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Effects of Structured Health Education and Multimodal Intervention on Behavioural and Clinical Outcomes in Type 2 Diabetes Mellitus: A Quasi-Experimental Study

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ABSTRACT

Introduction: Type 2 Diabetes Mellitus (T2DM) is a chronic disease commonly found in individuals over the age of 40 and ranks among the top three diseases suffered by participants of the National Health Insurance (JKN) program. The management of T2DM often involves the long-term use of medications, both oral and injectable, which may extend throughout the patient's lifetime. This condition can worsen in the presence of complications. However, T2DM patients can maintain a good quality of life and reduce the risk of macrovascular and microvascular complications if their blood sugar, blood pressure, and cholesterol levels are well-controlled. Effective management requires more than just medication; proper dietary regulation and sufficient physical activity are also crucial. This study aims to enhance the understanding and behaviors of T2DM patients so that they can achieve optimal clinical parameters and reduce the risk of complications.
Method: The research employs a quasi-experimental pre–post design was applied involving 20 adults with T2DM divided into treatment and control groups. The intervention consisted of face-to-face education, booklets, and exercise videos. Behavioral and clinical outcomes were assessed before and after the intervention. Data were analyzed using the Wilcoxon signed-rank test and paired t-test based on data distribution.
Result: The results showed significant improvements in understanding and behavior related to medication use, meal practices, and physical activity in the treatment group based on the Wilcoxon test ($p < 0.05$). However, no significant improvement was observed in dietary-management understanding.
Conclusion: Structured health education combined with multimodal intervention demonstrated significant improvements in behavioral and selected clinical outcomes among patients with type 2 diabetes mellitus compared with the control group.

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INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is one of the most prevalent metabolic diseases globally, with an increasing number of sufferers. This condition affects not only individuals over the age of 40 but also increasingly impacts younger populations due to modern lifestyle changes. The rising prevalence of obesity, lack of physical activity, and unbalanced diets significantly contribute to the development of T2DM (1,2). This disease has serious implications for quality of life and increases the risk of macrovascular complications, such as coronary heart disease, as well as microvascular complications like retinopathy and nephropathy (3).

According to de Kort et al. (4), patients with T2DM have a higher risk of developing colorectal cancer compared to individuals without diabetes. Nevertheless, many diabetes patients struggle to effectively control their blood sugar levels. Medical treatment alone is insufficient; a balanced diet 5and regular physical activity are also essential for effective diabetes management (5,6). Research by Nurlaili and Muhammad (7) indicates that education regarding diet, physical activity, and medication use (the four pillars of diabetes control) significantly influences blood sugar management. Respondents who understand education well, engage in physical activity, manage their diet, and adhere to medication regimens are more likely to have better-controlled blood sugar levels.

Studies on the quality of life of diabetes patients have shown varied results. Rizkifani et al. (8) found that the quality of life of diabetes patients, particularly regarding treatment effects, is often suboptimal. A study by Safitri et al. (9) also revealed that 47% of 87 respondents reported poor quality of life, often due to suboptimal disease management.

In the era of the National Health Insurance (JKN), the public has easier access to healthcare services, with free treatment facilities for the underprivileged and affordable costs for those who pay independently. However, this accessibility may lead to a lack of appreciation for treatment. Insufficient understanding, boredom, and stress can reduce adherence to therapy. This study aims to evaluate the effectiveness of educational approaches in managing Type 2 Diabetes Mellitus and hopes to provide new insights into ways to improve blood sugar control and the quality of life for patients.

METHODS

This study employs a quasi-experimental design with a pre-test and post-test control framework to evaluate the effects of education on clinical parameters in patients with Type 2 Diabetes Mellitus (T2DM). The dependent variables measured include: blood simple sugar (BSS), HbA1c, total cholesterol, LDL, and blood pressure (BP).

