

ORIGINAL RESEARCH

## Change in Adherence and Glycemic Control Following WhatsApp-Based Education and Interactive Reminders among Diabetes Patients

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## ABSTRACT

**Introduction:** Type 2 diabetes mellitus (DM) is a non-communicable disease with increasing prevalence and low adherence globally. Therefore, this study aims to evaluate changes in medication adherence and glycemic control after a WhatsApp-based education and interactive reminders among outpatients receiving insulin therapy.

**Methods:** A pre-experimental study used a prospective one-group pre-test-post-test design among outpatients receiving insulin in a hospital. The intervention included DM education at the initial meeting, followed by educational videos and weekly interactive reminders provided through WhatsApp for 6 weeks. Patient knowledge was assessed with Diabetes Knowledge Questionnaire (DKQ) and adherence to medication was assessed using Adherence to Refills and Medications Scale (ARMS). Glycemic control indices (fasting blood glucose (FBG), two hours of postprandial blood glucose (2hPPBG), glycated hemoglobin (HbA1c)) were measured before and after the intervention. Additionally, a paired t-test was used to measure the effect of the intervention on knowledge, adherence, and glycemic control indices.

**Results:** Among the 122 patients who fulfilled the inclusion criteria, there was a significant increase in knowledge ( $p < 0.001$ ), with the proportion of highly knowledgeable patients rising from 19.7% to 38.5%. The increase in adherence to medication from 30.3% to 39.3% was not statistically significant ( $p = 0.228$ ). Glycemic control indices showed a significant improvement ( $p < 0.001$ ), with mean HbA1C, FBG, and 2hPPBG decreasing from 8.63% to 7.85%, 152.18 mg/dl to 138.72 mg/dl, and 268.84 mg/dl to 228.66 mg/dl, respectively.

**Conclusion:** Following the 6 weeks WhatsApp-based education and interactive reminders, improvement were observed in patient knowledge and glycemic control indices, but medication adherence did not change significantly. This study lacked a control group, the findings represent observed changes after the study period and require confirmation in controlled studies with longer follow-up.

**Keywords:** Type 2 Diabetes; Adherence; Insulin; Glycemic Control

## INTRODUCTION

The global prevalence of diabetes mellitus (DM) in 2024 was reported to reach 11.1%, with approximately 588.7 million sufferers. This figure is projected to increase to 13.0%, with a total of 852.5 million sufferers by 2050. Indonesia ranked 5th in the world in 2024, with 20.4 million sufferers. Type 2 DM, which accounts for more than 90% of DM cases worldwide, currently ranks 8th as the leading cause of disease burden and is expected to rise to second place by 2050 (1).

Type 2 DM is a major cause of increased morbidity, mortality, disability, and healthcare costs (2). This is associated with a high rate of complications, particularly the types related to cardiovascular disease (3). A key strategy to mitigate the impact of DM is improving adherence to therapy.

Good adherence to DM medication is associated with reduced mortality, lower healthcare costs, reduced hospitalization risk, and improved control of risk factors (4). However, DM is a chronic disease with low adherence to medication rates. Adherence to long-term therapy for chronic disease is approximately 50% in high-income countries and is estimated to be lower in low- and middle-income countries (5).

Several studies on adherence to DM medication, particularly insulin, in Indonesia reported varying adherence levels. Fitriani et al. reported high adherence to medication (6), while July et al. detected that non-adherence to insulin medication reached 82.1% (7). Maifitrianti et al. observed an association between poor glycemic control and low adherence to medication (8). Dwiyantra et al. found that adherence to insulin use and achievement of glycemic control targets were suboptimal, as the duration of insulin use influenced both variables (9).

Adherence may be more difficult to achieve among patients receiving insulin therapy due to the greater complexity of treatment compared with oral antidiabetic medications. Barriers to insulin adherence include several factors. Patient-related factors include forgetting doses, incorrect dose or timing, fear of injections, and limited knowledge of diabetes and insulin therapy. Behavioral and psychological factors, such as inconsistent lifestyle, polypharmacy, stigma, and negative perceptions of insulin, also contribute to reduced adherence. In addition, improper insulin storage at home may also contribute to suboptimal insulin use (10–12).

