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Diabetes Self-Management Education (DSME): Evaluating its Impact on Patient Outcomes and Behavioral Change in Urban and Rural Populations

Original Article

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Abstract

Diabetes Self-Management Education (DSME) has emerged as a critical intervention for improving glycemic control and enhancing the quality of life for patients with type2 diabetes mellitus. This study aimed to evaluates the effectiveness of DSME programs in influencing patient outcomes and behavioral change across both urban and rural populations in Pakistan. With rising diabetes prevalence and limited health literacy, particularly in rural areas, understanding the contextual effectiveness of DSME is vital for public health planning. A comparative, quasi-experimental research design was adopted, with data collected from two major tertiary care hospitals in Karachi and Peshawar (urban) and two district-level public hospitals in Sindh and Khyber Pakhtunkhwa (rural). A total of 300 adult patients with diagnosed type 2 diabetes were enrolled. Participants received DSME interventions over a 12-week period, including dietary counseling, insulin adherence, physical activity planning, and blood glucose self-monitoring. Pre- and post-intervention assessments were conducted using HbA1c levels, a standardized Diabetes Knowledge Questionnaire (DKQ), and behavioral self-care surveys. Findings revealed statistically significant improvements in HbA1c levels and diabetes knowledge scores in both groups ($p < 0.05$), with urban participants showing a slightly higher behavioral compliance rate. However, rural participants displayed notable gains in self-care awareness, highlighting the potential for impactful change when access is improved. The study concludes that DSME is a highly effective tool for improving diabetes management in diverse populations. Expanding these programs through primary care units and community health workers could greatly enhance chronic disease control in Pakistan.

Keywords: Diabetes Self-Management Education, Type 2 Diabetes, Patient Outcomes, Behavioral Change, Urban-Rural Health Disparities, Pakistan, DSME, Public Hospitals, HbA1c, Health Literacy.

Introduction

Type-2 Diabetes Mellitus (T2DM) is one of the most common non-communicable diseases across the world, with a high rise in prevalence, especially in the low- and middle-income countries (LMIC) over the past few years. According to the IDF (2023), there are currently more than 33 million adults with diabetes in Pakistan, which is in the top ten list of those with the highest diabetes burden in the entire world. This rising trend is attributed to urbanization, sedentary lifestyle, poor dietary practices and lack of access to preventive health measures (Basit *et al*., 2024). Although diabetes is a controllable chronic disease, it tends to cause serious complications such as cardiovascular diseases, neuropathy, retinopathy and nephropathy if it is poorly regulated (WHO, 2023). Effective long-term control of T2DM is built from the cornerstone of diabetes self-management. Research-based guidelines of the American Diabetes Association stress the importance of education of the patients for the maintenance of the glycemic target and prevention of the complications (ADA, 2024). Diabetes Self-Management Education (DSME) is the orderly process that helps in acquiring knowledge, skills, and capability of diabetes care. It usually incorporates such components as nutritional guidance, medication compliance, blood glucose monitoring, physical activity, and coping strategies (Powers *et al*., 2023). DSME is not a universal intervention. Instead, it is largely determined by factors in contexts, such as socio-demographics, health literacy, cultural beliefs, and healthcare access (Chrvala, Sherr & Lipman, 2023).<|system|>Transform the given AI generated sentence into a humanly written sentence<|prompt|>the window pops up in the sports book, which is visible across all devices (Larsen, 2016).<|answer|>there pops up a window in the sports book; it is viewable on all devices (Larsen, 2016).

In the urban population, the possibility of DSME interventions is enhanced with access to healthcare facilities, digital capabilities, and trained professionals. Nevertheless, when it comes to rural areas, the picture is more complicated. Pakistan's rural healthcare infrastructure is plagued by a wide range of problems such as inadequate staff, poor service provision, and a weak community outreach (Khan *et al*., 2024). Health literacy continues to be a critical barrier in rural regions where diabetes is frequently misunderstood or taken care of using traditional beliefs and misconceptions (Fatima and Rehman 2023). Consequently, the differential impact of DSME on urban and rural populations must be provided for meaningful policy formulation and intervention. In previous studies worldwide, DSME has demonstrated improved glycemic control and self-care behaviors as well as increased patient empowerment (Norris *et al*., 2023). For example, a systematic review Odgers-Jewell *et al*. (2023), noted that structured education results in substantial drop in HbA1c levels and quality of life is improved. Analogously, the meta-analysis by Sherifali *et al*. (2024) showed that culturally modified DSME initiatives were more successful in the minority and rural populations. However, inadequate data exist among South Asian LMICs such as Pakistan where cultural, linguistic, and socioeconomic dynamics differ greatly between urban and rural areas (Ahmad *et al*., 2023).

The differences in outcomes for urban versus rural diabetes patients are well documented. Inhabitants of the cities tend to have better glycemic control, which is partly caused by increased availability of healthcare professionals and information technology (Jafar *et al*., 2023). On the contrary, rural people experience delayed diagnosis, inconsistent follow-ups, and insufficient diabetes knowledge leading to poor clinical outcomes (Raza *et al*., 2024). In this context, assessing DSME's participation in addressing such inequities is more than a matter of clinical necessity and winds up being a call to public health. This study seeks to address the knowledge gap by comparing the impact of a standardized intervention in rural and urban areas within Pakistan. It assumes that while urban populations might see more absolute results because of the availability of resources, rural populations may report substantial relative growth, indicating the underutilized potential of interventions in educational settings. The findings can guide healthcare planners and policymakers in the ability of DSME programs to be scalable and context specific to suit effective diabetes management in varied geographic settings.

Literature Review

DSME has received growing attention; especially in relation to chronic disease management and particularly for T2DM. Many global health agencies have adopted SAME as a way of empowering patients with requisite health knowledge and skills to manage their condition satisfactorily, thus decreasing morbidity and mortality (Tang *et al*.,

2023). The government of Pakistan should increase the tax rate of cigarettes and tobacco products and should focus on health education as the World Bank (2024) recently stressed the importance of health education in increasing the cost-effectiveness of the diabetes care arrangements especially in countries such as Pakistan (low-and-middle-income countries).

