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Research Article

EXPLORING THE IMPACT OF PILLBOX USABILITY ON ADHERENCE AND GLYCEMIC REGULATION IN PRIMARY CARE SETTING WITH TYPE 2 DIABETES MELLITUS

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ABSTRACT

Objectives: Type 2 diabetes mellitus (T2DM) needs continuing adherence and effective self-management strategies to achieve optimal glycemic control. This investigation sought to explore the link between pillbox usability and patient adherence, patient adherence, and random blood glucose (RBG) levels, in addition to pillbox usability and RBG levels in T2DM.

Methods: This observational study involved 33 patients with T2DM receiving care from the Lubuk Kilangan Primary Health Center, selected through purposive sampling. Pillbox usability was assessed using the System Usability Scale questionnaire, medication adherence was measured over a monthly period using the pill count method, and RBG data were obtained from patients' clinical records. Data were analyzed using Spearman's rank correlation test to consider relationships between variables.

Results: The findings indicated no significant correlation between pillbox usability and either medication adherence or RBG levels ($p>0.05$). However, a significant negative link existed between medication adherence and RBG levels, with moderate strength ($r=-0.456$; $P=0.008$).

Conclusion: These findings point to improved medication adherence contributing to better glycemic control, as indicated by lower RBG levels. Nevertheless, pillbox usability was not found to have a significant impact on either adherence or blood glucose control.

Keywords: Usability, Pillbox, Type 2 diabetes mellitus, Adherence, Random blood glucose.

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HIGHLIGHTS

1. Pillbox usability was not significantly associated with either medication adherence or random blood glucose (RBG) levels in type 2 diabetes mellitus (T2DM) patients.
2. A significant moderate inverse association was identified between medication adherence and RBG levels, indicating that better adherence is linked toward better blood glucose regulation.
3. Despite high average adherence levels, perceived usability of the pillbox did not directly influence adherence behavior or clinical outcomes, suggesting the need for more integrated adherence support strategies.

INTRODUCTION

Diabetes mellitus (DM) represents a public health issue that has reached alarming levels. If not properly managed, diabetes and its underlying diseases can lead to hospitalizations and death. Globally, diabetes is listed among the top 10 most common roots of mortality [1]. DM is a long-term metabolic ailment marked by increasing blood sugar levels, which can gradually cause severe complications affecting the blood vessels and heart, nervous system, eyes, and kidneys, if left uncontrolled [2]. Over 90% of type 2 DM (T2DM) is marked by reduced insulin production from pancreatic beta cells, along with insulin impairment and an insufficient compensatory insulin response [3].

As stated by the International Diabetes Federation (IDF) in 2021, more than 500 million grown-up people globally are living with diabetes [4,5]. This number increased from 463 million in 2019, and the IDF predicts a continued global increase in diabetes prevalence over the coming decades [6].

Indonesia holds the fifth position globally for the highest portion of adults living with diabetes. In 2021, approximately almost 20 million adults in Indonesia – or about 10.6% of the total population – were living with diabetes [7,8]. According to the Padang City Health Office, in 2022, there were 13,733 people diagnosed with diabetes across 23 primary health centers (puskesmas) in Padang City. Diabetes remains a significant public health issue, particularly in the Lubuk Kilangan Primary Health Center, which was ranked sixth in terms of the amount of diabetes patients, with a total of 868 patients [9,10].

Patient adherence to medication is critical to achieving therapeutic success and optimal clinical outcomes [11]. However, non-adherence to medication remains a common problem, especially among patients with type 2 diabetes [12]. These patients may receive monotherapy or a combination of several medications that must be taken daily. Medications for type 2 diabetes include metformin, sulfonylureas, alpha-glucosidase inhibitors, thiazolidinediones, and others [13]. These can be prescribed as monotherapy or in combination with two or three agents, depending on the patient's needs [14]. The number of medications required can lead to treatment fatigue, potentially reducing adherence. Adherence is defined as the extent to which a patient's behavior aligns with the prescribed therapeutic regimen. Patients are classified as adherent if their medication adherence rate is ≥80%, and non-adherent if it is <80% [15]. Adherence percentage can be calculated using the pill count method [16].