Interventions to improve medication adherence should focus on behavioral strategies, particularly those that promote habit change. As smartphone use has become part of daily life, technology can be used to support adherence (13). WhatsApp is freely available on smartphone, making it an affective health education platform (14). Sartori et al. reported that 15% increase in medication adherence after a WhatsApp-based educational intervention (13). Sap et al. found a significant increase in diabetes-related knowledge and a decrease in the incidence of complications following WhatsApp-based educational intervention (15).

Several studies have evaluated WhatsApp-based interventions in patients with diabetes. However, studies focusing on medication adherence among insulin-treated patients are still limited, especially in Indonesia, despite the greater complexity of insulin therapy compared to oral antidiabetic treatment. Poor insulin adherence has also been reported in previous studies, including Dwiyantra et al. (9), who found that adherence to insulin therapy among type 2 DM remains low and recommended improving medication adherence through enhanced patient education use some support tools. Therefore, this study aims to determine the effect of the intervention, namely education and interactive reminders with a self-management method using WhatsApp-based technology, on adherence and glycemic control indices in type 2 DM patients receiving insulin therapy in an outpatient hospital.

## METHODS

This pre-experimental study used a one-group pre-test-post-test design, at single centre health provider. The study was carried out prospectively from April to June 2024 at a government hospital in Bangil, Pasuruan, Indonesia. The population consisted of outpatients diagnosed with type 2 DM receiving insulin therapy. Samples were selected using an accidental sampling method based on inclusion criteria, such as type 2 DM patients aged  $\geq 18$  years with or without comorbidities, and previous administration of any insulin therapy (basal, bolus, or premixed) for  $\geq 1$  month prior to the study, which was in single form or in combination with other medications. Additionally, the eligible respondents had glycated hemoglobin (HbA1c) values  $> 7\%$ , attended routine check-ups for the past 3 months, showed willingness to participate by signing an informed consent, and were able to operate a mobile phone with WhatsApp. Exclusion criteria comprised of type 1 DM patients, type 2 DM patients with cognitive impairment, stage V kidney disorders, or medication therapy that interfered with blood glucose, such as steroids, and hospitalized type 2 DM patients.

This study started with the development of an educational module and the selection of subjects according to inclusion and exclusion criteria. The purpose, benefits, procedures, and data confidentiality were explained to patients, who then signed informed consent, including agreement to join WhatsApp group. All patients were instructed to complete a sociodemographic questionnaire, Diabetes Knowledge Questionnaire (DKQ), and Adherence to Refills and Medications Scale (ARMS) questionnaire developed by Kripalani et al. (16). The Indonesian version of DKQ and ARMS questionnaires have been validated in previous studies, with Cronbach's alpha reported as 0.757 for the DKQ and 0.829 for the ARMS questionnaire (7,17). Baseline clinical parameters, including HbA1c, fasting blood glucose (FBG), 2-hour postprandial blood glucose (2hPPBG), and the most recent antidiabetic medication regimen, were obtained from patients' medical records immediately prior to the initiation of the intervention.

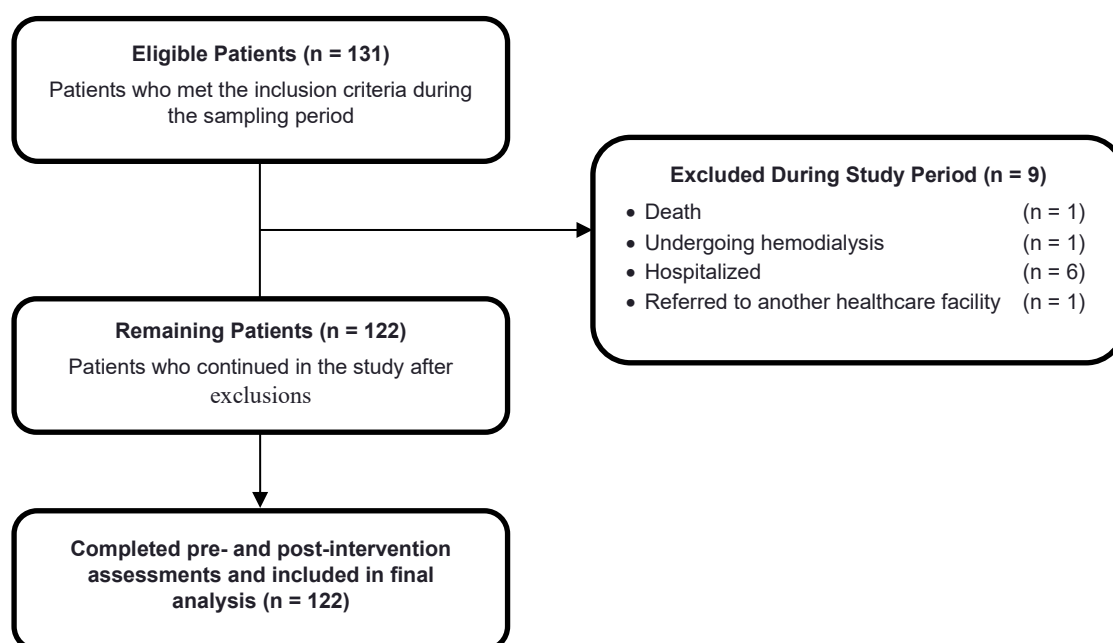
The intervention of education consisted of individualized and group-based sessions delivered by a pharmacist, supplemented by educational videos and weekly interactive reminders delivered through WhatsApp for a 6-week period. Education covered