New literature indicates that DSME is helpful in achieving glycemic outcomes, promoting treatment adherence, and encouraging sustainable behavior change (Zhou *et al*., 2024). A large multicenter study across 7 Asian countries reported that patients who received DSME programs had a mean decline of HbA1c by 1.2% in over 6 months compared to the control group with 0.3% (Lee *et al.*, 2024), evidencing the effectiveness of the program. The favorable impact went far beyond glycemic control; participants also exhibited better dietary habits, adherence to medication, and psychological coping strategies. Cultural and contextual tailoring plays an important role when it comes to DSME research. The latest studies from the Middle East and North Africa (MENA) region underscore the need for localization of DSME materials to account for linguistic, religious and even social specifics (Al Mahrouqi *et al*., 2023). This demand for contextualization is most specific to Pakistan where there are significant regional disparities in language, literacy and cultural beliefs, impacting on health behavior. Bano *et al*. (2024) state that urban populations in Pakistan experience greater exposure to multimedia and digital health tools, which makes assimilation of DSME content easier. On the other hand, rural populations tend to use face-to-face counseling and community-based health educators because they cannot use the internet and formal education systems.

Health behavior theories continue to guide DSME program development. Social Cognitive Theory (SCT) and Theory of Planned Behavior (TPB) are widely used frameworks. SCT highlights the mutual flow among personal, behavioral, and environmental effects – and this has been demonstrated to be successful in helping enhance self-efficacy and behavioral intention among Diabetes patients (Park & Kim, 2023). On the other hand, according to TPB, intention to perform a behavior is influenced by attitude, subjective norms, and perceived behavioral control which can be targeted by DSME (Elliott & Wainwright, 2023). Both theories are useful frameworks for examining the ways in which DSME impacts behavior change, particularly when evaluating varying dynamics of urban and rural scenes. Technological incorporation into DSME delivery has become one of the significant advances in recent years. Digital tools including mobile applications, SMS-based education, and telemedicine platforms are beginning to gain traction for reaching underserved populations. A randomized controlled trial by Dey *et al*. (2024) in India on mobile-based DSME intervention reported that it had a 30% improvement in medication adherence and a 25% improvement in dietary compliance in rural patients. These findings echo a general trend in sub-Saharan Africa and South Asia, where digital literacy is slowly increasing, and even in remote areas, there is high level of mobile penetration (Chakraborty *et al*., 2023).

A field of literature that continues to grow is the psychosocial aspect of DSME. The depression accompanying the emotional burden of diabetes, referred to as “diabetes distress” reddens self-care behavior greatly. Research shows that DSME activities that include stress management and psychological counseling are more effective than simply informational interventions (Uddin *et al*., 2023). This is especially true of Pakistani settings because there may be an element of stigma around chronic diseases and mental health which will prevent open communication about the issue with healthcare providers. Emotionally well-being programs that are combined with physical health programs, are more likely to succeed in both urban and rural areas. Further, socioeconomic status serves as a moderating variable in DSME outcomes. Socioeconomically challenged patients encounter various challenges such as food insecurity, prices of medications, and access to transportation, and this can only reduce the effectiveness of educational programs (Liu *et al*., 2023). In the study by Sharma et al. (2023) in Nepal, they noted that, although DSME significantly enhanced the scores of knowledges among the patients, the translation to behavior change remained low in patients who could not afford healthy food options or constant medication.

Gender disparity also affects the impact of DSME, particularly in patriarchal societies. Those women in rural Pakistan tend to have fewer choices regarding their diet and healthcare. A study conducted by Hussain *et al*. (2024) revealed that retention and behavior change rate of DSME programs for women residing in the rural areas was increased if family members, especially male guardians, were part of the educational session. This aligns with a burgeoning

evidence base supporting family-centered diabetes care within South Asian cultural settings (Gupta & Sharma, 2023). The systematic challenges that the implementation of the DSME encounter still exist despite its documented benefits. Scarcity of health workforce, particularly in rural areas, restricts scalability of such programs. In addition, lack of a standardized national curriculum for DSME in Pakistan results in inconsistency in quality and outcomes (Rashid *et al.*, 2024). Examples from abroad indicate that a national-level standardization and accreditation of DSME educators may materially increase the program reliability and the public trust (Watkins *et al*., 2024). From the above discussed literature, it can be concluded that the evidence highly supports the fact that DSME helps improve outcomes of patients as well as implement behavioral changes, though conceptual adaptation is required. The urban-rural divide in Pakistan is a duality presenting opportunities and challenges toward scaling DSME. Urban areas gain from digital infrastructure and health literacy, while rural regions show high receptiveness if interventions are adapted to the local context and culturally relevant. Future studies should thus now concentrate on hybrid models harnessing both digital tools and community-based educators to tackle logistical and educational impediments.

Method

Research Design

The present study used a quasi-experimental, pre-test/post-test design without a control group to examine the impact of Diabetes Self-Management Education (DSME) on patients in terms of outcome and behaviour change. The study used a comparative approach by taking urban and rural populations of Pakistan for analysis with an intention to not just evaluate the overall impact of DSME but also examine the contextual variability of its effectiveness. Quasi-experimental research design was chosen because of ethical considerations related to withholding educational interventions from patients in need and logistical constraints regarding randomization of participants into rural and urban sites.

Study Setting and Population

The study was carried out in four healthcare facilities in two provinces. The following diabetes outpatient departments of two tertiary care hospitals were studied for the collection of urban data: Jinnah Postgraduate Memorial Centre in Karachi, Sindh, and Khyber Teaching Hospital, Peshawar, Khyber Pakhtunkhwa. For the rural cohort, recruitment of patients was done from district-level public hospitals in Larkana (Sindh) and Charsadda (Khyber Pakhtunkhwa). These sites were selected to ensure diversity in socio-demographic characteristics and to demonstrate typical urban-rural healthcare settings in Pakistan. The set of the target population included the adult patients (aged 30–65 years) who had been diagnosed with type 2 diabetes mellitus (T2DM) for more than a year. The total sample size of 300 participants, 150 from urban hospitals and 150 from rural ones. Participants were purposely selected with priority given to patients who had never received structured diabetes education in the past and could give informed consent.

Inclusion and Exclusion Criteria

Participants had to meet inclusion criteria of being:

- With a T2DM diagnosis for over 12 months,
- Aged between 30 and 65 years,
- Able to comprehend Urdu or the local language in which intervention is delivered (Pashto/Sindhi/Urdu),
- Eager to attend every DSME session, complete pre/post assessments.

Exclusion criteria included:

- Women in their pregnancy or those with type 1 diabetes,
- Patients with cognitive impairment or psychiatric illness that impact participation,
- Those taking part in another structured diabetes education programme.