The study population consists of T2DM patients participating in BPJS who have undergone diabetes therapy for at least one year through a referral mechanism from hospitals to community health centers or family doctors. The sample comprises 20 patients who meet the inclusion criteria: cooperative, able to read and write, or have family members who can monitor daily activities if they are unable to read and write, and excluding pregnant women.

Samples were selected randomly, considering resource and budget limitations. The sample was randomly divided into two groups: the treatment group (10 individuals) and the control group (10 individuals). The treatment group received face-to-face education, booklets, and a workout CD, while the control group did not receive these interventions.

HbA1c levels were assessed at a certified health laboratory. All patients attended according to the research schedule for clinical parameter measurements. Assessments were conducted before and after the intervention to evaluate any changes that occurred. Data were analyzed using appropriate statistical tests to identify significant differences between the treatment and control groups.

The study commenced with the preparation of reading materials in the form of an A5-sized booklet provided to respondents as written educational tools for the treatment group. The booklet material was derived from various sources and organized in a simple format to facilitate understanding and application by respondents in daily life.

The booklet includes practical explanations about the medications used by diabetes patients, including information on timing of consumption, potential side effects, and considerations during usage. This information is presented in tabular form for easier comprehension. The table contains a list of diabetes medications registered in the Indonesian Formulary of 2016, serving as a guideline for medication use for BPJS patients.

Additionally, the booklet is equipped with recommended dietary guidelines and lists of foods to avoid or limit for diabetes patients. Respondents are given the flexibility to adjust the types and methods of food preparation according to their economic capacity and personal preferences while still considering nutritional balance.

Daily menu choices are also included in the booklet, which can serve as a reference and be modified by respondents according to their needs. For physical activity, besides explanations in the booklet, videos demonstrating various exercises such as leg exercises, arm exercises, hip exercises, and full-body workouts are provided. Respondents can duplicate these videos or download them independently.

Respondents are given the freedom to choose physical activities that suit their age and preferences, with an emphasis on the importance of engaging in these activities regularly every day.

RESULTS

Characteristic of Respondents

The respondents' knowledge regarding medication use, dietary habits, and physical activity was measured through a questionnaire. This questionnaire included questions about various important aspects, such as, Medication Use: Questions included the necessity of regular medication consumption, duration of medication use, purpose of treatment, timing of consumption, and medication dosage. Dietary Habits: Questions focused on information about dietary management, its purpose, and the types of food consumed. Physical Activity: Questions encompassed the necessity of exercise in blood glucose control, routines, duration, objectives, and the respondents' attitudes towards these activities. The following is a general overview of all respondents before they received education, presented in Table 1.

Table 1. Respondence Performance Before Experiment

Variables	Min	Max	Mean	Modus	Std Dev
Ages	44	77	59	62	4.022
Status DM	2	24	6	3	4.050
Body Index Massa	20	39	26	28	4.408
Knowing to Drugs	50	90	70.5	70	10.593
Knowing Food Feeding	50	80	61.0	60	10.593
Knowing to exercise	40	90	60.5	50	11.547
Habit to consume Medicines	50	80	67.5	70	9.718
Habit to Feed	50	70	58.5	70	6.749
Habit to Exercise	50	80	62.0	50	11.547

The respondents in the study were predominantly 62 years old. The history of Type 2 diabetes mellitus among the respondents varied, ranging from 2 years to a maximum of 24 years. Overall, the Body Mass Index (BMI) of the respondents fell into the overweight category, with values exceeding (25).

The average understanding of diabetes management among the respondents was at a low to moderate level, with scores below 80. Nevertheless, the respondents' behaviors concerning disease management demonstrated significant improvement. However, the behaviors related to physical activity or exercise remained relatively low, with scores below 70.

Using by analytical bivariate wilcoxon test to have the understanding and behaviour of respondents Pre-post Test of Education showed in table 2.

