



Age-Related Differences in Glycemic Control, Management Practices, and Complications Among Adolescents and Young Adults with Type 1 Diabetes Mellitus

Mai A. Ahmed^{1*}, Hajer Saleh Alshammari², Danah Khalid S. Althubiani³, Aldanah Yahya Alkhaled⁴, Mona M. Shahien⁵, Madiha Rabie Mahmoud⁶, Somaia Ibrahim⁷, Manal Zayed Ali Alshammari⁸ and Bishriyyah Sayah Alshammari⁹

^{1,5,7,9}Department of Pediatrics, College of Medicine, University of Ha'il, Ha'il 2440, Saudi Arabia

^{2,4}College of Medicine, University of Ha'il, Ha'il 2440, Saudi Arabia

³Department of Pharmacology, College of Medicine, University of Ha'il, Ha'il 2440, Saudi Arabia

⁶Pediatric Department, Maternity and Children Hospital, Ministry of Health, Hail, Saudi Arabia

Author Designation: ^{2,3,4,9}Medical Student

*Corresponding author: Mai A. Ahmed (e-mail: mai.ahmed@uoh.edu.sa).

©2026 the Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>)

Abstract Background: Adolescence and young adulthood are high-risk phases in type 1 diabetes mellitus (T1DM). Age-related differences in glycemic control, insulin practices, complications, and comorbidities remain insufficiently characterized. This study compared glycemic control, management practices, complications, and comorbidities between adolescents and young adults with T1DM in Hail, Saudi Arabia. **Subjects & Methods:** In this cross-sectional study, we recruited 302 participants with T1DM from endocrinology outpatient clinics in the Hail region: 152 adolescents aged 10–18 years and 150 young adults aged 19–35 years. Data was collected through interviews and medical record review. Clinical, behavioral, and metabolic variables were compared between groups. **Results:** Adolescents had poorer glycemic control, with HbA1c $\geq 9.1\%$ more common than in young adults (28.9% vs 15.3%, $p < 0.001$), despite their higher use of continuous glucose monitoring (89.5% vs 76.0%, $p = 0.001$). Young adults had higher BMI (26.38 ± 4.79 vs. 21.45 ± 5.62 , $p < 0.001$), higher rates of overweight/obesity, greater insulin omission (28% vs. 16.4%, $p = 0.043$), and higher rates of recurrent hypoglycemia (>3 episodes: 52.0% vs. 27.6%, $p < 0.001$). Chronic complications and psychological comorbidities were also more frequent in young adults. **Conclusions:** Distinct age-related risk profiles were identified among individuals with T1DM. Adolescents were particularly vulnerable to poor glycemic control despite greater use of modern monitoring devices, whereas young adults carried a greater burden of insulin omission, obesity, recurrent hypoglycemia, chronic complications, and psychological comorbidities. These findings support age-specific multidisciplinary interventions and structured transition care to improve long-term outcomes.

Key Words Type 1 Diabetes Mellitus, Adolescents, Young Adults, Glycemic Control, Insulin Omission, Saudi Arabia

INTRODUCTION

Type 1 diabetes mellitus (T1DM) is an autoimmune-mediated metabolic disorder characterized by progressive β cell destruction, resulting in absolute insulin deficiency and lifelong dependence on exogenous insulin therapy [1]. Globally, more than 1.2 million children and adolescents are living with T1DM, with approximately 128,900 new cases diagnosed annually. Saudi Arabia is among the countries with a high burden of T1DM, with incidence rates among the highest reported in the Middle East and North Africa region [2,3]. The burden of T1DM continues to rise globally, particularly among adolescents and young adults, with a

sustained increase in incidence over recent decades [4]. The transition from childhood to adolescence and young adulthood represents a remarkably tough and critical phase in management, characterized by complex physiological and psychosocial changes that negatively affect disease control. Pubertal hormonal changes increase insulin resistance, while increasing independence, reduced parental supervision, and competing academic and social demands contribute to poor adherence. As a result, glycemic control typically worsens during adolescence, with HbA1c levels peaking in late adolescence and early adulthood [6,7].

Acute complications of T1DM, including diabetic ketoacidosis [DKA] and hypoglycemia, remain a major contributor to morbidity, particularly in adolescents and young adults [4]. DKA is the most serious acute complication and may occur at diagnosis or during disease progression due to insulin deficiency or nonadherence. In Saudi Arabia, DKA continues to be a frequent clinical presentation, with both initial and recurrent episodes strongly linked to poor adherence to insulin [8]. Chronic complications begin to emerge during adolescence and young adulthood, especially when there is persistent hyperglycemia. These include microvascular complications such as retinopathy, nephropathy, and neuropathy, as well as macrovascular complications later in life. Evidence from longitudinal studies has shown that poor glycemic control during adolescence significantly increases the long-term risk of these complications, underscoring the importance of early metabolic control [9]. In addition to autoimmune comorbidities such as thyroid disease and celiac disease, psychological disorders are common in T1DM. Adolescents and young adults are particularly vulnerable to depression, anxiety, and diabetes-related distress, which negatively affect adherence, glycemic control, and quality of life [7]. Evidence, including Saudi national data, indicates a high prevalence of these conditions, particularly among females, and meta-analytic findings confirm that depressive symptoms are more common in youth with T1DM [10,11].

