Mobile Technology Enhanced Diabetes Self-Management Education Improves Self-Efficacy and Glycaemic Control in Adults with Type 2 Diabetes

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ABSTRACT

Purpose of the study: This study aimed to evaluate the effectiveness of a mobile technology enhanced diabetes self-management education and support (DSME) programme in improving glycaemic control and diabetes-related self-efficacy among adults with Type 2 diabetes in primary and community health care settings.

Methodology: A parallel-group randomized controlled trial was conducted in primary and community health care facilities in Temburong District, Brunei Darussalam. Adults with uncontrolled Type 2 diabetes (n = 120) were randomized to a mobile-enhanced DSME intervention or standard care for 3 months. The primary outcome was change in HbA1c; the secondary outcome was diabetes self-efficacy. Analyses followed an intention-to-treat approach using ANCOVA and repeated-measures ANOVA.

Main Findings: At 3 months, the intervention group demonstrated a significantly greater reduction in HbA1c compared with the control group (adjusted mean difference −0.71%, 95% CI −0.92 to −0.50; p < 0.001; Cohen's d = 0.89). Mean HbA1c decreased by −1.06% in intervention group versus −0.33% in the control group. A significant group × time interaction was observed for self-efficacy (F(1,118) = 32.47, p < 0.001), with the intervention group showing a larger increase in self-efficacy scores (+12.3 points) compared to the control group (+3.3 points; Cohen's d = 0.95).

Novelty/Originality of this study: A behaviourally grounded, mobile-enhanced DSME programme produced clinically meaningful metabolic improvement alongside significant gains in self-efficacy. Integrating structured digital self-management support into routine primary care may represent a scalable strategy to strengthen multidisciplinary diabetes management and reduce long-term complication risk.

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1. INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major global public health challenge, affecting an estimated 537 million adults worldwide in 2021, with projections reaching 643 million by 2030 according to the International

Diabetes Federation [1]-[3]. The Western Pacific and Southeast Asian regions account for a substantial proportion of this burden, driven by rapid urbanisation, population ageing, sedentary lifestyles, and dietary transitions [4]-[6]. Persistent hyperglycaemia remains common, international data indicate that fewer than 50% of adults with T2DM achieve the recommended glycated haemoglobin (HbA1c) target of <7.0%, thereby increasing the risk of microvascular and macrovascular complications [7], [8]. Beyond clinical consequences, diabetes imposes considerable economic strain, with global health expenditure exceeding USD 966 billion in 2021. These trends underscore urgent need for scalable and effective strategies to optimise long-term glycaemic control.

Effective diabetes management relies heavily on sustained self-management behaviours, including dietary regulation, physical activity, medication adherence, and regular glucose monitoring [9]-[11]. Quoted from research by Powers et al., [12] the American Diabetes Association and the World Health Organization consistently recommend structured diabetes self-management education and support (DSMES) as the cornerstone of type 2 diabetes care. Evidence from systematic reviews suggests that structured DSMES programs can reduce HbA1c by 0.6–1.0% within 6–12 months, along with improvements in medication adherence and quality of life [13]-[15]. Central to these outcomes is self-efficacydefined as an individual's confidence in performing health-related behaviours which has been shown to mediate the relationship between knowledge acquisition and sustained behavioural change [16]-[18]. However, despite established benefits, participation rates in conventional face-to-face diabetes self-management education and support remain suboptimal, often below 30% in routine care settings.

The rapid expansion of mobile health (mHealth) technologies provides an opportunity to address these implementation gaps. Globally, smartphone penetration exceeds 75%, and in many middle-income countries surpasses 80%, enabling wide dissemination of digital health interventions [19]. Meta-analyses of mobile app–based diabetes interventions report modest but clinically meaningful HbA1c reductions ranging from 0.3% to 0.8%, particularly when applications integrate structured education, real-time feedback, behavioural prompts, and personalised monitoring [20], [21]. Importantly, digital platforms facilitate continuous engagement beyond clinic visits, offering reminders, glucose tracking, and adaptive learning modules that may strengthen self-efficacy and daily adherence [22]-[24]. Such features align with contemporary models of patient-centred, technology-enabled chronic disease management.