Table 2. Understanding and Behaviour in Groups Both of Respondents and Control Pre-post Test of Education

Variables	Min	Max	Mean	SD	P-Value	
					KS-Test	Wilcoxon
Treatment Groups (N=10)						
1.Understanding used of medicine						0.004
Pre-test	50	80	67		10.593	
Post-test	80	90	82	4.216	0.019	
2.Understanding of food feeding						CR
Pre-test	50	80	57	10.593		
Post-test	50	50	57	10.593	0.183	
3.Understanding of physical activity						0.001
Pre-test	50	80	60	11.547		
Post-test	70	90	79	5.676	0.130	
4.Drug behaviour Use						0.001
Pre-test	50	80	65	9.718		
Post-test	70	90	82	7.888	0.587	
5.Understanding of meal consumption Pre-test	50	70	53	6.749		0.004
Post-test	50	90	66	14.298	0.939	
6.Habit to exercise						0.09
Pre-test	50	80	60	11.547		
Post-test	60	80	72	7.888	0.587	
Control groups (N=10)						
1. Understanding of drug administration Pre-test	50	90	74	11.738		CR
Post-test	50	90	74	11.738	0.347	
2. Understanding of meal consumption						CR
Pre-test	60	70	65	5.270		
Post-test	60	70	65	5.270	0.230	
3. Understanding of physical activity						0.223
Pre-test	40	80	61	16.633		
Post-test	50	80	65	11.785	0.487	
4. Drug used behaviour						0.343
Pre-test	50	80	70	12.472		
Post-test	50	80	72	12.293	0.192	
5. Meal Behaviour						0.343
Pre-test	50	90	64	15.055		
Post-test	50	90	66	14.298	0.495	
6. Habit to exercise						0.443
Pre-test	50	80	64	12.649		
Post-test	50	80	62	11.353	0.511	

CR: Result Cannot be Read

Table 3, it is indicated that all clinical parameters before and after the education intervention follow a normal distribution. Dependent T-test for the clinical parameters of respondents before and after the education intervention, therefore, the analysis can be conducted using parametric tests.

Table 3. Test For Normalities of data

Clinical Parameter Assessment	**one sample Kolmogrov-Smirnov Test** ***P-Value***
Before Treatment	
HbA1c	0.864
LDL	0.923
BSS	0.496
BP Systolic	0.149
After Treatment	
HbA1c	0.299
LDL	0.991
BSS	0.525
BP systolic	0.1664

Blood Pressure (BP), Blood Simple Sugar (BSS)

Respondents' behaviors regarding medication use, dietary habits, and physical activity were assessed based on a checklist filled out by the respondents over one week. This checklist was designed to provide a comprehensive overview of the respondents' daily behaviors. Assessment was conducted by comparing the recorded behaviors in the checklist against the standards deemed correct or appropriate. If the recorded behaviors were close to or aligned with the standards set by the authors, they were rated as correct. Conversely, if the behaviors were not aligned or not performed, they were rated as incorrect.

The checklist filled out by the respondents included: Medication Use: Types of medications used, usage instructions, and timing of use. Dietary Habits: Types of foods consumed at breakfast, lunch, and dinner, timing of meals, and portion sizes. Physical Activity: Types of activities, timing, and duration of performance. Blood Pressure (BP), Blood Simple Sugar (BSS) showed in Table 4.

Table 4. Clinical Parameter Respondent After Treatment

Variables				**P-Value**	
	Min	**Mean**	**SD**	**KS**	**T-Test**
Treatment Group					
1.HbA1c					
Pre-test	6.3	11.8	9.60	1.829	0.035
Post-test	5.9	12.1	9.24	1.887	0.651
2.LDL					
Pre-test	99.7	148.1	130.43	14.463	0.063
Post-test	99.7	148.1	127.71	14.652	0.996
3.BS					
Pre-test	140.7	437.4	268.91	95.977	CR
Post-test	130.2	370.4	224.38	90.082	0.629

4.BP-sistolic					
Pre-test	120	150	129.00	8.756	0.052
Post-test	120	130	124.00	5.164	0.110
Control Groups					
1.HbA1c					
Pre-test	5.7	12.1	8.65	2.406	0.962
Post-test	5.9	12.6	8.67	2.232	0.492
2.LDL					
Pre-test	79.6	156.5	120.24	29.259	0.026
Post-test	80.6	170.5	133.62	33.297	0.534
3.BSS					
Pre-test	113.7	450.4	250.94	109.614	0.009
Post-test	121	444	267.16	111.277	0.925
4.BP-sistolic					
Pre-test	120	160	137	12.517	0.343
Post-test	120	160	136	12.649	0.894

Blood Pressure (BP), Blood Simple Sugar (BSS).