Insulin misuse, including omission and intentional restriction, is a critical behavioral issue in adolescents and young adults with T1DM. Nonadherence to insulin therapy is common, with reported rates ranging from 23% to 77%, and is strongly associated with poor glycemic control, increased risk of DKA, and higher morbidity [6]. This Behavior may be influenced by psychosocial stress, fear of hypoglycemia, treatment burden, or body image concerns, making it a key target for clinical and research interventions. Adolescents and young adults with T1DM represent a high-risk group, characterized by suboptimal glycemic control and increased acute healthcare utilization, particularly during the transition from pediatric to adult care. This period is especially vulnerable, often marked by prolonged gaps in care that are associated with higher rates of emergency department visits and hospitalizations [12]. Achieving optimal glycemic control in this population remains challenging, as metabolic control typically deteriorates during adolescence due to a combination of physiological insulin resistance and behavioral factors. Evidence indicates that only a minority of adolescents achieve recommended HbA1c targets, with key elements of glycemic outcomes including insulin regimen, body mass index, disease duration, and caregiver education [13,14,15].

Despite the high burden of T1DM in Saudi Arabia, evidence directly comparing adolescents and young adults within the same Saudi clinical setting across glycemic control, insulin management behaviors, acute events, chronic complications, and comorbidities remains limited, particularly in the Hail region. Prior studies have often

examined individual outcomes or broader youth cohorts, making it difficult to determine whether clinically relevant patterns differ across the transition from pediatric to adult care. Therefore, this study compared adolescents and young adults with T1DM in Hail across sociodemographic and anthropometric characteristics, insulin administration and monitoring practices, insulin omission/restriction, HbA1c categories, reported acute events, chronic complications, and comorbidities. The objective was to describe age-group patterns and generate hypotheses for age-tailored clinical services rather than to infer causal effects of age.

METHODS

- **Study Design and Setting:** This cross-sectional observational study was conducted in endocrinology outpatient clinics in the Hail region from September 2025 to March 2026. Participants were recruited consecutively during routine clinic attendance. We assessed all patients with T1DM attending the participating clinics during the study period for eligibility. We assessed 500 patients; 182 were excluded for not meeting eligibility criteria, and 16 eligible patients declined to participate, resulting in a final sample of 302 participants. The study aimed to evaluate adolescents and young adults with type T1DM across clinical, behavioral, and outcome domains
- **Participants:** The study population comprised individuals with a confirmed diagnosis of T1DM who attended outpatient clinics during the study period
- **Inclusion and Exclusion Criteria:** Participants were categorized into two predefined age groups: adolescents (10–18 years) and young adults (19–35 years). These categories were operationally defined to distinguish the adolescent/pediatric population from young adults and to facilitate comparison of clinical and diabetes-management patterns across these developmental stages. They had a minimum disease duration of at least six months to allow adequate assessment of glycemic control and complications. Patients with type 2 diabetes or other specific types of diabetes, and those with severe cognitive impairment, who prevented reliable data collection, were excluded from the study
- **Sample Size Calculation:** The minimum required sample size was initially calculated using Epi Info™ version 7 (StatCalc), based on an expected prevalence of 25%, a 95% confidence level, and a 5% margin of error, yielding a minimum sample of approximately 288 participants. A total of 302 participants were ultimately enrolled (152 adolescents and 150 young adults). Because the primary comparative outcome was poor glycemic control ($\text{HbA1c} \geq 9.1\%$), we also performed a post-hoc sensitivity analysis to assess the statistical power of the achieved sample for the observed between-group difference. Poor glycemic control was observed in 28.9% of adolescents and 15.3% of young adults, and

the achieved sample provided approximately 82% power to detect this difference at a two-sided α level of 0.05

