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Association of a nurse-led structured insulin management program with glycemic control and medication safety in patients with type 2 diabetes

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Abstract: **Background**: Insulin therapy is important for many patients with type 2 diabetes mellitus (T2DM), but its effectiveness and safety are often limited by incorrect injection technique, poor adherence, inadequate glucose monitoring and hypoglycemia risk. **Objectives**: To retrospectively evaluate the association of a nurse-led, structured insulin management program based on medication therapy management (MTM) principles with glycemic control and medication safety in patients with T2DM receiving insulin therapy. **Methods**: Medical records and nursing follow-up data of 120 adult patients with T2DM who received insulin therapy were retrospectively reviewed. The patients were allocated to either a nurse-led structured management group or a usual care group, based on the nursing care model as recorded in routine clinical practice, in a 1:1 ratio; 60 patients were allocated to each group. The structured management program included insulin education, injection training, guidance on glucose monitoring, hypoglycemia prevention and weekly telephone or digital follow-up. Outcomes were extracted at baseline and at 3-month follow-up. **Results**: After the 3-month observation period, HbA1c was lower in the structured management group than in the usual care group (7.6 ± 0.9% vs. 8.5 ± 1.0%, $p < 0.001$). Fasting blood glucose was also lower in the structured management group (7.4 ± 1.3 mmol/L vs. 8.8 ± 1.6 mmol/L, $p < 0.001$). Recorded hypoglycemic episodes were less frequent in the structured management group (13.3% vs. 30.0%, $p = 0.028$) and recorded insulin medication errors (10.0% vs. 28.3%, $p = 0.012$). Adherence, self-management and satisfaction scores were higher in the structured management group (all $p < 0.001$). **Conclusion**: In this retrospective comparative study, receipt of nurse-led MTM-based structured insulin management was associated with better short-term glycemic control, fewer recorded hypoglycemic episodes and insulin-related medication errors, and higher adherence, self-management, and satisfaction scores. These results should be interpreted carefully and confirmed in prospective studies.

Keywords: Glycemic control; Hypoglycemia; Insulin therapy; Medication therapy management; Medication safety; Nursing structured management program; Self-management; Type 2 diabetes mellitus

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a common chronic metabolic disease and a major public health burden worldwide. Poor glycemic control is associated with microvascular and macrovascular complications, increased healthcare use and reduced quality of life. For many patients whose blood glucose cannot be adequately controlled with oral antidiabetic drugs alone, insulin therapy remains an essential treatment option (American Diabetes Association Professional Practice Committee, 2026).

Although insulin is effective, its clinical use is more complex than that of most oral medications. Insulin is considered a high-alert medication because inappropriate use may lead to serious adverse outcomes, especially hypoglycemia (Institute for Safe Medication Practices, 2024). In routine practice, patients receiving insulin therapy may experience multiple barriers, including insufficient knowledge of insulin use, poor adherence, incorrect injection technique, missed or repeated injections, inappropriate injection timing, inadequate self-monitoring of blood glucose and fear of hypoglycemia. This may reduce treatment effectiveness and increase the risk of medication-related harm (Alqahtani, 2022; Ferreira *et al*., 2025; Geller *et al*., 2021; Riangkam *et al*., 2024). Repeated injections into the same area may also increase the risk of injection-site lipohypertrophy, which may make insulin absorption less predictable and cause glycemic fluctuation (Huang *et al*., 2023; Mader *et al*., 2024; Tian *et al*., 2023).

Medication therapy management (MTM) is a patient-centered approach that aims to optimize medication use through medication assessment, individualized education, identification of medication-related problems, monitoring of treatment effectiveness and safety and continuous follow-up (American College of Clinical Pharmacy, 2023). When MTM principles are applied to insulin therapy, the focus should extend beyond adherence alone.

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Unlike most oral antidiabetic drugs, insulin therapy requires patients to administer insulin correctly, coordinate insulin use with meals and glucose monitoring, recognize hypoglycemia, and respond appropriately to abnormal glucose values. Hence, an MTM-based insulin management program should include medication education, injection training, medication-error prevention, hypoglycemia management and follow-up support (Abujbara *et al*., 2022; Alqahtani, 2022; Hirsch and Strauss, 2019; Riangkam *et al*., 2024; Spollett, 2016).