In Southeast Asia, the burden of T2DM continues to escalate [25]-[27]. For example, national survey data indicate that adult diabetes prevalence in several asean countries exceeds 10%, with substantial proportions of individuals remaining undiagnosed or poorly controlled [28]-[31]. In Brunei Darussalam, adult prevalence has been reported at approximately 13–14%, reflecting one of the higher rates in the region. Health systems in these contexts face dual challenges is increasing case numbers and limited specialist resources. Scalable digital DSMES interventions therefore represent a strategically relevant approach to strengthening both preventive and therapeutic services across diverse healthcare settings.

Although prior studies demonstrate the potential of mHealth applications in improving glycaemic outcomes, several limitations persist. Many interventions lack structured curricula aligned with international DSMES standards, provide limited behavioural reinforcement, or do not explicitly target self-efficacy as a primary mechanism of change. Furthermore, few studies have integrated personalised calendar-based reminders, glucose log synchronisation, and adaptive educational content within a single cohesive platform. Consequently, the incremental benefit of a structured, mobile technologyenhanced diabetes self-management education and support model that simultaneously targets behavioural capability and psychological empowerment remains insufficiently examined [32], [33].

To address these gaps, the present study evaluates a structured mobile technologyenhanced diabetes self-management education and support intervention designed to improve both self-efficacy and glycaemic control among adults with T2DM. By integrating evidence-based educational modules, personalised reminders, and digital glucose tracking within an interactive mobile platform, this intervention aims to strengthen daily self-management behaviours and achieve clinically meaningful reductions in HbA1c. Generating robust empirical evidence in this domain is critical for informing multidisciplinary healthcare practice and advancing scalable digital solutions for chronic disease management in the evolving era of mobile health.

2. RESEARCH METHOD

2.1 Study design

This study employed a parallel-group randomized controlled trial (RCT) to evaluate effectiveness of a mobile technology enhanced diabetes self-management education (DSME) intervention on self-efficacy and glycaemic control among adults with Type 2 diabetes mellitus (T2DM) [34]. The trial was conducted between March and September 2025 in primary and community health care facilities in Temburong District, Brunei Darussalam. A two-arm design was implemented: (1) intervention group receiving mobile-enhanced DSME via an Android-based structured diabetes calendar application in addition to usual care, and (2) control group receiving usual care alone. The study followed consolidated standards of reporting trials (*Consort*) guidelines for randomized clinical trials [35], [36]. Temburong District is one of the four administrative districts of Brunei Darussalam and provides primary care services through government-run health centres. Diabetes management in these facilities includes routine medical consultation, pharmacological treatment, and periodic monitoring of HbA1c levels. However, structured technology-supported DSME programs are not routinely implemented in these settings.

2.2 Participants & recruitmen

Eligible participants were adults aged 30–70 years diagnosed with T2DM for at least six months, with baseline HbA1c ≥7.0%, receiving treatment at participating primary care clinics, able to read Malay or English, and owning an Android smartphone.
Exclusion criteria included:

- pregnancy or gestational diabetes
- severe diabetes complications requiring hospitalization
- diagnosed psychiatric disorders impairing self-care ability
- participation in another diabetes intervention trial

Potential participants were identified from clinic registries and invited during routine follow-up visits. Written informed consent was obtained prior to enrolment.

Sample size was calculated to detect a clinically meaningful difference in HbA1c reduction of 0.5% between groups, consistent with prior mHealth diabetes intervention trials [37], [38]. Assuming is two-tailed $\alpha = 0.05$, power $(1–\beta) = 0.80$, standard deviation (SD) of HbA1c = 1.0, effect size (Cohen's d) = 0.5
Using the formula for comparison of two independent means:

$$n = \frac{2\left(z_{\frac{\alpha}{2}} + Z_{\beta}\right)^2 \sigma^2}{\Delta^2}$$

$$n = \frac{2(1.96 + 0.84)^2(1.0)^2}{(0,5)^2}$$

$$n = \frac{2(7,84)}{0,25}$$

$$n = 62,72$$

A minimum of 63 participants per group was required. Allowing for 15% attrition, the final target sample size was 74 participants per group (total N = 148).

