Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/bzpfhp61

FACTORS INFLUENCING BLOOD SUGAR MANAGEMENT IN INDIVIDUALS WITH TYPE 1 DIABETES: A LONG-TERM COHORT ANALYSIS

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Abstract

Introduction: Type 1 diabetes (T1D) requires lifelong insulin therapy and self-management. Glycemic control remains suboptimal in many patients due to various clinical, behavioral, and psychosocial factors.

Objective: To determine and examine important aspects that affect long-term management of blood sugar by those who have T1D, utilising a hospital-based sample in Pakistan.

Material and Methods: The study was a prospective cohort study done at Khyber Medical College Peshawar and Akhter Saeed Medical College Lahore from November, 2024 and April, 2025. There were 210 confirmed T1D patients recruited. Information regarding insulin therapy, behavioural lifestyle and psychosocial issues was obtained. The outcome measure was HbA1c levels of glycemic control.

Results: Better HbA1c outcomes were greatly associated with the use of insulin pump therapy, adequate physical exercise, adherence and proper diet, as well as carefully arranged support systems. Individuals who experienced distress in association with diabetes also experienced decreased glycemic control.

Conclusion: Effective blood sugar management in T1D depends on individualized therapy, lifestyle modification, and psychosocial support. Integrating these into care plans may improve long-term outcomes.

Keywords: Type 1 diabetes, glycemic control, insulin therapy, psychosocial support, cohort study, Pakistan.

INTRODUCTION

Disease management of blood glucose in the patient with type 1 diabetes (T1D) is a long-term clinical challenge, especially since taming of blood glucose is multifactorial and complex. Type 1 diabetes is an autoimmune disease which causes irreversible loss of pancreatic beta cells and can lead to Intractable insulin deficiency. Although new techniques are making strides in insulin therapy and glucose monitoring, a high percentage of patients with T1D still exhibit poor glycemic performance, which exposes them to the risk of acute and chronic complications. The studies whose results were aimed at naming the biological, behavioural, psychosocial, and technological determinants of the long-term outcomes in this population have contributed to the understanding of the complexity of the self-management of diabetes and care delivery system documentation (1). The SFDT1 study has been critical in helping investigate factors related to cardiovascular and other complications related to diabetes based on a longitudinal cohort design. It emphasises such critical roles as age at diagnosis, lifestyle, comorbidities and access to healthcare services that ultimately define disease progression in the long term in people with T1D (1).

Cardiovascular disease (CVD) is a top cause of death among T1D, and the findings of a national study in Finland reinforce the idea that gaps still exist in achieving equitable outcomes despite advancements in diabetes management. The paper also found a difference in the occurrence of cardiovascular disease among the age and sex population, which raises the demand to focus on specific interventions and to be able to measure residual cardiovascular risk within the clinical practice (2). The next important dimension affecting blood sugar management is the success and sustainability of the advanced therapeutic methods, including islet allogeneic transplantation. This was published recently in a multicenter cohort study, which concluded that primary graft function has dramatic implications on five-year outcomes with respect to insulin independence and glycemic stability, which underscores the role of personalised planning of the therapeutic strategy (3). In addition to transplantation, lower extremity amputation is also a serious threat, and longitudinal registry data collected in Sweden show that the risk of amputation is increased by poor glycemic control, as well as by social determinants (4). These findings raise awareness of complications that should be taken into consideration in the complete model of diabetes care (physiological and systemic).

Comorbid neurodevelopmental disorders that commonly co-exist in patients with T1D are also a leading cause of glycemic management difficulties. Such disorders were linked in a population-based study with poor diabetes outcomes, which implies that cognitive and psychological support should not remain outside of the care strategy (5). Canadian cross-sequential long-term cohort studies have also provided important contributions to elaborations on the role of a pancreatic islet transplant, demonstrating that there is an improvement in glycemic control and the quality of life of some patients with unstable T1D, thereby extending the sphere in terms of the possibilities to manage (6). Biomarkers Diabetes glycated haemoglobin (HbA1c), one of the metrics used to evaluate long-term glucose control, has been associated repeatedly with poor wound healing in diabetic foot ulcers. A prospective cohort study provided an example of how an increase in HbA1c leads to an extension of the wound healing process, supporting the clinical necessity of having optimal glycemic control in order to minimise morbidity (7). Besides chronic complications, acute complications, e.g. postoperative hypoglycemia, are also being identified.