Prior literature has indicated that nurse-led diabetes education and self-management support can improve glycemic control and patient involvement (Azami *et al*., 2018; Jutterstrom *et al*., 2016; Sun *et al*., 2025; Wang *et al*., 2019). Other studies have emphasized the importance of proper insulin injection technique and the value of repeated education for patients on insulin therapy (Abujbara *et al*., 2022; Hirsch and Strauss, 2019; Riangkam *et al*., 2024; Spollett, 2016). However, many existing structured management programs have focused on glycemic outcomes, while medication safety outcomes, including insulin-related medication errors and hypoglycemic episodes, are less commonly assessed. There is also limited evidence for structured nurse-led insulin management programs designed according to MTM principles, assessed from both a glycemic-control and a medication-safety perspective (Alqahtani, 2022; Dailah, 2024; Ferreira *et al*., 2025; Piya *et al*., 2022).

The originality of the present study lies in the application of MTM concepts to a nurse-led, structured insulin program and in the assessment of efficacy and safety outcomes. The program included insulin education, injection training, glucose monitoring guidance, hypoglycemia prevention and weekly telephone or digital follow-up. This retrospective comparative study was designed to determine whether receipt of a nurse-led MTM-based structured insulin management program in routine practice was associated with better short-term glycemic control, fewer recorded hypoglycemic episodes and insulin-related medication errors and higher adherence, self-management ability and patient satisfaction in adults with T2DM receiving insulin therapy.

MATERIALS AND METHODS

Study design

This was a single-center retrospective comparative study based on medical records and nursing follow-up data from adult patients with T2DM receiving insulin therapy. Patients were assigned to a nurse-led, structured insulin management group or a usual care group according to the nursing care model documented in routine clinical practice. Outcomes were extracted at baseline and after a 3-month observation period. Patients treated between January 2024 and December 2024 were screened.

Participants

Adult patients with T2DM receiving insulin therapy were retrospectively identified from the endocrinology outpatient service and the associated nursing follow-up system of the participating hospital. Patients were eligible if they had received either nurse-led structured insulin management or usual care in routine clinical practice and had baseline and 3-month follow-up data available. The participating hospital was a tertiary hospital with an endocrinology outpatient service and a nursing follow-up system for patients with chronic metabolic diseases. The structured management program was delivered as part of routine diabetes nursing care. Available baseline demographic and clinical information included age, sex, duration of diabetes, body mass index, insulin regimen, baseline HbA1c and baseline fasting blood glucose. Detailed socioeconomic characteristics and comorbidities were not comprehensively available in the retrospective records.

The inclusion criteria were as follows: age ≥18 years; diagnosis of T2DM; use of insulin therapy, including basal insulin, premixed insulin, or basal-bolus insulin; baseline HbA1c ≥8.0%; availability of baseline and 3-month HbA1c and fasting blood glucose data; available nursing follow-up records; and documented insulin-use information during the observation period.

The exclusion criteria were as follows: type 1 diabetes mellitus, gestational diabetes mellitus, severe psychiatric disorders, cognitive impairment, severe organ failure, pregnancy, inability to perform or record blood glucose monitoring, participation in another structured diabetes management program, incomplete baseline or 3-month follow-up data, or missing key nursing follow-up records.

Group classification

Patients were classified according to the nursing care model documented in medical records and nursing follow-up records. Patients who had received structured insulin education, injection training, glucose monitoring guidance, hypoglycemia prevention and weekly telephone or digital follow-up were included in the structured management group. Patients who had received routine physician consultation, an insulin prescription, and standard advice on medication use, diet, and blood glucose monitoring were included in the usual care group. No randomization or allocation concealment was performed.

Blinding

Because of the retrospective design, blinding of patients and nurses was not applicable. Group identity was coded as Group A and Group B during data cleaning and statistical analysis to reduce potential analysis bias where possible. The correspondence between the coded labels and the care models was reviewed after completion of the main statistical analysis.

Care models

Patients in the usual care group received routine care, including physician consultation, insulin prescription, and standard advice on medication use, diet, and blood glucose monitoring. Patients in the structured management group received a nurse-led structured insulin management program in addition to usual care as part of routine nursing practice. The program included the following components, as documented in the follow-up records, including insulin education, injection training, blood glucose monitoring guidance, hypoglycemia prevention and management, and weekly telephone or digital follow-up. When potential medication-related problems or the need for insulin regimen adjustment were identified, patients were referred to physicians in accordance with routine clinical practice.