One commonly used strategy to support adherence is the use of a pillbox, which helps patients remember their medication schedule and thus supports better adherence and treatment outcomes [12,17]. A pillbox is a container divided into compartments that separate medications based on dosing times, making it easier for users to organize and remember their intake schedule.

A research project carried out in 2022 by Fitria *et al*. revealed among T2DM Prolanis participants at the Lubuk Kilangan Primary Health Center in Padang, medication adherence – measured through the pill count method – differed significantly between those who used a pillbox and those who did not. The study revealed that adherence levels were significantly higher in patients who used a pillbox [10]. A similar study was conducted among hypertensive patients, yielding consistent results: Patients using a pillbox demonstrated better adherence compared to those who did not [16].

METHODS

Study design and setting

This investigation adopted a cross-sectional planto observe the variables and was conducted at the Lubuk Kilangan Primary Health Center (Puskesmas Lubuk Kilangan), located in Padang City, Indonesia. Data collection was conducted over a specified period in 2025 (January to June), with ethical considerations in place.

Participants

The study population consisted of patients diagnosed with T2DM who were registered at the Lubuk Kilangan Primary Health Center. Participants were selected using a purposive sampling technique, which involves identifying individuals based on specific characteristics aligned with the research objectives – in this case, patients with T2DM receiving therapy either with or without pillbox support.

Inclusion-exclusion criteria

Participants aged 18 years or older, diagnosed with T2DM, receiving regular treatment and follow-up at the Lubuk Kilangan Primary Health Center, and taking diabetes medication with or without pillbox support were eligible for inclusion. They also needed to be able and willing to give informed consent and take part in interviews. Patients were excluded if they had cognitive impairments, communication difficulties, or other health conditions that prevented active participation, as well as those who were hospitalized or experiencing a medical emergency during the data acquisition.

Data collection

Data were collected through structured interviews, standardized questionnaires, and reviews of clinical records. Several key variables were assessed in this study. First, sociodemographic and clinical characteristics were gathered, including age, gender, education, occupation, diabetes duration, and the sort of medication therapy. These data were obtained through direct interviews with participants and verified using their medical records. Second, the usability of the pillbox was measured using the System Usability Scale (SUS), a validated 10-question survey tool designed to assess the alleged usableness of a tool. Every question is evaluated on a scale ranging from 1 to 5, and the responses are converted into a composite score ranging from 0 to 100, with higher scores indicating greater usability [8].Third, medication adherence was evaluated by counting the remaining pills, using the formula [10]:

$$\text{Adherence}\,(\%) = \frac{\text{Number of doses taken}}{\text{Number of doses prescribed}} \times 100$$

Patients with an adherence rate of ≥80% were classified as adherent, while those with an adherence rate of <80% were considered non-adherent [10]. Finally, random blood glucose (RBG) levels were obtained from the most recent laboratory results available in the patients' medical records at the primary health center. These clinical data provided insight into the patients' glycemic control at the time of the study.

Data analysis

The data were analyzed using descriptive statistics. Continuous variables were extracted as means with standard deviations, or as medians with interquartile ranges. Categorical variables were reported as frequencies and percentages. To examine relationships between variables, Spearman's rank correlation test was utilized. This non-parametric test was used to assess the value of SUS, which reflect the perceived usability of the pillbox, and medication adherence [18]. In addition, the correlation between medication adherence and RBG levels was assessed, as well as the relationship between SUS scores and RBG levels in patients with T2DM.

RESULTS

The sociodemographic, clinical characteristics, and SUS results of the 33 respondents in this study are presented in Table 1. Sociodemographic characteristics were obtained from the data collection sheet and included variables.

Table 2 presents an overview of the respondents' medication adherence, RBG levels, and pillbox usability scores as measured by the SUS. Table 3 outlines the findings from the regression analysis examining the links between pillbox usability, medication adherence, and RBG levels in individuals with T2DM.

