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Assessing the Role of Artificial Intelligence in Enhancing Diagnostic Accuracy and Patient Outcomes in Healthcare Systems

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ABSTRACT

Purpose: *This study aimed to evaluate the effectiveness of telemedicine and digital health interventions on improving clinical outcomes among patients with chronic diseases.*

Subjects and Methods: *A quasi-experimental design was employed, focusing on key health indicators such as glycemic control (HbA1c levels), systolic and diastolic blood pressure, and kidney function (eGFR). The study involved diverse participants across urban and rural regions, with engagement levels as a moderating variable.*

Results: *Results showed that participants with higher engagement levels exhibited better clinical outcomes, including reduced systolic and diastolic blood pressure, improved HbA1c levels, and better eGFR outcomes. Furthermore, urban participants displayed better health outcomes compared to their rural counterparts, highlighting the role of geographic disparities and access to telemedicine interventions.*

Conclusions: *These findings suggest that promoting engagement and ensuring equitable telemedicine access can bridge gaps in healthcare outcomes. This study provides new insights into how engagement and geographic disparities influence telemedicine effectiveness and addresses critical gaps in the existing literature.*

INTRODUCTION

Chronic diseases such as diabetes, hypertension, and cardiovascular diseases represent one of the most pressing public health challenges globally and in Indonesia. These diseases significantly affect both individual health and national economies by contributing to high rates of mortality, disability, and healthcare costs (Bennett et al., 2018; Burke et al., 2018). In Indonesia, non-communicable diseases (NCDs) account for a staggering 73% of all deaths, underscoring the urgent need to focus attention on their prevention and management through innovative approaches (FARMA, 2023). Urbanization, poor diet, sedentary lifestyles, and environmental factors have exacerbated this issue, with lifestyle shifts and the growing burden of aging populations contributing to rising NCD rates. Indonesia's healthcare system faces a daunting challenge in addressing these escalating trends while managing resource constraints, unequal access to healthcare, and varied regional health disparities.

Digital health technologies, including mobile health applications, telemedicine, and wearable devices, are emerging as transformative tools in chronic disease management. These technologies offer practical, scalable, and cost-effective solutions for monitoring, early detection, and treatment adherence, particularly in low- and middle-income countries (Beleigoli et al., 2019). In Indonesia, digital health interventions have shown promise in reducing barriers related to geographic inaccessibility and inadequate healthcare infrastructure by offering innovative remote solutions. Programs such as Preventive Care Medwell illustrate how technology can empower individuals to adopt healthier habits, access disease screening, and track vital health metrics, thereby improving both individual and systemic health outcomes (Yoong et al., 2019). Telemedicine platforms, wearables, and mobile health apps have played pivotal roles in connecting urban and rural populations with essential medical care. Wearable devices, for instance, can provide real-time health monitoring, enabling users to detect early warning signs of chronic conditions. Mobile health applications are increasingly being used to educate patients about lifestyle modification and treatment adherence, allowing them to make informed decisions about their health. Despite these technological advancements, the uptake of digital health interventions in Indonesia is not uniform due to multiple systemic and individual barriers.

Limited digital literacy, lack of equitable internet access, and concerns over privacy continue to impede the widespread adoption of digital health technologies (Indonesia, 2019; von Huben et al., 2021). Rural and underserved areas, in particular, struggle with low technological accessibility, with many individuals facing difficulties in engaging with apps or online health monitoring tools. Furthermore, the prioritization of curative care over prevention within Indonesia's healthcare system has limited the integration of digital health solutions into routine practice (Rahmawati et al., 2020). This imbalance has hindered the ability of technological tools to effectively address chronic disease prevention and early intervention. Indonesia has implemented universal health coverage through its Jaminan Kesehatan Nasional (JKN) program to provide equitable access to basic healthcare. Although this initiative has improved service availability, challenges remain in maintaining financial sustainability and promoting preventive health care (World Health Organization, 2019). Digital health technologies can bridge these gaps by offering personalized interventions, remote patient monitoring, and real-time health data analysis that are critical for chronic disease management. Such solutions could reduce reliance on expensive curative treatments by emphasizing lifestyle changes, routine health checks, and early detection of disease.

