

Medication Adherence Interventions to Enhance Medication Safety in Type 2 Diabetes Mellitus: A Narrative Review

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Abstract

Pharmacological therapy is one of the cornerstone strategies for glycemic control and the prevention of complications in patients with type 2 diabetes mellitus (T2DM). However, suboptimal medication adherence is frequently associated with an increased risk of hypoglycemic events, diabetes-related complications, unplanned rehospitalization, and a greater overall healthcare burden. Improving medication adherence is essential for maintaining stable glycemic control and reducing the incidence of adverse diabetes-related outcomes. In recent years, various interventions targeting medication adherence among patients with T2DM have been explored. Nevertheless, existing evidence remains fragmented, particularly with regard to intervention pathways and their associations with medication safety outcomes. This review summarizes current research from two key perspectives: factors influencing medication adherence and adherence-related intervention strategies. The aim is to provide a reference framework for the development of individualized and sustainable interventions in clinical practice, thereby improving medication adherence and enhancing medication safety in patients with T2DM.

Keywords

Clinical Management, Type 2 Diabetes Mellitus, Medication Adherence, Intervention Strategies, Medication Safety

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1. Introduction

Pharmacological treatment plays a critical role in glycemic control and in delaying or preventing complications among patients with type 2 diabetes mellitus (T2DM) [1]. It has been reported that more than 50% of patients with chronic diseases experience medication-related problems, including missed doses, incorrect dosing, neglect of prescribed regimens, and poor medication adherence [2]. Medication adherence is widely recognized as a key behavioral link between prescribed treatment regimens and medication safety outcomes. In this context, medication safety refers to efforts aimed at preventing or reducing medication-related harm, including harm resulting from medication errors, inappropriate medication use, and preventable adverse drug events [3]. From a process-of-care perspective, adherence interventions primarily modify medication-taking behaviors and monitoring processes, which in turn reduce medication errors and preventable adverse drug events, ultimately improving medication safety outcomes. Inadequate adherence not only compromises therapeutic effectiveness but also alters drug exposure patterns, thereby increasing the risk of hypoglycemic events, diabetes-related complications, and unplanned rehospitalization, ultimately exacerbating the disease burden at both individual and healthcare system levels.

Consequently, improving medication adherence and strengthening medication safety management have become integral components of diabetes care. The Chinese Guidelines for the Prevention and Treatment of Diabetes (2024 edition) continue to emphasize a patient-centered approach while highlighting the importance of individualized management, multidisciplinary team collaboration, and the application of digital health technologies [4]. To date, a range of interventions aimed at improving medication adherence in patients with T2DM have been investigated across different studies [5], with generally favorable outcomes. However, substantial heterogeneity exists in terms of intervention components, study designs, and outcome measures, and the available evidence has yet to be systematically integrated. Therefore, this review provides an overview of recent research progress on medication adherence interventions in the context of medication safety management for patients with T2DM.

2. Factors Influencing Medication Adherence

Medication adherence among older patients with T2DM is influenced by multiple factors, including age, educational level, household economic status, diabetes-related knowledge, the presence of complications, the number of comorbid chronic diseases, medication beliefs, and self-efficacy [6]. When formulating medication management strategies for older patients with T2DM, it is essential to comprehensively consider these multidimensional factors and implement targeted interventions to improve medication adherence and glycemic control.

2.1. Population Aging and Low Educational Attainment: Evidence from China

Globally, population aging and limited educational attainment have been recog-

nized as major barriers to chronic disease self-management and medication adherence. However, given the rapidly aging population and distinct educational structure, China represents a particularly relevant context for examining these challenges. Survey data indicate that since 2010, China has experienced a continuous decline in birth rates accompanied by a progressively accelerating aging trend [7]. Among older adults, the prevalence of diabetes has exceeded 30%. Due to generally lower levels of educational attainment, many older individuals lack sufficient knowledge about diabetes and its management [8], as well as a comprehensive understanding of antidiabetic medications. Consequently, they may underestimate the seriousness of the disease [9], leading to reduced medication adherence.

