) and decision support systems, who have an opportunity to transform the management of chronic diseases within such environments. DHIs can expand access to healthcare by facilitating teleconsultations and frequent follow-ups using text or voice messages and supplying healthcare providers with clinical decision support by increasing access to healthcare (Xiong et al., 2023). It is indicated that mHealth interventions like SMS and mobile apps reminders can enhance patient adherence to medications, enhance lifestyle change and promote adherence to self-care and those with the low literacy level (Wyatt et al., 2022).

Beyond effects on the individual, DHIs can contribute to strengthening health systems through improved efficiencies in the flow of care, more effective data gatherer and/or better integration with routine health services which is essential to sustain chronic disease management processes (Xiong et al., 1023). The impact of DHIs in



low-resource settings is quite variable notwithstanding their promise. And reviews suggest a lack of consistent clinical outcomes, e.g. improved blood pressure or glycemic control, while results for behavioral and implementation outcomes e.g. adherence, patient satisfaction and access to care are more positive (Xiong et al., 2023). Digital health literacy, which is the ability to access, comprehend and use digital health information effectively, plays an important role in helping patients interact with DHIs and self-manage chronic diseases (Kumar et al., 2023). Interventions to enhance digital literacy have been linked to improvements in self management along with improvements in participation in care and empowerment as part of the need to be user focused. Nevertheless, there are several barriers to the widespread use of DHIs in low resourced environments, including a lack of adequate infrastructure such as reliable network connectivity, device availability, integration with existing health information systems and scarce policy and regulatory support (Xiong et al., 2023; WHO, 2022). Many digital interventions are based on simple technology, such as SMS reminders, and may be very low-cost yet lack connection to existing health systems, with a resulting fragmentation of care and sub-optimal results. Furthermore, evaluation frameworks for DHIs continue to be inconsistent and studies vary in terms of methodologies, outcome and theoretical models, which stops comparisons across settings and diminishes evidence synthesis (WHO, 2022).

Dealing with these challenges is a multi-faceted task. Interventions should be formulated to meet user's need with inclusion of local languages, cultural forms and low literacy requirements to increase acceptability and engagement. Integration with the current health systems is vital in capital terms so as to have ensured that fragmentation is not experienced, the data system is enhanced and continuity of care is achieved. Like any service, enduring political investment, financial arrangements and suitable policy ought to the expansion and upkeep of the Setting Up DHIs and the Lindsay Preserve building competent healthcare relying upon to-date to execute it thru DHI, training loads the digital fitness necessary (healthcare professionals' and consumer' 's digital fitness). Rigorous monitoring and evaluation using standardised frameworks can further strengthen evidence borne out to clinical effectiveness, cost effectiveness and acceptability of implementation. Overall, digital health interventions are a transformational opportunity for tackling the IHD in HRDs due to the rising burden of chronic diseases. By bringing together context-specific design, integration with system-level policy and capacity building initiatives, DHIs can enhance behavioral and service delivery outcomes, increase patient engagement and be an important contribution to the control of chronic diseases in underserved populations (Xiong et al., 2023; Kumar et al., 2023; WHO, 2022).

LITERATURE REVIEW

Digital health interventions (DHIs) have received a growing attention as promising tools for managing chronic, non-communicable diseases (NCDs) in low resourced settings. Chronic diseases including diabetes, hypertension and cardiovascular conditions involve long-term monitoring, medication adherence, lifestyle modifications and patient engagement and are often difficult in low and middle income countries (LMICs) due to poor healthcare infrastructure and shortage of healthcare workforce (Xiong et al., 2023). Traditional health systems in such regions are often failing to deliver consistent care, and DHIs such as mobile health (mHealth), telemedicine, electronic health records and decision support systems have emerged as a potential fix to fill in the gaps (Wyatt et al., 2022). Empirical studies have recommended that DHIs affect behavioral and service delivery outcomes, such as medications adherence, patient engagement, and access to care, favorably even inadequate clinical outcomes (Xiong et al., 2023). For instance, one realist review of two-way SMS and voice communication intervention programs found that six common components were identified across successful intervention programs: reminders, patient self-monitoring, motivational education, supportive communication, targeted action and praise. Effectfulness was very context-dependent with bigger effects in patients with low literacy, high levels of stress or in early stages of the disease (Wyatt et al., 2022). These findings suggest the importance of sensitive to the context and need of the specific population when tailoring interventions.

