

## **Effect of Green Pharmacy-Based MTM Education on Quality of Life among Elderly Patients with Type 2 Diabetes Mellitus**

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### **Abstract**

Diabetes Mellitus Type 2 (T2DM) is a chronic metabolic disease that commonly affects elderly ( $\geq 60$  years) populations and significantly impacts patients' quality of life due to long-term pharmacotherapy and disease complications. Medication Therapy Management (MTM) has been recognized as an effective pharmacist-led intervention to optimize medication use and improve clinical outcomes. However, its integration with environmental sustainability principles remains limited. This study aimed to evaluate the effect of Green Pharmacy-based MTM education on quality of life among elderly patients with type 2 diabetes mellitus. A quasi-experimental study with a pretest-posttest control group design was conducted among 84 elderly patients at primary healthcare centers in Semarang, Central Java, Indonesia, from September to October 2025. The application of rational medication principles, as emphasized in Green Pharmacy-based MTM education, plays a crucial role in minimizing adverse effects and optimizing therapeutic outcomes. Quality of life was assessed before and after the intervention using the Diabetes Quality of Life (DQoL) questionnaire, accompanied by clinical monitoring of random blood glucose levels. The results showed that the intervention significantly improved quality of life compared to control ( $p < 0.05$ ). These findings highlight the potential of sustainable, pharmacist-led educational interventions to enhance diabetes management and patient-centered outcomes.

**Keywords:** Elderly patient; Green pharmacy; Medication therapy management; Quality of life; Type 2 diabetes mellitus

### **1. INTRODUCTION**

Type 2 diabetes mellitus (T2DM) represents a chronic metabolic disorder with a high prevalence among older adults, requiring continuous pharmacological therapy accompanied by effective self-management to maintain glycemic stability and prevent disease-related complications (Bugianesi & Jepsen, 2025; Glaziou et al., 2015). Diabetes mellitus (DM) remains a major global health concern with an increasing prevalence worldwide. According to the International Diabetes Federation (2025), Southeast Asian countries reported the highest prevalence of diabetes mellitus globally, reaching 13.2% (Salsabilla et al., 2025). In elderly

patients, complex medication regimens, comorbidities, and age-related physiological changes often lead to suboptimal treatment outcomes and a decline in quality of life (Karandikar et al., 2013; Munugoti et al., 2024). Accordingly, the management of diabetes mellitus should encompass not only optimal glycemic control but also broader patient-oriented outcomes, including improvements in patients' quality of life (Castell et al., 2025). Medication Therapy Management (MTM) has been widely applied as a pharmacist-led intervention to optimize pharmacotherapy, enhance medication adherence, and reduce the occurrence of drug-related problems (Hu et al., 2025). Previous studies have demonstrated that MTM can improve glycemic control and enhance patient knowledge (Federation, 2025). However, most existing research has focused primarily on clinical parameters. At the same time, evidence on the impact of MTM on quality of life among elderly patients with T2DM remains limited, especially in primary healthcare settings (Joshi et al., 2025). The increasing use of long-term medications has also raised environmental concerns. Improper disposal of unused or expired drugs can contaminate the environment and threaten public health (Luykx et al., 2025; Moermond et al., 2025). The Green Pharmacy concept supports responsible medication use and environmentally friendly drug disposal. However, its implementation in patient education and pharmaceutical care services remains limited (Håkonsen & Hedenrud, 2024). Despite the recognized benefits of MTM and the growing relevance of Green Pharmacy principles, studies integrating both approaches into a structured educational intervention are scarce. Moreover, limited attention has been given to evaluating how such integrated interventions influence quality of life as a patient-reported outcome among elderly T2DM patients. This lack of evidence highlights a critical research gap in sustainable, patient-centered pharmaceutical care (Sánchez et al., 2023). Therefore, this study introduces a Green Pharmacy-based MTM educational intervention designed to enhance rational medication use, promote environmentally responsible drug disposal, and improve quality of life among elderly patients with type 2 diabetes mellitus. By integrating clinical pharmaceutical care with sustainability principles, this study provides novel evidence on the role of pharmacist-led, environmentally conscious educational interventions in improving patient-centered outcomes in diabetes management.

Although MTM has been widely used in diabetes management, most previous studies have focused mainly on clinical outcomes such as glycemic control. At the same time, its effect on the quality of life of elderly patients has received less attention. In addition, the integration of Green Pharmacy principles into MTM-based patient education is still rarely discussed, particularly in primary healthcare settings. Therefore, this study was conducted to address this gap by incorporating Green Pharmacy principles into MTM education and evaluating their impact on quality of life as a patient-centered outcome. This approach provides a different perspective by combining pharmaceutical care with environmental sustainability in diabetes management.