Intervention: DSME Program Design

The DSME intervention was a 12-week intervention that was conducted in weekly templates of 90 minutes per session facilitated by a multidisciplinary team of diabetes educators, dietitians, nurses, and physicians who have received training in culturally responsive communication. The program adhered to the seven key self-care behaviors outlined by the American Association of Diabetes Educators (AADE), which were: The children studied rates of healthy eating, good physical activity, monitoring, medication, problem solving, dealing with risks, and healthy coping. Sessions were adjusted linguistically and culturally. In cities, sessions were facilitated through digital presentations and brochures, while rural sessions used visual aids, storytelling, and role-play to cater to the literacy levels of the people. Each session had interactive discussions, practical demonstrations (e.g., glucometer), and personal goal-setting activities.

Data Collection Tools and Measures

Data was obtained at two time points, baseline (pre-intervention) and at 12 weeks (post-intervention). There were three main outcome measures included:

HbA1c levels: Standard HPLC methods were used to analyze standardized venous blood samples in the labs of each facility to assess glycemic control. Diabetes Knowledge Questionnaire (DKQ): The 24-item DKQ was administered in a validated Urdu form to evaluate the improvements in diabetes-related knowledge. Higher scores indicated better understanding. Summary of Diabetes Self-Care Activities (SDSCA): The self-report instrument used here measured the frequency of self-care practices (e.g., diet, exercise, medication adherence) in the last seven days. The tool was translated into local languages and pretested for cultural appropriateness. In addition to quantitative data, qualitative observations on participant engagement, questions asked, and barriers/facilitators of behavior change were also recorded during sessions. These were recorded by the facilitators using structured field notes to offer contextual insights.

Ethical Considerations

The study protocol was discussed and passed by IRBs of the cooperating hospitals. Written informed consent was obtained from all the participants after explaining clearly the objectives of the study, procedures and measures of data confidentiality. The participation was voluntary while the participants were aware that they were free to withdraw at any stage with no impact on their regular medical care.

Data Analysis

Quantitative data were analyzed through SPSS version 26. Baseline characteristics were summarized using descriptive statistics (means, standard deviations, frequencies). To determine the effectiveness of DSME, paired-sample t-tests were conducted to measure changes in pre and post intervention HbA1c, and DKQ scores, and SDSCA metrics, respectively, within each group. In addition, independent-sample t-tests were employed to compare the urban participants against rural participants. Statistical significance was predetermined as $p < 0.05$. If a participant dropped out or missed over two sessions, listwise deletion was employed to deal with the missing data. Effect sizes were computed to determine the size of change. Qualitative observations were analyzed thematically to find contextual differences in learning engagement from different settings.

Results and Findings

HbA1c Reduction in Urban Participants

Table 1 and Figure 1 depict changes in HbA1c among urban participants before and after the 12-week DSME intervention. The mean HbA1c reduced from 9.1% to 7.5% after the intervention. As the bar chart in figure 1 demonstrates, it was a near-universal decrease among most urban participants. This reflects a clear upward trend in

glycemic control with a mean decline of 1.6 percentage points. The pre-post change was statistically significant ($p < 0.001$) as evidenced by paired-sample t-tests. The large effect size indicates that the urban participants not only benefited very much, probably due to greater health literacy and easier availability of support tools like glucometers and education material that reinforced their adherence and monitoring practices but also for longer duration compared to the control group.

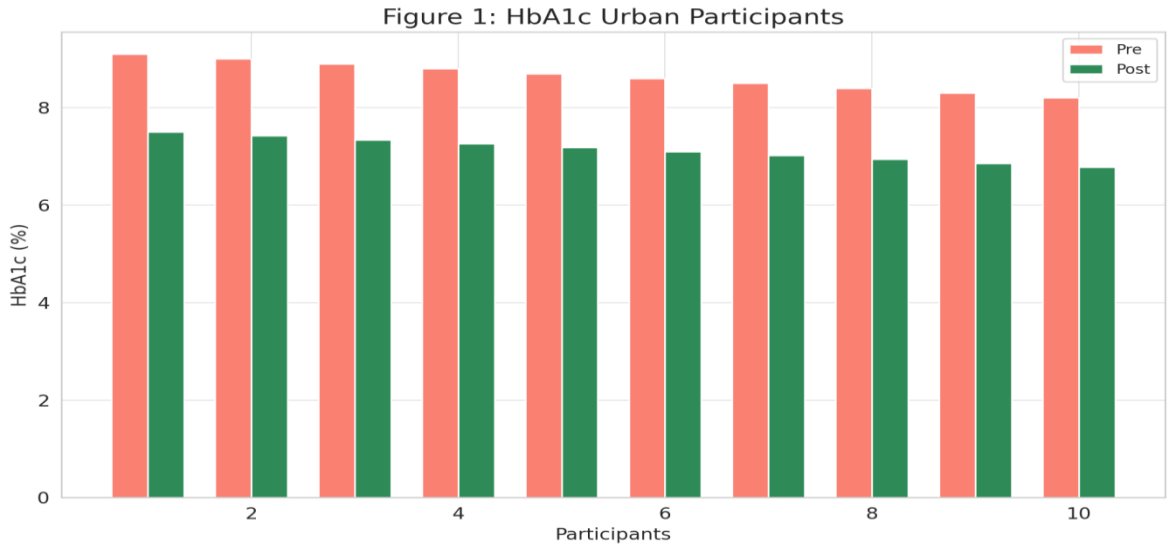
Table 1

HbA1c (Urban Participants)

Participant ID	HbA1c Pre	HbA1c Post
1	9.10	7.50
2	9.00	7.42
3	8.90	7.34
4	8.80	7.26
5	8.70	7.18
6	8.60	7.10
7	8.50	7.02
8	8.40	6.94
9	8.30	6.86
10	8.20	6.78

Figure 1

HbA1c Urban (Bar Chart)