diabetes mellitus, self-monitoring and blood glucose control, diet management, physical activity, stress management, and the proper use of insulin. Sessions were delivered at baseline and continued progressively either individually or in groups. Interactive reminders were delivered weekly via a WhatsApp group as part of ongoing educational support, consisting of motivational messages to reinforce adherence to insulin therapy and reminders of prescribed dosing schedules, along with short educational videos. Subsequently, after the intervention period, respondents completed ARMS and DKQ questionnaire assessments and engaged in HbA1c, FBG, and 2hPPBG tests. FBG was measured following an overnight fast of 8–10 hours, while 2hPPBG was measured 2 hours after the start of a regular meal.

DKQ, developed by Starr County, comprised 24 items assessing patient knowledge with true, false, and do not know response options. The scoring process was calculated based on the number of correct responses, with correct answers allocated a score of 1, and incorrect or do not know was given 0. The levels of knowledge were categorized as high (17–24), moderate (10–16), or low (0–9) (18). Meanwhile, ARMS questionnaire consisted of 12 items for 2 indicators, evaluated on a 4-point Likert-type scale. Total scores ranged from 12 to 48, with scores  $\leq 12$  representing adherence and  $>12$  signifying non-adherence (16). Insulin therapy effectiveness was evaluated by considering the values of HbA1c, FBG, and 2hPPBG. Moreover, the targeted values of HbA1c, FBG, and 2hPPBG were  $<7\%$ , 80–139 mg/dl, and  $<180$  mg/dl, respectively (19). Collected data were analyzed through bivariate analysis, including paired t-tests, which were conducted to determine the intervention impact on knowledge, adherence, and glycemic control indices pre- and post-intervention among patients. Statistical significance was defined as a p-value  $<0.05$ , while  $\geq 0.05$  implied no significant difference.

### Ethical Approval

This study received approval under the ethical feasibility certificate for research implementation number 00.9.2/1437/424.072.01/2024, issued by the hospital ethics team.



**Figure 1.** Flow Diagram of the Study Participants

## RESULTS

A total of 122 patients completed the post-intervention assessment and were included in final analysis. The majority of respondents were employed female, with a mean age of 55 years, normal weight, and secondary education. Most respondents had no family history of DM, showed comorbidities, had DM for 1–5 years, used insulin for 1–5 years, engaged in polypharmacy therapy ( $\geq 5$  medications), and did not report any adverse drug events (Table 1).

**Table 1.** Characteristics of Subjects (n=122)

| Characteristics of Subjects |                             | Frequency (n) | Percentage (%) |
|-----------------------------|-----------------------------|---------------|----------------|
| Gender                      | Male                        | 50            | 41             |
|                             | Female                      | 72            | 59             |
| Age Group                   | 18–44 years (Adult)         | 14            | 11.5           |
|                             | 45–59 years (Pre-Elderly)   | 71            | 58.2           |
|                             | $\geq 60$ years (Geriatric) | 37            | 30.3           |
| BMI Status                  | Underweight                 | 11            | 9.0            |
|                             | Normal                      | 73            | 59.8           |
|                             | Overweight                  | 36            | 29.5           |
|                             | Obesity                     | 2             | 1.7            |