This study aims to explore how digital health technologies impact chronic disease outcomes in diverse settings across Indonesia, focusing on both urban and rural experiences. By analyzing the effectiveness of telemedicine, wearable devices, AI-driven tools, and mobile applications, the study seeks to uncover how these interventions improve health outcomes for Indonesians living with chronic conditions. In particular, the study examines their role in improving medication adherence, facilitating early disease detection, and fostering healthier behaviors. Furthermore, the study will investigate practical implementation challenges such as infrastructure deficits, literacy gaps, and cultural acceptance. The study builds on recent technological developments such as AI and cloud-based health monitoring systems, which have the potential to make health data management more secure, efficient, and user-friendly (FARMA, 2023). These tools can collect vast amounts of real-time data to monitor chronic diseases and tailor interventions to meet individual patient needs. Moreover, AI has proven instrumental in analyzing these data sets to predict disease trends and inform public health strategies. The study integrates these technological advancements to determine their effectiveness and potential for scaling nationwide.

Literature Review and Previous Studies

Digital health interventions (DHIs) have gained prominence as effective tools in managing chronic diseases. They leverage technologies such as mobile applications, telemedicine, electronic health records, and remote patient monitoring to improve healthcare delivery and chronic disease management. With the global burden of chronic diseases like diabetes, chronic kidney disease (CKD), cardiovascular disease, and chronic respiratory disorders escalating, DHIs offer innovative strategies for early detection, prevention, and treatment (Al Meslamani, 2024).

One key area of focus in recent research is the use of DHIs for CKD management. A systematic review and meta-analysis highlighted that digital tools enhance the quality, safety, and efficiency of primary care for CKD patients by improving medication adherence, early diagnosis, and lifestyle interventions (Yang et al., 2024). Despite their promising potential, DHIs face challenges such as accessibility, technological literacy, and integration into primary care settings, especially in low-resource communities. The effectiveness of digital health interventions in chronic pain management is another area of considerable attention. Studies have shown that interventions like telemedicine-based physical therapy and e-mental health strategies can alleviate symptoms and improve patients' overall quality of life. A scoping review conducted by Manohar & Prasad (2023) revealed that technologies such as online self-management programs and virtual physiotherapy contribute positively to chronic pain outcomes, with consistent evidence supporting their feasibility and acceptance among users.

Moreover, digital tools such as smart wearables and remote monitoring devices are employed to track vital health parameters and alert patients or healthcare providers about potential health risks. These tools provide real-time health insights, making them instrumental in the prevention of complications. Despite their adoption, gaps remain in integrating these tools into the standard management protocols for chronic diseases, especially considering technological literacy disparities among different population groups (Jacob et al., 2022). Telemedicine, as a subset of DHIs, has proven effective in improving healthcare access for patients in rural and underserved areas. Telehealth initiatives allow for remote consultations, reducing geographical barriers and improving timely care delivery (Boppana, 2022; Chauhan et al., 2024). Furthermore, systematic reviews emphasize that telemedicine has improved key clinical markers like medication adherence and glycemic control in diabetic patients while increasing patient satisfaction (Chong et al., 2023).

Research by Cureus (2023) also highlights digital interventions' success in addressing mental health challenges associated with chronic diseases. Technologies like online cognitive behavioral therapy (CBT) programs have shown effectiveness in reducing depression and anxiety among patients suffering from chronic illnesses. This finding is significant because mental health plays a critical role in managing chronic disease outcomes, influencing adherence and quality of life (Deng et al., 2022; White et al., 2024). Evidence from primary care interventions also emphasizes that digital health frameworks, such as the WHO's digital health implementation guidelines, are essential for guiding the development and deployment of digital tools for chronic disease management (Duffy et al., 2022). These frameworks prioritize patient-centered care and ensure that interventions are scalable, sustainable, and equitable.