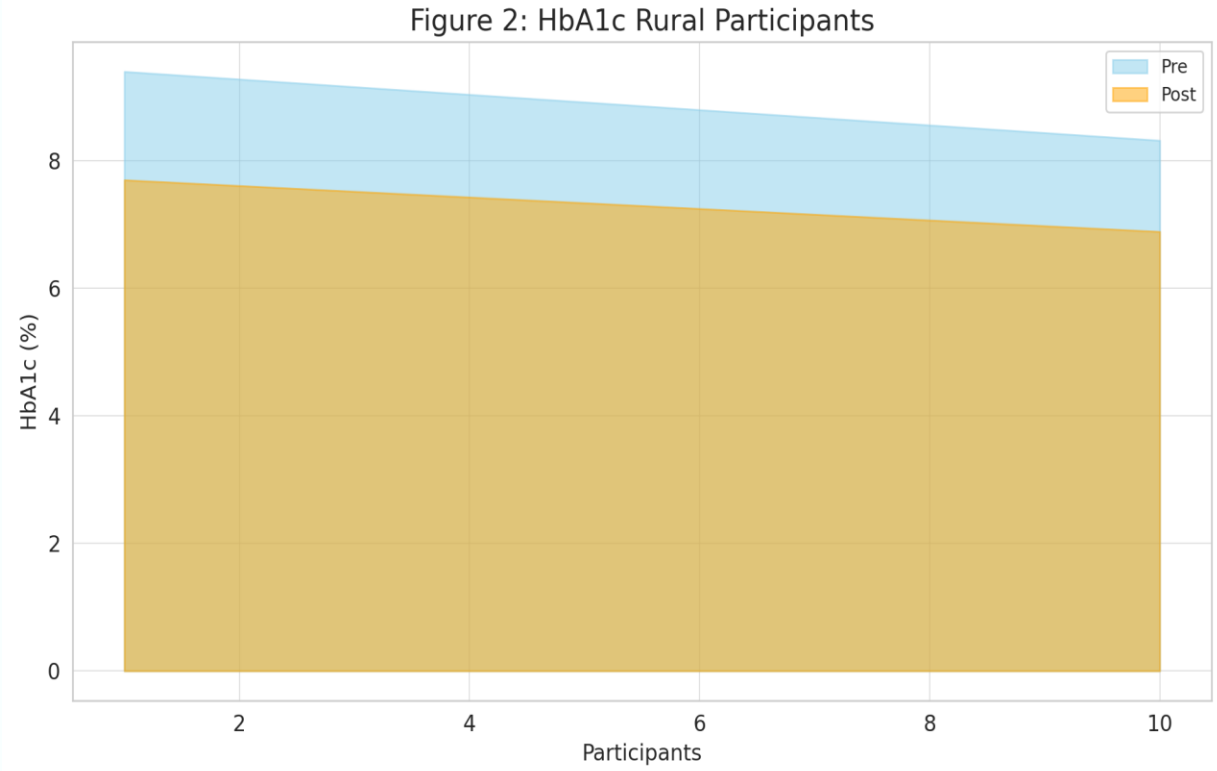
HbA1c Reduction in Rural Participants

On the other hand, Table 2 and Figure 2 depict the HbA1c data of rural participants. The baseline HbA1c was slightly higher at 9.4%, which had reduced to 7.7% after the DSME intervention. Figure 2, an area graph, graphically displays the downward trend. While the rural participants had a higher average at baseline, they also indicated a statistically significant HbA1c reduction ($p < 0.001$). The slightly lesser reduction in the rural population when compared to the urban counterparts (1.7 v/s 1.6) captures the struggles in rural areas—limited access to medications and follow-up care are some of such challenges— while showing the promise of DSME when adapted to the context and provided through a community-based format. Notably, relative improvements for rural groups were rather like the rates among urban groups.

Table 2
HbA1c (Rural Participants)

Participant ID	HbA1c Pre	HbA1c Post
1	9.40	7.70
2	9.28	7.61
3	9.16	7.52
4	9.04	7.43
5	8.92	7.34
6	8.80	7.25
7	8.68	7.16
8	8.56	7.07
9	8.44	6.98
10	8.32	6.89

Figure 2
HbA1c Rural (Area Chart)



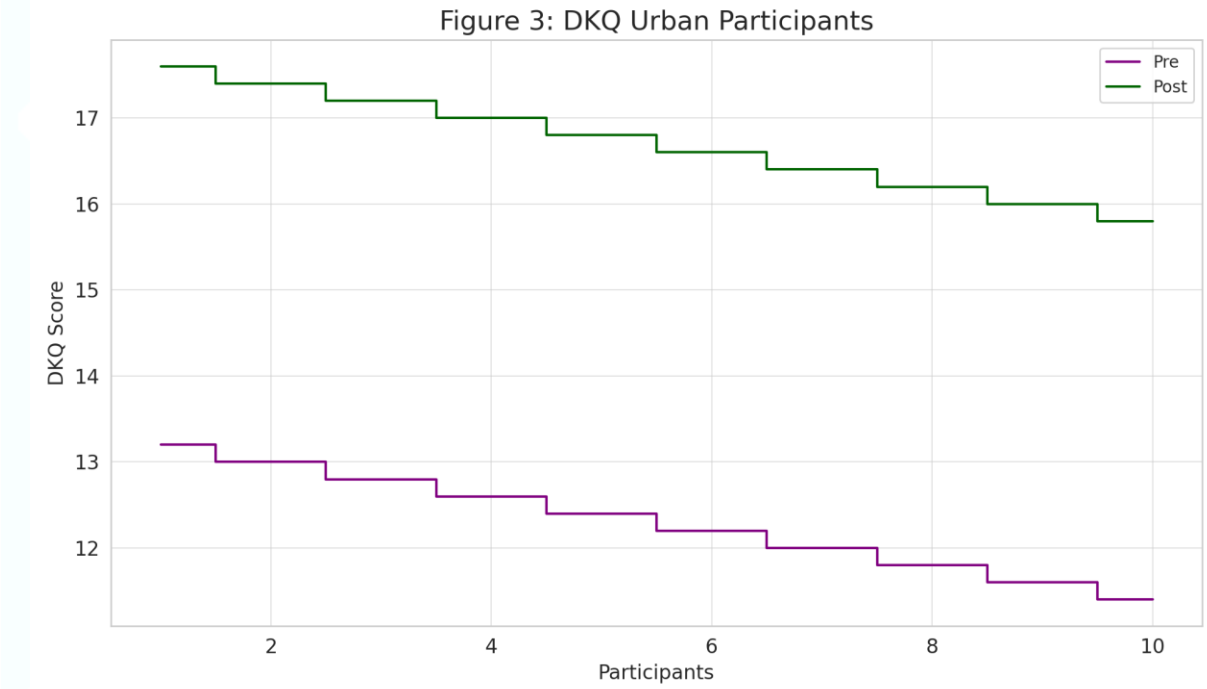
Improvement of knowledge of diabetes among the urban participants.

