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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

The following table presents the demographic characteristics of the study participants, including age, gender, and residence. This information is important for understanding the context of the population involved and ensuring that subsequent analyses take into account the diversity of respondents' backgrounds.

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%

Demographic data indicate that the participants were fairly gender balanced, allowing for unbiased analysis of any one group. The diverse age distribution reflects the involvement of participants from different life stages, providing a broader picture of the diversity of their experiences and needs. Furthermore, the proportional representation of urban and rural areas indicates variations in environmental context, which may influence patterns of access to and

experiences with healthcare. Overall, this distribution indicates that the sample has sufficient diversity to support a more comprehensive analysis.

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

Preliminary findings indicate that the participants' clinical condition before the intervention was at a level that required attention, particularly related to suboptimal blood sugar management. Recorded blood pressure also indicated a tendency toward hypertension, which can increase the risk of cardiovascular complications. Furthermore, the participants' kidney function was within a range that suggests monitoring is necessary, as some individuals may be in the early stages of kidney decline. Overall, this baseline health profile underscores the importance of intervention to prevent the progression of chronic conditions.

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

Post-intervention results showed an improvement in the participants' overall clinical condition. Blood sugar management appeared to improve, reflecting the effectiveness of the measures implemented during the monitoring period. Participants' blood pressure also showed improvement, indicating a positive response to both health behavior changes and intervention support. Furthermore, kidney function appeared to improve, indicating that the condition had stabilized or even improved compared to baseline. These findings generally demonstrate that the intervention had a positive impact on key health indicators.

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)

Comparisons of pre- and post-intervention results showed consistent improvements in various participant adherence behaviors. Medication use became more regular, indicating that participants were increasingly adhering to the recommended treatment regimen. Physical activity also increased, reflecting healthier lifestyle changes. Furthermore, the use of digital health technology increased significantly, indicating that participants were becoming more familiar with and accepting the use of devices or apps as part of their health management. Overall, these findings indicate that the intervention was able to drive positive changes in key health behaviors.

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%

Changes seen in pre- and post-test results indicate consistent health improvements among participants. Blood glucose management appeared to improve after the intervention, indicating

that the strategies provided were helping participants more effectively manage their condition. Blood pressure also showed an improving trend, reflecting the intervention's positive impact on cardiovascular health. Furthermore, medication adherence behaviors significantly improved, indicating that participants were increasingly committed to following the recommended treatment plan. Overall, these findings underscore the intervention's effectiveness in driving positive changes in both clinical indicators and health behaviors.

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

Paired t-test results indicated significant changes in all health indicators after the intervention. Each clinical variable showed a statistically significant difference between baseline and post-intervention levels, indicating that participants experienced consistent health improvements. Decreased blood glucose levels, improved blood pressure, and improved kidney function confirmed that the intervention approach had a positive impact on participants' physiological responses. Overall, these findings confirm that the program was effective in promoting clinical health improvements.

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 results of the regression analysis showed that the use of digital health services contributed significantly to improving participants' clinical conditions. More frequent use of telemedicine was associated with better health outcomes, as was engagement with health monitoring devices. Furthermore, adherence to treatment plans was also shown to play a significant role in supporting health improvements. Overall, these findings confirm that the combination of health technology use and adherence behaviors has a strong influence on more positive clinical 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

Correlation analysis results indicate a significant relationship between adherence behavior and clinical health indicators. Medication adherence patterns appear to be associated with improved glycemic control, suggesting that consistency in following a therapy regimen positively impacts blood sugar stability. More regular physical activity also appears to support cardiovascular health, particularly in helping to maintain better blood pressure control. Furthermore, the use of health technology such as digital apps or monitoring devices is associated with improved kidney function, suggesting that digital support can strengthen overall health management.

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		

ANOVA results showed significant differences in post-intervention measurement outcomes based on geographic location. This finding indicates that participants in urban areas tended to achieve better glycemic management outcomes than those living in rural areas. This difference may reflect variations in access to healthcare services, availability of supporting facilities, use of health technology, and unequal levels of health literacy across the two regions. These findings underscore the importance of considering geographic context when designing health interventions to ensure a more equitable impact.

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

ANCOVA results showed that after controlling for differences in baseline conditions, the intervention still had a significant impact on participants' health indicators. Adjusted values for glycemic parameters indicated that participation in the intervention contributed to improvements in overall metabolic control. Meanwhile, changes in systolic blood pressure showed a trend toward improved cardiovascular health, although the effect was closer to the borderline of significance. Overall, these findings confirm that the intervention had a positive impact even after accounting for individual variations in baseline clinical conditions.

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			

ANOVA results showed significant differences in post-intervention glycemic control outcomes between participants living in urban and rural areas. These findings suggest that geographic location may influence intervention effectiveness, possibly through variations in the availability of healthcare services, ease of access to supportive resources, and levels of participation in health programs. These differences in environmental context may contribute to disparities in health outcomes, which should be considered when planning more inclusive interventions.

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			

ANOVA results showed a clear difference in post-intervention systolic blood pressure based on participant engagement levels. Participants who more actively utilized telemedicine services and digital health tools tended to achieve better cardiovascular outcomes than those with lower engagement levels. These findings confirm that more intensive participation in digital

interventions plays a crucial role in supporting blood pressure management and increasing the effectiveness of health programs.

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 study demonstrated significant differences between groups based on geographic location and level of engagement in the intervention. Participants living in urban areas with high levels of engagement appeared to experience greater kidney health benefits than other groups. Conversely, participants from rural areas with low levels of engagement showed the least favorable outcomes. This pattern suggests that the combination of geographic context and level of engagement with digital interventions influences kidney health outcomes. These findings strengthen evidence that active use and engagement in digital health tools can contribute to improved 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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