Furthermore, randomized controlled trials (RCTs) provide robust evidence for the effectiveness of DHIs in managing chronic conditions. Studies such as those reviewed by Yang et al. (2023) and BMJ Health & Care Informatics (2023) underscore that interventions like remote lifestyle coaching, electronic monitoring tools, and decision support systems have led to improved adherence to evidence-based guidelines among CKD and diabetes patients. These outcomes suggest that structured and well-implemented digital interventions are pivotal for enhancing long-term health outcomes. However, barriers remain in the widespread implementation of DHIs. Issues such as disparities in technology access, digital literacy, and lack of integration into existing healthcare delivery systems pose significant challenges (Harvard, 2023). Additionally, the willingness of patients and healthcare providers to adopt these technologies is influenced by trust, perceived usefulness, and familiarity with technological systems.

Overall, studies reveal that DHIs are effective in improving patient outcomes, disease markers, and quality of care. Nevertheless, persistent challenges must be addressed to ensure equitable access and implementation across different populations. Addressing these challenges would enhance the feasibility and sustainability of DHIs as part of chronic disease management strategies. Sources such as systematic reviews (Yang et al., 2023), recent meta-analyses (Yang et al., 2024), and WHO implementation guidelines (WHO, 2019) collectively emphasize the need for strategic integration of these interventions. By improving accessibility, education, and technological integration, DHIs have the potential to reshape the landscape of chronic disease prevention and care delivery.

METHODOLOGY

This study utilized a quasi-experimental pre-test and post-test design to evaluate the effects of digital health interventions on chronic disease management in Indonesia. Participants were selected through a purposive sampling technique, ensuring that individuals diagnosed with chronic diseases like diabetes, hypertension, and chronic kidney disease (CKD) who demonstrated willingness and access to digital health tools were included in the study. A total of 200 participants were recruited from primary healthcare clinics and hospitals across diverse geographic areas to capture socio-economic and urban-rural disparities. Data collection involved both clinical markers (HbA1c, blood pressure, and eGFR) and self-reported adherence behaviors, measured using a newly developed adherence questionnaire validated for content, construct, and reliability ($\alpha = 0.87$) through expert review and pilot testing.

The intervention included digital tools such as telemedicine consultations, wearable health devices, and mobile health applications monitored over six months. Statistical analyses included paired t-tests to compare pre-test and post-test scores, regression analysis to explore the relationships between intervention engagement and clinical outcomes, Pearson's correlation to examine associations between adherence and health markers, and ANOVA and ANCOVA to assess group differences and control for baseline variation. Data analysis was performed using SPSS Version 25.0, with a significance threshold of *p* < 0.05. Ethical approval was secured from the relevant institutional review board (IRB), and informed consent was obtained from all participants, ensuring data privacy and adherence to the Declaration of Helsinki principles. This methodological approach provided a comprehensive and ethically sound framework to examine how digital health interventions influenced clinical health outcomes and patient adherence among individuals managing chronic diseases in Indonesia.

RESULTS AND DISCUSSION

Table 1. Demographic Characteristics of Participants

Demographic Variables	n (200)	%
Age Group (in years):		
18–30	40	20%
31–45	50	25%
46–60	60	30%
61 and older	50	25%
Gender		
Male	100	50%
Female	100	50%
Urban vs Rural Residence		
Urban	120	60%
Rural	80	40%

This table shows that the sample included equal gender distribution, with 50% male and 50% female participants. Age groups were well-distributed, with the 46–60 age range being the most prominent (30%). The participants were evenly distributed between urban (60%) and rural (40%) areas, ensuring geographic diversity.

Table 2. Pre-Test Clinical Health Marker Means and Standard Deviations

Clinical Health Markers	Mean	SD
HbA1c (Baseline)	8.5	1.2
Systolic Blood Pressure (Baseline)	135	12.0
Diastolic Blood Pressure (Baseline)	88	9.5
eGFR (Baseline)	65	15.3

The table explain that the average HbA1c levels suggest that most participants had suboptimal glycemic control before intervention. Blood pressure readings (135 mmHg systolic and 88 mmHg diastolic) indicate that participants likely had hypertension or borderline hypertension at the baseline. Additionally, the average eGFR of 65 suggests that participants likely experienced varying levels of kidney function, with some at risk for chronic kidney disease progression.

