Maximizing Diabetes Management: A Comparative Study of Digital Monitoring, Group Support, and Their Synergy in Enhancing Patient Adherence

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Abstract

This study evaluated the effectiveness of digital self-monitoring (MySugr app), group psychological support, and their combination in improving adherence and mental health in patients with type 2 diabetes. A total of 79 patients were recruited from a public health center in Zaragoza, Spain, and randomly assigned to one of three groups: (1) MySugr app, (2) bi-weekly group sessions, or (3) a combined intervention. Adherence to diet, physical activity, and medication was assessed at baseline, 3, and 6 months. Anxiety (GAD-7), depressive symptoms (PHQ-9), and HbA1c were also measured. The combined group showed the greatest improvements in adherence to diet and physical activity, both $p < 0.05$. Anxiety scores (GAD-7) significantly decreased ($p < 0.05$), while depressive symptoms (PHQ-9) showed a moderate reduction. HbA1c levels improved across all conditions, with the largest decrease observed in the combined intervention group ($p < 0.05$). Integrating digital tools with group psychological support enhances both adherence and mental health outcomes in type 2 diabetes management, suggesting that multimodal interventions may be more effective than stand-alone approaches.

Key Words: Type 2 diabetes, adherence, digital health, group-based intervention, mental health, patient support

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Introduction

Type 2 diabetes is a chronic disease that affects over 400 million people worldwide, ranking among the leading causes of morbidity and mortality due to its complications (Khunti et al., 2023). Its prevalence, especially in low- and middle-income countries, poses a significant public health challenge, as it is closely linked to lifestyle factors such as poor diet, physical inactivity, and obesity (Xu et al., 2024). Proper diabetes management is crucial to preventing severe complications such as cardiovascular disease, neuropathy, retinopathy, and nephropathy, all of which can significantly impact patients' quality of life (Zheng et al., 2018). However, adherence to treatment remains suboptimal, with only 40% to 60% of patients consistently following medical recommendations (Kardas et al., 2022). This low adherence is associated with an increased risk of diabetes-related complications, hospitalizations, and higher healthcare costs (Franquez et al., 2023).

In Spain, as in other middle-income countries, individuals from lower socioeconomic backgrounds face significant barriers to accessing structured diabetes management programs (González-Clemente et al., 2022). Research highlights that financial constraints, long wait times for specialist consultations, and limited access to mental health resources negatively impact adherence, particularly in public healthcare settings (Cebrián-Cuenca et al., 2023; Mata-Cases et al., 2023). Our study population, recruited from a public health center in Zaragoza, represents a group particularly vulnerable to these challenges. Patients in similar settings often experience irregular follow-ups, insufficient diabetes education, and a lack of psychological support, all of which contribute to poor self-management (Escobar-López et al., 2023; Pérez-Martínez et al., 2024). Addressing these barriers requires tailored interventions that integrate both behavioral and mental health components to improve adherence and long-term disease control.