| Characteristics of Subjects    |                                                   | Frequency (n) | Percentage (%) |
|--------------------------------|---------------------------------------------------|---------------|----------------|
| Education                      | Up to elementary school graduation                | 47            | 38.5           |
|                                | Junior and Senior high school                     | 54            | 44.2           |
|                                | Diploma and Bachelor's degree                     | 21            | 17.2           |
| Occupation                     | Employed                                          | 76            | 62.3           |
|                                | Not employed                                      | 46            | 37.7           |
| Family History of Diabetes     | Yes                                               | 37            | 30.3           |
|                                | No                                                | 85            | 69.7           |
| Medical History/ Comorbidities | Hypertension                                      | 29            | 23.7           |
|                                | Cardiovascular disorders                          | 19            | 15.5           |
|                                | Dyslipidemia                                      | 4             | 3.3            |
|                                | Diabetic retinopathy                              | 12            | 9.8            |
|                                | Infection and gangrene                            | 22            | 18.0           |
|                                | None                                              | 52            | 42.6           |
| Duration of Diabetes           | ≤ 1 year                                          | 30            | 24.6           |
|                                | 1 - 5 years                                       | 55            | 45.0           |
|                                | > 5 years                                         | 37            | 30.3           |
| Duration of Insulin Use        | ≤ 1 year                                          | 47            | 38.5           |
|                                | 1 - 5 years                                       | 52            | 42.6           |
|                                | > 5 years                                         | 23            | 18.9           |
| Polypharmacy                   | < 5 medications                                   | 42            | 34.4           |
|                                | ≥ 5 medications                                   | 80            | 65.5           |
| Ever Experienced ADR           | Yes                                               | 3             | 2.5            |
|                                | Never                                             | 119           | 97.5           |
| ADR Type                       | Hypoglycemia                                      | 2             | 1.6            |
|                                | Digestive disorders (dyspepsia, nausea, diarrhea) | 1             | 0.8            |

Patient knowledge levels were measured using DKQ questionnaire. Table 2 shows the distribution of patient knowledge levels before and after the intervention, categorized as low, moderate, and high. The results showed an improvement in the high knowledge category. Adherence to medication in this study was measured using ARMS questionnaire. According to Table 3, among the 122 patients, a greater proportion were non-adherent, both before and after the intervention. Table 4 shows the results of adherence to medication based on question categories, both before and after the intervention. Table 5 presents insulin therapy achievements of respondents. These results showed that the blood glucose control of patients improved after the intervention.

**Table 2.** Measurement Results of Patient Knowledge Level Before and After Intervention Based on DKQ Questionnaire

| DKQ Questionnaire Measurement Results | Pre-intervention |                | Post-intervention |                | P-value |
|---------------------------------------|------------------|----------------|-------------------|----------------|---------|
|                                       | Frequency (n)    | Percentage (%) | Frequency (n)     | Percentage (%) |         |
| Low (1-9)                             | 47               | 38.5           | 18                | 14.8           | <0.001  |
| Moderate (10-16)                      | 51               | 41.8           | 57                | 46.7           |         |
| High (17-24)                          | 24               | 19.7           | 47                | 38.5           |         |
| Mean ± SD                             | 11.75 ± 5.07     |                | 15.13 ± 4.07      |                |         |

**Table 3.** Adherence to Medication Measurement Results Based on ARMS Questionnaire

| Adherence Category | Pre-intervention |                | Post-intervention |                | P-value |
|--------------------|------------------|----------------|-------------------|----------------|---------|
|                    | Frequency (n)    | Percentage (%) | Frequency (n)     | Percentage (%) |         |
| Adherent (=12)     | 37               | 30.3           | 48                | 39.3           | 0.228   |
| Non-adherent (>12) | 85               | 69.7           | 74                | 60.7           |         |
| Mean ± SD          | 13.66 ± 2.04     |                | 13.27 ± 1.26      |                |         |

**Table 4.** Summary of Changes in Key Adherence Behaviors Before and After Intervention Based on ARMS Questionnaire

| Key Adherence Behavior                                                            | Pre-intervention n (%) | Post-intervention n (%) | Change (%) |
|-----------------------------------------------------------------------------------|------------------------|-------------------------|------------|
| <b>Indicator: Adherence to medication (Adherence in insulin injections)</b>       |                        |                         |            |
| Never forgot insulin injection                                                    | 73 (59.8)              | 93 (76.2)               | +16.4      |
| Never decided not to inject insulin                                               | 83 (68.0)              | 104 (85.2)              | +17.2      |
| Never skipped insulin before physician visit                                      | 85 (69.7)              | 114 (93.4)              | +23.7      |
| Never adjust insulin dose independently                                           | 102 (83.6)             | 109 (89.3)              | +5.7       |
| <b>Indicator: Adherence to refill (Adherence in filling repeat prescriptions)</b> |                        |                         |            |
| Always planned insulin refill before running out                                  | 85 (69.7)              | 87 (71.3)               | +1.6       |
| Never forgot to refill insulin prescription                                       | 102 (83.6)             | 122 (100)               | +16.4      |

Note: Detailed responses for all ARMS questionnaire items are provided in Supplementary Table S1.