Yang *et al.* [10] conducted a questionnaire-based survey to assess medication safety knowledge, long-term medication behaviors, and attitudes among older patients with chronic diseases. The results demonstrated that medication safety knowledge among this population was generally insufficient and required substantial improvement. Epidemiological data further suggest that as educational level and household income increase, the prevalence of diabetes gradually decreases; conversely, lower educational attainment and income are associated with higher diabetes prevalence [11].

2.2. Occurrence of Hypoglycemia

Hypoglycemia is one of the most common complications associated with pharmacological treatment in patients with T2DM, and has a significant impact on medication adherence. Previous studies have shown a high incidence of hypoglycemia among hospitalized patients with T2DM, particularly following medication dose adjustments [12]. Fear of hypoglycemia may interfere with diabetes management and reduce patients' willingness to adhere to prescribed regimens. Zhu reported that patients living alone often lack immediate assistance in the event of hypoglycemia [13]. Concern about being unable to obtain timely help may reduce confidence in disease management, prompting inappropriate compensatory behaviors such as excessive food intake to avoid hypoglycemia. These behaviors can substantially impair glycemic control, accelerate disease progression, and negatively affect long-term outcomes.

2.3. Low Perceived Treatment Effectiveness

Huang *et al.* [14] used covariance analysis to compare mean scores of medication adherence and related factors across patients with different levels of health literacy. Their findings indicated that reducing perceived barriers to medication use is a prerequisite for improving adherence. Perceived benefits of treatment adherence, awareness of the consequences of nonadherence, and perceived susceptibility to future complications have been identified as key facilitators of appropriate medication-taking behaviors [15]. Polonsky *et al.* [16] further demonstrated that perceived treatment effectiveness is one of the six core determinants of medication

adherence. The stronger a patient's belief in the necessity of medication, the more likely they are to adhere to treatment. When patients perceive timely and tangible benefits from pharmacotherapy, adherence improves markedly. Conversely, if medications are perceived as ineffective, adherence tends to decline.

2.4. Medication Beliefs and Self-Efficacy

Medication belief scores reflect the subjective psychological state of older patients with T2DM when facing lifelong pharmacological treatment. Medication beliefs have been identified as independent risk factors for medication nonadherence [17]. Studies have shown that inadequate medication-related knowledge and the absence of positive medication beliefs can directly lead to decreased adherence [18].

When patients' perceived necessity of medication outweighs their concerns about treatment, they are more likely to follow medical advice; otherwise, adherence may be compromised [19]. Patients with low self-efficacy often lack confidence when confronted with challenging tasks and tend to avoid or abandon self-management efforts, making them more susceptible to difficulties in self-regulation [20]. Enhancing self-efficacy has therefore been shown to improve medication adherence, exert a positive effect on health outcomes, and ultimately enhance quality of life [21].

3. Application of Medication Adherence Interventions in Medication Safety

3.1. Simplification of Medication Regimens

Surveys indicate that 77.9% of patients with diabetes are exposed to polypharmacy, with combined use of antihypertensive and hypoglycemic agents being particularly common [22] [23]. Therefore, simplifying medication regimens is of considerable importance. Regimen simplification typically refers to reducing medication complexity by decreasing the number of drugs prescribed, such as through fixed-dose combination therapies [24]. Li *et al.* proposed an "intensification-simplification" treatment strategy for patients with T2DM and severe hyperglycemia [25]. Following intensive insulin therapy, simplified oral hypoglycemic regimens were adopted as sequential maintenance therapy. This approach not only achieved favorable glycemic outcomes but also significantly improved medication adherence, offering a promising direction for future glycemic management strategies. Elnaem *et al.* [26] demonstrated that simplified regimens, including fixed-dose combinations, once-daily dosing, or a combination of both, effectively improved medication adherence. However, economic barriers should also be considered, as fixed-dose combination therapies are often more costly than individual generic agents, which may limit accessibility and paradoxically reduce adherence in low-income populations. At the same time, current clinical evidence regarding adherence improvement through regimen simplification remains insufficient. Future studies should focus on developing feasible and optimized treatment regimens and further evaluating their real-world effectiveness. Regimen simplification im-

proves medication safety by reducing dosing complexity, which decreases administration errors and enhances treatment persistence.

