

EFFECTIVENESS OF A NURSE-LED DIGITAL INTERVENTION FOR IMPROVING ANTIRETROVIRAL THERAPY ADHERENCE IN HUMAN IMMUNODEFICIENCY VIRUS

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ABSTRACT

Objective: To examine the effectiveness of the HIV Integrated Visual Interface (HIVI) in improving antiretroviral therapy (ART) adherence among people living with HIV. **Methods:** A quasi-experimental pretest–posttest control group study was conducted at a private hospital in Jakarta, Indonesia. Eighty participants were recruited using purposive sampling and non-randomly allocated to intervention (n = 40) and control (n = 40) groups. Adherence was measured using the Morisky Medication Adherence Scale (MMAS-8), alongside questionnaires assessing knowledge and family support. The intervention group received HIVI for four weeks, while the control group received standard care. Data were analyzed using paired and independent t-tests and a General Linear Model (GLM). **Results:** ART adherence increased significantly in the intervention group (3.95 to 6.05), while the control group showed minimal change (4.00 to 4.05). Significant improvement was observed in the intervention group ($p < 0.001$), with no significant change in the control group ($p = 0.160$). Post-intervention differences between groups were significant ($p < 0.001$). Knowledge ($p = 0.004$) and family support ($p = 0.020$) were significant predictors of adherence. **Discussion:** The findings indicate that digital-based educational interventions combined with psychosocial reinforcement may enhance medication adherence by improving patient understanding, motivation, and engagement in long-term HIV treatment management. **Conclusion:** HIVI effectively improved ART adherence by strengthening educational and psychosocial support. The findings support HIVI as a scalable nurse-led digital intervention for improving treatment adherence among people living with HIV.

Keywords: antiretroviral therapy adherence, digital health, Human Immunodeficiency Virus, mobile health, nursing intervention.

INTRODUCTION

Human Immunodeficiency Virus (HIV) remains a major global public health concern and continues to pose a significant challenge to healthcare systems worldwide. HIV infection targets the human immune system, particularly CD4 lymphocytes, leading to progressive immune deterioration and potentially advancing to Acquired Immunodeficiency Syndrome (AIDS) if not properly managed (UNAIDS, 2024; Aksak-Waş *et al.*, 2022). Although HIV is not yet curable, antiretroviral therapy (ART) has been proven highly effective in suppressing viral replication, increasing CD4 cell counts, prolonging life expectancy, and reducing the risk of transmission when taken consistently (World Health Organization, 2024; Fan *et al.*, 2023).

The effectiveness of ART is critically dependent on patient adherence, with optimal adherence commonly defined as at least 95% (Tandon *et al.*, 2019; World Health Organization, 2024). However, adherence among people living with HIV remains suboptimal, particularly in developing countries. In Indonesia, adherence rates have been reported to range between 40% and 70%, falling below national targets and contributing to increased viral load, decreased CD4 counts, drug resistance, and treatment failure (Kementerian Kesehatan Republik Indonesia, 2023; Suryana, Suharsono, & Antara, 2019).

Non-adherence to ART is a multifactorial issue influenced by individual, social, and treatment-related factors, including knowledge, family support, medication side effects, psychological conditions, social stigma, and daily life demands. Adults living with HIV often experience greater adherence challenges due to work-related responsibilities, fatigue, and psychosocial stress. At the same time, this population demonstrates a strong capacity to engage with and benefit from technology-based

interventions (Nabunya, Samuel, & Ssewamala Bahar, 2023).

Various strategies, such as counseling, family support, and community-based interventions, have been implemented to improve adherence. Nevertheless, these approaches have not consistently achieved optimal outcomes, as reflected in persistent rates of loss to follow-up. With advances in information technology, mobile health (mHealth) has emerged as a promising approach to support adherence in chronic disease management. Evidence from multiple settings indicates that digital applications incorporating medication reminders and health education can improve adherence, particularly in the short term (Osei & Mashamba-Thompson, 2021; Mehra *et al.*, 2021). However, in Indonesia, the development and evaluation of digital interventions specifically targeting ART adherence remain limited. Existing applications largely focus on other conditions, such as tuberculosis and non-communicable diseases, highlighting a gap in HIV-specific digital health innovations (Setyani, Indrawati, & Nurtyas, 2025).