**Table 5.** Insulin Therapy Achievement Results in Respondents

| Achievement | HbA1c (%) |       | FBG (mg/dl) |        | 2hPPBG (mg/dl) |        |
|-------------|-----------|-------|-------------|--------|----------------|--------|
|             | Pre       | Post  | Pre         | Post   | Pre            | Post   |
| Minimum     | 7.1       | 6.1   | 128         | 81     | 115            | 71     |
| Maximum     | 14.1      | 10.9  | 244         | 212    | 475            | 424    |
| Median      | 8.50      | 7.70  | 143.00      | 134.00 | 248.00         | 219.50 |
| Mean        | 8.63      | 7.85  | 152.18      | 138.72 | 268.84         | 228.66 |
| Std. Dev    | 1.205     | 0.917 | 23.728      | 20.420 | 68.187         | 59.484 |
| p-value     | <0.001    |       | <0.001      |        | <0.001         |        |

## DISCUSSION

Sociodemographic factors play an important role in the epidemiology of DM and insulin use patterns. According to Table 1, most respondents were female (59.0%) and in the pre-elderly age group (58.2%). The majority had a normal weight (59.8%), secondary education (44.2%), and were employed (62.3%).

Ghassab-Abdollahi et al. and Puig-García et al. both reported that females have a higher prevalence and risk of developing type 2 DM compared to males (20,21). This difference is attributed to variations in body fat distribution, insulin sensitivity, and sex hormones between genders, where premenopausal females have better insulin sensitivity due to higher subcutaneous fat and protective estrogen effects. In contrast, postmenopausal shifts toward visceral fat and reduced estrogen contribute to insulin resistance, further influenced by lower sex hormone-binding globulin (SHBG) levels. In contrast, testosterone in males may enhance insulin sensitivity (22,23).

The prevalence of type 2 DM increases with age, with higher risk observed in individuals aged  $\geq 45$  years and a peak incidence in the late 50s (24,25). While some studies found no significant association between education level and adherence (26), others reported that lower education is linked to poorer adherence, negative attitudes, and worse glycemic control. In contrast, higher education is associated with better outcomes (27–30). Additionally, low physical activity occupations and rotating night shifts have been associated with increased risk of DM due to reduced activity levels and disruption of circadian rhythms (31,32).

Most respondents in this study had comorbidities, with hypertension showing the highest prevalence (23.7%). Hypertension prevalence increases in conditions of insulin resistance and DM, with pathophysiological mechanisms including activation of the renin-angiotensin-aldosterone system (RAAS) and increased sympathetic nervous system activity contributing to elevated blood pressure (33).

The majority (97.5%) did not experience any suspected adverse drug reactions (ADR), signifying the relative safety of antidiabetic medication use. However, two of the three respondents who experienced ADR reported hypoglycemia as the primary side effect, which was thought to be caused by delayed mealtimes or reduced meal portions.

Most respondents had used insulin for 1 to 5 years (42.6%), followed by those with less than 1 year of use (38.5%) and more than 5 years (18.9%). Insulin is generally administered as part of combination therapy in cases of severe hyperglycemia, specifically when catabolic signs are present, such as weight loss, hypertriglyceridemia, and ketosis. Insulin use is considered in individuals with blood glucose levels  $\geq 300$  mg/dL or A1C  $> 10\%$ , or when patients show symptoms of hyperglycemia or evidence of catabolism (34).

Patient knowledge levels were measured with DKQ questionnaire comprising two sections, namely basic DM information and DM complications. Table 2 showed that 41.8%, 38.5%, and 19.7% of respondents had moderate, low, and high knowledge, respectively. These correspond with the report by Sękowski et al. that public awareness of DM, the risk factors, and prevention remains limited (35).