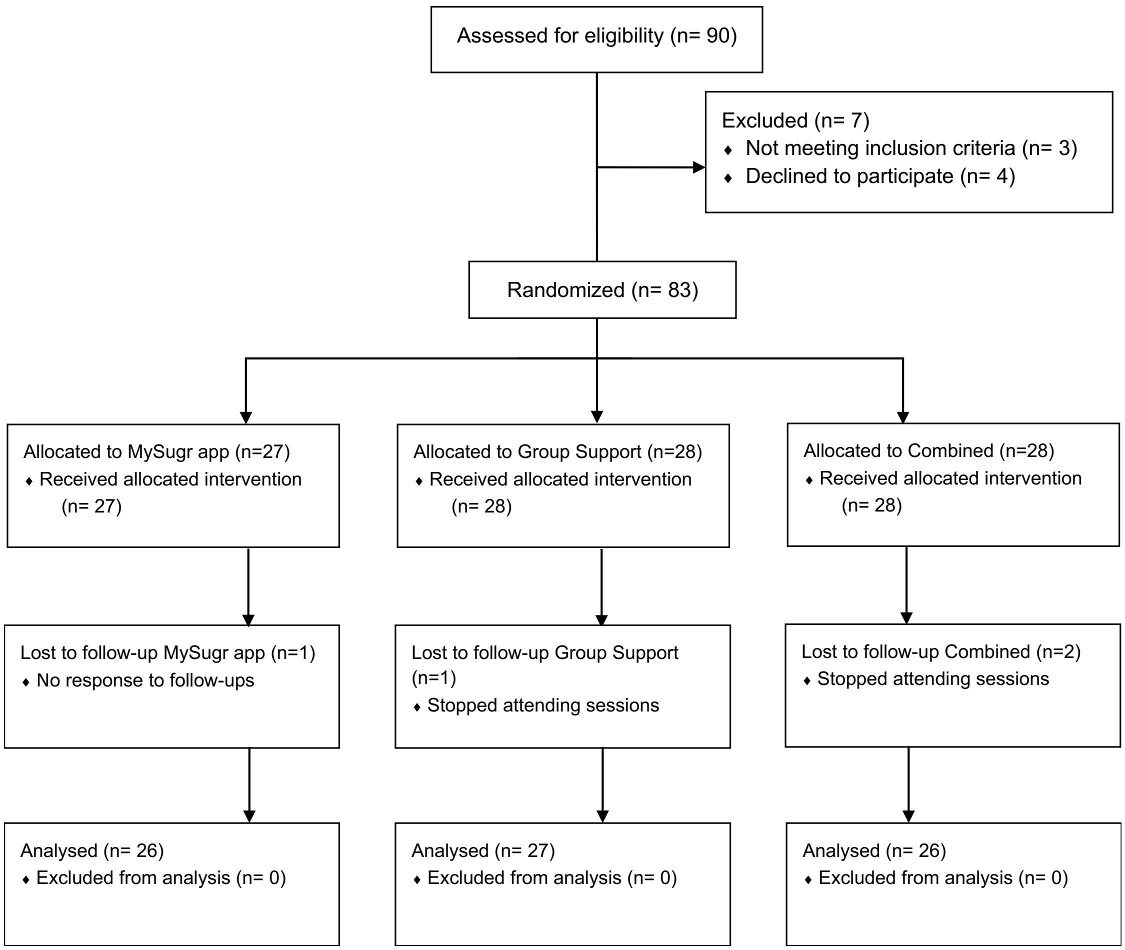
Beyond practical challenges, mental health factors also play a crucial role in diabetes management. Many patients experience anxiety, depression, and chronic stress, which can negatively affect their ability to adhere to treatment recommendations (Albai et al., 2024). Psychological distress has been linked to poorer self-care behaviors, making it essential to incorporate mental health support into diabetes interventions (Escobar et al., 2021; Pal et al., 2018). Group-based interventions have been shown to enhance adherence by fostering emotional resilience, promoting peer support, and encouraging sustained engagement in diabetes self-care (Bullard et al., 2019; Rosli et al., 2022).

At the same time, digital tools have emerged as promising solutions for diabetes self-management. Apps such as MySugr allow patients to monitor glucose levels, diet, and physical activity in real time, providing continuous feedback and facilitating adherence (Ehrmann et al., 2022). While these tools improve disease control, they lack the social and emotional support offered by group interventions (Albai et al., 2024). Consequently, integrating digital monitoring with peer support could provide a more comprehensive and effective approach to diabetes management, addressing both practical and mental health barriers. Recent studies suggest that multimodal interventions, which combine technological solutions with group support, lead to better adherence outcomes than when used separately. Digital platforms enhance self-monitoring and engagement, while group-based support fosters accountability, emotional resilience, and motivation (Rosli et al., 2022). However, to better understand the factors underlying adherence improvement, this study is grounded in two well-established theoretical frameworks: Self-Regulation Theory and Social Support Theory.

Self-Regulation Theory (Carver & Scheier, 1998) posits that individuals regulate their behaviors through feedback mechanisms that guide them toward their health goals. Digital tools such as MySugr facilitate self-regulation by providing real-time feedback on glucose levels, diet, and physical activity, helping patients adjust their behaviors accordingly (Schunk & DiBenedetto, 2021). However, self-monitoring alone may not be sufficient, as behavioral change is also influenced by psychological and social factors.

Social Support Theory (Cohen & Wills, 1985) emphasizes the role of emotional and peer support in sustaining health behaviors, particularly in chronic disease management (Heaney & Israel, 2008). Group interventions create a sense of community, enhance motivation, and provide emotional reinforcement, which are critical in overcoming mental health barriers to adherence (Rosland et al., 2022). Recent studies support that interventions integrating both self-regulation mechanisms and social support yield superior outcomes in adherence and mental health among patients with diabetes (Greenwood et al., 2017; Ritholz et

Figure 1
Participant Flowchart from Recruitment to Analysis.



al., 2019). By leveraging these theoretical perspectives, this study evaluates whether a multimodal intervention—combining MySugr's self-regulation features with the mental health benefits of group support—can lead to improved patient outcomes in diabetes management.