In addition, the selection of the study setting was justified by its relevance to the research problem. The study was conducted at a private referral healthcare facility in Jakarta, Indonesia, providing outpatient HIV services, including antiretroviral therapy management, adherence counseling, laboratory monitoring, and long-term follow-up care for people living with HIV. The facility serves a stable population of patients receiving continuous ART, making it an appropriate setting for evaluating interventions aimed at improving medication adherence.

Despite the availability of routine counseling and clinical follow-up services, challenges related to medication adherence, including forgetfulness, limited patient

engagement, and variability in psychosocial support, remained evident in clinical practice. Furthermore, the widespread use of smartphones among patients in this setting provided a feasible platform for implementing digital health interventions. These contextual factors supported the need to evaluate a technology-based adherence intervention within this clinical environment.

To address this gap, the HIV Integrated Visual Interface (HIVI) application was developed by the research team as a technology-based intervention integrating medication reminders, adherence monitoring, health education, and communication with healthcare providers. This intervention was grounded in Sister Callista Roy's Adaptation Model (Harris, 2021), which conceptualizes individuals as adaptive systems responding to internal and external stimuli through biological, cognitive, and social processes. Recent evidence supports the use of Roy's Adaptation Model as a theoretical framework for nursing interventions aimed at improving adaptation, self-management, psychosocial adjustment, and treatment adherence among patients with chronic conditions (Demirel & Kılıç, 2024; Wang *et al.*, 2020). Within this framework, the HIVI application was designed to function as a contextual stimulus that facilitates adaptive responses through medication reminders, adherence monitoring, health education, and communication with healthcare providers, particularly in sustaining medication adherence among people living with HIV (Demirel & Kılıç, 2024; Chen, 2025).

Given the ongoing challenges in achieving optimal ART adherence and the limited availability of context-specific digital interventions in Indonesia, there is a clear need for innovative, evidence-based approaches. Therefore, this study aimed to examine the effectiveness of HIVI in improving medication

adherence among people living with HIV in a clinical setting in Indonesia.

METHODS

This study employed a quasi-experimental design using a pretest-posttest control group approach. This design enabled comparison of changes in adherence outcomes between intervention and control groups over time in a real-world clinical setting where randomization was not feasible. The reporting of this study follows the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) guidelines (Des Jarlais *et al.*, 2004).

The study was conducted at a private referral hospital in Jakarta, Indonesia, that provides comprehensive HIV care services, including long-term antiretroviral therapy (ART) management. The study population comprised adult people living with HIV who were receiving ART at the study site. The sample size was calculated using G*Power version 3.1 for paired comparisons, with a significance level (α) of 0.05, statistical power of 0.80, and a medium effect size (0.50), resulting in a minimum requirement of 27 participants. To increase statistical robustness and account for potential attrition, a total of 80 participants were recruited, consisting of 40 participants in the intervention group and 40 in the control group.

Purposive sampling was applied to ensure that participants met predefined clinical and technological criteria relevant to the intervention. Participants were allocated to intervention and control groups using a non-randomized approach based on clinical scheduling and participant availability, as randomization was not feasible in this setting.

Participants were included if they (1) were diagnosed with HIV, (2) were aged 18 years or older, (3) had been receiving ART for

at least three months to ensure stable treatment engagement, (4) were able to use a smartphone, and (5) provided informed consent. This study required participants to own an Android-based smartphone with sufficient storage capacity and internet access. Exclusion criteria included (1) severe cognitive impairment, (2) critical illness requiring intensive care, and (3) conditions that could prevent participation in the intervention procedures (e.g., inability to use a mobile application at baseline).

Data were collected using structured questionnaires. Sociodemographic and clinical characteristics included age, sex, education, occupation included age, sex, education level, employment status, CD4 count, knowledge, family support, and medication side effects. These data were obtained from patients' medical records and confirmed through participant self-report at baseline.

Medication adherence was assessed using the 8-item Morisky Medication Adherence Scale (MMAS-8), a widely used self-report instrument for evaluating long-term medication adherence (Morisky *et al.*, 2008). The MMAS-8 consists of eight items, including seven dichotomous (yes/no) questions and one item with a Likert-type response. Item 5 is positively worded, while the remaining items are negatively worded. Scoring is performed by assigning values of 1 or 0 based on response patterns, with total scores ranging from 0 to 8. Adherence levels are categorized as low (<6), medium (6 to <8), and high (8).