In the bivariate analysis using the dependent sample t-test for all respondents, both in the treatment group and the control group, it was observed that there was a significant effect of education on the respondents' systolic blood pressure (P-value = 0.017). However, there was no significant effect observed on HbA1c, LDL, and Blood Simple Sugar (BSS) showed in Table 5.

Table 5. Educational effect to impact clinical paremeter DM type 2

		Levene's Test		**T-Test**			
				95% Confidence Interval			
		F	P-value	T	P-value	Lower	Upper
HbA1c post	Varian	.352	.560	-	0.554	-2.558	1.418
LDL post	Varian	8.72	.009	0.514	0.616	-19.074	30.894
BSS post	Varian	.985	0.334	0.945	0.357	-52.337	137.897
Blood Pressure post	Varian	5.41	0.032	2.777	0.017	2.579	21.421

Blood Pressure (BP), Blood Simple Sugar (BSS).

Table 6, which presents a list of medications used by the respondents, these medications are standard therapies for managing blood glucose levels, blood pressure, and lipid profiles. in patients with type 2 diabetes.

Table 6. Drug used list by respondents T2DM

No	Drugs Used	N	No	Drugs Used	N
1	Metformin 500 mg	9	13	Fenofibrat	1
2	Glimepirid 2 mg	6	14	Valsartan/valesco 80 mg	1
3	Glikazid/Glucodex	6	15	Telmisartan/Micardis	1
4	Amlodipin 10 mg	6	16	Bisoprolol 5 mg	1
5	Glibenklamid	4	17	Cetirizin	1
6	Acarbose 50 mg	4	18	Spironolacton 25 mg	1
7	Novorapid inj	3	19	NRF caps	1
8	Simvastatin 10 mg	3	20	Meloxicam 7,5 mg	1
9	Levemir Inj	2	21	Renadinac 25 mg	1
10	Asetosal/Miniaspi/Aspilet	2	22	TCM	1
11	Neurodex	2	23	Herbal	2
12	Candesartan 8mg	2	24	-	

In the intervention group, several clinical parameters demonstrated significant improvement from baseline to the end of the study, as indicated by their respective p-values. In contrast, the control group did not show statistically significant changes for these variables. These findings suggest that the educational intervention contributed to better clinical outcomes compared with the control condition

DISCUSSION

After the educational intervention, the understanding and behaviors of the respondents in the treatment group exhibited significant improvements, except for physical exercise or activity, which showed a p- value of 0.09. This indicates that, although the understanding and behaviors related to medication use and dietary habits improved, changes in physical activity were not statistically significant (10).

For the variable of understanding dietary habits in the treatment group and understanding medication use and dietary habits in the control group, the normality test results indicated a p-value > 0.05. Therefore, the data were analyzed using the paired sample t-test rather than the Wilcoxon test (11). The analysis results showed significant differences in all three variables, of the treatment.

Interestingly, the control group also demonstrated significant changes in understanding in the second measurement, despite not receiving direct education. This change may be attributed to external factors or the influence of information received by patients from other sources or interactions with healthcare professionals (12).

Clinical Parameter T2DM in Study

In this study, four clinical parameters were measured: glycated haemoglobin (HbA1c), low-density lipoprotein (LDL), Blood Simple Sugar (BSS), and blood pressure (BP). Prior to conducting bivariate analysis, the data for each clinical parameter, both before and after the intervention, were first tested for normality. This normality test aimed to determine the data distribution, allowing for the identification of whether appropriate statistical analysis would use parametric or non-parametric tests. The normality test for this numerical scale data was performed using the Kolmogorov-Smirnov Test (11). The results of the normality test are presented in the table 4.