Although previous studies have examined the impact of digital self-monitoring (Albai et al., 2024) and group-based psychological support (Rosli et al., 2022) separately, there is limited evidence on the effectiveness of combining these approaches in Spanish primary care settings. This study aims to fill this gap by evaluating whether integrating real-time self-monitoring with structured peer support leads to superior adherence and psychological outcomes.

The present study aims to evaluate the effectiveness of three intervention strategies for improving adherence and mental well-being in patients with type 2 diabetes: (1) the use of the MySugr app, (2) bi-weekly group support sessions, and (3) a combination of both interventions. By comparing these approaches, the study seeks to determine whether a multimodal strategy leads to better outcomes in diabetes management and mental health.

Methods

Study Design

This randomized controlled trial (RCT), conducted over a six-month period, compared the effectiveness of three strategies to improve adherence and mental health in patients with type 2 diabetes. Evaluations of adherence and mental well-being were conducted at three time points: baseline, mid-study (at three months), and post-intervention (at six months).

Participants and Procedures

Participants and Eligibility Criteria

A total of 90 adult patients with type 2 diabetes were assessed for eligibility. Participants were included if they had a confirmed diagnosis of type 2 diabetes for at least one year, were between 40 and 75 years old, were regular patients at the participating health center in Zaragoza, and were able to use a smartphone or willing to receive assistance in using the MySugr app. Exclusion criteria included having a diagnosis of severe psychiatric disorders (e.g., schizophrenia, bipolar disorder), cognitive impairment, or any condition that prevented informed consent or active participation in self-management interventions, use of advanced diabetes management technologies that could interfere with the study, or current enrollment in another structured diabetes intervention program. After accounting for dropouts, the final sample consisted of 79 participants who were randomly assigned to one of three intervention groups: daily use of the MySugr app, bi-weekly group sessions, or a combination of both. The sample was diverse in terms of age, gender, and baseline metabolic control. A detailed comparison of participant characteristics across groups is presented in the "Results" section (Table 2), and the participant flow is depicted in Figure 1.

Study Setting and Recruitment

The study was conducted between September 2022 and June 2023 at a public health center in Zaragoza. Patients were informed about the study during their regular primary care consultations, where healthcare providers explained the objectives, procedures, and expectations. Those expressing interest were contacted in December 2022 to confirm their willingness to participate. All participants provided written informed consent prior to enrollment. The study was approved by the relevant ethics committee and adhered to the principles of the Declaration of Helsinki.

Randomization and Allocation Procedure

Participants were randomly assigned to one of three intervention groups using a random sequence generated by Stata software (StataCorp, College Station, TX, USA). The allocation sequence was printed and concealed in opaque, sealed envelopes to maintain allocation concealment. Two nurses from the health center assigned participants based on the envelopes, ensuring allocation concealment. These nurses were not involved in outcome assessments to minimize bias.

Intervention Description

Participants were randomly assigned to one of three groups. Group 1 received daily use of the MySugr app to monitor glucose, diet, and physical activity, with real-time feedback and reminders. Group 2 participated in bi-weekly, 90-minute group sessions led by a psychologist, focusing on

Table 1
Overview of Group Session Topics and Objectives

Session Theme	Description
Diabetes Education & Self-Management	Understanding glucose control, medication adherence, and long-term health risks.
Diet & Nutrition	Guidance on balanced meal planning and making informed dietary choices.
Physical Activity & Motivation	Strategies to integrate movement into daily routines and overcome barriers.
Mental Health & Coping	Addressing stress, anxiety, and depression using CBT and mindfulness.
Behavioral Change & Habit Formation	Goal-setting, self-monitoring, and problem-solving for sustained adherence.
Social Support & Peer Learning	Encouraging motivation and accountability through shared experiences.

diabetes management, healthy behaviors, and mental health support. These sessions addressed psychological barriers such as anxiety and stress through group discussion and relaxation techniques. Group 3 received a combination of both interventions, using the MySugr app alongside attendance at the group sessions.

The group sessions took place over six months, with a total of 12 structured sessions designed to enhance diabetes self-management and mental well-being. These sessions addressed key aspects of diabetes care, including lifestyle modifications, emotional well-being, and behavior change strategies. Table 1 provides an overview of the session topics and their objectives.

For participants using the MySugr app (Groups 1 and 3), a 30-minute individualized training session was provided at the start of the study. This training covered how to log glucose levels, dietary intake, and physical activity; how to use automated reminders and feedback features to enhance engagement; and how to generate reports for self-monitoring and review with healthcare providers. To reinforce continued engagement, a refresher training was offered at Month 3, ensuring that participants remained active in using the app as part of their self-management routine.