This study used an Indonesian-adapted version of the MMAS-8, which has previously been applied among people living with HIV in Indonesia (Huda *et al.*, 2022). The original English version of the MMAS-8 demonstrated good reliability and validity in HIV-related research, with values ranging from 0.79 to 0.83 (Chekole *et al.*, 2025). Meanwhile, the Indonesian-adapted version also demonstrated

acceptable reliability, with a value of 0.81, indicating good internal consistency for measuring medication adherence among Indonesian patients (Amirudin *et al.*, 2026).

Knowledge regarding HIV and antiretroviral therapy was measured using a 10-item questionnaire adapted from Awanis, Rahman, & Abdullah (2024). The instrument assesses understanding of ARV therapy, including definition, indications, and potential side effects of improper use. Similar assessments have been widely used in HIV studies, which demonstrate that knowledge of antiretroviral therapy is an important factor associated with medication adherence among people living with HIV (Nguyen, Nguyen, & Thach, 2021). Items were measured using a Guttman scale (true/false), with total scores ranging from 0 to 10, where higher scores indicate better knowledge.

Family support was assessed using a 10-item Likert-scale questionnaire adapted from Andriani, Rika, & Sandhita (2014). The instrument evaluates emotional, informational, instrumental, and appraisal support received by patients during ART. Recent studies have confirmed that family and social support are significantly associated with ARV adherence among people living with HIV; patients receiving adequate support are more likely to maintain treatment adherence and reduce the risk of loss to follow-up (Arizwansyah, Hermawan, & Sary, 2023; Kristia *et al.*, 2025). Response options ranged from 1 (never) to 4 (always), with total scores ranging from 10 to 40, where higher scores reflect greater perceived family support.

Prior to the main study, all instruments underwent validity and reliability testing in a pilot study conducted between October and November 2025 involving 30 respondents recruited from a healthcare facility with characteristics similar to the study population.

Validity testing showed that all questionnaire items had corrected item-total correlation coefficients exceeding the critical value ($r > 0.361$), indicating acceptable construct validity. Reliability analysis was conducted separately for each questionnaire. Coefficients were 0.980 for the adherence questionnaire, 0.980 for the knowledge questionnaire, and 0.922 for the family support questionnaire, indicating high internal consistency. Examination of corrected item-total correlations showed that all items contributed adequately to their respective constructs. The relatively high values may reflect similarity among items measuring closely related behavioral and psychosocial domains.

The HIV Integrated Visual Interface (HIVI) was developed between August and September 2025 through collaboration between nursing researchers, HIV clinicians, and digital health developers. The intervention was conceptually informed by Roy's Adaptation Model, which views individuals as adaptive systems who respond to internal and external stimuli through physiological, self-concept, role function, and interdependence modes (Elsalous *et al.*, 2024; Msosa, 2023; Purwati *et al.*, 2025; Wang *et al.*, 2020). In this study, the HIVI application functioned as a contextual stimulus designed to support adaptive responses, particularly in maintaining consistent antiretroviral therapy (ART) adherence.

The HIV Integrated Visual Interface (HIVI) application was developed as an Android-based mobile health application using the Agile development model. The Agile model was selected because it allows iterative development, continuous feedback, and progressive refinement based on user needs. The development process included needs assessment, interface design, feature development, usability testing, and application refinement. HIVI was specifically designed to

support antiretroviral therapy (ART) adherence through medication reminders, adherence monitoring, structured educational content, and communication support. The application has an installation size of approximately 73 MB, which was considered manageable for installation on most Android smartphones. Stable internet access was required to support optimum application functionality.

Prior to enrollment, participants' smartphones were assessed to ensure compatibility with the application. HIVI was distributed via a secure installation link, and participants received a brief orientation session on how to download, install, and use the application. Technical support was provided throughout the study to address any issues related to installation or functionality.

HIVI integrates several core features, including medication reminders, real-time medication logging, structured educational content, and bidirectional communication with healthcare providers. These components were designed to address key barriers to adherence, such as forgetfulness, limited knowledge, and lack of ongoing support, by reinforcing treatment routines and facilitating continuous engagement.