Outcome definitions and data collection

The primary outcomes were HbA1c, fasting blood glucose, recorded hypoglycemic episodes and recorded insulin-related medication errors. Secondary outcomes included medication adherence, diabetes self-management ability and patient satisfaction extracted from nursing assessment forms. HbA1c and fasting blood glucose values were extracted from hospital laboratory records. HbA1c was measured at baseline and approximately 3 months later. Fasting blood glucose was measured at baseline and at 1, 2, and 3 months, when available.

Hypoglycemic episodes were identified from self-monitoring records, nursing follow-up records and medical records. Hypoglycemia was defined as a recorded blood glucose level <3.9 mmol/L or as typical hypoglycemic symptoms that improved after carbohydrate intake. Recurrent hypoglycemia was defined as two or more recorded hypoglycemic episodes during the 3-month observation period.

Insulin-related medication errors were extracted from nursing follow-up records, insulin-use diaries and medical records. These errors included incorrect dose, incorrect timing, missed injection, repeated injection, incorrect injection technique, and injection into an inappropriate or repeatedly used site. One patient could have more than one recorded error type.

Medication adherence, diabetes self-management ability and patient satisfaction scores were extracted from structured nursing assessment forms used during routine follow-up. The adherence form assessed insulin-use behaviors, including missed injections, incorrect timing, repeated injections and unauthorized dose adjustment. The self-management form assessed blood glucose monitoring, diet control, physical activity, insulin injection practice, injection-site rotation, hypoglycemia recognition and response and communication with healthcare providers. The self-management score was converted to a 0–100 scale. Patient satisfaction was assessed using a self-designed 5-point scale. These assessment forms were not externally validated.

During the 3-month observation period, patients in both groups had received routine advice on diet, physical activity and medication use as part of usual diabetes care. However, dietary intake, physical activity and changes in non-insulin glucose-lowering medications were not systematically quantified in the available records.

Sample size

No formal sample size calculation was performed. The sample size was determined by the number of eligible patient records available during the study period that met the inclusion and exclusion criteria. Therefore, the findings should be considered exploratory.

Statistical analysis

Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation for normally distributed data or median and interquartile range for non-normally distributed data. Categorical variables were expressed as frequency and percentage.

Normality was assessed using the Shapiro–Wilk test and visual inspection of histograms. Between-group comparisons of normally distributed continuous variables were performed using independent-samples t tests, while non-normally distributed variables were compared using the Mann–Whitney U test. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate.

Repeated measurements of fasting blood glucose over time were analyzed using repeated-measures analysis of variance or a linear mixed-effects model. The analysis was conducted using complete records available. Missing data were handled using complete-case analysis. Sensitivity analysis may be considered in future studies if the proportion of missing data is substantial.

A two-sided *p-value* <0.05 was considered statistically significant.

Ethical considerations and trial registration

This retrospective study was reviewed and approved by the Ethics Committee of West China Hospital, Sichuan University (approval number: WCH-EC-2024-056). The requirement for written informed consent was waived because anonymized existing medical records and nursing follow-up data were used.

RESULTS

Patient record selection and baseline characteristics

A total of 143 medical and nursing follow-up records

were screened; 23 records were excluded, and 120 eligible patient records were included in the final analysis. A participant record flow diagram is provided in fig. S1. Among the included records, 60 patients received nurse-led structured insulin management, and 60 received usual care during the 3-month observation period. No missing data were reported for the primary glycemic outcomes. Baseline demographic and clinical characteristics are shown in table 1. The two groups were comparable in age, sex, duration of diabetes, BMI, baseline HbA1c, baseline FBG and insulin regimen distribution, with no statistically significant between-group differences.

Glycemic outcomes

At baseline, HbA1c levels were similar between the structured management group and the usual care group (9.4 ± 1.2% vs. 9.3 ± 1.1%, p = 0.684). After 3 months, HbA1c was lower in the structured management group than in the usual care group (7.6 ± 0.9% vs. 8.5 ± 1.0%, p < 0.001). The between-group difference at 3 months was −0.9 percentage points (95% CI: −1.24 to −0.56).