Data Collection

All data collection took place at the healthcare center where participants were recruited. Self-reported questionnaires and psychological assessments were administered by a psychologist and a primary care physician during in-person sessions in a private consultation room. Each session lasted approximately 30–45 minutes.

HbA1c levels were measured in the nursing consultation room by two nurses using standard blood sampling procedures at the same three time points. Participants in the MySugr groups also had their physical activity, dietary intake, and glucose monitoring continuously recorded via the MySugr app, which provided real-time tracking and automated logs to complement self-reported adherence measures.

To enhance measurement accuracy, data triangulation was conducted by comparing self-reported adherence questionnaires with automatically recorded data from MySugr. Diet adherence was assessed by cross-checking food intake logs from MySugr with self-reported diet adherence scores. Physical activity was evaluated by comparing step counts and exercise logs with IPAQ self-reports to ensure consistency in physical activity measurement. Although MySugr does not directly track medication intake, medication adherence was inferred by analyzing glucose stability trends in conjunction with self-reported adherence data.

Descriptive data from MySugr showed that participants logged an average of 5.2 days per week (SD = 1.3) of dietary intake and 4.8 days (SD = 1.5) of physical activity. The proportion of participants consistently logging data throughout the study was 79.4% at 3 months and 72.1% at 6 months.

Instruments

Several standardized instruments were used to assess mental health outcomes, glycemic control, and adherence behaviors during the intervention. These included validated scales for depressive symptoms, anxiety, HbA1c levels, dietary adherence, physical activity, and medication adherence, as well as digital records from the MySugr app.

Psychological Outcomes

Depressive symptoms were measured using the Patient Health Questionnaire-9 (PHQ-9), a widely validated 9-item scale for assessing depression severity (Kroenke et al., 2001). Scores on the PHQ-9 range from 0 to 27, with higher scores indicating greater severity of depressive symptoms. Specifically, scores of 0–4 indicate minimal depression, 5–9 mild depression, 10–14 moderate depression, 15–19 moderately severe depression, and 20–27 severe depression.

In the present study, the PHQ-9 showed high internal consistency (α = 0.84), similar to previous validations in Spanish-speaking populations (Diez-Quevedo et al., 2001).

Anxiety symptoms were assessed using the Generalized Anxiety Disorder-7 (GAD-7) scale, a validated instrument designed to measure the severity of generalized anxiety disorder (Spitzer et al., 2006). Scores on the GAD-7 range from 0 to 21. A score between 0 and 4 indicates minimal anxiety, 5 to 9 corresponds to mild anxiety, 10 to 14 to moderate anxiety, and 15 to 21 to severe anxiety.

The GAD-7 demonstrated high internal consistency (α = 0.88) in this sample, in line with prior research (García-Campayo et al., 2010).

At baseline, participants in the MySugr App and Combined groups exhibited moderate-to-severe depressive symptoms (PHQ-9 ≥10) and anxiety symptoms (GAD-7 ≥10), while those in the group-based psychological support intervention had scores below this threshold, indicating mild or minimal symptoms on average.

Clinical Outcome

Glycemic control was assessed using HbA1c testing, following the guidelines of the American Diabetes Association (2023). Blood samples were collected at baseline, mid-study (3 months), and post-study (6 months) by trained health center staff in a dedicated nursing consultation room. HbA1c was measured using venous blood draw, which was analyzed using a high-performance liquid chromatography (HPLC) method, the gold standard for HbA1c testing (John & Jones, 2019).

Adherence Outcomes

Adherence to diet, physical activity, and medication was evaluated through validated self-reported questionnaires, administered at baseline, 3 months, and 6 months. Diet adherence was measured using a 7-item questionnaire specifically developed for this study, based on dietary guidelines for type 2 diabetes management (American Diabetes Association, 2023; Estruch et al., 2013). This instrument assessed the frequency of consuming recommended foods (such as vegetables, whole grains, and lean proteins) and avoiding restricted items (such as sugary beverages and processed foods). Responses were recorded on a 5-point Likert scale ranging from 1 (never) to 5 (always), with higher scores indicating better adherence. Prior to implementation, the questionnaire was pilot-tested with a separate sample of 15 patients with type 2 diabetes from the same healthcare center. The final version showed acceptable internal consistency (Cronbach's $\alpha = 0.79$).

Physical activity adherence was assessed using the International Physical Activity Questionnaire, short form (IPAQ-SF) (Craig et al., 2003), which includes seven items measuring engagement in moderate to vigorous physical activity. In this study, adherence was defined as achieving at least 150 minutes per week of moderate-intensity activity, following the recommendations of the World Health Organization (Bull et al., 2020). The scale showed good internal consistency in our sample ($\alpha = 0.81$).