The educational content within HIVI was developed by the research team based on current HIV treatment guidelines issued by the World Health Organization and the Indonesian Ministry of Health (World Health Organization, 2024; Kementerian Kesehatan Republik Indonesia, 2023). The content covered four main domains: (1) basic understanding of HIV and ART, (2) the importance of adherence, (3) management of medication side effects, and (4) the role of family and social support. Content development involved drafting, expert review, and iterative revision to ensure clinical accuracy and contextual relevance.

Content validity of the educational materials was evaluated in September 2025 by a panel of three experts in HIV nursing, clinical practice, and digital health. The evaluation focused on relevance, clarity, accuracy, and cultural appropriateness of the educational content embedded within the application. The Content Validity Index (CVI) for the educational component of the intervention exceeded 0.80, indicating acceptable validity. Revisions were made based on expert feedback to improve clarity, usability, and user engagement.

Educational content was delivered automatically through the application in a structured and progressive manner over a four-week period. Participants accessed the content independently via the application, while reinforcement and clarification were provided by the research team when needed through the in-app communication feature.

Following expert validation, usability testing was conducted between September and October 2025 with 10 participants who had characteristics similar to the target population. This phase evaluated system functionality, navigation, clarity of instructions, and overall user experience. Feedback from usability testing led to minor refinements in interface design, navigation flow, and instructional features to improve accessibility.

Participants in the intervention group were instructed to engage with the application daily for four weeks. Intervention fidelity was ensured through weekly monitoring of application usage logs, including frequency of access and medication logging. The intervention was supervised by two trained nursing staff who monitored participant engagement, provided technical assistance, and offered adherence support throughout the study period. Participants in the control group received standard care, including routine clinical follow-up and adherence counseling,

in accordance with institutional protocols at the study site.

Participants were allocated to the intervention and control groups using a non-randomized approach based on purposive sampling and feasibility considerations within the clinical setting. Eligible participants were consecutively recruited and assigned in a parallel-group design to either the intervention group, which received the HIV Integrated Visual Interface (HIVI) intervention, or the control group, which received standard care.

To minimize selection bias, identical inclusion and exclusion criteria and standardized recruitment procedures were applied across both groups. Baseline equivalence between groups was assessed using homogeneity tests prior to the intervention.

Baseline data (pretest) collection was conducted in December 2025 from both groups prior to the intervention, including adherence, knowledge, and family support. The intervention group then received access to the HIVI application, while the control group continued with standard care. To support participant retention and intervention fidelity, weekly follow-up communication and monitoring were conducted by trained nursing staff throughout the four-week intervention period. Participants also received guidance regarding application use and ongoing support when technical or adherence-related issues were identified. After four weeks, posttest data were collected using the same instruments. To ensure ethical fairness, participants in the control group were granted access to the application after completion of the study. Participants who discontinued participation after enrollment were defined as loss to follow-up.

Data were analyzed using statistical software. Descriptive statistics were used to summarize participant characteristics. Paired t-tests were conducted to evaluate within-group

changes, while independent t-tests were used to compare differences between the intervention and control groups.

A General Linear Model (GLM) was performed to examine the effect of the intervention while controlling for potential confounding variables, including knowledge, family support, medication side effects, and CD4 count. Statistical significance was established at $p < 0.05$. Prior to GLM analysis, model assumptions including linearity, homoscedasticity, normality of residuals, and multicollinearity were assessed, and no substantial violations were identified. Effect sizes were reported using partial eta squared (partial η^2).

Several strategies were implemented to minimize bias. Baseline equivalence between groups was assessed using homogeneity tests. Standardized data collection procedures were applied across groups, and validated instruments were used to ensure measurement consistency. Although randomization was not feasible, strict inclusion criteria and comparable group characteristics were used to reduce selection bias. Additionally, multivariate analysis (GLM) was conducted to control for potential confounding variables.

This study was approved by the Health Research Ethics Committee of Universitas Muhammadiyah Jakarta (Approval No. 1529/F.9-UMJ/X/2025). Permission to conduct the study was obtained from the participating healthcare facility. All participants provided written informed consent prior to participation. Confidentiality was ensured through anonymization of data, and participants were informed of their right to withdraw at any time without consequences.

RESULTS

Participant Characteristics and Baseline Equivalence

A total of 85 individuals were assessed for eligibility; 80 met the inclusion criteria and were enrolled and equally allocated to the intervention and control groups. All participants completed the study, with no loss to follow-up. The mean age of participants was comparable between groups (36.23 ± 8.52 vs. 31.60 ± 8.83 years; $p = 0.688$). Baseline CD4 counts, knowledge scores, and family support levels were also similar across groups ($p > 0.05$), indicating homogeneity at study entry (Tables 1 and 2).