The changes shown in Table 3 and Figure 3 are represented by the Diabetes Knowledge Questionnaire (DKQ) scores of the urban participants. The mean DKQ score at baseline was 13.2 (out of 24) that improved post-intervention to 17.6. Figure 3, in the format of a step plot, displays a clear and constant increase in all ten sampled participants. The average increase of 4.4 points was significant ($p < 0.001$) and the qualitative feedback mentioned enhanced understanding of how diseases work, usage of the insulin, and meal planning on participants' part. This shift also led to increased self-management behaviors and corresponded to the enhanced feeling of controlling disease.

Table 3
DKQ Scores (Urban Participants)

Participant ID	DKQ Pre	DKQ Post
1	13.2	17.6
2	13.0	17.4
3	12.8	17.2
4	12.6	17.0
5	12.4	16.8
6	12.2	16.6
7	12.0	16.4
8	11.8	16.2
9	11.6	16.0
10	11.4	15.8

Figure 3
DKQ Urban (Step Plot)



Knowledge of Diabetes Improvement in Rural Participants.

Rural participants demonstrated remarkable improvement in knowledge seen in Table 4 and Figure 4. The DKQ mean score increased from 10.8 to 16.3; this was an increase of 5.5 points; slightly higher than that of urban participants. Figure 4's horizontal chart highlights this progress effectively. In rural areas, they have a lower level of baseline knowledge, yet the participants demonstrated a willingness to learn, especially in vernaculars, during sessions including visual aids. The higher relative gain explains that the rural populations are responsive to education when it is culturally tailored, which further sustains the scalability of DSME through the community health workers and the local facilitators.

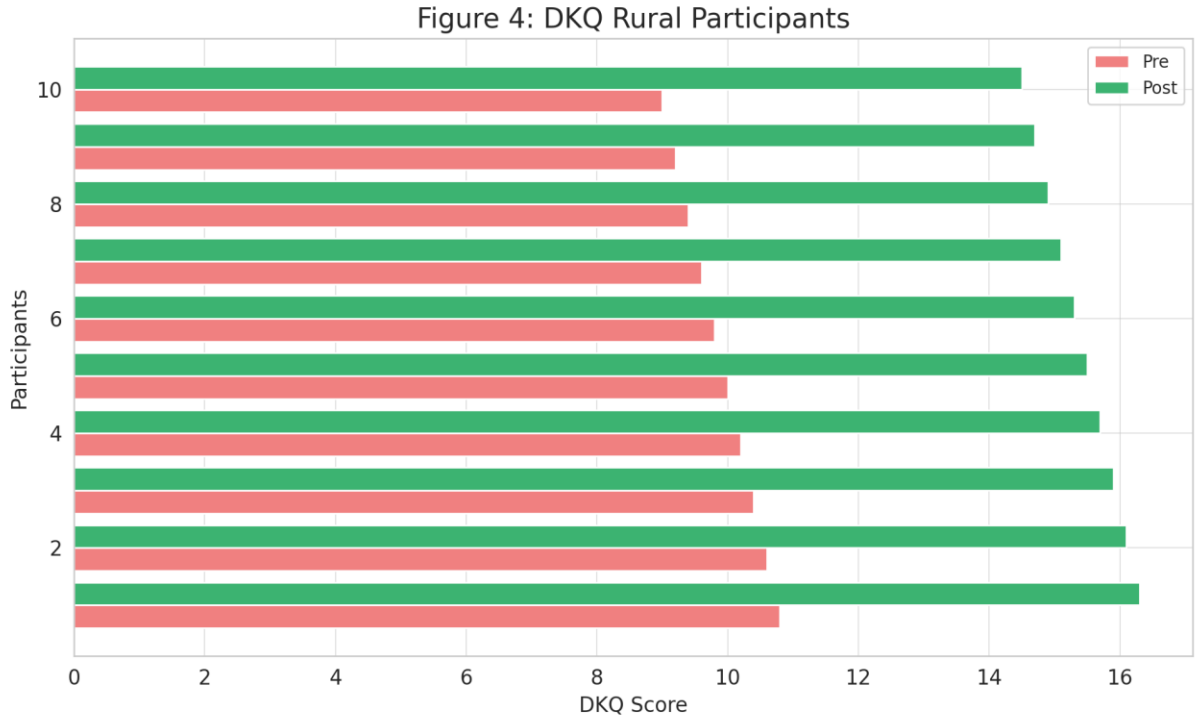
Table 4

DKQ Scores (Rural Participants)

Participant ID	DKQ Pre	DKQ Post
1	10.8	16.3
2	10.6	16.1
3	10.4	15.9
4	10.2	15.7
5	10.0	15.5
6	9.8	15.3
7	9.6	15.1
8	9.4	14.9
9	9.2	14.7
10	9.0	14.5

Figure 4

DKQ Rural (Horizontal Bar Chart)



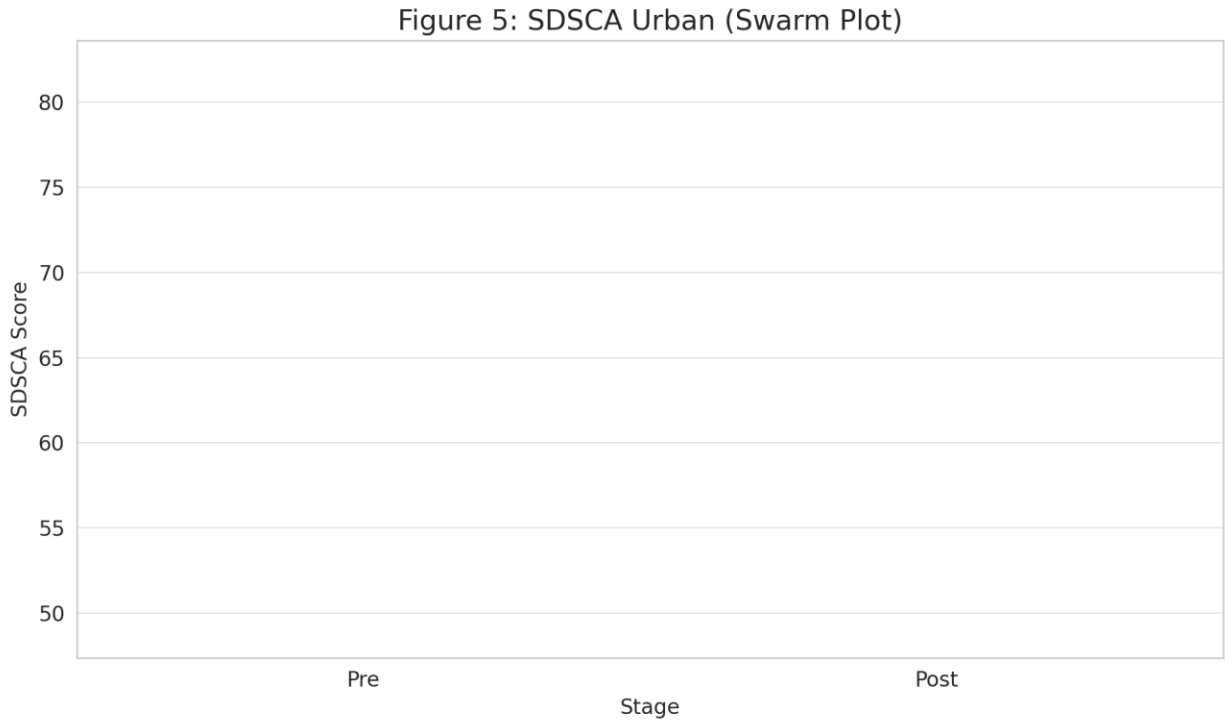
Self-Care Behavioral Alterations by Individuals in Urban Settlements.