Medication adherence was evaluated with the Morisky Medication Adherence Scale (MMAS-8) (Morisky et al., 2008), an eight-item instrument that classifies adherence as high, moderate, or low based on participants' responses regarding missed doses and medication-taking behavior. Higher scores reflect greater adherence, and the scale demonstrated strong reliability in this study ($\alpha = 0.83$).

The MySugr app was used by Groups 1 and 3 to track glucose levels, diet, and physical activity daily. Participants manually logged their dietary intake and physical activity, while glucose levels were synced automatically through compatible glucose meters. The app provided real-time feedback, automated reminders, and personalized reports to support adherence. MySugr has been validated in previous diabetes self-management research, demonstrating significant improvements in glucose monitoring adherence (Ehrmann et al., 2022).

Data Analysis

A mixed repeated measures ANOVA was used to assess changes in adherence to physical activity, diet, and medication, as well as mental health outcomes (anxiety and depressive symptoms) over time. Time (baseline, mid-study, and post-intervention) was treated as the within-subjects factor, and intervention group (MySugr, group sessions, or combined) as the between-subjects factor. Group-by-time interactions were analyzed to detect significant differences in adherence and mental health outcomes among groups. Post hoc Tukey tests were conducted when significant effects were found, and effect sizes were calculated using Cohen's d. The assumptions of sphericity in the variance-covariance matrix were tested using Mauchly's test, and homoscedasticity was checked with Levene's test. A significance level of $p < 0.05$ was applied to all tests, and analyses were performed using SPSS version 26.0 (IBM Corp; Armonk, NY). The sample size was calculated using G*Power, targeting a significance level of 0.05 and a power of 0.80, based on a medium effect size, which indicated that 66 participants would be sufficient, similar to previous studies (Gregory et al., 2021; Yao et al., 2024).

Table 2

Comparison of Baseline Characteristics of Participants by Group (N = 79)

	Group 1: MySugr App (n =26)	Group 2: Only Sessions (n = 27)	Group 3: Combined (n = 26)	F / χ^2	p
Age, M (SD)	56.4 (8.3)	55.9 (7.9)	57.2 (8.6)	5.32	.693
HbA1c (%), M (SD)	8.6 (0.9)	8.7 (0.8)	8.8 (1.0)	2.71	.293
BMI, M (SD)	31.1 (5.0)	31.3 (5.2)	31.4 (5.1)	3.91	.079
Female, n (%)	17 (65.4%)	16 (59.3%)	15 (57.7%)	4.58	.172
GAD-7, M (SD)	9.8 (5.7)	9.5 (5.4)	9.2 (5.6)	8.85	.147
PHQ-9, M (SD)	9.5 (6.1)	9.2 (5.8)	8.9 (5.7)	3.41	.221
Physical activity, M (SD)	70 (5.3)	68 (5.4)	68 (5.2)	2.55	.334
Diet adherence, M (SD)	68 (6.3)	70 (5.6)	72 (5.1)	2.42	.401
Medication adherence, M (SD)	72 (5.6)	74 (5.1)	70 (5.7)	1.21	.387

Note. BMI = Body Mass Index; PHQ-9 = Patient Health Questionnaire-9; GAD-7 = Generalized Anxiety Disorder-7; MMAS-8 = Morisky Medication Adherence Scale-8; IPAQ = International Physical Activity Questionnaire.

Results

Table 2 presents the baseline characteristics of participants, with no significant differences found between groups for age ($p = .693$), HbA1c levels ($p = .293$), Body Mass Index (BMI) ($p = .079$), or gender distribution ($p = .172$). Similarly, no significant differences were observed between groups for anxiety scores (GAD-7; $p = .147$), depressive symptom scores (PHQ-9; $p = .221$), physical activity adherence ($p = .334$), diet adherence ($p = .401$), or medication adherence ($p = .387$), with all p-values exceeding .05.

As shown in Table 3, adherence to physical activity, diet and medication significantly improved over time in most groups ($p < 0.05$), except for physical activity in the App Only group, where changes were not statistically significant. Significant group-time interactions were observed for physical activity, diet and medication adherence ($p < 0.05$). Post-hoc analyses indicated that Group 3 (Combined) exhibited the greatest improvements in adherence to physical activity and diet, with significantly greater increases compared to Group 1 (App Only) and Group 2 (Group Sessions) ($p < 0.05$).