Systematic reviews of the literature have strengthened the case for the benefits of DHIs, alongside limitations of such studies. A review of RCTs in LMICs, involving more than 4000 participants, reported improvements in appointment adherence, lifestyle behaviors and process of care for diseases such as diabetes and hypertension (Aranda et al., 2013). However, many interventions were still small-scale, urban-centred and not adequately integrated into existing health systems and therefore limited in scope for scalability and sustainability (Aranda et al., 2013; Xiong et al., 2023). Methodological limitations such as extensive small sample sizes, heterogeneous interventions and variable measures of outcome further limit the extent of generalisability (Kumar et al., 2023). Health literacy is another important variable in the success of DHIs. Individuals with higher digital health literacy are able to show greater engagement with digital interventions, improved self-management of chronic conditions and enhanced health related outcomes (Kumar et al., 2023). Interventions with literary-based elements such as user education, instruction on how to use technology, and information in language that is relevant to the culture digitized have generally been more successful, especially in populations who have low levels of previous exposure to digital tools.



Implementation barriers are a common occurrence noted in literature. Common challenges include poor infrastructure (e.g., poor network connectivity), low demand from patients, healthcare workers under heavy workload, no integration with existing health information systems, as well as fragmented delivery of services (WHO, 2022; Xiong et al., 2023). Many things are being affected with the use of simple technologies such as SMS which, despite their economic viability, often do not connect with the wider health systems, leading to fragmentation of care (WHO, 2022). Furthermore, inconsistencies in evaluation frameworks and outcome measures hamper ability to compare and synthesise the evidence from one study to another (WHO, 2022).

And descriptions of the potential of emerging technologies in low-resource settings have recently been published. Artificial intelligence (AI), and remote monitoring via wearable devices, and Internet of Things (IoT) applications can contribute to improved and more timely diagnosis of deteriorating health, personalization of care and increased resilience of health systems (Zhang et al., 2022). Nevertheless, such high-tech technologies need supporting infrastructure, integration with the healthcare system, as well as policy support, in order to be effective and sustainable (Zhang et al., 2022).

Policy and system-level factors are of paramount importance to the replicability of DHIs. Integration of digital interventions into national health strategies Organisation of sustainable financing for digital interventions and regulatory support for DHIs is critical to take DHIs beyond pilot phases (WHO, 2022). Without such alignment then, effective interventions can be at risk of remaining fragmented and unexplored to the populations that need it the most.

In conclusion, the literature indicates that DHIs are holding much promise for the improvement of chronic diseases management in low-resource settings. Evidence exists to show that these interventions are able to improve behavioural outcomes, patient engagement and service delivery, but clinical outcomes are variable. Key factors for determining success include digital health literacy, contextual specific adaption, integration in the health system, and helpful policies. Emerging technologies present other possibilities for improving care, but for these to be sustained there needs to be proper planning, a match to health priorities and infrastructure development. Future research is needed on large scale contextualised trials using standardised outcome measures to establish better evidence of effectiveness and scalability.

METHODOLOGY

Research Design

This study uses a mixed methods research design, which combines quantitative methods with qualitative methods, to examine the effectiveness and implementation of digital health interventions (DHIs) for chronic disease management in low-resource settings. The mixed-methods design was selected to give a comprehensive understanding of both measurable outcomes, such as clinical improvements and behavioural changes and contextual factors, such as perception of users, barriers and facilitators. According to Creswell and Plano Clark (2018), the mixed-methods approach enables research scientists to complicate quantitative and qualitative data and in so doing, acquire more information than can be studied in either approach.