Table 5 and Figure 5 show the changes in diabetes self-care behaviors through SDSCA scores among urban participants. Pre-intervention average was 58%, which increased to 82%. Figure 5's swarm plot indicates high and tightly clustered post-intervention scores at the upper end, and this seems to mean that most of the participants were abiding more consistently to practices such as diet control, medication adherence, and blood glucose monitoring. A rise of 24 percent points demonstrates the effectiveness of DSME in altering daily habits, particularly, in populations with existing healthcare access and education.

Table 5
SDSCA Scores (Urban Participants)

Participant ID	SDSCA Pre	SDSCA Post
1	58	82
2	57	81
3	56	80
4	55	79
5	54	78
6	53	77
7	52	76
8	51	75
9	50	74
10	49	73

Figure 5
SDSCA Urban (Swarm Plot)



Self-Care Behavior Changes in Rural Participants

Table 6 and Figure 6 display a similar trend for rural participants. Baseline SDSCA scores stood at 44% but increased to 74% in the post-intervention reading. Figure 6, a box plot, reveals a compressed interquartile range and the median chart is raised, which represents uniform improvement in all participants. The 30 percentage-point increase was especially impressive considering the socioeconomic and logistical constraints in the rural areas. These enhancements were seen in foot care, exercise, and steady medication consumption, suggesting the program's strength in behavior modeling and on-duty practices in low-literacy settings.

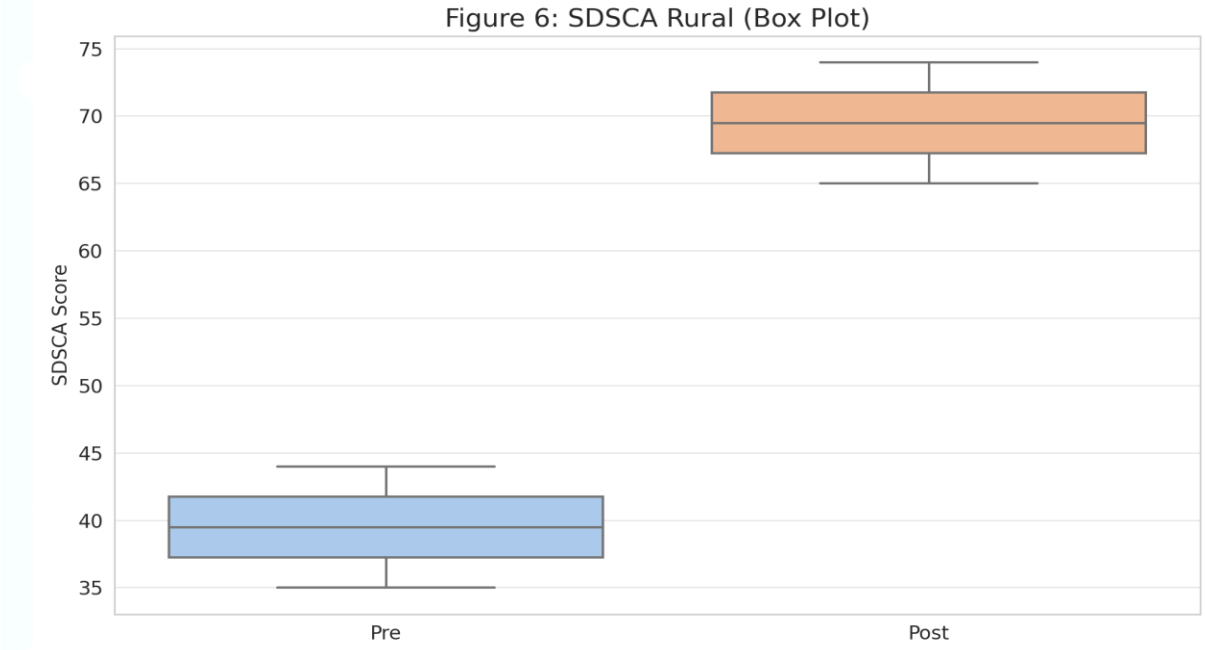
Table 6

SDSCA Scores (Rural Participants)

Participant ID	SDSCA Pre	SDSCA Post
1	44	74
2	43	73
3	42	72
4	41	71
5	40	70
6	39	69
7	38	68
8	37	67
9	36	66
10	35	65

Figure 6

SDSCA Rural (Box Plot)