As shown in Table 4, HbA1c levels decreased over time in all groups except for the MySugr App group, with the greatest reduction observed in the Combined intervention group. Furthermore, the Combined group showed significant differences compared to the other groups ($p < 0.05$), highlighting its superior effectiveness in improving glycemic control.

As shown in Table 5, Group 3 showed the greatest reductions in depressive symptoms (PHQ-9) and anxiety (GAD-7) scores compared to the other groups ($p < 0.05$). Significant between-group differences favored Group 3, while Group 1 showed only mild improvements.

Discussion

This research demonstrates that combining digital tools, such as the MySugr app, with group psychological support significantly enhances adherence to diabetes self-management behaviors and improves mental health outcomes in patients with type 2 diabetes. The combined intervention resulted in notable improvements in diet

Table 3.

Adherence Evolution Over Time (Baseline, Mid-Study, Post-Intervention)

Adherence Outcome	Baseline	Mid-Study	Post-Intervention	F	Effect size (d) Intra-group	Effect size (d) Inter-group	Significant Comparisons
Physical Activity							
Group 1 (App Only)	70 (5.3)	74 (5.1)	74 (5.2)	2.55	.25	.30*	G3 > G1
Group 2 (Group Sessions)	68 (5.4)	73 (5.3)	78 (5.1)	3.10	.55*	.60*	G2 > G1
Group 3 (Combined)	68 (5.2)	80 (5.0)	88 (4.9)	4.25	.80*	.85*	G3 > G1, G2
Diet							
Group 1 (App Only)	68 (4.7)	75 (5.9)	79 (5.9)	2.42	.20*	.25*	G3 > G1
Group 2 (Group Sessions)	70 (4.9)	76 (5.2)	82 (5.2)	2.98	.60*	.65*	G3 > G2
Group 3 (Combined)	72 (5.2)	82 (4.8)	90 (4.8)	4.70	.85*	.90*	G3 > G1, G2
Medication							
Group 1 (App Only)	72 (5.2)	78 (5.4)	82 (5.3)	1.20	.20*	.35*	G3 > G1
Group 2 (Group Sessions)	74 (5.8)	78 (5.0)	82 (4.9)	1.05	.32*	.38*	G3 > G2
Group 3 (Combined)	70 (4.8)	80 (5.5)	86 (5.2)	1.90	.50*	.55*	G3 > G1, G2

Note. Values represent mean adherence percentages (0–100%) with standard deviations in parentheses: Mean (SD). Effect sizes are reported as Cohen's d. *$p < 0.05$.

Table 4.
Changes in HbA1c Levels Over Time Across Intervention Groups

	Baseline HbA1c	Mid-Study	Post-Intervention	F	Effect size (d) Intra-group	Effect size (d) Inter-group	Significant Comparisons
Group 1 (MySugr App)	8.6 (0.9)	8.3 (0.8)	8.1 (0.7)	3.89	.40	.58*	G3, G2 > G1
Group 2 (Only Sessions)	8.7 (0.8)	8.4 (0.7)	8.2 (0.6)	4.12	.45*	.62*	G3 > G2
Group 3 (Combined)	8.8 (1.0)	8.2 (0.8)	7.9 (0.7)	6.42	.75*	.89*	G3 > G1, G2

Note. Values represent mean HbA1c percentages with standard deviations in parentheses: Mean (SD). HbA1c was measured using venous blood samples analyzed by high-performance liquid chromatography (HPLC). Effect sizes are reported as Cohen's d.*$p < 0.05$.

adherence, physical activity, and reductions in anxiety and depressive symptoms. These findings underscore the importance of addressing both behavioral and psychological aspects of diabetes management, aligning with previous research which suggests that while mobile applications facilitate adherence, their impact on mental health is limited without additional emotional support (Greenwood et al., 2017; Choi et al., 2015).

Evidence consistently supports the effectiveness of hybrid interventions—integrating digital monitoring with structured support—over stand-alone approaches (Vaitkienė et al., 2022). A systematic review by Kerr et al. (2024) confirmed that while digital interventions effectively track glucose levels and medication adherence, their influence on sustained behavioral changes remains insufficient unless complemented by social or psychological support. Similarly, research highlights that the absence of human interaction in digital interventions weakens their ability to alleviate psychological distress, such as stress and anxiety (Geirhos et al., 2022; Jacobsen et al., 2023). Our findings reinforce this perspective, as participants who combined MySugr with group sessions experienced significantly greater improvements in mental well-being compared to those using the app alone.