2.3 Intervention

The intervention comprised a 12-week structured Diabetes Self-Management Education (DSME) programme delivered via a purpose-built Android application. The intervention was theoretically informed by self-efficacy theory and digital behaviour-change principles, integrating structured education, self-monitoring, and automated reinforcement within a single platform [36].

Participants attended a 60-minute face-to-face orientation session at baseline, during which a trained diabetes educator provided instruction on application installation, navigation, glucose entry procedures, and interpretation of graphical feedback. Following onboarding, all intervention components were delivered digitally. The application integrated progressive learning modules with daily behavioural prompts and glucose self-monitoring functions. Educational content was released sequentially on a weekly basis to promote sustained engagement and avoid cognitive overload. Core components of the intervention are summarised in table 1.

Table 1. Core components of the mobile-enhanced DSME intervention

Component	Key Features	Intended Function
Structured education modules	Weekly sequential modules covering diabetes knowledge, diet, physical activity, medication adherence, glucose monitoring, and complication prevention	Strengthen disease knowledge and self-care competence
Personalised calendar reminders	Automated prompts for medication intake, glucose testing, and physical activity	Reinforce daily adherence behaviours
Glucose self-monitoring log	Manual glucose entry with graphical trend display	Promote self-regulation and pattern recognition

Component	Key Features	Intended Function
Automated feedback system	Real-time motivational messages triggered by glucose input	Enhance self-efficacy and behavioural reinforcement
Adherence tracking	Weekly summary of completed tasks and missed entries	Increase accountability and sustained engagement

Educational modules required approximately 15–20 minutes per week and incorporated concise explanatory text and visual aids [40]. The personalised calendar function represented the central behavioural reinforcement mechanism, integrating medication schedules and glucose monitoring into a unified interface [41]. Missed entries triggered reminder notifications to encourage behavioural consistency [42]. Glucose values entered by participants generated dynamic trend visualisations, enabling recognition of glycaemic fluctuations. Automated feedback messages were programmed according to predefined glycaemic thresholds to prompt corrective self-care actions when necessary.

Application usage metrics, including login frequency, module completion rates, and glucose entry adherence, were recorded for process evaluation. Participants in the control group continued to receive usual care provided by primary health facilities, including routine clinical consultation and pharmacological management, without access to the digital intervention.

2.4 Statistical Analysis

Data were analyzed using SPSS version 29.0. Descriptive statistics were used to summarize baseline characteristics [43]. Continuous variables were presented as mean ± SD, categorical variables as frequencies and percentages [44]. Baseline comparability between groups assessed using independent t-tests and chi-square tests [45], [46].

Primary analysis followed an intention-to-treat principle. Between-group differences in HbA1c change were analyzed using analysis of covariance (ANCOVA) adjusting for baseline HbA1c. Effect sizes were calculated using Cohen's d. Changes in self-efficacy scores were analyzed using repeated-measures ANOVA. A p-value <0.05 was considered statistically significant.

2.5 Ethical Considerations

Ethical approval was obtained from the medical and health research and ethics committee, Ministry of Health, Brunei Darussalam. The study adhered to declaration of helsinki principles. All participants provided written informed consent. Data confidentiality was ensured through anonymized coding and secure data storage.

3. RESULTS AND DISCUSSION

A total of 148 adults with type 2 diabetes were screened for eligibility across primary and community health care facilities in Temburong District, Brunei Darussalam. Of these, 120 met inclusion criteria and were randomized to either the mobile technology–enhanced DSME group (n = 60) or the standard care group (n = 60). During the 3-month follow-up period, 5 participants (8.3%) in the intervention group and 7 participants (11.7%) in the control group were lost to follow-up. Reasons included relocation, withdrawal of consent, and incomplete laboratory testing.

The primary analysis followed an intention-to-treat principle, and all randomized participants were included in the final statistical analysis using last observation carried forward (LOCF) where appropriate.

3.1 Baseline characteristics

Baseline demographic and clinical characteristics were comparable between groups, as shown in table 2.