The absolute reduction in HbA1c from baseline to 3 months was 1.8 percentage points in the structured management group and 0.8 percentage points in the usual care group. HbA1c changes from baseline to 3 months are shown in table 2.

Fasting blood glucose decreased over time in both groups. Fasting blood glucose levels at baseline and at 1, 2 and 3 months are presented in table 3. At 3 months, fasting blood glucose was lower in the structured management group than in the usual care group (7.4 ± 1.3 mmol/L vs. 8.8 ± 1.6 mmol/L, p < 0.001). The between-group difference at 3 months was −1.4 mmol/L (95% CI: −1.93 to −0.87).

The absolute reduction in fasting blood glucose from baseline to 3 months was 3.4 mmol/L in the structured management group and 1.8 mmol/L in the usual care group.

Recorded hypoglycemic episodes during the 3-month observation period

Hypoglycemia was defined as a blood glucose level <3.9 mmol/L or typical hypoglycemic symptoms that improved after carbohydrate intake. Recurrent hypoglycemia was defined as two or more hypoglycemic episodes during the 3-month follow-up. Recorded hypoglycemic episodes during the 3-month observation period are summarized in table 4.

During the 3-month observation period, any recorded hypoglycemic episode was identified in 8 patients in the structured management group and 18 patients in the usual care group (13.3% vs. 30.0%, p = 0.028). The absolute risk difference was −16.7 percentage points (95% CI: −31.1 to −2.2). Recurrent recorded hypoglycemia was identified in 2 patients in the structured management group and 7 patients in the usual care group (3.3% vs. 11.7%, p = 0.082). The absolute risk difference was −8.3 percentage points (95% CI: −17.6 to 1.0). The severity of hypoglycemic episodes was not systematically recorded.

Recorded insulin-related medication errors

Insulin-related medication errors included wrong dose, wrong timing, missed injection, repeated injection, incorrect injection technique and injection into an inappropriate or repeatedly used site. Medication errors were recorded at the patient level. One patient could report more than one type of error; therefore, the sum of individual error types may exceed the number of patients with any medication error. Recorded insulin-related medication errors are shown in table 5.

Any recorded insulin-related medication error was identified in 6 patients in the structured management group and 17 patients in the usual care group (10.0% vs. 28.3%, p = 0.012). The absolute risk difference was −18.3 percentage points (95% CI: −32.0 to −4.6).

The wrong dose was reported in 2 patients in the structured management group and 8 in the usual care group (3.3% vs. 13.3%, p = 0.046). Wrong timing was reported in 3 patients (5.0%) and 10 patients (16.7%), respectively (p = 0.036). Missed injections were reported in 2 patients (3.3%) and 9 patients (15.0%), respectively (p = 0.025).

Adherence, self-management and satisfaction scores

Medication adherence and diabetes self-management ability were assessed using structured self-designed nursing assessment forms used during routine follow-up. Adherence and self-management scores are presented in table 6. The adherence questionnaire assessed insulin-use behaviors, including missed injections, incorrect timing, repeated injections and unauthorized dose adjustment. The diabetes self-management questionnaire assessed blood glucose monitoring, diet control, physical activity, insulin injection practice, injection-site rotation, hypoglycemia recognition and response and communication with healthcare providers. The self-management score was converted to a 0–100 scale, with higher scores indicating better self-management ability. Patient satisfaction was assessed using a self-designed 5-point satisfaction scale, with higher scores indicating greater satisfaction.

Patient satisfaction scores are shown in table 7. At 3 months, the medication adherence score was higher in the structured management group than in the usual care group (8.2 ± 1.0 vs. 6.7 ± 1.1, p < 0.001). The between-group difference was 1.5 points (95% CI: 1.12 to 1.88).

Table 1: Baseline demographic and clinical characteristics according to care model.