## 2. MATERIAL AND METHODS

This prospective quasi-experimental study used a pretest-posttest control group design and was conducted at primary healthcare centers in Semarang, Indonesia, from September to

October 2025. Elderly patients ( $\geq 60$  years) with T2DM who had received antidiabetic therapy for at least one month. Participants were recruited consecutively from eligible patients attending the primary healthcare centers during the study period until the required sample size was achieved. Patients with cognitive impairment or incomplete follow-up were excluded. Participants were assigned to intervention and control groups. The minimum sample size was calculated using the LEMESHOW formula, yielding 80 participants after accounting for potential dropouts. The intervention group received pharmacist-led Medication Therapy Management (MTM) education integrated with Green Pharmacy principles, supported by a pocketbook entitled "Kendalikan Diabetes Mellitus". The MTM education was delivered in four sessions over eight weeks (biweekly), with each session lasting approximately 30-45 minutes. The sessions included medication review, adherence counseling, lifestyle education, and guidance on environmentally responsible drug disposal. Quality of life was assessed as the primary outcome using the Diabetes Quality of Life (DQoL) questionnaire at baseline and post-intervention. Random blood glucose levels were measured as a secondary outcome using a calibrated glucometer (Accu-Chek® Active, Roche Diagnostics, Mannheim, Germany), which has been validated for clinical use. Data were analyzed using paired t-tests or Wilcoxon signed-rank tests for within-group comparisons and independent t-tests or Mann-Whitney U tests for between-group comparisons, depending on data distribution. Statistical significance was set at  $p < 0.05$ . To minimize potential bias, baseline comparability between groups was assessed using the Chi-square test and the independent t-test. Standardized inclusion and exclusion criteria were applied during participant recruitment to control confounding variables. Validated instruments (DQoL questionnaire) and consistent measurement procedures were used, with all assessments conducted using the same protocol and device to reduce measurement and observer bias. The intervention was delivered by the same pharmacist using a standardized pocketbook to ensure consistency and minimize performance bias. Participants with incomplete follow-up data were excluded from the final analysis to address attrition bias. Appropriate statistical analyses were selected based on data distribution to ensure the validity of the results. Ethical approval was obtained from UNISULA Hospital under No. 343/VI/2025/Komisi Bioetik.

### 3. RESULTS AND DISCUSSION

#### 3.1. Patient demography

A total of 84 elderly patients with T2DM were included in this study. The demographic characteristics of the respondents are summarized in Table 1. Many participants were female (75%), while male patients accounted for 25% of the total sample. The distribution of gender between the control and intervention groups showed that most respondents were aged 65 years or older (52.3%), followed by those aged 55-64 years (47.6%). No participants were in the 45-54 years age category. Statistical analysis showed that age distribution was comparable between groups ( $p = 0.505$ ). In addition, Asians are typically diagnosed with diabetes at younger ages compared with other ethnic groups, in whom the disease generally occurs at age 55 years or older (Bradley & Hsueh, 2019). There are many potential etiological reasons for the increase in T2D prevalence with advancing age. These include lifestyle and cultural factors (obesity and

sedentary lifestyle), (Han et al., 2011; K.M.V. Narayan, Md James P. Boyle, Phd Theodore J. Thompson, Ms, Edward W. Gregg, Phd David F. Williamson, 2007) potential age-related changes in insulin action and secretion, (Gong & Muzumdar, 2012) inflammatory and hormonal dysregulation, (Dandona & Dhindsa, 2014; Goldberg, 2016) genetic factors, (Valeriya Lyssenko, Md, Phd, Markku Laakso, Md, 2013) changes in sleep pattern, (Hublin et al., 2016; Lam et al., 2006) increased oxidative stress, (Bonomini et al., 2015) and increased use of medications that increase hyperglycemic propensity (Leslie et al., 2007; Pandit et al., 2015). Several organ systems and tissues are therefore affected during the aging process, with profound ramifications for diabetes risk. This is consistent with the findings of Nugroho et al. (2025), who reported a higher risk of diabetes mellitus among women due to pregnancy-related factors and a greater likelihood of elevated body mass index (BMI), with risk increasing from the age of 35 years.