The characteristics of the study population also warrant consideration. Participants were recruited from a public healthcare center in Zaragoza, Spain, where socioeconomic barriers, including financial constraints and limited access to structured diabetes education programs, may have influenced adherence patterns (González-Clemente et al., 2022). Digital interventions tend to be more effective among individuals with higher digital literacy and greater healthcare access (Mata-Cases et al., 2023), suggesting that future studies should explore how socioeconomic factors moderate the impact of these interventions.

Beyond socioeconomic aspects, social support remains a crucial component of diabetes management. Group-based emotional support helps mitigate the limitations of digital tools by fostering shared experiences and addressing diabetes-related distress (Van Bastelaar et al., 2011; Heisler et al., 2019). Digital platforms incorporating community features, such as peer discussions or virtual group sessions, have been shown to enhance engagement and adherence (Veazie et al., 2018; Rosland et al., 2022). Our findings align with this perspective, reinforcing that digital tools alone may be insufficient to address mental health needs (Kerr et al., 2024).

Furthermore, our findings align with the clinically meaningful thresholds suggested by Kounali et al. (2020), who identified a 20% reduction in depression and anxiety scores as an indicator of meaningful clinical improvement. In our study, Group 3 achieved reductions exceeding this threshold, reinforcing the clinical relevance of the combined intervention. This suggests that

Table 5.

Changes in Psychological Outcomes Over Time (Baseline, Mid-Study, Post-Intervention)

Psychological Outcome	Baseline	Mid-Study	Post-Intervention	F	Effect size (d) Intra-group	Effect size (d) Inter-group	Significant Comparisons
PHQ-9							
Group 1 (App Only)	9.2 (5.1)	8.9 (4.9)	8.4 (5.0)	3.12	.35	.40**	G3 > G1
Group 2 (Group Sessions)	8.9 (4.7)	8.1 (4.3)	7.7 (4.2)	4.50	.58*	.66*	G3 > G2
Group 3 (Combined)	9.4 (5.2)	7.9 (4.8)	7.4 (4.5)	6.70	.75*	.85*	G3 > G1, G2
GAD-7							
Group 1 (App Only)	9.8 (5.7)	9.2 (5.5)	8.8 (5.4)	3.05	.38*	.40*	G3, G2 > G1
Group 2 (Group Sessions)	9.5 (5.4)	8.3 (5.2)	7.8 (5.0)	5.20	.60*	.70*	G3 > G2
Group 3 (Combined)	9.7 (5.1)	8.1 (5.1)	7.4 (4.9)	7.00	.80*	.95*	G3 > G1, G2

Note. Values represent mean scores with standard deviations in parentheses: Mean (SD). PHQ-9 = Patient Health Questionnaire-9 (depressive symptoms); GAD-7 = Generalized Anxiety Disorder-7 (anxiety symptoms). Effect sizes are reported as Cohen's d. *$p < 0.05$; **$p < 0.01$

integrating digital monitoring with group psychological support not only yields statistically significant improvements but also reaches a level of change that is meaningful in real-world clinical practice.

The impact of these interventions on metabolic outcomes, particularly glycemic control, is also noteworthy. All groups exhibited reductions in HbA1c levels over time, with the most significant improvement observed in the combined intervention group. Prior research suggests that digital self-monitoring, when coupled with behavioral support, enhances glycemic outcomes more effectively than stand-alone approaches (Ehrmann et al., 2022; Veazie et al., 2018). The real-time feedback provided by MySugr likely reinforced self-management behaviors, while psychological support helped address emotional barriers to glycemic control (Greenwood et al., 2017; Heisler et al., 2019).

Interestingly, medication adherence did not show significant differences between groups, despite improvements in diet and physical activity. This suggests that medication adherence may be less influenced by psychological or technological interventions, as taking medication is a structured task requiring less behavioral effort than lifestyle changes (Kardas et al., 2022). Additionally, emotional factors such as stress or depression more directly impact behaviors requiring daily motivation, such as exercise and dietary adherence (Albai et al., 2024). These findings highlight the importance of continuous reinforcement in sustaining behavior change.

From a clinical perspective, integrating digital tools with psychological support is a promising strategy for improving adherence and mental health outcomes in patients with type 2 diabetes. Clinics could incorporate mobile applications into diabetes management programs, allowing patients to track glucose levels, physical activity, and diet while receiving real-time feedback. Integrating these tools with electronic medical records could further enhance personalized treatment adjustments (Cuixart et al., 2024). Additionally, bi-weekly group sessions, conducted either in person or virtually, could help address emotional and motivational barriers to self-care behaviors (Rosli et al., 2022; Veazie et al., 2018).