The interventions provided in this study included education about DM, how to measure and control blood glucose levels, diet management, physical activity, stress management, and understanding the use of medications or insulin. Post-intervention, knowledge of respondents increased, with the highest proportion of increases occurring in the high knowledge category. This increase was statistically significant ( $p$ -value  $< 0.001$ ), suggesting that the intervention was effective in improving knowledge. The observation corresponded with a systematic review by Hoe et al., which found educational videos about DM to be capable of enhancing patient knowledge, improving self-care behaviors, and lowering HbA1c levels (36). However, improved knowledge alone may not necessarily lead to changes in medication adherence, as multiple psychological and contextual factors influence behavioural change.

In chronic conditions such as DM, having knowledge is often not enough on its own to bring about long-term changes in self-management behavior. The way patients apply what they know in their daily lives is shaped by several related factors, including self-efficacy, habit formation, perceived treatment burden, and social and environmental support. Clinical evidence also suggests that diabetes knowledge is not consistently associated with glycemic control once these factors are taken into account. In contrast, self-efficacy tends to show a stronger relationship with clinical outcomes (37). For this reason, improving knowledge should be viewed as an important starting point, but not sufficient by itself to achieve sustained adherence and effective self-management.

Adherence to medication was measured using ARMS questionnaire. According to Table 3, 37 respondents (30.3%) adhered to medication, with an ARMS score equal to 12, while 85 (69.7%) were classified as non-adherent, with ARMS score greater than 12. Post-intervention, patient adherence increased to 39.3%, but the increase was considered insignificant ( $p$ -value = 0.228).

The findings of this study were consistent with a previous study that reported a 15% increase in medication adherence after a 16-week WhatsApp-based intervention, but the difference was not statistically significant (13). This improvement may have been explained by the Hawthorne effect and social desirability, which can encourage participants to report more positive health behaviors during a study. However, the observed increase may still be clinically relevant and suggest a positive change in medication adherence.

Although the overall ARMS classification did not change significantly, based on Table 4, the adherence to medication indicator showed an increase in patient adherence to insulin injections. The proportion of patients who did not miss an insulin injection increased from 59.8% to 76.2%, while those who did not intentionally miss an insulin injection increased from 68.0% to 85.2%. Similarly, adherence related to taking insulin before doctor's appointments increased from 69.7% to 93.4%, and patients maintaining insulin dosage increased from 83.0% to 89.3%.

The information provided above shows that the most common non-adherence indicator is forgetting to inject insulin, suggesting that unintentional non-adherence is a major barrier in this population. This suggests that the intervention may have increased patient awareness and improved some daily self-care habits, but this was not enough to make a meaningful difference in overall medication adherence. Medication adherence is not only about reminders, but it is a complex behaviour. Family support, self-efficacy, and patient motivation have been associated with medication adherence. Previous studies have shown that family support could improve adherence to medication (38,39). Therefore, reminder-based strategies may help patients remember and carry out their medication routines, but they may not address the deeper reasons behind long-term adherence.

Based on adherence to refill indicator (Table 4), pre-intervention, 85 respondents (64.4%) often filled insulin prescriptions before the exhaustion of supplies. Post-intervention, this number increased to 87 (71.3%), which signified a small increase in adherence to filling insulin prescriptions before supplies finished. A total of 102 respondents (83.6%) did not forget to fill insulin prescriptions prior to intervention. Subsequently, there was a significant increase, with 100% (122 patients) ensuring to fill insulin prescriptions.

Patient non-adherence in filling prescriptions on time was influenced by limited access to healthcare services. There was a larger coverage area in the hospital where this study was conducted. However, transportation for patients living in remote areas is limited, potentially leading to difficulty to fill prescriptions early. Araya et al. found that proximity to healthcare access played a significant role in improving patient adherence to medication (40). This finding suggests that prescription refill behaviour is influenced more by how easily patients can access healthcare services and use them than by adherence behaviour alone. Therefore, higher refill rates do not necessarily mean that patients are consistently taking their medication as prescribed in their daily life at home.

Glycemic control in DM patients was evaluated using three indicators, namely HbA1c, FBG, and 2hPPBG. Table 5 presents insulin therapy achievements of respondents. These results showed that the blood glucose control of patients improved after the intervention. The mean HbA1c value before the intervention was 8.63% (range 7.1-14.1%), which decreased to 7.85% (range 6.1-10.9%). Subsequently, the mean FBG decreased from 152.18 mg/dl to 138.72 mg/dl, and the mean 2hPPBG decreased from 268.84 mg/dl to 228.66 mg/dl post-intervention. Statistical analysis of each indicator showed a p-value <0.001, representing a significant improvement in glycemic control.