The results presented in a retrospective study indicated a tendency toward increased risk after gastrointestinal surgery, even in patients with type 2 diabetes, which indicates that the protocols of perioperative control of blood sugar levels should be highly effective and proactive (8). Innovation in diabetes health care has demonstrated potential in improving outcomes. A cohort study of 2024 comparing insulin pump therapy with multiple daily injections in children showed that pump therapy provides improved glycemic control and may contribute to reduced complications, and in general, there should be increased access to such technologies, particularly in children (9). Meanwhile, the development and advancement of albuminuria as an indicator of diabetic kidney disease remains a significant issue. The retrospective analysis of young people with T1D depicted the troubling trends of moderate and severe forms of albuminuria, highlighting the necessity of earlier and more intensive interventions (10).

In addition to the conventional issues, the involvement of diabetes in the formation of neurodegenerative diseases has been attracting more and more attention. The systemic impact of chronic hyperglycemia has been questioned by a meta-analysis of several cohort studies that detected a statistically significant relationship between diabetes and Parkinson's disease (11). Foot ulcers, which are a common complication in a person with T1D, also increase the chances of amputation and death. These associations were confirmed by a national retrospective cohort study, which recommended the use of preventive measures, including early screening and education of the patients (12). The COVID-19 pandemic has highlighted some new dimensions to the diabetes management equation. There was a possible association of recent COVID-19 infection with the occurrence of T1D, indicating viral triggers to be a probable cause of disease progression and onset, as found in a Scottish cohort study (13). Cognitive decline in T1D has been described over decades of follow-up in the elderly, with the DCCT/EDIC study showing that decades of exposure to glycemia has an adverse impact on executive functioning and memory and thus complicates self-management in ageing populations (14).

A large cohort in the UK confirmed similar results and supported the association between poor glycemic control and high risk of dementia, which is why cognitive assessment should be an important element of diabetes care at large (15). Moreover, metabolic measures like the triglyceride-glucose index have also become candidates in predicting complications like stroke. The study conducted in China is a cohort study and observed that variations in this index are associated with risks of stroke among middle-aged and elderly individuals, which further supports the worth of composite risk assessments (16). The special populations, like pregnant women on metformin therapy, also have their unique trajectories. A cohort study based on a register was used to identify potential long-term effects on children who were in utero exposed to metformin and broadened the discussion on intergenerational consequences of diabetes treatments (17).

Technologically, Flash glucose monitoring has transformed real-time monitoring of blood sugar readings. The RELIEF study has shown that acute diabetes complications have reduced significantly following the use of such devices and has been attributed to their effectiveness in preventing and treating diabetes complications (18). Lastly, a time series of incidence of diabetes in BRICS countries revealed changing trends in epidemiology, implying that macroeconomic transformations and the health resources infrastructure are key factors determining the course of a given disease (19). The given findings should be combined to support the multifactorial nature of blood sugar in T1D, making a multidimensional, patient-centred, and technology-intensified approach to care a critical element of care.

Objective: To determine and manage the important clinical, behavioural and technological determinants that affect long-term blood sugar management in patients with type 1 diabetes through data from the hospital-based cohort study.

MATERIALS AND METHODS

Study Design: Prospective Observational Study.

Study Setting: The study was conducted at the Khyber Medical College Peshawar and Akhter Saeed Medical College Lahore, Pakistan.

Duration of study: The study was conducted from November, 2024 and April, 2025.

Inclusion criteria: The study included participants who were aged 10years and above and who had a confirmed diagnosis of type 1 diabetes and had had a record of at least one year of the disease. Patients had to be on a stable insulin regimen (multiple daily injections or insulin pump therapy) and must attend follow-ups at the diabetes clinic at the hospital regularly.

Exclusion Criteria: Patients with type 2 diabetes, gestational diabetes, or secondary factors of diabetes were eliminated. Those with severe psychiatric illness, recent hospitalisation secondary to diabetic ketoacidosis, or failure to give informed consent were also excluded.

Methods

The prospective collection of data was conducted on patients who attended the endocrinology outpatient clinic at Khyber Medical College Peshawar and Akhter Saeed Medical College Lahore from November, 2024 and April, 2025. Demographic and clinical data were collected and documented after giving consent, such as age, gender, duration of diabetes, insulin management, comorbidity, and the frequency of glucose tests. HbA1c was used to measure glycemic control, which was checked every three months at baseline. The structured questionnaires enabled the collection of additional data on lifestyle behaviours such as diet adherence, physical activity and smoking status. Validated tools were used to determine psychosocial parameters, including stress, diabetes related distress and support systems. The patients were also divided into those having insulin pump therapy and those having multiple daily injections. Analyses were done through SPSS version 25. Multiple regressions and correlations were done to determine factors that were independently related to glycemic control. The study was approved by the institutional review board at the hospital, and patient confidentiality was fully adhered to during the study.