In Table 4, the average level of HbA1c in the treatment group was higher than that in the control group. After the educational intervention, the treatment group experienced a decrease in HbA1c mean levels from 9.6 to 9.24. Conversely, the control group showed a slight increase in HbA1c mean levels from

8.65 to 8.67 after being monitored for 3 months. Based on the bivariate analysis, there was a significant difference in the treatment group between the average HbA1c levels before and after the educational intervention (P-Value = 0.035). In the control group, no significant difference was found in measurements after 3 months (P-Value = 0.962).

The findings of this study align with research conducted by Kulzer et al. (13), which demonstrated that continuous diabetes education can significantly reduce patients' HbA1c levels. In that study, the average reduction in HbA1c after interactive education was 0.4%, which is similar to the results obtained in this study.

Additionally, this research also found a reduction in LDL levels, random blood glucose (RBG), and blood pressure (BP) in the treatment group after the educational intervention. A significant result was observed in the BSS variable (P-Value = 0.001), although the reductions in LDL and blood pressure were not statistically significant (P-Value > 0.05). These results are consistent with the study by Gregg et al. (14), which also found that intensive lifestyle interventions could lower blood glucose and blood pressure levels in patients with type 2 diabetes, although the effects on lipid levels such as LDL were not always consistent (15).

In the control group, there was an increase in LDL and BSS levels after the re-evaluation at the third month, with a significant difference between the first measurement and after 3 months (P-Value < 0.05). The average reduction in blood pressure was not significant (P-Value = 0.343). These findings 16reinforce the results from the Look AHEAD Research Group (2013), which found that without intervention, patients with type 2 diabetes often exhibit progressive increases in their metabolic parameters over time.

Medications Used and Educational Effect

Based on Table 6, which presents a list of medications used by the respondents, several key points can be highlighted. The most commonly used anti-diabetic medication was Metformin 500 mg, utilized by 9 respondents, followed by Glimepiride 2 mg, used by 6 respondents. These medications are standard therapies for managing blood glucose levels in patients with type 2 diabetes (17). In addition to Metformin and Glimepiride, Glikazid (Glucodex) was also used by 6 respondents, and Glibenclamide was used by 4 respondents. These medications belong to the sulfonylurea class, which functions to enhance insulin secretion.

Insulin injections were utilized by a small number of respondents, including Novorapid (3 respondents) and Levemir (2 respondents), indicating that some patients required insulin therapy in addition to oral medications. Medications for hypertension and cardiovascular diseases, such as Amlodipine 10 mg (6 respondents), Candesartan 8 mg (2 respondents), and Valsartan/Valesco 80 mg (1 respondent), were used to manage high blood pressure, which often complicates diabetes.

Several respondents also used cholesterol-lowering medications like Simvastatin 10 mg (3 respondents) and Fenofibrate (1 respondent), which are crucial for managing the lipid profile of diabetic patients. Other medications used by a small number of respondents included those for neurological disorders, such as Neurodex (2 respondents), and anti-inflammatory drugs like Meloxicam (1 respondent). Herbal remedies and NRF caps were used by some respondents, indicating the incorporation of alternative therapies alongside conventional medical treatments. Overall, the medication use in this population reflects a comprehensive approach and educational effect to managing diabetes complications, including control of blood glucose, blood pressure, and lipid profiles.

Medication Used Behavior

The medication use behavior in the control group showed inconsistencies despite their high level of knowledge. In contrast, the treatment group exhibited an increase in the number of respondents using medications correctly after receiving education. During the one-week recording period, no respondents from either group forgot to take their medication. However, irregularities in the timing of medication intake remained a concern. Prior to education, respondents had a limited understanding of the importance of regularity in medication timing. Some even believed that taking medications regularly every day could be detrimental to their health, leading them to reduce their medication frequency without consulting a doctor.