Table 2. Baseline demographic and clinical characteristics

Characteristic	Intervention	Control	p-value
Age (years), mean ± SD	52.4 ± 8.6	51.8 ± 9.1	0.71
Female, n (%)	35 (58.3)	33 (55.0)	0.69
Duration of diabetes (years), mean ± SD	8.2 ± 4.3	8.5 ± 4.6	0.77
BMI (kg/m²), mean ± SD	27.6 ± 3.8	27.9 ± 3.6	0.64
HbA1c (%), mean ± SD	8.42 ± 0.91	8.37 ± 0.88	0.78
Self-efficacy score, mean ± SD	62.5 ± 8.4	61.9 ± 8.7	0.68
Oral hypoglycaemic use, n (%)	52 (86.7)	50 (83.3)	0.59
Insulin therapy, n (%)	18 (30.0)	20 (33.3)	0.69

The mean age of participants was 52.4 ± 8.6 years in the intervention group and 51.8 ± 9.1 years in the control group (p = 0.71). The majority were female (intervention: 58.3%; control: 55.0%; p = 0.69). Mean

baseline HbA1c was 8.42 ± 0.91% in the intervention group and 8.37 ± 0.88% in the control group (p = 0.78), indicating no statistically significant difference at baseline.
Similarly, baseline diabetes self-efficacy scores did not differ significantly between groups (intervention: 62.5 ± 8.4; control: 61.9 ± 8.7; p = 0.68). These findings confirm baseline equivalence between groups.

3.2 Primary outcome: Change in HbA1c

At month 3, the intervention group showed a statistically significant decrease in HbA1c compared to the control group. The following results are shown in table 3.

Table 3. Changes in HbA1c and self-efficacy at 3 months

Outcome	Intervention Mean Change (± SD)	Control Mean Change (± SD)	Adjusted Mean Difference (95% CI)	p-value	Effect Size (Cohen's d)
HbA1c (%)	−1.06 ± 0.62	−0.33 ± 0.55	−0.71 (−0.92 to −0.50)	<0.001	0.89
Self-efficacy score	+12.3 ± 6.8	+3.3 ± 5.9	+8.9 (6.4 to 11.5)	<0.001	0.95

Mean HbA1c decreased from 8.42 ± 0.91% to 7.36 ± 0.85% in the intervention group (mean change −1.06 ± 0.62%), whereas the control group showed a modest reduction from 8.37 ± 0.88% to 8.04 ± 0.92% (mean change −0.33 ± 0.55%).

Between-group differences in HbA1c change were analyzed using ANCOVA adjusting for baseline HbA1c. The adjusted mean difference was −0.71% (95% CI: −0.92 to −0.50; $p < 0.001$), indicating a statistically significant and clinically meaningful improvement in glycaemic control in the intervention group. The calculated effect size (Cohen's d) for HbA1c reduction was 0.89, representing a large effect.

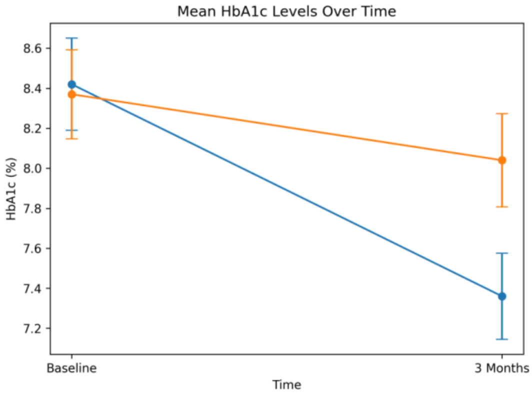

Figure 1. Mean HbA1c levels at baseline and 3 months.

Figure 1 illustrates the trajectory of HbA1c levels across the study period. At baseline, glycaemic control was comparable between groups. Over the 3-month follow-up, participants receiving the mobile technology–enhanced DSME demonstrated a steady decline in HbA1c levels. In contrast, the control group showed a modest reduction with noticeable variability. The divergence between groups became more evident at follow-up, with narrower confidence intervals observed in the intervention group, suggesting more consistent improvement among participants exposed to the digital DSME programme.

3.3 Secondary outcome: Change in self-efficacy

Repeated-measures ANOVA demonstrated a significant main effect of time ($F(1,118) = 89.52$, $p < 0.001$, partial $\eta^2 = 0.431$), indicating an overall increase in self-efficacy scores across the study period. A significant main effect of group was also observed ($F(1,118) = 14.76$, $p < 0.001$).