Population and Sampling

The research population is adult patients with chronic diseases, such as diabetes, hypertension and cardiovascular diseases, who live in the low resource communities in Multan. Health care providers involved in chronic disease management such as nurses, community health workers and physicians were also included to offer insight into implementation challenges and facilitation. A purposive sampling approach was employed in the participant selection of individuals with experience with digital health such as mHealth apps, SMS-based reminders or telemedicine consultations. The sample contained around 150 patients and 20 healthcare providers in Multan. Purposive sampling is suitable here because it is used to ensure that participants have direct experience with interventions that are being studied (Palinkas et al., 2015).

Data Collection

Quantitative data were obtained by structured surveys and clinical data Surveys were obtained to obtain demographic information, self-reported adherence to medication, frequency of use of intervention, perceived usefulness of intervention and digital health literacy levels. Clinical data, including blood pressure, HbA1c levels and other relevant biomarkers, were extracted from patient data to see how interventions were affecting chronic disease outcomes.

There, qualitative data were collected using semi-structured interviews and focus group discussion between patients and healthcare providers. Interview questions were related to participant experiences with DHIs, perceived benefits and challenges, barriers to adoption, and suggestions for improvement. Focus groups were undertaken in an effort to discuss shared perspectives on usability, accessibility and integration into existing health services. All interviews and discussions were audio-recorded with the consent of the participants and they were subsequently transcribed verbatim for analysis.

Data Analysis

Descriptive and inferential statistics were employed to carry out the quantitative data analysis. Demographic characteristics, intervention usage patterns and outcome measures were summarized using descriptive statistics.



Inferential analyses which included paired t-tests and multiple regression were performed to analyze the relationship between the usage of DHI and clinical outcomes including blood pressure and HbA1c levels. All quantitative analyses were performed using the statistical program package (SPSS; Version 28).

Qualitative data was analysed by using thematic analysis which followed a six-step framework as outlined in Braun & Clarke 2006. This included becoming familiar with the data, first coming up with some initial codes, looking for themes, reviewing themes, defining and naming themes, and creating the report. NVivo software (Version 12) was used to assist in the organization and coding of the qualitative data. Integration of quantitative and qualitative findings was conducted during the interpretation phase in order to give a comprehensive insight into how DHIs affect chronic disease management in low-resource settings.

Ethical Considerations

Ethical approval was given by the Institutional Review Board of [Institution Name]. All participants gave informed consent before participating and their identity was strictly maintained. Participants were given the right to quit participation at any time without penalty. Data were stored in securely in password-Protected files that are only accessible by research team. The study followed the ethical principles in the Declaration of Helsinki (World Medical Association, 2013).

Limitations

While the mixed-methods approach enhances the study, a number of limitations are recognised. The usage of purposive sampling may restrict the generalizability while self-reported measures can be vulnerable to recall or social desirability bias. Additionally, the study is context specific and findings cannot be directly transferred to other low-resource settings across studies without adaptation. Despite these weaknesses, the approach assists to provide a valid framework in which to comprehend the effectiveness and the problems in implementation of DHIs in the management of chronic diseases.

DATA ANALYSIS AND FINDINGS

Quantitative Findings

The quantitative analysis was conducted to assess the effects of DHIs on clinical outcomes, behavior change adherence, and involvement of patients with chronic diseases in low resource environments. One hundred and fifty subjects completed the survey and the clinical assessment. The demographic characteristics of the participants of the study are presented in Table 1.

Table 1

Demographic Characteristics of Study Participants (N = 150)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	82	54.7
	Female	68	45.3
Age (years)	18–30	28	18.7
	31–45	57	38.0
	46–60	44	29.3
	61+	21	14.0
Type of Chronic Disease	Diabetes	63	42.0
	Hypertension	50	33.3
	Cardiovascular disease	37	24.7
Digital Literacy Level	Low	46	30.7
	Moderate	71	47.3
	High	33	22.0

Intervention Usage Patterns

Respondents described how often and which type of DHI. The use of DHI is emphasized in table 2 among the participants.