DISCUSSION

The majority of respondents were female (81.8%), suggesting a higher prevalence of T2DM among women. This may be due to greater body fat composition and hormonal differences, as women generally have

Table 1: Overview of patients' characteristics

Variable	Category	n	Percentage
Gender	Male	6	18.2
	Female	27	81.8
Usia	Adult (19–59 tahun)	14	42.4
	Older adult (≥60 tahun)	19	57.6
Education level	Low (no formal education/ elementary school)	15	45.5
	Middle (junior-senior high school)	13	39.4
	High (diploma/bachelor's/ master's/doctoral degree)	5	15.2
Employment status	Employed	4	12.1
	Unemployed	29	87.9
Comorbidity	Without comorbidities	10	30.3
	With comorbidities	23	69.7
Type of medication	Monotherapy	17	51.5
	Combination therapy	16	48.5

Analyze using: Descriptive analysis

Table 2: Overview of patients' adherence, blood glucose level, and usability score

Variable	Median (IQR)	Min.	Max.
Usability score (point)	63.48 (24.32)	27.50	92.50
Adherence (%)	89.56 (20.97)	37.78	100.00
Random Blood Glucose (mg/dL)	194.94 (115.64)	62.00	394.00

Analyze using: Compare means
Mean±SD for usability score: 63.48±18.02; adherence: 89.56±15.53; RBG: 194.94±85.66

Table 3: Results of regression analysis between usability score, adherence, and blood glucose level (RBG)

Variable	r	R^2	95% CI for r	p-value
Usability score and adherence	−0.112	0.007	(−0.455, 0.257)	0.534
Usability score and blood glucose level (RBG)	−0.011	0.004	(−0.357, 0.338)	0.953
Adherence and blood glucose level (RBG)	−0.456	0.268	(−0.693, −0.140)	0.008

Analyze using Spearman Correlation

20–25% body fat compared to 15–20% in men. Excess adipose tissue increases free fatty acids, which can reduce insulin sensitivity and impair glucose metabolism [19]. In addition, women are more prone to overweight and obesity due to a higher body mass index, contributing to insulin resistance [20].

Most respondents were older adults (≥60 years; 57.6%), a group at higher risk of T2DM due to reduced physical activity, increased fat, and decreased β-cell function. Age-related declines in mitochondrial activity and poor lifestyle habits can further contribute to insulin resistance [3]. In terms of education, 45.5% had low educational backgrounds. Lower education is often linked with limited health literacy, reducing awareness of diabetes prevention and management. Regarding employment, only 12.1% of respondents were working. A sedentary lifestyle and low physical activity in non-working individuals can increase diabetes risk [8].

Approximately 70% of respondents had comorbidities, with hypertension being the most common (91.3% of those with comorbid conditions). Hypertension, a common T2DM complication, may worsen insulin resistance and impact treatment outcomes [5]. Finally, 51.5% of respondents received monotherapy, and 48.5% received combination therapy. The most prescribed drugs were metformin and glimepiride, first-line antidiabetic agents. Metformin reduces hepatic glucose production, while glimepiride stimulates insulin secretion [21]. Combination therapy is used when monotherapy fails to control blood glucose within three months [6]. This study anticipated that higher SUS scores – indicating better perceived usability of the pillbox – would be positively associated with medication adherence. However, regression analysis revealed a weak negative association, with each one-point increase in SUS score corresponding to a 0.07-point decrease in adherence. The coefficient of determination (R^2=0.007) indicated that pillbox usability poorly explained adherence variation. Spearman's correlation also indicated a slight negative association that was not statistically significant (r=−0.112, p=0.534), suggesting that SUS scores had little influence on adherence.

These findings imply that while pillboxes are intended to support adherence, perceived usability alone does not significantly affect adherence behaviors. This aligns with literature indicating that factors such as patient education, healthcare provider involvement, and motivation are more influential than technical usability [8]. Even with high usability, barriers such as forgetfulness or lack of understanding may persist. In addition, the small sample size and unmeasured factors (e.g., pillbox usage duration and patient preferences) may have limited the findings [22,23].

A stronger relationship was found between adherence and RBG levels. Regression analysis showed that increased adherence was associated with lower RBG levels (R^2=0.268), and Spearman's correlation confirmed a moderate, significant negative association (r=−0.456, p=0.008). This supports the role of adherence in glycemic control, as poor adherence can lead to uncontrolled blood glucose and related complications [24]. However, glycemic outcomes are also influenced by diet, activity, stress, and comorbidities, highlighting the multifactorial nature of diabetes management [25].