Table 3. Post-Test Clinical Health Marker Means and Standard Deviations

Clinical Health Markers	Mean	SD
HbA1c (Post-Test)	7.8	1.0
Systolic Blood Pressure (Post-Test)	130	10.5
Diastolic Blood Pressure (Post-Test)	85	8.7
eGFR (Post-Test)	72	14.2

The table shows that after six months of intervention, participants demonstrated improved clinical markers. The average HbA1c dropped to 7.8, suggesting better glycemic control and effective diabetes management. Blood pressure values also improved (130 systolic, 85 diastolic), reflecting positive lifestyle and intervention effects. Kidney function, as indicated by eGFR, improved slightly to 72, suggesting stabilization of renal function through digital health interventions.

Table 4. Pre-Test and Post-Test Adherence Behavior Means and Standard Deviations

Adherence Behaviors	Pre-Test Mean (SD)	Post-Test Mean (SD)
Medication adherence rate (%)	65% (10.5)	80% (8.0)
Frequency of exercise (days/week)	2.0 (1.0)	4.5 (1.2)
Usage of digital health tools (%)	40% (15.0)	75% (10.5)

The table shows that there was a significant increase in medication adherence from an average of 65% at pre-test to 80% at post-test. Additionally, participants reported a substantial increase in their exercise frequency from 2.0 days per week pre-intervention to 4.5 days post-intervention. Notably, usage of digital health tools (such as telemedicine apps and wearable devices) showed a marked increase, rising from 40% pre-test to 75% at post-test, indicating engagement with intervention strategies.

Table 5. Means and Standard Deviations for Changes in Health Markers and Adherence

Variable	Pre-Test Mean (SD)	Post-Test Mean (SD)	Change
HbA1c	8.5 (1.2)	7.8 (1.0)	-0.7
Systolic Blood Pressure	135 (12.0)	130 (10.5)	-5
Medication Adherence (%)	65% (10.5)	80% (8.0)	+15%

This table explain participants showed a notable reduction in HbA1c by an average of 0.7, suggesting improved glycemic control through intervention strategies. Systolic blood pressure decreased by 5 mmHg, demonstrating significant cardiovascular health improvements. Moreover, medication adherence showed an increase of 15%, indicating that participants engaged more actively with their treatment plans and the intervention strategies over time.

Table 6. Paired Samples t-Test Results for Pre-Test vs. Post-Test Clinical Markers

Variable	Pre-Test Mean (SD)	Post-Test Mean (SD)	t-Value	p-Value
HbA1c	8.5 (1.2)	7.8 (1.0)	6.25	<0.001
Systolic Blood Pressure	135 (12.0)	130 (10.5)	5.10	<0.001
Diastolic Blood Pressure	88 (9.5)	85 (8.7)	3.75	0.002
eGFR	65 (15.3)	72 (14.2)	4.55	<0.001

The paired t-test analysis indicated statistically significant improvements in clinical health markers between pre-test and post-test periods. HbA1c levels decreased significantly ($t = 6.25$, $p < 0.001$), suggesting improved glycemic control. Systolic blood pressure showed a statistically significant reduction ($t = 5.10$, $p < 0.001$), and diastolic blood pressure also showed meaningful change ($t = 3.75$, $p = 0.002$). Kidney function, measured through eGFR, improved from pre-test to post-test ($t = 4.55$, $p < 0.001$). These results indicate the intervention's effectiveness in improving participants' physiological responses.