However, this improvement may not be fully attributable to changes in medication adherence alone, suggesting that other self-management behaviors may also contribute to glycemic outcomes. This is particularly relevant given that overall adherence did not show a significant improvement in this study. Numerous factors beyond medication adherence, including dietary practices, physical activity, disease duration, and comorbidities, influence glycemic control. Consequently, improvements in glycemic outcomes may occur even when changes in measured adherence are limited (41).

Poor glycemic control in DM patients could be influenced by several factors, including age, gender, DM medication type, as well as the presence of acute complications and comorbidities. Besides these demographic and clinical factors, knowledge level plays a significant role (42). Previous studies have shown that better glycemic control is associated with higher levels of diabetes knowledge and educational attainment (43). In addition, medication adherence has been reported to significantly contribute to HbA1c reduction among patients with DM (44).

The discrepancy between knowledge improvement, limited adherence change, and improved glycemic control has also been reported in a previous study. Haskani et al. stated that despite good knowledge about DM, there was low adherence to medication because of the failure to take medication (86.49%). Patients with polypharmacy have difficulty sorting out medication information, leading to frequent missed doses (45). Treatment-related adverse effects, especially hypoglycemia, may negatively affect medication adherence among patients with diabetes (46). Additionally, psychological factors, including depression, anxiety, and DM-related stress, influence adherence to medication (47). These factors may contribute to explaining why improvements in glycemic control were observed despite the absence of a significant improvement in overall medication adherence.

These findings indicate a complex relationship between knowledge, adherence, and glycemic control that is not strictly linear. This study shows that a 6-week intervention with educational videos and interactive reminders can improve knowledge of patients on DM self-management, but insulin adherence remains suboptimal, probably due to the relatively short duration.

Several limitations should be considered when interpreting these findings. First, this study was conducted at a single center, so a one-group pre-test–post-test design was used; a control group was not possible, which would bias the results, patients could exchange information with each other. To ascertain whether the observed improvement in knowledge, adherence indicators, and glycemic control were solely attributable to the WhatsApp-based intervention or influenced by other factors. In addition, medication adherence was assessed using a self-reported questionnaire, which may be subject to recall bias and

social desirability bias. The study also did not evaluate other factors that may influence adherence, such as family support, self-efficacy, and psychological status.

Furthermore, the relatively short intervention period of 6 weeks may not have been sufficient to produce sustained behavioral changes in medication-taking practices. According to Singh et al., forming new health-related habits takes between 2 and 5 months (48). Therefore, a longer intervention and follow-up period may be necessary to capture meaningful changes in adherence behaviour.

Despite these limitations, the findings suggest that WhatsApp-based education and reminders may support diabetes self-management and contribute to improved glycemic outcomes. Effective communication and empathy from healthcare professionals are needed to build patient trust, improve adherence, and achieve better glycemic outcomes. Further studies with longer durations are recommended to gain a better understanding of adherence to medication and glycemic control.

## CONCLUSION

This 6-week WhatsApp-based education and interactive reminder intervention was associated with improved diabetes knowledge and better glycemic control indices (HbA1c, FGB, and 2hPPBG) among patients with type 2 DM using insulin. However, medication adherence did not show much improvement. The study had some limitations, such as the lack of a control group, a short intervention period, and the use of self-reported adherence data. While this study improves knowledge and glycemic outcomes, more intensive and well-designed strategies are still needed to achieve lasting improvement in medication adherence in future studies.

## DECLARATIONS

**Author contributions:** The contributions of the authors are as follows: DW developed the research concept, conducted the study, collected and analyzed the data, and contributed to the interpretation of the results; BS and AKJ provided supervision and academic mentorship in the fields of clinical pharmacy; RSW acted as both an academic advisor and a clinical consultant, contributing specialized expertise in internal medicine; VST was responsible for drafting, revising, and finalizing the manuscript for publication.

**Conflicts of interest:** The authors declare no conflicts of interest related to the research, authorship, or publication of this article.

**Declaration of Generative AI And AI-Assisted Technologies in the Writing Process:** Generative AI tools were used solely to support language refinement, clarity, and structural improvement during the writing process. These technologies were not involved in the study's design, data collection, analysis, or interpretation. The authors maintain full responsibility for the scholarly content, accuracy, and integrity of the work presented.

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