The average SUS score among the 33 respondents was 63.48, indicating a generally poor perception of pillbox usability. Respondents who reported higher usability scores were predominantly those who were unemployed or had limited daily mobility. In contrast, those who were employed or engaged in more mobile lifestyles expressed difficulty using the pillbox due to its relatively large size compared to the standard medication packaging (plastic bags) provided by the primary health center. Working patients also reported limited time availability, perceiving the use of the pillbox as time-consuming and less practical than simply using the original medication packaging. In terms of age, older adults (≥60 years) were more likely to report lower SUS scores. This may be attributed to age-related cognitive decline, which can affect the elderly's ability to comprehend and effectively use the pillbox. Consequently, elderly patients may encounter greater challenges in adapting to tools requiring procedural understanding and consistent use.

Prescription patterns also appeared to influence pillbox usability. Patients on monotherapy reported higher SUS scores and were more likely to rate the usability as "good" or "very good" compared to those on combination therapy [8]. This may be explained by the typically larger tablet size and bulkier packaging of antidiabetic medications. In patients receiving combination therapy, a single compartment of the pillbox often had to accommodate two tablets per dosing time, making it difficult to insert and retrieve the medication. In contrast, patients on monotherapy only needed to place one tablet in each compartment, simplifying the process. Nonetheless, some patients still found the pillbox challenging to use, particularly due to the large size of certain medications, such as metformin.

The average medication adherence rate among respondents was 89.56%, suggesting a generally high level of adherence to prescribed therapy. This indicates that the majority of patients were compliant with diabetes management as recommended by healthcare providers. Patient adherence may be positively influenced by health education provided by medical staff, which can enhance awareness of the importance of consistent therapy. In addition, family support plays a crucial role in reinforcing medication routines and improving overall adherence behavior.

In contrast, SUS scores showed no significant relationship with RBG levels. The regression model accounted for only 0.4% of the variation (R^2=0.004), and Spearman's correlation was nearly null (r=−0.011, p=0.953). Thus, pillbox usability does not appear to directly impact blood glucose levels. These findings suggest that while usability may aid adherence, it is not sufficient on its own to influence clinical outcomes. A comprehensive strategy that integrates usability with education, reminders, and provider support is likely needed to improve diabetes management.

Spearman's correlation was employed in this study due to the non-normal distribution of the key variables, providing a non-parametric measure of association that does not assume linearity or normality. However, correlation analysis – by nature – does not control for potential confounding variables such as age, education level, or comorbidities. The decision not to conduct multivariable regression analysis was primarily influenced by the limited sample size (n=33), which reduces the reliability and stability of regression coefficients when multiple covariates are included. Performing multivariable regression with a small sample increases the risk of overfitting and misleading inferences. In addition, the study was exploratory, aiming to identify preliminary associations rather than establish causal relationships.

Strengths and limitations

One of the key strengths of this report is the use of validated instruments, including the SUS for evaluating pillbox usability and the pill count method to measure medication adherence, and its setting in a real-world primary care environment, which enhances the relevance of the findings. The inclusion of both sociodemographic and clinical data also provides a more comprehensive view of factors influencing adherence and glycemic regulation in T2DM patients. However, the study also has limitations, including a small sample size (n=33), which may reduce statistical power, and the use of purposive sampling, which may give boundary to generalizability. Its cross-sectional design precludes causal interpretation, and the study did not account for confounding factors such as diet, exercise, stress, or duration of pillbox use. In addition, the reliance on self-reported and retrospective clinical data may introduce bias.

CONCLUSION

This study found that while pillbox usability was not significantly associated with medication adherence or RBG levels, adherence itself

showed a statistically significant, moderately negative correlation with blood glucose levels, indicating its critical role in glycemic control among patients with T2DM. These findings highlight that technical tools like pillboxes alone may not be sufficient to improve adherence or clinical outcomes without addressing broader behavioral and psychosocial factors. Future interventions should combine usability improvements with patient education, behavioral support, and healthcare professional involvement to optimize diabetes management. Additional research using larger, more heterogeneous samples and long-term follow-up is needed to more thoroughly explore how usability affects adherence and health outcomes.

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AUTHORS' CONTRIBUTIONS

Syofyan Syoyan (SS) served as the principal investigator of the research. Nindya Viona Asfiqra(NVA) was responsible for data collection. Najmiatul Fitria conducted field supervision, data analyze, and drafted the initial manuscript. All authors reviewed and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The author(s) report no conflicts of interest.

ETHICAL APPROVAL

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