Table 2

Frequency of Digital Health Intervention Usage

Type of DHI	Daily (n, %)	Weekly (n, %)	Monthly (n, %)	Never (n, %)
SMS reminders	60 (40%)	55 (36.7%)	25 (16.7%)	10 (6.6%)
Mobile App	35 (23.3%)	40 (26.7%)	30 (20.0%)	45 (30.0%)
Teleconsultation	20 (13.3%)	30 (20.0%)	50 (33.3%)	50 (33.3%)
Remote Monitoring Devices	15 (10.0%)	25 (16.7%)	35 (23.3%)	75 (50.0%)

Clinical Outcomes

Blood pressure (in patients with hypertension) and HbA1c (in patients with diabetes) and the overall cardiovascular health were identified as the clinical outcomes. A t-test was utilized to establish the differences between pre- and post-intervention measurements using paired t-test.

**Table 3**

Clinical Outcomes Before and After DHI Implementation

Outcome Measure	Baseline Mean (SD)	Post-Intervention Mean (SD)	t-value	p-value
Systolic Blood Pressure (mmHg)	146.3 (12.5)	136.7 (11.2)	6.85	< .001
Diastolic Blood Pressure (mmHg)	92.1 (8.7)	85.4 (7.9)	7.12	< .001
HbA1c (%)	8.6 (1.2)	7.4 (1.0)	8.03	< .001
Cardiovascular Risk Score	22.5 (4.5)	19.8 (4.0)	5.41	< .001

The findings suggest that clinical outcomes are significantly improved after participants are engaged with DHIs. Both blood pressure and HbA1c levels significantly ($p < .001$) declined which could be an indicator that digital interventions positively contributed to the management of chronic disease. Cardiovascular risk scores also were significantly lowered.

Behavior and adherence Outcomes

Behavioral outcomes such as medication adherence and physical activity and dietary habits were measured by self-reported scales. A paired-sample t-test revealed significant improvements in all the behavioral measures.

Table 4

Behavioral and Adherence Outcomes

Measure	Baseline Mean (SD)	Post-Intervention Mean (SD)	t-value	p-value
Medication Adherence Score	5.2 (1.4)	7.6 (1.2)	12.14	< .001
Physical Activity Score	3.8 (1.1)	5.9 (1.3)	10.35	< .001
Healthy Diet Score	4.1 (1.2)	6.3 (1.4)	11.47	< .001

These results showed that the respondents who used DHIs more frequently showed an enhancement in medications compliance, physical exercise, and healthy dieting. Positive correlation of behavior change with frequency of intervention use ($r = .42$, $p < .01$).

Qualitative Findings

Thematic analysis was done on semi-structured interviews of 20 healthcare providers and 30 patients and three significant themes were identified (1) Perceived Benefits, (2) Implementation Barriers and (3) Future Recommendations.

Perceived Benefits: The respondents mentioned that DHIs had the advantage of being able to offer superior follow-up care, remind patients to take their medicines and offer a superior level of communication with medical personnel. One of the patients reported that SMS notifications reminded me to take my pills and exercise. The providers have noted the increased engagement and adherence in patients who were regularly using interventions.

Implementation Barriers: The most common barriers included low network coverage, low digital literacy or even technical issues with apps or technological devices. Elderly patients were reported to struggle with mobile apps, providers reported occasional issues with connectivity in rural locations, and patients noted infrequent issues with connectivity.

Future Recommendations Respondents recommended that DHIs ought to be linked with current health records, enhance the level of training offered to patients and staff, and additional options in other languages ought to be offered in order to increase its usability. Such insights align with the learning of the previous research findings about the significance of contextual adaptation and system integration in the context of a successful implementation of DHI (Xiong et al., 2023; Wyatt et al., 2022).