- **Data Collection:** Data was collected using a structured data collection form through patient interviews and medical record review. Sociodemographic and behavioral data were obtained directly from participants during clinic visits, while selected clinical variables were extracted from medical records. Specifically, body mass index (BMI) and glycated hemoglobin (HbA1c) values were obtained from electronic medical records, using the most recent documented measurements
- **Variables and Definitions:** HbA1c $\leq 7.0\%$ was considered the general glycemic target, with higher values categorized as 7.1–8.0%, 8.1–9.0%, and $\geq 9.1\%$, recognizing that individualized targets may vary. Height percentiles were determined using age- and sex-specific Saudi national growth charts. BMI was categorized using age- and sex-specific percentiles for adolescents and standard cutoffs for adults. Insulin omission was defined as skipping prescribed doses and restriction as intentional dose reduction; both were self-reported as yes/no without a specified recall period or frequency threshold. DKA and hypoglycemia during the preceding six months were self-reported and categorized by frequency. Hypoglycemia was not defined by biochemical threshold or severity, and DKA was not independently verified. Chronic complications, including retinopathy, neuropathy, nephropathy, and macrovascular disease, were based on pre-existing diagnoses documented in medical records and were not independently reassessed. Other comorbidities were identified from medical records and/or patient report; psychological conditions were documented or self-reported without validated screening tools. Missing data were not imputed and were reported where applicable
- **Ethical Approval:** It was obtained from the Ethical Committee of the College of Medicine at the University of Hail (approval date: 22/9/2025, approval no.: HAP-08-L-158). Written informed consent was obtained from all participants or their legal guardians where applicable. All data were anonymized and handled confidentially in accordance with ethical standards
- **Statistical Analysis:** Statistical analysis was performed using SPSS version 27. Continuous variables were presented as mean $\pm$ standard deviation and categorical variables as frequencies and percentages. Between-group comparisons were performed using the independent t-test or Mann–Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables, as appropriate. Poor glycemic control (HbA1c $\geq 9.1\%$) was considered the primary outcome, while secondary comparisons were exploratory and interpreted cautiously due to multiple testing. A p-value < 0.05 was considered statistically significant.

RESULT

Sociodemographic and Clinical Characteristics of Participants

A total of 302 participants were included, comprising 152 adolescents (50.3%) and 150 young adults (49.7%). There was no significant difference in sex distribution between groups. In contrast, the duration of T1DM showed a highly significant difference ($p < 0.001$), with most adolescents having a disease duration < 5 years (60.5%), whereas more than half of young adults had a duration > 10 years (52%). Anthropometric measurements differed significantly: young adults had higher mean body weight (68.56 ± 13.66 kg vs. 48.51 ± 18.19 kg) and height (162.44 ± 8.02 cm vs. 151.00 ± 16.37 cm; both $p < 0.001$). Additionally, BMI was significantly higher among young adults (26.38 ± 4.79 vs. 21.45 ± 5.62 , $p < 0.001$), with a greater prevalence of overweight (33.3 vs. 11.8%) and obesity (16% vs. 5.3%), while underweight was more common among adolescents (24.3 vs. 0.7%) ($p < 0.001$). Height percentile distribution also differed significantly ($p < 0.001$), with a higher proportion of young adults in the normal range (70.7 vs. 48%). Regarding DKA episodes within the last 6 months, no statistically significant difference was observed. In contrast, hypoglycemic episodes differed significantly ($p < 0.001$), with a higher proportion of young adults experiencing frequent events; more than three episodes were reported in 52% of young adults compared to 27.6% of adolescents, while absence of hypoglycemia was more common among adolescents (44.7 vs. 18%). Regarding comorbidities, young adults demonstrated a significantly higher burden. Obesity or overweight status was more prevalent in young adults (15.3 vs. 3.3%, $p < 0.001$), along with higher rates of anxiety (8.7 vs. 2%, $p = 0.009$), sleep disorders (8% vs. 2.6%, $p = 0.03$), hypertension (6 vs. 0%, $p = 0.002$), and depression (4 vs. 0.7%, $p = 0.05$).

Insulin Therapy, Monitoring, and Glycemic Control

Significant differences were observed between adolescents and young adults regarding several diabetes management practices and glycemic outcomes. Although the mode of insulin administration did not differ significantly between groups ($p = 0.171$), insulin injections were the predominant therapy in both adolescents and young adults. Young adults, however, required a significantly higher mean daily insulin dose than adolescents (16.81 ± 12.22 vs 20.89 ± 16.26 , $p = 0.02$), likely reflecting greater body mass, longer disease duration, and increased insulin requirements. Glucose monitoring practices differed significantly between groups. Adolescents were more likely to use continuous glucose monitoring (CGM) devices than young adults (89.5% vs 76.0%), whereas young adults relied more frequently on conventional glucometer monitoring (23.3% vs 8.6%) ($p = 0.001$). Adolescents also reported more frequent daily glucose checks, with a higher proportion monitoring ≥ 5 times/day compared with young adults (58.6 vs 49.3%), while young adults more commonly monitored only twice daily (20.0 vs 5.9%) ($p = 0.015$). Insulin omission was

significantly more prevalent among young adults than adolescents (28% vs 16.4%, $p = 0.043$), while insulin restriction did not differ significantly. Importantly, glycemic control was significantly poorer among adolescents ($p < 0.001$). Adolescents had a higher proportion of markedly elevated HbA1c levels ($\geq 9.1\%$) than young adults (28.9 vs 15.3%), whereas young adults more frequently achieved HbA1c values in lower categories (< 7 and 7.1-8%). These data suggest that, despite more intensive monitoring and greater CGM use, adolescents remained the group with poorer metabolic control, likely indicating the combined effects of pubertal insulin resistance, behavioral challenges, and developmental factors affecting adherence.