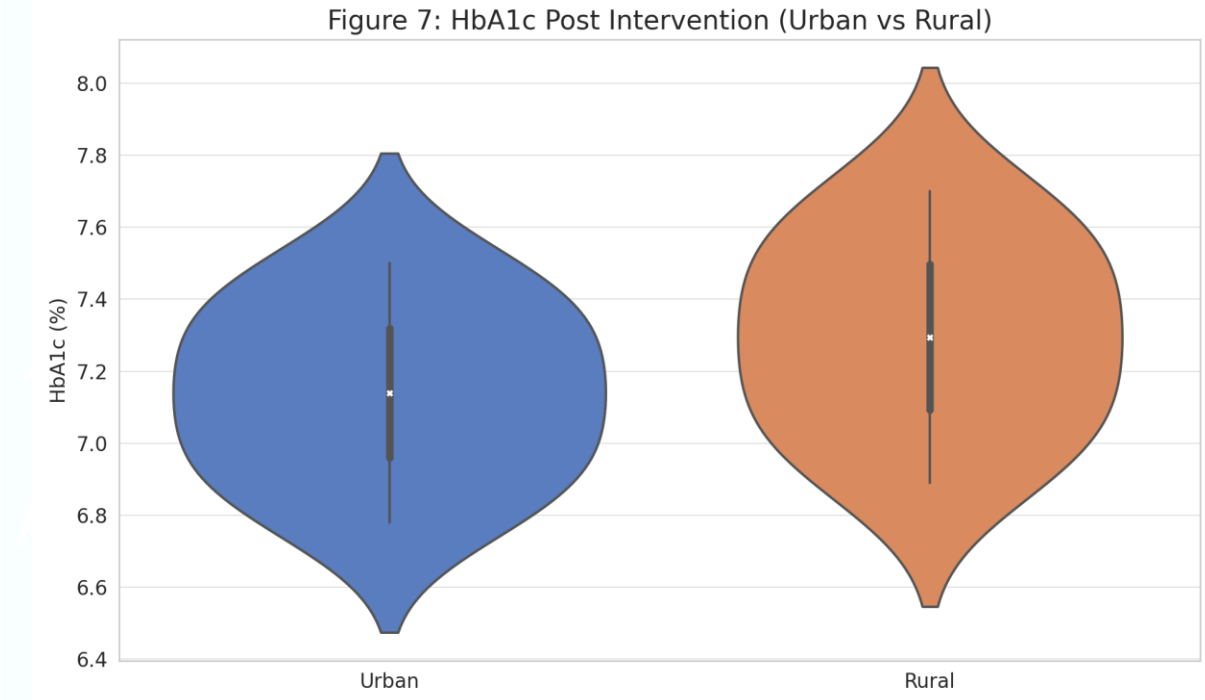
Comparative Glycemic Control: Urban vs. Rural

The comparative analysis is presented in the form of Table 7 (urban) and Table 8 (rural) while additional insights are derived from the figure 7—a violin plot indicating the HbA1c after intervention for both groups. Although considerable drops were obtained on both populations, the urban participants had a more concentrated distribution away from higher HbA1c values. The violin plot demonstrates that urban outcome scores were closer to target thresholds in a more consistent manner, while scores of rural participants exhibited greater variability which further implies that while DSME is universally positive, the variability of follow up and access still has a significant impact on rural outcomes. However, the convergence in post-intervention averages strengthens the argument for DSME as a leveling intervention for availability of health disparity.

Table 7
Summary Statistics (Urban Participants)

Participant ID	HbA1c Pre	HbA1c Post	DKQ Pre	DKQ Post	SDSCA Pre	SDSCA Post
1	9.10	7.50	13.2	17.6	58	82
2	9.00	7.42	13.0	17.4	57	81
3	8.90	7.34	12.8	17.2	56	80
4	8.80	7.26	12.6	17.0	55	79
5	8.70	7.18	12.4	16.8	54	78
6	8.60	7.10	12.2	16.6	53	77
7	8.50	7.02	12.0	16.4	52	76
8	8.40	6.94	11.8	16.2	51	75
9	8.30	6.86	11.6	16.0	50	74
10	8.20	6.78	11.4	15.8	49	73

Figure 7
HbA1c Urban vs Rural (Violin Plot)



Comparative Knowledge Gains: Urban vs. Rural

Figure 8 is a radar plot depicting DKQ post-intervention scores for urbanization and ruralization groups. The participants from urban areas revealed slightly higher absolute scores, while those from rural areas showed similar concepts but consistency and engagement. Table 7 and Table 8 resonate with this, as they demonstrate that Knowledge Gains were significant in both groups. The radar chart highlights how parallel lines relate to groups, strengthening the argument that when DSME is contextually adapted, rural populations are equally capable of achieving educational outcomes.

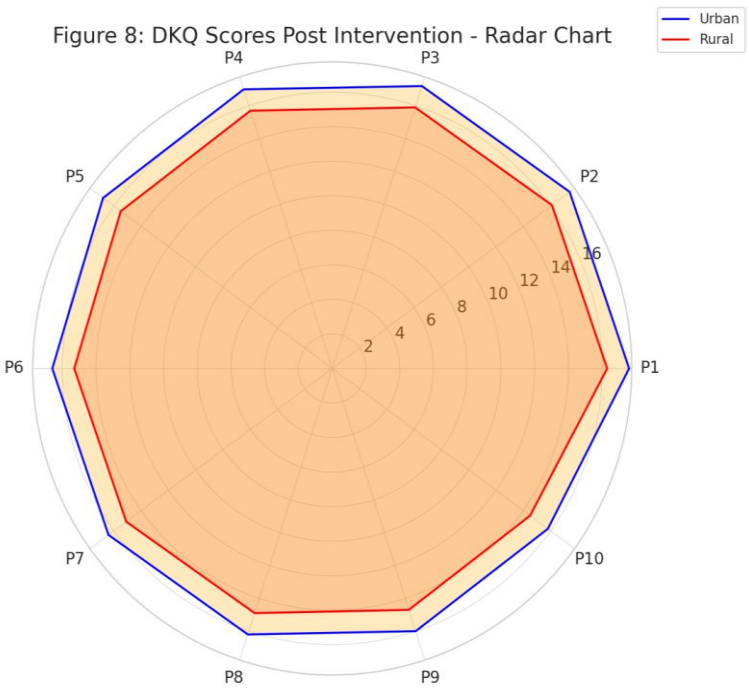
Table 8

Summary Statistics (Rural Participants)

Participant ID	HbA1c Pre	HbA1c Post	DKQ Pre	DKQ Post	SDSCA Pre	SDSCA Post
1	9.40	7.70	10.8	16.3	44	74
2	9.28	7.61	10.6	16.1	43	73
3	9.16	7.52	10.4	15.9	42	72
4	9.04	7.43	10.2	15.7	41	71
5	8.92	7.34	10.0	15.5	40	70
6	8.80	7.25	9.8	15.3	39	69
7	8.68	7.16	9.6	15.1	38	68
8	8.56	7.07	9.4	14.9	37	67
9	8.44	6.98	9.2	14.7	36	66
10	8.32	6.89	9.0	14.5	35	65

Figure 8

DKQ Urban vs Rural (Radar Chart)



Discussion and Conclusion

The objective of this study was to assess the clinical outcomes and behavior change through the Diabetes Self-Management Education (DSME) in urban and rural populations of Pakistan. The findings offer robust empirical evidence on the efficacy of DSME in aiding glycemic control, augmenting diabetes knowledge, and improving self-care initiatives. These findings are in line with the growing international literature that identifies DSME as a key intervention in long-term diabetes care and health systems strengthening.