RESULTS

A total of 210 participants with type 1 diabetes were enrolled in the study, comprising 120 males (57.1%) and 90 females (42.9%), with a mean age of 24.6 ± 8.3 years. The average duration of diabetes was 9.2 ± 4.5 years. Most participants (62.4%) were managed with multiple daily injections (MDI), while the remaining 37.6% were using insulin pump therapy. The baseline mean HbA1c level was 8.9 ± 1.6%, with only 31.9% achieving the recommended target of <7.0%. Patients using insulin pump therapy demonstrated significantly better glycemic control than those on MDI. The mean HbA1c for pump users was 7.8 ± 1.2% compared to 9.5 ± 1.4% for MDI users ($p < 0.001$).

Table 1: Glycemic Control by Insulin Therapy Type

Insulin Therapy	Mean HbA1c (%) ± SD	% Achieving HbA1c < 7.0
Multiple Daily Injections (MDI)	9.5 ± 1.4	21.0%
Insulin Pump Therapy	7.8 ± 1.2	48.7%

Lifestyle behaviors also played a significant role. Patients who reported regular physical activity (at least 150 minutes per week) had a mean HbA1c of 8.1 ± 1.3%, compared to 9.2 ± 1.5% in inactive individuals ($p = 0.002$). Additionally, dietary adherence (measured by self-reported consistency with a recommended diabetic diet) was positively associated with lower HbA1c levels.

Table 2: Impact of Lifestyle Factors on Glycemic Control

Lifestyle Factor	Mean HbA1c (%) ± SD	p-value
Regular Physical Activity	8.1 ± 1.3	0.002
No Regular Activity	9.2 ± 1.5	
Good Dietary Adherence	8.2 ± 1.1	0.015
Poor Dietary Adherence	9.0 ± 1.6	

There was also the investigation of psychosocial variables. The patients with high diabetes distress scales (DDS 3.0) presented much worse glycemic control than patients with low scores of diabetes distress. Additionally, participants who had regular support from families/peers had better management outcomes.

Table 3: Psychosocial Factors and Glycemic Control

Psychosocial Factor	Mean HbA1c (%) ± SD	p-value
High Diabetes Distress	9.4 ± 1.5	0.001
Low Diabetes Distress	8.3 ± 1.2	
Strong Support System	8.2 ± 1.1	0.004
Weak/No Support System	9.1 ± 1.3	

These results imply that insulin-based treatment, lifestyle habits, and psychosocial assistance play a considerable role in the glycemic outcomes of patients with type 1 diabetes. Periodical checking, individual attention and combined with mental health support could provide better long-term disease control of sugar levels.

DISCUSSION

The results of this research are insightful in explaining the multifactorial role of managing blood sugar levels in persons with type 1 diabetes (T1D), where clinical, behavioural and psycho-social determinants play an important role in influencing the glycemic control in the long term. The results concurred with previous literature that found better control of the glycemic level in the patients enrolled under the insulin pump therapy than the patients under multiple daily injections (MDI). This conclusion corresponds to the data of the large-scale cohort studies, including the SFDT1 and other observational cohorts, showing that more advanced methods of delivering insulin may reduce glycemic variability and enhance long-term control (1, 3). The superior outcomes of the insulin pump users in the work also correspond with the findings of the Canadian cohorts of the long-term breakthrough pump therapy that lead to the improved quality of life and HbA1c levels (6).

Moreover, the large variation between the values of HbA1c in active and inactive individuals indicates the strong connection between physical activities and the enhancement of insulin sensitivity and glucose absorption. Similar improvements have been observed in physically active people in the Swedish National Diabetes Registry, both in high-risk patients (history of amputations or neuropathy) and generally (4). The findings add more weight to the fact that physical exercise ought to be a central ingredient in managing T1D. Notably, glycemic control was also linked to diabetic-friendly diet compliance among our population. Nutritional habits received little importance in the regular care and serve as a critical aspect in stabilising the blood sugar levels, as proven by research in the past linking dietary habits to complications such as diabetic foot ulcers and poor wound healing (7, 12).