Most participants were male, had higher educational attainment, and were employed. All participants reported experiencing medication side effects. No statistically significant differences were observed across sociodemographic or clinical variables ($p > 0.05$), confirming baseline comparability (Table 1). All participants were included in the final analysis.

Effects of the HIV Integrated Visual Interface on ART Medication Adherence

At baseline, ART adherence scores were comparable between the intervention and control groups (3.95 ± 1.04 vs. 4.00 ± 1.09 ; $p = 0.834$). Following the intervention, adherence increased substantially in the intervention group (6.05 ± 1.18), whereas the control group showed minimal change (4.05 ± 1.06).

Within-group analysis demonstrated a significant improvement in adherence in the intervention group (mean change = 2.10; $p < 0.001$), while no significant change was observed in the control group (mean change = 0.05; $p = 0.160$). Between-group comparison at post-intervention revealed a statistically significant difference (mean difference =

Table 1. Baseline Characteristics and Group Comparability of Participants (n = 80)

Variable	Intervention (n = 40)	Control (n=40)	p-value
Age (years), mean ± SD	36.23 ± 8.52	31.60 ± 8.83	0.688
CD4 count, mean ± SD	179.50 ± 18.25	182.00 ± 17.42	0.621
Sex, n (%)			0.814
	Male	21 (52.50)	
	Female	19 (47.50)	
Education, n (%)			0.814
	Low	15 (37.50)	
	High	25 (62.50)	
Employment, n (%)			0.817
	Unemployment	13 (32.50)	
	Employed	27 (67.50)	
Medication Side Effect, n (%)			
	Yes	40 (100)	

Notes:

- Values are presented as mean ± standard deviation (SD) or frequency (%).
- p-values were derived from independent t-tests for continuous variables and Chi-square tests for categorical variables.
- No statistically significant baseline differences were observed between groups ($p > 0.05$), indicating baseline comparability. Statistical comparison for medication side effects was not performed because all participants reported experiencing side effects.

2.00; $p < 0.001$), confirming the effectiveness of the HIV Integrated Visual Interface.

The magnitude of the intervention effect was large (Cohen’s $d = 1.82$), whereas the control group demonstrated a negligible effect ($d = 0.05$) (Table 3). This magnitude of change suggests not only statistical significance but also clinically meaningful improvement in adherence behavior. This pattern is further illustrated in Figure 1.

Multivariate Analysis

The pre-intervention GLM model was not statistically significant ($p = 0.297$), indicating no significant baseline influence of the assessed covariates on ART adherence. However, the post-intervention model was statistically

significant ($F(5,74) = 10.702$, $p < 0.001$), explaining 38% of the variance in adherence (Adjusted $R^2 = 0.380$). Post-intervention knowledge ($p = 0.004$) and family support ($p = 0.020$) were identified as significant predictors of adherence. In contrast, CD4 count was not significantly associated with adherence outcomes ($p = 0.405$).

The model demonstrated a large overall effect (partial $\eta^2 = 0.420$), indicating that the included variables explained a substantial proportion of variance in adherence (Table 4).

DISCUSSION

This study demonstrated that the HIV Integrated Visual Interface (HIVI) significantly

Table 2. Baseline Equivalence of Medication Adherence, Knowledge, and Family Support Between Groups

Variable	Pre-intervention Intervention group Mean ± SD	Pre-intervention Control group Mean ± SD	p-value
Medication adherence	3.95 ± 1.04	4.00 ± 1.09	0.834
Knowledge	5.17 ± 1.72	5.05 ± 1.54	0.817
Family support	22.42 ± 3.38	22.90 ± 2.88	0.142

Notes:

- Values are presented as mean ± standard deviation (SD).
- p-values were derived from independent t-tests.
- No statistically significant baseline differences were observed between groups ($p > 0.05$).