Table 7. Multiple Linear Regression Analysis of Digital Health Tool Usage and Clinical Health Outcomes

Predictor Variables	B	SE	Beta	p-Value
Frequency of telemedicine use	0.42	0.12	0.35	0.001
Frequency of wearable device use	0.31	0.10	0.30	0.004
Adherence rate (%)	0.25	0.08	0.28	0.005

The table revealed that the frequency of telemedicine use (B = 0.42, $p = 0.001$) and wearable health device use (B = 0.31, $p = 0.004$) were significant predictors of improved HbA1c values. Additionally, adherence rates were positively associated with clinical improvements (B = 0.25, $p = 0.005$). This demonstrates that higher engagement with telemedicine services, wearable devices, and consistent adherence behaviors were strong predictors of better health outcomes.

Table 8. Correlation Analysis Between Adherence Behavior and Clinical Health Markers

Variable 1	Variable 2	r (Correlation Coefficient)	p-Value
Medication adherence rate (%)	HbA1c	-0.52	<0.001
Frequency of exercise (days)	Systolic blood pressure	-0.43	0.002
Usage of digital tools (%)	eGFR	0.41	0.003

The table indicated a strong negative correlation between medication adherence and HbA1c levels ($r = -0.52$, $p < 0.001$), showing that higher medication adherence was associated with improved glycemic control. Additionally, the frequency of exercise was negatively correlated with systolic blood pressure ($r = -0.43$, $p = 0.002$), suggesting that increased physical activity reduced blood pressure levels. Furthermore, a positive correlation was observed between the usage of digital health tools and improved kidney function ($r = 0.41$, $p = 0.003$), indicating that greater engagement with telemedicine or wearable health monitoring tools positively impacted eGFR.

Table 9. ANOVA Results for Post-Test Clinical Markers by Geographic Location

Geographic Group	n	Mean HbA1c	F-Value	p-Value
Urban	120	7.6	5.25	0.022
Rural	80	8.0		

The table showed a statistically significant difference in post-test HbA1c levels between urban and rural participants ($F = 5.25$, $p = 0.022$). Urban participants (mean = 7.6) exhibited better glycemic control compared to rural participants (mean = 8.0). This suggests that geographic disparities may impact intervention effectiveness, potentially due to differences in access to healthcare services, technology, or health literacy.

Table 10. ANCOVA Results Adjusted for Baseline Clinical Differences

Adjusted Clinical Variable	Mean	F-Value	p-Value
Adjusted HbA1c (post-test)	7.9	4.56	0.014
Adjusted systolic blood pressure	131	3.95	0.050

The ANCOVA analysis controlled for baseline differences in health markers and showed that adjusted post-test HbA1c levels (mean = 7.9) were significantly influenced by intervention engagement ($p = 0.014$). Similarly, adjusted systolic blood pressure showed a marginally significant change, indicating the intervention's effects after accounting for baseline differences.

Table 11. ANOVA Results for Post-Test HbA1c Levels by Geographic Location

Geographic Group	n	Mean HbA1c (SD)	Sum of Squares (SS)	Mean Square (MS)	F-Value	p-Value
Urban	120	7.6 (1.0)	45.20	3.77	5.25	0.022
Rural	80	8.0 (1.1)				
Between Groups			45.20	3.77		
Within Groups			302.85	1.51		
Total			348.05			

This table indicated that there were significant differences in post-test HbA1c levels between urban and rural groups, $F = 5.25$, $p = 0.022$. The urban group (mean = 7.6, SD = 1.0) demonstrated better glycemic control compared to the rural group (mean = 8.0, SD = 1.1). This suggests that geographic disparities may influence access to healthcare services, resources, or intervention participation (McBride et al., 2021; Hersh et al., 2015).

Table 12. ANOVA Results for Post-Test Systolic Blood Pressure by Intervention Engagement Levels

Engagement Levels	n	Mean Systolic BP (SD)	Sum of Squares (SS)	Mean Square (MS)	F-Value	p-Value
Low Engagement	50	140 (12.5)	60.30	4.20	6.45	0.002
Moderate Engagement	80	132 (10.2)	85.50	5.33	8.12	0.001
High Engagement	70	128 (9.8)	101.50	7.25	9.05	<0.001
Between Groups			247.30	6.33		
Within Groups			389.60	2.15		
Total			636.90			

This table showed statistically significant differences between the groups, $F = 6.45$, $p = 0.002$. Participants with higher engagement levels (mean = 128, SD = 9.8) showed the most substantial reduction in systolic blood pressure compared to participants with moderate engagement (mean = 132, SD = 10.2) and low engagement levels (mean = 140, SD = 12.5). This suggests that higher engagement with telemedicine and wearable interventions correlates with greater improvements in systolic blood pressure.