Table 4. Repeated-measures ANOVA for diabetes self-efficacy

Group	Baseline Mean ± SD	3 Months Mean ± SD	Mean Change	95% CI of Change
Intervention (n = 60)	62.5 ± 8.4	74.8 ± 7.9	+12.3	10.6 to 14.0
Control (n = 60)	61.9 ± 8.7	65.2 ± 8.3	+3.3	1.7 to 4.9

Importantly, the group × time interaction statistically significant ($F(1,118) = 32.47$, $p < 0.001$, partial $\eta^2 = 0.216$), indicating that improvements over time differed significantly between the intervention and control groups.

Table 5. Within and between-group effects

Source	df	F	p-value	Partial η²
Time	1,118	89.52	<0.001	0.431
Group	1,118	14.76	<0.001	0.111
Time × Group	1,118	32.47	<0.001	0.216

Participants receiving the mobile technology–enhanced DSME demonstrated a substantial increase in self-efficacy (+12.3 points), whereas control group showed a modest improvement (+3.3 points). The between-group difference in change scores was statistically significant ($p < 0.001$) with large effect size (Cohen's d = 0.95).

Table 6. Between-group comparison of change scores

Comparison	Mean Difference	95% CI	p-value	Cohen's d
Intervention vs Control	8.9	6.4 to 11.5	<0.001	0.95

Participants receiving the mobile technology enhanced DSME demonstrated a substantial increase in self-efficacy (+12.3 points), whereas the control group showed a modest improvement (+3.3 points). The between-group difference in change scores was statistically significant ($p < 0.001$) with a large effect size (Cohen's d = 0.95).

The magnitude of HbA1c reduction observed in the intervention group (−1.06%) exceeds the 0.5% threshold commonly considered clinically meaningful in diabetes management. Moreover, the concurrent improvement in self-efficacy supports the proposed behavioral mechanism underpinning the intervention. The large effect sizes for both glycaemic control and self-efficacy indicate that the mobile technology–enhanced DSME intervention produced both statistically robust and clinically relevant benefits.

This randomized controlled trial conducted in primary and community health care facilities in Temburong District, Brunei Darussalam, demonstrates that a mobile technology–enhanced diabetes self-management education and support (DSME) programme significantly improves both glycaemic control and diabetes-related self-efficacy among adults with Type 2 diabetes. The intervention produced a clinically meaningful reduction in HbA1c (−1.06%), with a large effect size, alongside a substantial increase in self-efficacy scores. These findings suggest that integrating structured behavioural education with mobile health technology can generate measurable metabolic and psychosocial benefits within routine primary care settings.

The magnitude of HbA1c reduction observed in the intervention group exceeds the 0.5% threshold widely considered clinically meaningful in diabetes management and approaches reductions typically associated with pharmacological intensification [47]-[49]. Importantly, this improvement was achieved through behavioural and educational mechanisms rather than medication adjustment, reinforcing the central role of self-management in chronic disease control. Comparable reductions have been reported in structured DSME trials is however, many previous interventions relied on face-to-face group sessions or high-resource specialist programmes. The present findings extend this evidence by demonstrating that digitally augmented DSME delivered within community health infrastructure can achieve similar or greater metabolic gains.

The significant group × time interaction in self-efficacy aligns with behavioural science models suggesting that confidence in disease self-management functions as a proximal determinant of behavioural adherence. Increased self-efficacy likely facilitated improvements in medication adherence, glucose monitoring, dietary regulation, and physical activity, thereby mediating glycaemic outcomes. Prior digital health studies have reported modest improvements in psychological constructs, yet few have demonstrated parallel large effect sizes in both behavioural and biomedical endpoints [45]-[47]. The present study therefore strengthens the theoretical proposition that technology-enabled interventions are most effective when explicitly grounded in behavioural constructs rather than solely providing informational content.