Table 3. Changes in ART Medication Adherence and Between-Group Comparisons

Group	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	Mean Difference (Δ)	Within group p-value	Between group p-value	Cohen's d
Intervention (n=40)	3.95 ± 1.04	6.05 ± 1.18	+ 2.10	< 0.001	< 0.001†	1.82
Control (n=40)	4.00 ± 1.09	4.05 ± 1.06	+ 0.05	0.160	-	0.05

Notes:

- Values are presented as mean ± standard deviation (SD).
- Within-group comparisons were performed using paired t-tests.
- Between-group comparisons were conducted using independent t-tests.
- † Between-group p-value refers to post-intervention comparison; baseline equivalence was confirmed at pre-intervention assessment ($p = 0.834$).
- Cohen's d represents within-group effect size.

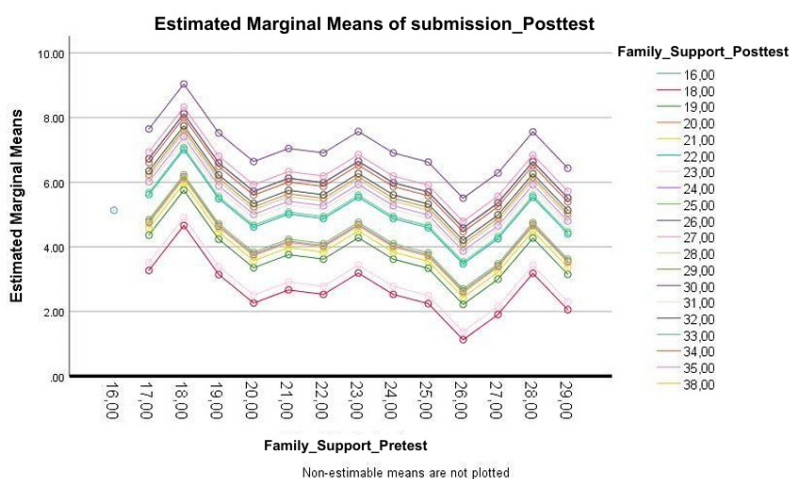


Figure 1. Adjusted Mean ART Medication Adherence Scores by Group After Intervention

Table 4. General Linear Model Analysis of Factors Associated with Post- Intervention ART Medication Adherence

Predictor Variable	F	p-value	Partial η^2
Post-intervention knowledge	8.710	0.004	0.105
Post-intervention family support	5.656	0.020	0.071
CD4 count	0.703	0.405	0.009

Notes

- Posttest GLM model: $F(5,74) = 10.702, p < 0.001$
- Adjusted $R^2 = 0.380$
- Medication side effects were excluded from inferential analysis because all participants reported side effects.
- Partial η^2 interpretation: 0.01 = small, 0.06 = medium, 0.14 = large.

improved antiretroviral therapy (ART) adherence among people living with HIV compared with standard care. Participants receiving the intervention showed a substantial increase in adherence scores, whereas the control group demonstrated minimal change. In addition, post-intervention knowledge and family support were identified as significant predictors of adherence, highlighting the importance of combining educational, behavioral, and psychosocial approaches within digital health interventions.

Effectiveness of the HIVI Intervention on ART Adherence

The findings of this study demonstrate that the HIV Integrated Visual Interface (HIVI) application significantly improved ART medication adherence among people living with HIV. The intervention group showed substantial improvement in adherence scores, whereas the control group demonstrated minimal change. The large effect size further indicates that the intervention produced not only statistically significant outcomes but also clinically meaningful improvement in adherence behavior.

These findings are consistent with previous research demonstrating that mobile health (mHealth) interventions, particularly

those incorporating reminders and educational components, are effective in improving ART adherence (Purwati *et al.*, 2025; Tolley *et al.*, 2023). Digital health technologies provide continuous, real-time support that enables patients to integrate medication-taking behaviors into their daily routines, especially in populations with high activity levels and competing priorities.

From a behavioral perspective, the effectiveness of the HIVI application can be explained using the COM-B Model, which posits that behavior is influenced by capability, opportunity, and motivation (MacPherson & Kapadia, 2023). The HIVI application enhances capability through structured education, opportunity through flexible reminders and accessibility, and motivation through continuous engagement and monitoring (Tang *et al.*, 2026; Purwati *et al.*, 2025; Herawati *et al.*, 2024). In addition, within Sister Callista Roy’s Adaptation Model, the HIVI application functions as a contextual stimulus that supports adaptive responses to the demands of long-term ART. The observed improvement in adherence reflects a positive adaptive response to the demands of long-term ART, indicating improved adjustment to treatment requirements.