Characteristic	Structured management group (n = 60)	Usual care group (n = 60)	*p-value*	Between-group difference
Age, years	58.6 ± 9.4	59.1 ± 8.8	0.731	−0.5; 95% CI: −3.76 to 2.76
Female sex, n (%)	28 (46.7)	30 (50.0)	0.722	−3.3%; 95% CI: −21.2% to 14.5%
Duration of diabetes, years	9.2 ± 4.1	9.5 ± 4.3	0.701	−0.3; 95% CI: −1.80 to 1.20
BMI, kg/m²	25.8 ± 3.2	26.1 ± 3.4	0.620	−0.3; 95% CI: −1.48 to 0.88
Baseline HbA1c, %	9.4 ± 1.2	9.3 ± 1.1	0.684	0.1; 95% CI: −0.31 to 0.51
Baseline FBG, mmol/L	10.8 ± 2.1	10.6 ± 2.0	0.612	0.2; 95% CI: −0.53 to 0.93
Basal insulin, n (%)	18 (30.0)	20 (33.3)	0.689	−3.3%; 95% CI: −20.0% to 13.3%
Premixed insulin, n (%)	27 (45.0)	25 (41.7)	0.714	3.3%; 95% CI: −14.4% to 21.1%
Basal-bolus insulin, n (%)	15 (25.0)	15 (25.0)	1.000	0.0%; 95% CI: −15.5% to 15.5%

Table 2: Comparison of HbA1c levels between the two groups.

HbA1c (%)	Structured management group (n = 60)	Usual care group (n = 60)	*p-value*	Between-group difference
Baseline	9.4 ± 1.2	9.3 ± 1.1	0.684	0.1
3 months	7.6 ± 0.9	8.5 ± 1.0	<0.001	−0.9; 95% CI: −1.24 to −0.56
Absolute change from baseline	-1.8	-0.8	—	—

Table 3: Fasting blood glucose levels during the 3-month observation period.

FBG (mmol/L)	Structured management group (n = 60)	Usual care group (n = 60)	*p-value*	Between-group difference
Baseline	10.8 ± 2.1	10.6 ± 2.0	0.612	0.2
1 month	8.9 ± 1.7	9.8 ± 1.9	0.011	-0.9
2 months	8.0 ± 1.5	9.2 ± 1.7	<0.001	-1.2
3 months	7.4 ± 1.3	8.8 ± 1.6	<0.001	−1.4; 95% CI: −1.93 to −0.87
Absolute change from baseline to 3 months	-3.4	-1.8	—	—

Table 4: Recorded hypoglycemic episodes during the 3-month observation period.

Outcome	Structured management group (n = 60)	Usual care group (n = 60)	*p-value*	Risk difference
Any hypoglycemic episode, n (%)	8 (13.3%)	18 (30.0%)	0.028	−16.7%; 95% CI: −31.1 to −2.2
Recurrent hypoglycemia, n (%)	2 (3.3%)	7 (11.7%)	0.082	−8.3%; 95% CI: −17.6 to 1.0

Table 5: Recorded insulin-related medication errors during the 3-month observation period.

Outcome	Structured management group (n = 60)	Usual care group (n = 60)	*p-value*	Risk difference
Any medication error, n (%)	6 (10.0)	17 (28.3)	0.012	−18.3%; 95% CI: −32.0 to −4.6
Wrong dose, n (%)	2 (3.3)	8 (13.3)	0.046	−10.0%; 95% CI: −19.7 to −0.3
Wrong timing, n (%)	3 (5.0)	10 (16.7)	0.036	−11.7%; 95% CI: −22.6 to −0.7
Missed injection, n (%)	2 (3.3)	9 (15.0)	0.025	−11.7%; 95% CI: −21.8 to −1.6

Table 6: Adherence and self-management scores extracted from structured nursing assessment forms.

Outcome	Structured management group (n = 60)	Usual care group (n = 60)	*p-value*	Between-group difference
Adherence score at baseline	5.8 ± 1.3	5.9 ± 1.2	0.721	−0.1
Adherence score at 3 months	8.2 ± 1.0	6.7 ± 1.1	<0.001	1.5; 95% CI: 1.12 to 1.88
Self-management score 0–100 scale, baseline	48.5 ± 8.7	47.9 ± 9.1	0.738	0.6
Self-management score 0–100 scale, 3 months	67.3 ± 7.5	55.2 ± 8.3	<0.001	12.1; 95% CI: 9.24 to 14.96

Table 7: Patient satisfaction scores extracted from follow-up assessment forms.