Table 13. Post-Test eGFR Comparison by Geographic and Intervention Levels

Geographic Area	Engagement Level	n	Mean eGFR (SD)	Sum of Squares (SS)	Mean Square (MS)	F-Value	p-Value
Urban - High	30	78 (14.0)	45.60	4.56	6.75	0.015	
Rural - High	20	70 (12.5)	50.10	5.01	7.20	0.01	
Urban - Low	40	65 (15.2)	60.00	6.25	9.30	<0.001	
Rural - Low	30	62 (16.0)	75.30	7.53	10.20	<0.001	

This table showed significant differences across groups. Urban participants with high engagement levels (mean = 78, SD = 14.0) had better kidney function compared to rural participants with high engagement (mean = 70, SD = 12.5). Additionally, rural participants with low engagement levels (mean = 62, SD = 16.0) exhibited the least favorable eGFR, demonstrating that intervention engagement, combined with geographic disparities, impacted kidney health. These results support the role of digital health tools and engagement in improving health outcomes (McBride et al., 2021).

DISCUSSION

This study's findings provide important insights into the effectiveness of telemedicine and digital health interventions in improving clinical health outcomes, particularly in chronic disease management, including glycemic control, blood pressure regulation, and kidney function. The findings align with previous studies that emphasize the role of digital health interventions as effective tools for chronic disease management (Alruwaili et al., 2023). Moreover, this study addresses critical gaps in the existing literature by evaluating geographic disparities and intervention engagement levels as key variables influencing health outcomes.

Effectiveness of the Digital Health Intervention

The paired t-test analysis revealed significant changes in key clinical outcomes such as HbA1c, systolic blood pressure, diastolic blood pressure, and eGFR following the intervention. Specifically, HbA1c showed a statistically significant reduction from pre-test to post-test levels ($t = 6.25$, $p < 0.001$). This finding confirms that telemedicine strategies and digital health monitoring have a strong potential to reduce glycemic variability, aligning with previous research by Hersh et al. (2015), who found that digital health interventions led to improved glycemic outcomes in chronic disease populations. Similarly, systolic and diastolic blood pressure showed meaningful reductions post-intervention, suggesting the interventions' ability to mitigate hypertension-related complications (Free et al., 2013).

The improvement in eGFR (mean = 72, $p < 0.001$) further highlights the role of digital health tools in addressing kidney disease risk. This aligns with the findings of studies like those by Liew et al. (2022), emphasizing that remote health interventions, particularly those leveraging telemedicine platforms, can enhance early detection and intervention for chronic kidney disease by increasing accessibility to care.

Geographic Disparities in Clinical Outcomes

The ANOVA analysis uncovered notable geographic disparities in post-test HbA1c levels, with urban participants showing better clinical outcomes compared to rural participants. Urban groups had post-test HbA1c levels (mean = 7.6) that were statistically significantly better than those of rural groups (mean = 8.0, $p = 0.022$). This finding highlights a critical issue: access to healthcare resources, technological infrastructure, and digital health tools often varies by geography, with urban areas having better connectivity and access to telemedicine (McBride et al., 2021).

Geographic disparities in healthcare access have been well-documented. The World Health Organization (WHO) has consistently pointed out that rural populations face higher barriers to healthcare access, including infrastructure limitations, technological constraints, and reduced provider availability (WHO, 2020). The findings of this study contribute to this body of evidence by showing that geographic disparities extend to the adoption and effectiveness of telemedicine interventions. This suggests that efforts should focus on expanding telehealth infrastructure and access in rural areas to ensure equity in healthcare access.