In terms of educational background, most respondents had completed elementary school (39.2%), followed by those with no formal education (21.4%), senior high school (17.8%), junior high school (16.6%), and university (4.7%). Educational attainment may affect an individual's ability to understand health information, make informed decisions, and adopt healthier lifestyles, particularly in preventing T2DM. Previous research by Arania et al. (2021) reported that 47.6% of respondents with type 2 diabetes mellitus had a low level of education (Resti Arania, Tussy Triwahyuni, Toni Prasetya, 2021). Lower educational attainment is associated with an increased risk of T2DM due to limited health knowledge, whereas higher education promotes healthier dietary patterns and lifestyle behaviors (Nugroho & Purwo Setiyo, 2025). No significant difference in educational level was found between the groups ( $p = 0.261$ ). This finding indicates that factors such as lifestyle and dietary habits may have a greater influence on blood glucose control than educational background alone. More than half of the respondents (52.3%) had no comorbidities, while 47.6% had one to three comorbid conditions, with no respondents reporting more than three. The distribution of comorbidities did not differ significantly between the control and intervention groups ( $p = 0.129$ ). Regarding medication use, most respondents reported taking two medications (53.5%), followed by three (42.8%) and one (3.5%). The number of medications used was comparable between groups ( $p = 0.115$ ). Most respondents had been diagnosed with diabetes mellitus for 1–5 years (70.2%), followed by 6–10 years (26.1%), while only a few had lived with the disease for more than 10 years. No significant difference in disease duration was identified between groups ( $p = 0.247$ ).

Overall, the baseline demographic characteristics of the control and intervention groups were statistically similar, indicating that both groups were homogeneous before the intervention. Previous studies have also shown that multiple factors, including patient characteristics, therapy complexity, socioeconomic conditions, and healthcare support, influence medication adherence in patients with diabetes and comorbid hypertension. Therefore, multidisciplinary and individualized approaches are considered important to improve adherence outcomes. (Oforiwaa et al., 2024).

**Table 1.** Demographic characteristics of elderly patients with type 2 diabetes mellitus. *Note:* Statistical analysis was performed using the Chi-square test with a confidence interval 95%.

Characteristic	Total		Group				p-value
	Respondents (n=84)	%	Control (n=41)	%	Intervention (n=43)	%	
<b>Gender</b>							0.900
Male	21	25	10	24.3	11	25.5	
Female	63	75	31	75.6	32	74.4	
<b>Aged</b>							0.505
55-64 years	40	47.6	18	43.9	22	51.1	
>64 years	44	52.3	23	56.1	21	48.8	
<b>Education Level</b>							0.261
No formal education	18	21.4	10	24.3	8	18.6	
Elementary school	33	39.2	12	29.2	21	48.8	
Junior high school	14	16.6	10	24.3	4	9.30	
Senior high school	15	17.8	7	17.1	8	18.6	
University	4	4.7	2	4.8	2	4.6	
<b>Comorbidity Status</b>							0.129
Without comorbidity	44	52.3	18	43.9	26	60.4	
1-3	40	47.6	23	56.1	17	39.5	
>3	0	0	0	0	0	0	
<b>Total medication consumed</b>							0.115
1 medication	3	3.5	0	0	3	6.9	
2 medications	45	53.5	14	31.1	31	72.1	
3 medications	36	42.8	27	65.8	9	20.9	
<b>Duration of DM</b>							0.247
1-5 years	59	70.2	33	80.4	26	60.4	
6-10 years	22	26.1	8	19.5	14	32.5	
11-15 years	1	1.1	0	0	1	2.3	
16-20 years	1	1.1	0	0	1	2.3	
21-25 years	1	1.1	0	0	1	2.3	

### 3.2. Quality of life in type 2 diabetes mellitus patients using DQoL questionnaire

Quality of life was evaluated using the Diabetes Quality of Life (DQoL) questionnaire. Assessments were performed before and after the educational intervention. The instrument demonstrated good validity (value = 1.96) and acceptable reliability, with a Cronbach's alpha coefficient of  $\geq 0.70$  (Al-qerem et al., 2022; Permana et al., 2021). The distribution of responses is presented in Table 2. The questionnaire responses reflected patients' perceptions of satisfaction and the frequency of T2DM-related experiences, with response options ranging from very dissatisfied to very satisfied and from never to all the time. Quality of life was assessed using the Diabetes Quality of Life (DQoL) questionnaire before and after the intervention. The total score was calculated by summing all item responses, with higher scores indicating better quality of life. The results were analyzed as continuous variables and are presented as mean  $\pm$  standard deviation.

**Table 2.** Quality-of-life scores for elderly patients with type 2 diabetes mellitus, assessed using the Diabetes Quality of Life (DQoL) questionnaire.