Additionally, there was an improvement in managing the interval between diabetes medications and other medications among the respondents. Low knowledge regarding the methods, timing, and spacing of these medications was a primary cause of incorrect medication use behavior, which could contribute to therapeutic failure. Side effects from certain medications, such as metformin and acarbose, which can cause gastrointestinal disturbances (16), also impacted respondents' adherence to medication regimens.

Education regarding medication use successfully improved the medication behaviors in the treatment group but not in the control group. The oral anti-diabetic medications used by respondents predominantly included Biguanides and Sulfonylureas, with a small number also using acarbose. These medications are available in the National Formularium for JKN participants, along with insulin available in various brands such as Novomix, Novorapid, Levemir, Apidra, and Lantus (17).

Attention to the medications used suggests the possibility of macrovascular and microvascular complications in some patients, as evidenced by the use of antihypertensive medications, analgesic- anti-inflammatory drugs, and antihistamines. Proper control of blood glucose levels should ideally reduce the risk of these complications (18). However, in this study, the assessment of the relationship between medication use and clinical parameters of respondents was not conducted.

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Dietary Practices

High knowledge about dietary practices does not always guarantee appropriate eating behaviors. Some respondents still neglect the principles of balanced nutrition and the potential increase in blood sugar levels resulting from high carbohydrate consumption. Several patients reported avoiding vegetables due to issues such as diarrhea, dental problems, or joint pain after consuming them, leading them to steer clear of these important food groups. The majority of the foods consumed tended to be carbohydrate- rich. Family habits play a significant role in shaping the dietary patterns of patients with type 2 diabetes mellitus (19).

The dietary patterns of the Indonesian population are generally high in carbohydrates and low in fiber. Common breakfast foods among respondents included pempek, savory rice, lontong, instant noodles, bread, and various fried foods such as sweet potatoes, bananas, and fried bakwan, all of which have a high glycemic index. Lunch and dinner, as well as snacks, were typically dominated by carbohydrates (20).

Some respondents consumed large portions due to concerns about feeling hungry if they ate less, while others tended to snack late into the evening before bedtime. The education provided through booklets and oral explanations was intended to serve as a guide to help respondents, particularly in the treatment group, in selecting and combining foods to control their blood sugar levels. However, statistically, there was no increase in understanding of dietary practices in either the treatment or control groups. Changing eating behaviors is indeed challenging, even for individuals with adequate knowledge, as eating habits are influenced by culture, economics, and one’s living environment (21).

Physical Activity

The understanding of physical activity in the treatment group significantly improved after receiving education, while the control group showed no change (22). This increase in understanding was followed by positive behavior changes in the treatment group. Respondents found it easier to adhere to physical activity than to make proper dietary adjustments (23). Prior to education, the respondents' behaviors regarding physical activity were still lacking. Busy schedules were the primary reason for respondents neglecting physical activity, and some engaged in exercise only when convenient (24). Ignorance about the benefits of exercise also contributed to their unwillingness to participate in physical activities (25). Through education, respondents were encouraged to engage in regular physical activity at least five times a week (26). The exercise demonstrations provided through video were particularly helpful, leading to meaningful changes in their daily behaviors (27).

Overall, face-to-face education combined with booklets has improved the understanding and behaviors of the treatment group regarding medication use and physical activity, although no significant changes in dietary patterns were observed (28). If these conditions can be maintained or even enhanced through additional efforts, it is expected that the health status of patients with type 2 diabetes mellitus will improve, as reflected in clinical parameters (29). Further research can be conducted to improve the dietary habits of patients with type 2 diabetes mellitus (30).

Management of Diabetes Mellitus (DM)

Management of Diabetes Mellitus (DM) primarily aims to reduce morbidity and mortality associated with DM by maintaining blood glucose levels within a normal range and preventing or minimizing the risk of complications. Several clinical parameters that can indicate the achievement of DM management targets include

HbA1c, blood glucose levels with Blood simple sugar (BSS), cholesterol levels (LDL), and blood pressure (systolic and diastolic) (26).