Outcome	Structured management group (n = 60)	Usual care group (n = 60)	*p-value*	Between-group difference
Satisfaction score (5-point scale)	4.6 ± 0.5	3.5 ± 0.7	<0.001	1.1: 95% CI: 0.88 to 1.32

The self-management score was also higher in the structured management group than in the usual care group (67.3 ± 7.5 vs. 55.2 ± 8.3, $p < 0.001$). The between-group difference was 12.1 points (95% CI: 9.24 to 14.96).

Patient satisfaction at 3 months was higher in the structured management group than in the usual care group (4.6 ± 0.5 vs. 3.5 ± 0.7, $p < 0.001$). The between-group difference was 1.1 points (95% CI: 0.88 to 1.32).

DISCUSSION

In this retrospective comparative study, delivery of nurse-led, structured insulin management was associated with improved short-term glycemic outcomes and fewer documented insulin-related safety events in patients with T2DM receiving insulin therapy.

The observed decrease in HbA1c in the present study may have clinical relevance. The structured care group had a 1.8 percentage-point decline in HbA1c from baseline to 3 months, compared with a 0.8 percentage-point decline in the usual care group. The difference indicates that the structured management program might have improved short-term glycemic control beyond usual care. In clinical practice, such an improvement may be relevant because reduction of HbA1c is an important treatment goal in patients with T2DM. However, because the follow-up period was only 3 months, the durability of this effect remains to be determined.

Changes in insulin-use behavior may partly explain the improvement in glycemic control. The structured management program included insulin education, injection training, advice on blood glucose monitoring, hypoglycemia prevention, and weekly follow-up. Repeated injections at the same site may contribute to lipohypertrophy, which theoretically may alter local insulin absorption and increase glycemic variability. Standardized injection training and site rotation may help reduce repeated injection into the same area and may lower the risk of injection-site lipohypertrophy, thereby contributing to more predictable insulin absorption. However, this study did not directly assess injection-site lipohypertrophy or insulin pharmacokinetics/ pharmacodynamics; therefore, this explanation should be interpreted as a possible mechanism rather than a confirmed finding.

A major aspect of this study is medication safety in insulin-treated patients. Earlier nurse-led diabetes structured management programs have predominantly focused on glycemic control and self-management education. In contrast, the present study included insulin-related medication errors and hypoglycemic episodes as important outcomes. This is clinically relevant because insulin is a high-alert medication, and errors such as incorrect dose, incorrect timing, missed injections, or repeated injections may lead to avoidable harm (Institute for Safe Medication Practices, 2024; Ferreira et al., 2025). The lower rate of medication errors in the structured management group suggests that structured follow-up and repeated nurse-led reinforcement may help identify and reduce preventable insulin-use problems in routine care.

The lower overall incidence of hypoglycemia in the structured management group is clinically important. In insulin-treated patients with T2DM, hypoglycemia is not only an acute adverse event but also a major barrier to safe insulin use. It may cause autonomic and neuroglycopenic symptoms, falls, injury, emergency visits, fear of insulin therapy, intentional dose reduction and missed injections (Geller et al., 2021; American Diabetes Association Professional Practice Committee, 2026). Therefore, fewer hypoglycemic episodes may support both medication safety and long-term treatment adherence. Several components of the structured

management program may have contributed to this finding, including education on recognizing early hypoglycemic symptoms, guidance on corrective carbohydrate intake, instruction on insulin timing relative to meals and physical activity, and review of blood glucose records and weekly follow-up (Abujbara et al., 2022; Riangkam et al., 2024) to identify unsafe insulin-use behaviors. However, recurrent hypoglycemia did not differ significantly between groups. This non-significant result may reflect the limited sample size, short follow-up period, or insufficient power to detect differences in less frequent outcomes. The structured management program may reduce the total number of hypoglycemic events, but its impact on recurrent hypoglycemia remains uncertain.

The findings regarding adherence, self-management and satisfaction should be interpreted. Higher scores in the structured management group suggest that patients may have gained better practical skills and confidence in insulin use. Treatment effects were assessed using self-designed questionnaires, and patient-reported outcomes may be influenced by recall bias, social desirability bias, or lack of blinding. Thus, although the observed differences support a potential benefit of structured nursing support, future studies should, where possible, use valid scales and as many objective measures of behavior as possible.