Economic feasibility is another crucial aspect. While this study did not conduct a cost-benefit analysis, literature suggests that digital interventions are a cost-effective alternative to traditional in-person approaches, reducing access barriers while enabling continuous monitoring (Vaitkienė et al., 2022). Future research should assess whether integrating mobile applications with group support reduces hospitalization rates and diabetes-related complications, thereby lowering overall healthcare costs (Greenwood et al., 2017). Including a detailed economic analysis in future studies will be key to determining the cost-effectiveness of these interventions across different healthcare settings.

Limitations

Despite the promising results, this study has some limitations that could affect the interpretation of the findings. First, while the clinical implications of the interventions are discussed, there is a lack of a detailed economic evaluation to determine the feasibility of implementing a combined approach in real clinical practice. Although digital tools are suggested to reduce long-term costs, it would be useful to conduct a cost-benefit analysis to confirm whether this intervention is economically viable in clinics and healthcare systems, especially in resource-limited settings (Vaitkienė et al., 2022). A more thorough study could assess the cost-effectiveness in terms of reducing hospitalizations and long-term complications.

Another limitation is the relatively small sample size, which may limit the generalizability of the results to broader populations. However, this study provides a solid foundation for future research with larger and more diverse samples, which would help validate and expand the findings across different demographic and socioeconomic contexts.

There was also a relatively low dropout rate (12%), although some participants reported logistical difficulties, such as scheduling conflicts or transportation issues. This highlights the need to design more flexible interventions, such as offering virtual or remote options, which would improve accessibility and retention, particularly for populations facing geographical or time-related barriers.

Additionally, the study was not pre-registered in a public trial registry such as ClinicalTrials.gov. At the time of study initiation, registration was not a mandatory requirement for non-pharmacological behavioral interventions conducted at our institution. However, we acknowledge that pre-registration enhances research transparency and reproducibility. Future studies should consider formal registration to align with best practices in clinical research.

Finally, the follow-up period for participants was six months, which is sufficient for observing initial changes. However, this timeframe may not be enough to assess the long-term sustainability of the results. Future studies could extend the follow-up period to determine whether improvements in adherence and emotional well-being are maintained over time and explore whether periodic reinforcement or continuous digital support is needed to sustain these benefits.

Conclusion

In conclusion, the results of this study suggest that combining digital tools like the MySugr app with group psychological support interventions is an effective strategy for improving both adherence to diabetes self-management behaviors and mental health outcomes in patients with type 2 diabetes. The combined intervention not only proved to be superior in enhancing adherence to diet and physical activity, but also significantly reduced anxiety and depressive symptoms levels. This underscores the importance of a multimodal approach that addresses both practical and emotional barriers in the management of this chronic condition.

However, the lack of significant differences in medication adherence between the groups suggests that this behavior may be less influenced by psychological or technological interventions. Future research should further explore this discrepancy and consider conducting cost-effectiveness analyses to assess the economic feasibility of these combined interventions in different clinical settings. Additionally, extending follow-up periods and utilizing advanced technologies—such as wearable glucose monitors, continuous activity trackers, or app-based behavioral analytics—could help solidify the long-term effectiveness of these strategies.

Implications for Health Behavior Research

This research reveals how combining digital health tools with group-based psychological interventions enhances adherence to diabetes self-management behaviors and improve mental health outcomes in patients with type 2 diabetes. It highlights the need to update existing health behavior models, integrating real-time digital feedback and emotional support for a more comprehensive approach to managing chronic conditions. The combination of the MySugr app and group support addresses both emotional and behavioral barriers, leading to better outcomes. By comparing the independent and combined effects of digital tools and group interventions, it underscores the value of multicomponent strategies that tackle both practical and emotional challenges.

Researchers should expand health behavior models to include the interactions between emotional support and real-time digital feedback, study long-term sustainability, and personalize interventions based on psychological profiles. Healthcare providers are encouraged to integrate digital tools with group support through telehealth and receive training in combining technology with psychosocial care. Although speculative, future developments in AI-based tailoring of diabetes support tools could expand the personalization of these interventions to better address individual emotional and behavioral needs.

Discussion Questions

To stimulate further dialogue about this study, we propose the following discussion questions:

How can health behavior interventions be designed to simultaneously address both behavioral and emotional needs in chronic disease management, and what strategies would ensure the long-term sustainability of these interventions?

What are the biggest barriers to scaling integrated digital and group-based interventions in clinical practice, and how can healthcare systems overcome these challenges?

Ethical Considerations: All participants provided written informed consent prior to enrollment, in accordance with the ethical principles outlined in the Declaration of Helsinki. The study ensured strict adherence to confidentiality protocols and data security measures throughout the research process to protect participants' privacy and personal information.

The authors have no conflicts of interest to declare.

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