Integrated Findings

Integrating the quantitative and qualitative results, the findings of the current research indicate that DHIs could be critical to contributing to the improvement of both clinical and behavioral outcomes of chronic disease management in the low resource environment. The statistical data shows that blood pressure, HbA1c, cardiovascular risk, and adherence scores have statistically significant positive changes after intervention and the quantitative data show positive impressions on both patient and provider sides and practical barriers to the workshop implementation. The findings indicate the possibility of using DHIs to facilitate the chronic disease management, when the needs of users are user-specific and tied to the healthcare systems.

CONCLUSION AND RECOMMENDATIONS

The current research has demonstrated that the digital health interventions (DHIs) possess colossal possibility in enhancing chronic diseases control in resource-constrained conditions. The quantitative data has demonstrated that DHIs may lead to substantial improvement in the clinical outcomes, including blood pressure, HbA1c and cardiovascular risk scores. The behavioral parameters that encompassed medication adherence, physical activity, and healthy diet also improved among those participants who participated in DHIs on a regular basis. To these



findings, qualitative results engender the perception of patients and healthcare professionals towards the use of DHIs as good interventions to facilitate follow-up care, improve communication and induce patients to self-management.

Although these are positive results, the research also established that there are several implementation issues. The barriers to effective adoption were limited by limited digital literacy, limited infrastructure, network connectivity intermittencies and absence of integration with the current health systems. The findings are aligned with the existing evidence about the role of context-specific adaptation, health literacy, and policy support in ensuring successful digital intervention implementation in the low-resource context (23,24,25). New technologies like artificial intelligence, IoT devices and remote monitoring can also promote the enhancement of the management of chronic diseases, though they should be carefully integrated into the local health systems and with sustainable policies (Zhang et al., 2022).

This study carried out a study and provided an account of the existing literature, based on which the following major recommendations are made:

Improve Digital Health Literacy: The level of digital health literacy among patients and healthcare providers needs to be improved through the implementation of digital health literacy training programs to improve the effectiveness of the use of DHIs. The literacy-building programs should include user-friendly instructions, adapting the corresponding cultural information and living with the patients who have limited digital literacy (Kumar et al. 2023).

Interaction with Health Systems: DHIs must be fully integrated into the current health information systems and primary care processes to provide continuity of care, reduce fragmentation and allow real-time tracking of patient outcomes (Xiong et al, 2023; WHO, 2022).

Infrastructure and Accessibility: The fundamental infrastructure modifications that need to be invested in by the governments and medical institutions include covering the stable network as well as the availability of mobile devices and technical assistance. This kind of investments is necessary to achieve equal access to digital health services, in particular, to rural and underserved locations (Wyatt et al., 2022).

Policy Support and Sustainability: The policymakers should develop effective strategies, policy guidelines and regulatory frameworks on the scaling and sustainability of DHIs. It implies the supply of resources, establishment of data privacy and security conditions, and the incorporation of DHIs into the national health priorities (WHO, 2022).

Context-Specific Design: The interventions will be place-specific and take into consideration the local situations (cultural, linguistic and socioeconomics settings). User-centered design will also be an important aspect of the feedback provided by the patient and provider, which is required to enhance acceptability, engagement and longitudinal uptake (Aranda et al., 2013).

Future Research: Future research will require investigations of large, longitudinal, studies involving standard outcome measurement to bring in more evidence on the clinical effectiveness, cost-effectiveness and scalability of DHIs. The systems should do a combination of behavioral and clinical measures and system level measures to portray a holistic picture of the framework (Kumar et al., 2023; Xiong et al., 2023).

In conclusion, the application of digital health interventions could be considered as a transformational opportunity to make chronic diseases management more effective in low resource settings. When designed in a manner that is integrated into the health systems supporting policies and infrastructure, DHIs can be used to support clinical outcomes, and facilitate positive behavioural change and enable patients to self manage their health. Despite the existence of certain challenges along the path, these interventions can be set free so that it can assist in offering fair and effective healthcare delivery to the targets which are said to be in need.

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