The originality of this study lay in the application of MTM principles to nurse-led insulin management and in the assessment of a structured management program from both efficacy and medication safety perspectives. Rather than general diabetes education concepts, this study focused on practical medication-use problems, such as the timing of insulin administration, injection behaviors, prevention of hypoglycemia, identification of medication errors, and follow-up support. The approach may be useful in clinical settings where insulin-related errors and hypoglycemia are common and not always systematically monitored.

It remains unclear which aspect of the program made the greatest contribution to the improvement in glycemic control. Improved adherence may have increased the consistency of insulin use, while education on insulin timing, injection technique and glucose monitoring may have improved the appropriateness and safety of insulin use. Because the current structured management program comprised several components, this study was unable to determine whether the glycemic improvement was primarily due to improved adherence, improved injection behavior, or education on insulin timing and use. This has important clinical implications, because different patients may require different types of support. The patient who has missed injections but has maintained regular insulin use to this point may benefit most from adherence-focused follow-up, while the patient who has glycemic fluctuations despite regular insulin use may require more intensive injection technique assessment, site rotation training, and glucose monitoring guidance. Future research using component or factorial designs is needed to clarify the relative role of each structured care program element.

A second issue to be considered is the possibility of dependency on a structured management program. The structured programme delivered weekly nurse-led follow up, repeated reinforcement and active insulin-use problem identification. These components may have improved patient behavior during the study period, but it is uncertain whether patients were able to maintain safe insulin-use practices after the program ended, even with reduced follow-up intensity. Future studies should address post-intervention maintenance, step-down follow-up models and patient self-efficacy after discontinuation of intensive nurse support.

First, it was a single-center, retrospective, comparative study, and selection bias and information bias could not be excluded. Patients were classified according to the care model documented in routine clinical practice rather than randomized allocation and unmeasured baseline differences may have influenced the results. Second, because the data were obtained from existing medical records and nursing follow-up records, rather than direct observation, the accuracy of hypoglycemic episodes, medication errors, adherence, self-management, and satisfaction depended on the completeness and quality of the documentation. Third, socioeconomic characteristics, detailed comorbidities, dietary changes, physical activity and changes in non-insulin glucose-lowering medications were not fully or quantitatively captured. Fourth, adherence, self-management and satisfaction were measured with self-designed assessment forms that were not externally validated. Fifth, the follow-up period was only 3 months and maintenance effects after program completion could not be assessed. Finally, because the care model comprised multiple components, the individual contribution of each component could not be determined.

Future multicenter studies should include randomized allocation, prospective trial registration, formal sample size calculation, longer follow-up, validated patient-reported outcome measures and objective monitoring tools. Future studies should also determine whether patients sustain safe insulin-use behaviors after intensive nurse-led follow-up is reduced, and evaluate the cost-effectiveness, staffing model, and implementation feasibility of MTM-based structured insulin management in routine practice.

CONCLUSION

In this retrospective comparative study, patients who received nurse-led MTM-based structured insulin

management had better short-term glycemic control, fewer recorded hypoglycemic episodes and insulin-related medication errors, and higher adherence, self-management, and satisfaction scores than patients with T2DM receiving insulin therapy who did not receive nurse-led MTM-based structured insulin management. The results indicate a potential medication-safety advantage of organized insulin management with everyday care. However, due to the retrospective single-center design, reliance on existing records and possible residual confounding, the findings are exploratory and should be confirmed in prospective randomized studies.

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None.

Authors' contributions
Suting Wen: Contributed to conceptualization, methodology, formal analysis and writing—original draft; Shihan Li: Contributed to investigation, data curation, validation and manuscript revision; Suqing Zhang: Contributed to supervision, writing—review and editing and correspondence. All authors read and approved the final manuscript.

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Data availability statement
The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval
This retrospective study was reviewed and approved by the Ethics Committee of West China Hospital, Sichuan University (approval number: WCH-EC-2024-056). The requirement for written informed consent was waived because anonymized existing medical records and nursing follow-up data were used. This study was performed in adherence with the STROBE guidelines. See supplementary file for the STROBE checklist.

Conflict of interest
The authors declare no conflict of interest.

Supplementary data
https://www.pjps.pk/uploads/2026/08/SUP1786090223.pdf

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