Although adherence improved significantly in the intervention group, the

mean post-intervention MMAS-8 score remained within the moderate adherence category rather than reaching optimal/high adherence. This finding suggests that while the HIVI application was effective in improving medication-taking behavior, adherence among people living with HIV remains influenced by complex behavioral, psychosocial, and contextual factors that may require longer-term intervention and continuous support. Therefore, future interventions may benefit from extended follow-up duration, integration of psychosocial counseling, enhanced family involvement, and sustained digital engagement strategies to achieve optimal adherence outcomes.

Lack of Change in the Control Group

In contrast, the control group did not demonstrate a significant improvement in ART medication adherence. This finding suggests that adherence behavior may remain relatively unchanged in the absence of structured and continuous intervention. Previous studies have shown that adherence levels often remain stable when patients receive only routine care without additional supportive strategies (Patel, Sharma, & Gupta, 2025).

Patients receiving standard care alone frequently encounter persistent barriers to adherence, including forgetfulness, treatment fatigue, and lack of ongoing motivation (Rueda *et al.*, 2009). Adherence in chronic conditions such as HIV is strongly influenced by personalized and sustained interventions (Whiteley *et al.*, 2021). Without such support, patients are more likely to maintain existing behavioral patterns despite understanding the importance of treatment adherence.

From the perspective of Roy's Adaptation Model, the absence of an external stimulus in the control group limited the adaptive process required to improve adherence (Harris, 2021; Elsalous *et al.*, 2024). As a result, participants did not demonstrate significant behavioral

change, particularly in relation to physiological and self-concept adaptation modes. This finding underscores the importance of continuous and structured interventions in facilitating meaningful behavioral change.

Role of Knowledge and Family Support in Adherence

The multivariate analysis identified post-intervention knowledge and family support as significant predictors of ART medication adherence. This finding highlights the critical role of educational and psychosocial factors in shaping adherence behavior. Previous studies have similarly reported that adherence is more strongly influenced by knowledge, beliefs, and social support than by short-term clinical indicators such as CD4 count (Brown, Bussell, & Dutta, 2016; Lee *et al.*, 2016).

Within the COM-B framework, improved knowledge enhances patients' psychological capability to adhere, while family support strengthens social opportunity. These factors collectively increase motivation, leading to sustained adherence behavior. In Roy's Adaptation Model, knowledge operates within the cognator subsystem, facilitating informed decision-making, while family support contributes to the interdependence mode by reinforcing emotional and social stability (Demirel & Kılıç, 2024).

The findings suggest that interventions targeting both cognitive and social domains are more effective in improving adherence than those focusing solely on clinical parameters. This aligns with the growing recognition that HIV management requires a holistic approach that integrates behavioral, psychological, and social dimensions of care.

Mechanisms Underlying the Effectiveness of the HIVI Application

The effectiveness of the HIVI application can be attributed to its ability to provide

structured, personalized, and continuous support. The intervention integrated complementary components that addressed behavioral, cognitive, and psychosocial barriers to adherence, thereby facilitating more consistent engagement with antiretroviral therapy (Tang *et al.*, 2026; Purwati *et al.*, 2025).

Digital interventions such as HIVI enable patients to actively participate in their own care, fostering a sense of autonomy and engagement (Karekla *et al.*, 2019). The combination of real-time feedback, accessible information, and consistent reminders creates a supportive environment that promotes sustained behavior change. This integrated approach supports sustained adherence while promoting patients' adaptation to living with HIV.

The operational mechanisms of the HIVI application can also be understood through Roy's Adaptation Model. Medication reminder features supported physiological adaptation by helping participants maintain consistent medication-taking behavior. Educational components strengthened the cognator subsystem and self-concept adaptation through improved knowledge, treatment awareness, and understanding of ART adherence. In addition, communication and support features reinforced interdependence adaptation by enhancing perceived support and patient engagement throughout the treatment process. The COM-B framework further complements Roy's model by explaining how the intervention improved adherence through enhancement of capability, opportunity, and motivation, thereby facilitating sustained behavioral change (MacPherson & Kapadia, 2023).

From a theoretical perspective, the HIVI application acts as a comprehensive adaptive stimulus that strengthens multiple adaptive modes simultaneously. It supports physiological adaptation by promoting consistent medication intake, enhances self-

concept through increased confidence and understanding, and reinforces interdependence by fostering a sense of support and connection. As a result, the intervention facilitates a more stable and sustainable adherence pattern over time.