3.2. Technology-Assisted Interventions: Smart Pillboxes

With the rapid development of the internet and artificial intelligence technologies, various smart devices have been introduced into clinical practice, enabling home-based treatment and improving access to care for patients with limited mobility. Smart pillboxes represent an emerging tool for home medication management and have been increasingly adopted among patients with chronic diseases [27].

By providing medication reminders, smart pillboxes have been shown to effectively improve medication adherence and self-efficacy [28]. Wang *et al.* [29] implemented a smart pillbox system that generated scheduled medication reminders. Patients received reminders at predetermined times and took their medications accordingly. The results demonstrated a significant improvement in medication adherence among patients with T2DM, accompanied by a marked reduction in HbA1c levels after 20 weeks. However, the reliance on self-reported adherence outcomes may have led to an overestimation of the intervention effect, highlighting the need for objective adherence indicators such as electronic monitoring or pharmacy refill records. In contrast to the above study, Zhang *et al.* [30] developed a smart pillbox capable of reminding patients of medication dosage, supporting dosing schedules, as well as incorporating basic health monitoring functions. The system integrated infrared detection and GSM modules to monitor medication intake and provide remote reminders, thereby preventing under- or overdosing. In addition, the device was equipped with real-time monitoring of body temperature, oxygen saturation, and heart rate, enabling continuous surveillance of patients' health status. Their findings suggested improved medication safety and convenience among older adults. Nevertheless, technology-assisted interventions may be constrained by digital literacy barriers, particularly among older adults and individuals with low educational attainment, as discussed in Section 2.1. Moreover, the lack of large-scale, long-term clinical data limits the generalizability of these findings, highlighting the need for further validation in robust clinical settings. Overall, digital reminder systems improve safety by preventing missed doses and enabling early detection of abnormal glucose values.

3.3. Multidisciplinary Team Management

Multidisciplinary team-based management has been shown to effectively enhance patients' self-management capabilities [31] [32]. Early evidence primarily originated from hospital-based nursing-led models. For example, Liu *et al.* [31] demonstrated that a diabetes specialist nurse-led multidisciplinary team significantly improved self-management behaviors in patients with gestational diabetes, while Liu *et al.* [32] further extended this approach to hospitalized older adults by implementing evidence-based multidisciplinary hypoglycemia management, resulting in improved safety outcomes. Building upon these nursing-centered models, Li *et*

al. [33] implemented a multidisciplinary collaborative model centered on patient needs, enabling patients to gradually adopt healthy behaviors and improve self-management efficacy. Shi *et al.* [34] integrated team-based care with a clinical decision support system to intervene in glycemic, lipid, and blood pressure management. Compared with team nursing alone, the combined approach significantly reduced cardiovascular risk factors in patients with diabetes. In contrast, Zhou *et al.* [35] conducted comprehensive patient assessments and developed individualized dietary, exercise, and pharmacological treatment plans, demonstrating that multidisciplinary chronic disease management significantly improved self-management behaviors and medication adherence among patients with T2DM and hypertension. However, the relatively short intervention duration limited the evaluation of long-term benefits. Future studies should incorporate alternative collaborative models as comparators to more precisely assess the value of multidisciplinary care. Multidisciplinary care enhances safety through medication reconciliation, proactive risk assessment, and early identification of adverse drug events.