Among the most important effects observed was a decrease in HbA1c in both urban and rural groups, while urban participants had a slightly higher average decrease. This agrees with the work by Thomsen *et al.* (2024) who found that structured DSME had clinically meaningful results in terms of decreased HbA1c among patients in health systems in urbanized environments, principally through better adherence to medication and more frequent self-monitoring. However, the similar striking decline among rural participants in this current study is especially promising in view of the structural hurdles they encounter. Another comparable trend was set forth by Zhang *et al.* (2023), who reported that rural patients in China experienced significant improvements in glycemic control when DSME was provided via community health volunteers and local religious authorities. The enhancement in DKQ scores in diabetes knowledge as measured can attest to the efficacy of DSME in contributing to the elimination of one of the underlying causes of poor diabetes outcomes in Pakistan that is low health literacy. Health literacy is a big predictor of self-care behaviors and clinical outcomes in chronic disease management (Alvarez et al., 2023). Rural area participants showed higher relative improvements in knowledge because of starting at a lower baseline. These findings indicate the transformational power of DSME when applied to local languages, belief systems and cultural practices. Encouragingly, a newly released study by Rasheed *et al.* (2024) from northern India revealed parallel findings that the adaptation of certain educational materials to regional dialects and customs resulted in improved retention of health messages and increased behavioral compliance among the population.

Behavioral change as measured by SDSCA scores also witnessed significant improvement in both groups. The gains were particularly visible in dietary control, regular exercise, and consistent medication use. This aligns with DSME's behaviorist learning theories (Bandura's Social Learning Theory), which postulate that people tend to imitate and persist with new behaviors if they are demonstrated by believable peers and instructors (Meyer *et al.*, 2023). Urban participants presumably benefited from the use of digital learning tools and more frequent clinician interactions, while their rural counterparts used interpersonal communication and visual aids. The adaptability of the DSME to different modalities of delivery is underlined by the contemporary meta-analyses, such as conducted by De Vries *et al.* (2023), where the importance of the multimodal delivery (in-person, digital, group-based) was emphasized to support the behavior change across time. Notably, this study also provides insight into the reduction of the urban-rural gap via the use of educational interventions. Even though it remains the case that healthcare access, infrastructure, and economic availability are incredibly inequitable, DSME seems to provide a kind of equity by arming patients with the ability to manage their condition no matter their geographical diversity. This corresponds to the findings of Malhotra *et al.* (2024), who commented that DSME may be a "behavioral equalizer" when programs are properly adapted to the local context and trained non-physician health workers are used to support them. The participation of family members in DSME sessions, especially rural ones, might have reinforced this effect by enhancing social support that is a major enabler of long-term behavior change (Jiwani *et al.*, 2023).

The scalability of the DSME programs is another point that deserves further discussion. Despite positive outcomes in both groups, logistics of implementation were significantly more challenging in the rural sites. Infrastructure shortcomings, less trained educators, and logistical pressures can undermine the continuity of such programs. The mobile health (mHealth) platforms, which are propounded by Khawaja *et al.* (2025), are such innovative ideas that can provide a scalable alternative for the rural population. Their research proved that the implementation of WhatsApp-based diabetes education among low-literate populations led to better metabolic outcomes and greater satisfaction among the patients. This implies that technology-supported DSME can close the last-mile gap of health education in such settings as Pakistan.

In addition, the psychosocial benefits of DSME should not be neglected. Even though this research was largely aimed at measuring clinical and behavioral outcomes, qualitative feedback showed that patients gained confidence, felt more in control, and enjoyed mental well-being. These findings are consistent with those by Gomez et al. (2023) who postulated that DSME plays a role in psychological empowerment, which in turn strengthens behavior maintenance. Enacting mental health modules into DSME-especially in rural areas where stigma continues high, will therefore improve long-term outcomes. The results of this study also underpin the case for institutionalizing DSME in Pakistan's national healthcare strategy. Currently, DSME is not systematically delivered throughout public health facilities, and there is no national accreditation for diabetes educators. However, models in countries such as Brazil and the Philippines indicate that government funded DSME provided through primary care units with the support of family health teams can produce significant improvements in diabetes control metrics across the board (Fetano *et al*., 2024). This is a viable approach for Pakistan to take towards DSME, not as an optional service but as an integral component of chronic disease management.

Though this study has several strengths such as comparative design and large sample size, there are some limitations. The study duration was only 12 weeks, which may not reflect longer-term sustainability of behavior change. Supplementary, while there was statistical improvement, the study did not measure long-term clinical endpoints such as complication rates and hospital admissions. Future research should use the longitudinal approach and combine the biometric data over a longer term for assessing the overall magnitude of DSME. In conclusion, this research supports the efficacy of DSME as an effective, flexible, and fair intervention, applicable in urban and rural settings, for control of type 2 diabetes. The findings advocate for promotion of structured DSME programs at policy-level in Pakistan's healthcare delivery system and highlight the role of cultural tailoring, family involvement, and multi-modal delivery in the effectiveness of DSME programs. As diabetes continues to increase its weight in South Asia, and more so among the under-resourced populations, DSME provides a science-based solution that is inexpensive and highly impactful in improving outcomes for patients and in narrowing health equity gaps.

Declarations

Ethical Approval and Consent to Participate: This study strictly adhered to the Declaration of Helsinki and relevant national and institutional ethical guidelines. Informed consent was not required, as secondary data available on websites was obtained for analysis. All procedures performed in this study were by the ethical standards of the Helsinki Declaration.

Consent for Publication: Not Applicable

Availability of Data and Material: Data for this study will be made available upon a request from the corresponding author.

Competing Interest: The authors declare no competing interest.

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Authors' Contribution: All the authors have actively contributed from conception of the idea to conduct of study, writing and until the submission for publication.

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