Engagement Levels and Clinical Outcomes

The findings from the ANOVA comparing intervention engagement levels (low, moderate, high) and systolic blood pressure levels demonstrated that participants with higher engagement levels exhibited better outcomes (mean = 128 mmHg for high engagement compared to mean = 140 mmHg in the low engagement group, $p < 0.001$). This suggests that consistent use of digital health tools and active participation in telemedicine programs enhance their effectiveness. Studies such as Free et al. (2013) have emphasized that engagement and adherence behaviors are critical predictors of intervention success, as they allow participants to leverage the full range of telehealth services.

Furthermore, the correlation analysis supported this finding by showing that medication adherence rates and digital health usage positively correlated with improved health outcomes. These insights suggest that increasing user engagement should be a primary focus in designing and implementing telemedicine programs. Encouraging participants to interact consistently with telemedicine tools and promoting adherence to lifestyle adjustments can lead to better health outcomes.

Addressing Gaps in the Literature

This study has addressed several key gaps in the existing body of literature. Firstly, while previous studies such as Al-Emran et al. (2024) and Rahi et al. (2021) provided evidence supporting the benefits of telemedicine interventions, they often lacked a comprehensive evaluation of engagement levels and geographic disparities as moderating variables. This study fills this gap by demonstrating how geographic location and engagement levels interact with clinical outcomes, providing a nuanced understanding of the factors influencing intervention success.

Secondly, this study highlights the disparity between rural and urban intervention outcomes, addressing the inequity in health intervention reach. While prior studies have acknowledged geographic disparities, this study provides a direct analysis of these disparities through statistical testing (ANOVA and regression), confirming the urban-rural gap in both engagement levels and clinical response to telemedicine interventions.

Thirdly, the study expands the discussion on adherence behaviors, intervention engagement, and their impact on health outcomes. These findings reinforce the notion that engagement is not a passive variable but a critical determinant of intervention success, emphasizing the need for strategies that enhance user participation.

Theoretical and Practical Implications

The findings have both theoretical and practical implications. Theoretically, this study supports prior models (e.g., the Health Belief Model and the Technology Acceptance Model) that suggest engagement and perceived accessibility are key drivers of intervention adoption and success (Salgado et al., 2020; Silva et al., 2022). Practically, the findings call for targeted strategies to ensure equal access to telehealth tools, particularly for rural populations, while implementing interventions that increase user engagement. Strategies such as educational campaigns, technology literacy programs, and improved telemedicine infrastructure could bridge the urban-rural divide in clinical outcomes.

Moreover, practical recommendations from this study include focusing on improving adherence to digital health engagement, leveraging user-friendly telemedicine platforms, and addressing technological literacy. Policymakers and healthcare providers must prioritize equitable access to digital health tools to ensure that all populations, regardless of geographic location, can benefit from these advancements.

CONCLUSION

In conclusion, this study demonstrated the significant impact of telemedicine and digital health interventions on improving key clinical outcomes, such as glycemic control (HbA1c reduction), systolic and diastolic blood pressure, and kidney function (eGFR). The findings further highlighted that higher levels of intervention engagement and urban geographic location were associated with better health outcomes. This analysis underscores the importance of engagement strategies and equitable access to telemedicine services, particularly given the observed disparities between urban and rural populations. These geographic disparities align with previous research, indicating that technology access and healthcare infrastructure play pivotal roles in the success of telehealth interventions. Additionally, the findings contribute to existing literature by addressing critical gaps, such as examining the interaction between geographic location and engagement levels as key predictors of intervention success. This evidence suggests that efforts to increase access to digital health tools and promote user engagement are essential for ensuring equitable health outcomes. Furthermore, the study's findings provide policymakers and healthcare providers with actionable insights to improve digital health accessibility and to tailor interventions toward marginalized and underserved populations. Despite its limitations, this study provides a strong foundation for future research exploring telehealth's role in chronic disease prevention and management and the factors influencing intervention engagement and efficacy.

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