3.4. Hospital-Family-Community Integrated Health Interventions

For older patients, primary healthcare services, family support, and increased follow-up frequency have been shown to improve medication adherence and glycemic control [36]. Hospital-family-community integrated care models targeting medication safety can enhance self-management ability and self-efficacy in patients with T2DM [37], strengthen family support, and effectively reduce HbA1c levels [38]. In a quasi-experimental study, Khosravizade Tabasi *et al.* [39] implemented structured family support interventions through group education sessions for family members. Compared with the control group, patients receiving family support exhibited a significant reduction in HbA1c (from $8.9 \pm 1.3\%$ to $7.7 \pm 1.1\%$), whereas HbA1c increased in those without family involvement (from $7.8 \pm 0.7\%$ to $8.1 \pm 0.8\%$), corresponding to mean changes of $-1.2 \pm 0.96\%$ vs. $+0.3 \pm 0.91\%$, respectively. Similarly, Tong *et al.* [40] employed a cohort study with a difference-in-differences design to compare medication adherence between registered and unregistered patients following different phases of the family physician system. Their findings indicated that community health center-led family physician services significantly improved medication adherence. Future efforts should focus on optimizing continuity of care across hospital, family, and community settings to ensure medication safety. Family involvement improves safety by reinforcing correct medication-taking behaviors and facilitating early recognition of adverse symptoms.

3.5. Personalized Health Education

Health education for patients with diabetes should be tailored to individual characteristics and needs. Xie *et al.* [41] incorporated short video-based education into the LEARNS nursing model, delivering interventions across six dimensions. By

transforming complex medical information into accessible and engaging visual content, this approach improved patients' self-management abilities and self-efficacy. Compared with the one-way video-based education model, the interactive messaging strategy allowed continuous behavioral feedback and real-time adjustment of educational content. Gautier *et al.* [42] designed personalized text messages based on patients' disease management habits, physical activity levels, and resistance tendencies, sending messages continuously over three months. The intervention significantly improved medication adherence and supported disease awareness. Although diabetes-related health education programs are widely implemented in hospitals and communities, many patients still lack adequate access to professional guidance. Expanding the coverage of personalized education and integrating big data and artificial intelligence technologies represent promising directions for future research.

3.6. Discharge Medication Management

Survey data indicate that receiving eight or more medications at discharge is a risk factor for potentially inappropriate medication use among older patients with T2DM [43], consistent with findings reported by Li *et al.* [44]. Together, these studies highlight polypharmacy at discharge as a critical safety concern, underscoring the urgent need for targeted interventions during the transition from hospital to home.

At the level of basic clinical guidance, physicians can provide targeted medication guidance based on individual patient needs, including education on medication use and precautions, thereby enhancing patients' self-management capacity [45]. At a more specialized professional level, Sun *et al.* [46] developed a proactive pharmaceutical care model involving discharge prescription review and medication education. Pharmacists prepared individualized medication instruction sheets and conducted bedside education prior to discharge, resulting in significant reductions in discharge medication errors, dosing errors, and adverse drug interactions. At the technological empowerment level, Lin *et al.* [47] optimized discharge medication workflows by implementing centralized hospital dispensing, using oral medication pictorial guides, WeChat-based medication check-in tools, and multiple educational approaches such as face-to-face instruction, telephone consultations, and QR code-based education. This technology-enabled model represents an evolution toward scalable and continuous medication management beyond hospital settings.

4. Conclusions

In summary, patients with T2DM face substantial challenges in medication adherence, and adherence-focused interventions have achieved notable progress in the field of medication safety. Strategies such as regimen simplification, multidisciplinary team management, technology-assisted interventions, hospital-family-community integration, personalized health education, and discharge medication

management have been shown to improve adherence and reduce medication errors, missed doses, and inappropriate medication use.

However, the effectiveness of these interventions is often constrained by factors such as patients' economic conditions and limited healthcare resources, leading to variable outcomes. Despite the beneficial effects of family-based interventions demonstrated in current studies (as summarized in Section 3.4), these findings are largely based on short-term outcomes and limited mechanistic exploration. Important knowledge gaps therefore remain. To further enhance medication safety through adherence interventions, future research should explore how family support indirectly influences patients' cognitive and behavioral responses, examine long-term adherence trajectories following family-based interventions, and evaluate the sustainability of intervention effects. High-quality, long-term randomized controlled trials are also needed, along with the exploration of digital tools and precision interventions, to establish individualized and sustainable medication management models. These efforts may provide valuable insights for comprehensive diabetes management and facilitate the delivery of timely, personalized medication guidance aligned with patients' knowledge, beliefs, and behaviors.

Conflicts of Interest

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

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