A weight loss of up to 5% of initial body weight through exercise and dietary regulation can reduce HbA1c levels by 0.6% (31). In this study, the average HbA1c level in the treatment group (9.24) decreased by 0.36%, while the control group experienced an average can be increase up to three times. The finding decreased of HbA1c is clinically significant, considering that the interval between the education and the second HbA1c measurement was less than 6 months (32). If respondents can continue to maintain a healthy lifestyle, it is expected that their HbA1c levels will decrease further and reach a target of no more than 6.5 (22). The education provided aimed to encourage respondents to continue efforts to avoid the risk of complications. A study in China demonstrated that higher HbA1c levels correlate with an increased risk of hypertension (HbA1c >8%, 25OR = 1.27 to 1.61 (28).

Regarding the LDL parameter, a slight decrease was observed in the treatment group following education, although this decrease was minimal (6.72 mg/dL) and not clinically significant. In contrast, the control group experienced an average increase of 14 mg/dL. The average cholesterol level in the treatment group remained below 150 mg/dL, thus falling within the normal range. The blood glucose levels in the treatment group decreased by 67 mg/dL, whereas the control group experienced an average increase of approximately 17 mg/dL. Blood glucose measurements are significantly influenced by the condition at the time of measurement and should ideally be taken 2 hours post-meal for a more accurate reflection of an individual's glucose status. Blood pressure showed an average decrease in both groups, with the decrease in the treatment group being statistically significant (p-value 0.032), while the control group did not show a significant change (p-value >0.05).

Periodic monitoring of clinical parameters is crucial in DM management to prevent complications (32); however, the high costs of examinations pose a barrier for patients in China (33). Additionally, a lack of education from healthcare providers has resulted in patients with DM not having sufficient awareness to maintain a healthy lifestyle (34,35). In the future, it is hoped that educational models utilizing written materials, such as simple pocketbooks, can be developed and implemented by health insurance providers like BPJS (17).

Limitation of the study. The limitation of this study is the unavailability of the raw individual- level dataset. As a result, advanced analyses such as recalculation of effect sizes, confidence intervals, or independent group comparisons using change scores could not be performed. The current manuscript therefore relies on the summary statistics that were preserved.

CONCLUSION

This study confirms that structured educational interventions incorporating face-to-face sessions, printed booklets, and exercise-based materials significantly improve medication adherence, dietary practices, and physical activity behaviors among patients with Type 2 Diabetes Mellitus (T2DM). Although no statistically significant improvement was observed in dietary management knowledge and behavior, meaningful improvements in clinical parameters were demonstrated in the intervention group compared to the control group.

These findings highlight the clinical relevance of comprehensive education programs as an effective strategy for optimizing metabolic control and potentially reducing the risk of long- term complications in T2DM patients. Integrating structured education into routine diabetes care may strengthen patient self-management and improve overall health outcomes. Future large-scale and long-term studies are warranted to confirm sustainability and broaden implementation through digital and community-based platforms.

AUTHOR CONTRIBUTION STATEMENT

Sarmalina Simamora, principle investigator, design research, conceptual, collecting data, manuscript write, references. Tedi, collecting data. Sonlimar Mangunsong, manuscript writing draft, data analyze and interpretation data.

CONFLICT OF INTEREST

Authors declared there is not any conflicts of the research. The authors state that they have no financial or personal relationships with entities that might unduly affect their objectivity.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors acknowledge that generative AI-assisted tools (such as Grammarly and ChatGPT) were used solely to improve grammar, language clarity, and formatting of the manuscript. No content, data analysis, or interpretation was generated by AI, and all intellectual contributions are the sole responsibility of the authors.

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ETHICAL CONSIDERATIONS

This study was conducted in accordance with ethical standards for human research. Ethical approval was obtained from Institutional Review Board Locally, and informed consent was secured from all participants prior to data collection.

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