Domain	Group	Pretest (Mean $\pm$ SD)	Posttest (Mean $\pm$ SD)	Mean Difference ( $\Delta$ )
How satisfied	Control	47.41 $\pm$ 5.71	49.31 $\pm$ 5.47	+1.02
	Intervention	51.58 $\pm$ 4.24	54.48 $\pm$ 3.63	+5.20
How often	Control	45.51 $\pm$ 3.55	44.49 $\pm$ 5.03	+1.02
	Intervention	47.12 $\pm$ 3.55	42.49 $\pm$ 5.03	+4.63

The control group reported moderate satisfaction with their diabetes treatment, disease management, and healthcare services (Table 2). Following the observation period, slight improvements were observed across several satisfaction-related items, particularly in satisfaction with diabetes treatment and knowledge about diabetes. In the intervention, a more pronounced improvement was observed after the implementation of Green Pharmacy-based MTM education. Posttest results demonstrated increased satisfaction, especially regarding diabetes treatment, time spent obtaining medical check-ups, and knowledge of diabetes management. In the "how satisfied" domain, the intervention group (+5.20) showed greater improvement than the control group (+1.02), as reflected in a larger mean difference (Table 2). This finding indicates a marked enhancement in patients' satisfaction with diabetes treatment, disease management, and healthcare utilization after receiving Green Pharmacy-based Medication Therapy Management education (Despain & Hoffman, 2024). Similarly, in the "how often" domain, the intervention group demonstrated greater improvement than the control group, with a higher mean increase (+4.63 vs +1.02). These findings indicate that pharmacist-led interventions improve patient-reported outcomes, particularly in long-term diabetes management. Healthcare professional involvement is crucial in supporting appropriate medication use, especially among patients on long-term treatment, given its potential impact on blood glucose levels (Hu et al., 2025).

### 3.3 Effectiveness of Green Pharmacy-based MTM education on quality of life

The effectiveness of Green Pharmacy-based Medication Therapy Management (MTM) education on quality of life was evaluated using the Diabetes Quality of Life (DQoL) questionnaire. Changes in DQoL scores were analyzed within each group before and after the intervention, as well as between the control and intervention groups. As shown in Table 3, both groups demonstrated an increase in mean DQoL scores after the study period. In the control group, the mean DQoL score increased slightly from 47.41  $\pm$  5.71 at pretest to 49.31  $\pm$  5.47 at posttest, with a mean difference ( $\Delta$ ) of 1.9  $\pm$  2.02. This change was statistically significant ( $p < 0.05$ ), although the magnitude of improvement was relatively small. In contrast, the intervention group showed a more pronounced improvement in quality of life following Green Pharmacy-based MTM education.

The mean DQoL score increased from 51.58  $\pm$  4.24 at pretest to 54.48  $\pm$  3.63 at posttest, resulting in a mean difference ( $\Delta$ ) of 5.2  $\pm$  1.52. Statistical analysis using the Wilcoxon test indicated that this improvement was highly significant ( $p < 0.05$ ). Comparative analysis

between groups revealed significant differences in DQoL scores at both the pretest and posttest ( $p < 0.05$ ). The greater increase in DQoL scores observed in the intervention group indicates that Green Pharmacy-based MTM education was more effective than standard care alone in improving the quality of life of elderly patients with T2DM. Overall, these findings demonstrate that structured MTM education integrated with Green Pharmacy principles has a substantial positive impact on patients' perceived quality of life, supporting the role of pharmacist-led educational interventions in geriatric diabetes management.

**Table 3.** Effectiveness of Green Pharmacy-Based Medication Therapy Management (MTM) education on Quality of Life among elderly patients with type 2 diabetes mellitus. *Note:* Statistical significance was determined at  $p < 0,05$  with a 95% confidence interval. Data analysis was performed using the Wilcoxon test;  $p$ -value<sup>1</sup>= test the difference between before and after the intervention;  $p$ -value<sup>2</sup>=difference test between groups; \*=significance ( $p < 0,05$ ).

Group	Mean score DQoL $\pm$ SD		Difference (delta $\Delta$ )	$p$ - value <sup>1</sup>
	Pretest (Mean $\pm$ SD)	Posttest (Mean $\pm$ SD)		
Control	47,41 $\pm$ 5,713	49,31 $\pm$ 5,465	1,9 $\pm$ 2,022	0,000 <sup>a*</sup>
Intervention	51,58 $\pm$ 4,238	54,48 $\pm$ 3,628	5,2 $\pm$ 1,516	0,000 <sup>a*</sup>
$p$ - value <sup>2</sup>	0,000 <sup>a*</sup>	0,000 <sup>a*</sup>	0,000 <sup>a*</sup>	

#### 4. CONCLUSION

This study demonstrates that Green Pharmacy-based MTM education significantly improves the quality of life among elderly patients with T2DM. The integration of sustainability principles into pharmaceutical care enhances patient self-management and rational medication use.

These findings suggest that pharmacist-led educational interventions incorporating environmental aspects can be implemented in primary healthcare settings. Future studies with longer follow-up and randomized designs are recommended to strengthen the evidence.

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#### CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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