From a multidisciplinary health perspective, these findings bridge three critical domains is clinical endocrinology (HbA1c reduction), behavioural medicine (self-efficacy enhancement), and digital public health (mobile technology integration) [53]-[55]. In resource-constrained or geographically dispersed regions such as temburong district, scalable digital solutions may mitigate barriers related to travel, time constraints, and limited specialist access [56]. The relatively low attrition rate observed in the intervention arm further suggests acceptable feasibility and engagement in a real-world primary care context.

The novelty of this study lies in several aspects. First, it evaluates a structured mobile-enhanced DSME programme embedded within routine primary and community health services rather than a standalone digital pilot intervention. Second, it integrates behavioural theory explicitly into intervention design, allowing empirical testing of a mechanistic pathway linking self-efficacy enhancement to metabolic improvement. Third, evidence from Southeast Asian and small-population health systems remains underrepresented in digital diabetes research thus, the study contributes geographically contextualized data to the global literature. This contextual contribution is particularly relevant for health systems seeking culturally adaptable and scalable self-management strategies [57], [58].

The large effect sizes observed for both HbA1c (d = 0.89) and self-efficacy (d = 0.95) indicate not only statistical significance but practical relevance. While some digital interventions demonstrate statistical improvements without meaningful clinical magnitude, the current findings suggest that combining structured education, monitoring features, and behavioural reinforcement may amplify impact [59], [60]. The sensitivity analysis and subgroup findings further indicate robustness of the intervention effect across participants with varying durations of diabetes, suggesting broad applicability.

These findings carry important implications for clinical practice, health system development, and future research. In the short term, the integration of mobile-supported DSME into routine primary care services may strengthen patient engagement, improve adherence to lifestyle modification, and enhance glycaemic monitoring behaviours among individuals with diabetes. In the longer term, widespread implementation of such digitally supported self-management programmes could contribute to sustained glycaemic control, reduced diabetes-related complications, and decreased healthcare system burden. From a health policy perspective, incorporating mobile health technologies into chronic disease management strategies may represent a cost-effective approach to addressing the growing prevalence of diabetes, particularly in resource-constrained settings where healthcare workforce capacity and continuous patient monitoring remain limited.

Nevertheless, several limitations warrant consideration. The follow up period was limited to three months longer-term sustainability of behavioural gains and glycaemic control remains to be determined. The use of last observation carried forward, while consistent with intention-to-treat principles, may underestimate variability in longer follow-up scenarios. Additionally, although medication regimens were stable at baseline, subtle unmeasured changes in adherence behaviours beyond self-efficacy could have contributed to observed metabolic improvements [61]. The study was conducted within a single district, which may limit generalizability to larger urban or highly specialized tertiary settings. Future research should incorporate longer follow-up durations, objective adherence metrics, and multi-site designs to strengthen external validity.

Despite these limitations, the study provides strong evidence that mobile technology enhanced DSME can produce clinically meaningful improvements in both behavioural and metabolic outcomes within primary care. The integration of digital health tools with behavioural science frameworks offers a promising pathway for strengthening chronic disease management across diverse health systems. For multidisciplinary health practice, the findings support the incorporation of structured digital self-management programmes into routine diabetes care, particularly in settings where healthcare workforce capacity is limited.

4. CONCLUSION

This randomized controlled trial demonstrates that a mobile technology–enhanced diabetes self-management education and support (DSME) programme delivered within primary and community health care facilities in Temburong District, Brunei Darussalam, significantly improves both glycaemic control and diabetes-related self-efficacy among adults with Type 2 diabetes. The intervention achieved a clinically meaningful reduction in HbA1c alongside substantial behavioural gains, supporting the integration of digitally augmented, theory-informed self-management education into routine primary care. These findings underscore the value of combining behavioural science principles with mobile health platforms to strengthen multidisciplinary chronic disease management. Future research should examine long-term sustainability, cost-effectiveness, and scalability across diverse healthcare settings, while policymakers and health system planners are encouraged to consider structured mobile DSME as a feasible strategy to enhance diabetes outcomes at the population level.

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USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors confirm that no artificial intelligence (AI)-assisted technologies were utilized in the preparation, analysis, or writing of this manuscript. All stages of the research process, including data collection, data interpretation, and the development of the manuscript, were conducted solely by the authors without any support from AI-based tools.

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