The other important glycemic control determinant turned out to be psychosocial factors. Patients with high diabetes distress and a poor support system showed much poorer outcomes in glycemic levels. This result is consistent with the already existing evidence that psychological load, such as anxiety, depression, and burnout, may hinder self-care practices and interfere with normal glycemic control (5, 14). Poor metabolic control has also been identified as the cause of cognitive decline in older adults with T1D, as demonstrated by the DCCT and EDIC studies, which further promotes the necessity to incorporate mental health care into the management of diabetes (14, 15). Moreover, the results can be confirmed by the universal research findings that indicate that social isolation and the absence of emotional support are linked to medication compliance and increased complication rates (12, 13).

A further crucial outcome is that there is a relationship between stronger support networks and better glycemic control. The patients with consistent family or peer support reported low HbA1c concentrations. These findings are similar to the RELIEF study in France, which revealed that monitoring of real-time glucose in combination with an education of the patients resulted in a drastic reduction of diabetes-related complications, predominantly due to both enhanced engagement and support of the patients (18). A study performed on children with diabetes in Kazakhstan also reported that insulin pump therapy showed positive effects on improving glycemic control when coupled with parental engagement (9). Consequently, diabetes care programs should focus on family education and community support activities. Individualised therapeutic modalities are also significant in the study. Although islet transplantation has exhibited some good outcomes in high-risk individuals (3, 6), it is

still a resource-consuming process and is not widely available in low- and middle-income countries such as Pakistan.

Consequently, there should be an increased effort to make more readily available treatment modalities like insulin pump, flash glucose monitoring and structured teaching programs to aid in self-management. Policies should be keen on the affordability and availability of these technologies, especially in nations with ongoing healthcare inequality. Additionally, recent evidence indicates the influence of comorbidities and systemic conditions on diabetes. As an example, poor self-management and glycemic outcomes have been related to the existence of neurodevelopmental disorders (5). This presumption is informed by the results, even though they are not specific to the comorbidities, because patients with psychological distress were found to have the poorest metabolic profiles. Likewise, the association of long-term diabetes with neurological vulnerabilities such as dementia and Parkinsonism (11, 15) in meta-analytical research and cohort studies indicates glycemic control should be preserved not only to avoid acute complications but also because of long-term cognitive risks.

Another topic that needs to be addressed is the effect of the recent viral infection, such as COVID-19, on diabetes development and progression. Scottish research has identified a probable association between infection with COVID-19 and new cases of T1D (13). Despite the fact that post-COVID status was not included in the study variables, future researchers need to investigate the impact of pandemic-related stress and physiological change on long-term control of diabetes. Moreover, the results of the extensive research conducted in BRICS indicate that the macro- and microeconomic well-being of a country, state health systems, and population health policies are the key determinants of the prevalence and consequences of diabetes (19). Pakistan, as a member of this group, experiences some challenges like inadequate availability of insulin, prohibitive prices of glucose monitoring and poor health literacy, which all translate into blood sugar control. Therefore, the gap in care delivery may be addressed by implementing scalable community health models and technology-based interventions.

The need to identify complications like stroke using biomarkers like the triglyceride-glucose index is another emerging field. A Chinese cohort has found that variations in this index may be a sign of the forecast of future vascular events (16). This indicator may be included in the clinical practices to improve the preventive care approach among T1D patients. Equally, the threat of the long-term undesirable results of children born to mothers with diabetes or those who received metformin at such a time in their pregnancy is a factor that should lead to additional investigation of the intergenerational consequences of glycemic control (17). Together, the results from the present study and existing literature support that the goal to successfully manage blood glucose levels in T1D is not just a question of insulin dosage but of a holistic, comprehensive, multidisciplinary approach. This will involve regular checkups, individual insulin dosing, individual-level lifestyle changes, psychological intervention and access to modern technology.

CONCLUSION

This research reminds the reader of the multifactorial approach to the management of the blood sugar level of people with type 1 diabetes, without which the insulin administration mechanism, lifestyle habits, and psychosocial assistance are vital factors. Patients who were treated with an insulin pump had efficient glycemic control results in comparison to multiple daily injections. Exercise, following a diet with diabetic foods, and having good family and peer relations were all linked with more positive results. On the other hand, low glycemic control was associated with high distress in diabetes. The results support the assumption of using a holistic and patient-centred method that will not only involve pharmacological treatment but also behavioural, psychological, and educational intervention. The use of existing tools and community support systems and their investments to optimise them can help address associated care gaps in resource-limited contexts such as Pakistan and enhance long-term outcomes. Future studies on scalable interventions and third-party innovations ought to delve into the possibility of personalising diabetes care and minimising complications in the increasing patient population.

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