Baseline Characteristics and Clinical Context

The participants in this study were predominantly within the productive age group, with a mean age of 36.23 years, reflecting the population most affected by HIV both globally and nationally. More than 60% of HIV cases occur among individuals of productive age, a group characterized by high mobility and increased exposure to risk behaviors (UNAIDS, 2024; Kementerian Kesehatan Republik Indonesia, 2023). Although this group often faces adherence challenges due to work demands and psychosocial stress, they also demonstrate greater adaptability to technology-based interventions due to higher levels of digital literacy (Pan *et al.*, 2025). Within Roy's Adaptation Model, age functions as a contextual stimulus influencing individuals' coping mechanisms and adaptive responses to long-term treatment.

The majority of participants were male, consistent with epidemiological data indicating a higher prevalence of HIV among men, often associated with behavioral factors and sociocultural norms related to masculinity (UNAIDS, 2024; Kementerian Kesehatan Republik Indonesia, 2023; Jacques-Aviñó *et al.*, 2019). Despite this, the balanced distribution between groups suggests that sex did not act as a confounding variable in this study. Most participants also had higher educational attainment and were employed. While education contributes to improved health literacy and understanding of antiretroviral therapy (ART), it does not necessarily ensure sustained adherence, as adherence behavior

is also shaped by psychological and social influences (Lee *et al.*, 2016). Similarly, employment may act as both a facilitating and inhibiting factor: economic stability supports treatment continuity, whereas occupational demands may increase the likelihood of missed doses (Supriyatni *et al.*, 2024).

All participants reported experiencing medication side effects; however, adherence remained stable at baseline across both groups. This suggests that side effects alone do not determine adherence behavior when patients receive adequate support and education (Patel, Huang, & Miliara, 2025). In Roy's framework, side effects represent a physiological stimulus that requires adaptive responses, which can be strengthened through supportive interventions (Elsalous *et al.*, 2024). The relatively low and comparable baseline CD4 counts further indicate compromised immune status among participants, emphasizing the importance of sustained ART adherence to improve clinical outcomes.

This study has several limitations that should be considered when interpreting the findings. First, the quasi-experimental design without full randomization may introduce selection bias and limit causal inference, although baseline equivalence between groups was established and multivariate analysis was conducted to control for potential confounding variables. Participant allocation based on clinical scheduling and feasibility may also have contributed to unmeasured confounding. Second, the relatively small sample size and single-center setting may limit the generalizability of the findings to broader populations and different healthcare contexts.

Third, the intervention period and follow-up duration were relatively short (four weeks), limiting conclusions regarding the long-term sustainability of adherence improvement. Although no participants were lost to follow-

up during the study period, this may have been influenced by intensive nurse monitoring, weekly participant engagement, and the manageable sample size. The scalability of maintaining similar retention rates in larger or longer-term studies remains uncertain.

Adherence was assessed using self-reported measures, which are subject to recall and social desirability bias, and may overestimate actual adherence behavior. Furthermore, the lack of variability in medication side effects also limited its analytical contribution in the multivariate model. Finally, although reliability testing demonstrated high internal consistency, the elevated values may reflect similarity among items measuring closely related constructs.

Future research should employ randomized controlled trial designs with larger, multi-center samples and longer follow-up periods to confirm the effectiveness and sustainability of the intervention. The use of objective adherence measures, such as electronic monitoring or pharmacy refill data, is also recommended to enhance measurement accuracy. Additionally, further studies should explore the integration of digital interventions with broader psychosocial and clinical support systems to better understand their impact on long-term adherence and clinical outcomes among people living with HIV.

CONCLUSION

The HIV Integrated Visual Interface (HIVI) significantly improved antiretroviral therapy (ART) adherence among people living with HIV, demonstrating both statistically and clinically meaningful effects. Improvements in knowledge and family support contributed to better adherence outcomes, highlighting the importance of integrating educational and psychosocial components into digital health interventions. These findings support the use of

nurse-led digital interventions as a practical and scalable strategy to strengthen sustained ART adherence and improve HIV care outcomes.

Future research should involve larger and more diverse populations, multicenter settings, and longer follow-up periods to evaluate the long-term effectiveness and generalizability of HIVI. Integration of digital adherence interventions into routine HIV care may further enhance patient monitoring, health education, and continuity of adherence support.

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