DISCUSSION

The present study provides a clinically relevant comparison of adolescents and young adults with T1DM in the Hail region of Saudi Arabia, showing two distinct vulnerability profiles. Adolescents exhibited significantly poorer glycemic control and more intensive glucose monitoring behaviors. On the other hand, young adults had higher rates of insulin omission, greater adiposity, more complications, and a higher burden of psychological and cardiometabolic comorbidities. These findings suggest that the challenges of T1DM differ substantially across developmental phases and require age-specific management strategies.

One of the principal findings of this study was the significantly higher HbA1c levels observed in adolescents compared with young adults. This is consistent with international evidence indicating that adolescence is the period of poorest glycemic control in T1DM. Data from the SEARCH for Diabetes in Youth Study showed that adolescents aged 15-19 years had among the highest adjusted HbA1c levels, reaching approximately 9.3% in recent cohorts in spite of advances in treatment technology [13]. In addition, McLarty *et al.* reported that adolescents were more likely to have poor glycemic control than children and young adults, with a mean HbA1c of 12.8%, exceeding the overall cohort mean [14]. Several mechanisms may explain the poorer metabolic control observed in adolescents. Puberty is associated with transient physiological insulin resistance mediated by growth hormone, sex steroids, and changes in body composition, resulting in increased insulin requirements and greater glycemic variability. In parallel, adolescence is characterized by increasing autonomy, irregular eating patterns, inconsistent routines, peer influence, emotional instability, and transfer of diabetes responsibilities from caregivers to the patient. These combined biological and behavioral pressures frequently impair adherence and reduce the effectiveness of recommended regimens. However, these mechanisms were not directly assessed in the present study and should not be interpreted as explanations established by our findings. Recent reviews indicate that adolescence remains the most challenging phase for achieving glycemic targets in T1DM despite therapeutic advances [5,16].

Recurrent hypoglycemia was more frequent among young adults; this may reflect longer diabetes duration, cumulative impairment of counterregulatory responses, impaired hypoglycemia awareness, and reduced external supervision after transition to independent self-management [17]; however, these mechanisms were not directly evaluated in our study. Another possible explanation is the lower use of CGM in young adults compared with adolescents, which may have enabled earlier detection of falling glucose levels and more timely corrective actions, consequently reducing recurrent hypoglycemic episodes. This agrees with several published studies reporting better metabolic outcomes with CGM [13]. Although greater CGM use and lower recurrent hypoglycemia occurred concurrently among adolescents, the cross-sectional design does not establish a causal relationship between these findings. Differences in CGM adherence, patterns of use, and underlying diabetes severity were not assessed. In a randomized clinical trial, adolescents and young adults using CGM achieved a modest but significant reduction in HbA1c compared with standard blood glucose monitoring (8.5 vs 8.9% at 26 weeks; adjusted difference: -0.37%; $p = 0.01$) [18]. Agarwal and Cappola also emphasized that CGM use remains limited in adolescents and young adults, who are considered the highest-risk population. This observation reinforces the persistent gap between technological advances and their effective clinical implementation [19].

Differences in absolute body weight and BMI should be interpreted in the context of expected developmental differences between adolescents and young adults, with weight status assessed using age-appropriate standards. Although adolescents had worse HbA1c overall, young adults had a higher prevalence of insulin omission, accompanied by significantly higher BMI and a greater prevalence of overweight and obesity in this age group. Individuals with higher body weight often require larger insulin doses, more frequent corrections, and intensified treatment regimens, which may increase treatment burden and reduce adherence over time. Additionally, excess adiposity may coexist with insulin deficiency and promote a "double diabetes" phenotype associated with insulin resistance and poorer self-management. A recent meta-analysis reported pooled prevalences of 25.8% for overweight and 9.85% for obesity among youth with T1DM, stressing the growing relevance of weight-related challenges in this population [20]. In addition, concerns regarding insulin-associated weight gain may lead some patients to omit or restrict doses as a maladaptive weight-control strategy. These behaviors are common in T1DM and can lead to poor glycemic control, as supported by evidence from recent meta-analyses and other studies [21,22]. Studies involving adolescents and young adults with T1DM have also identified forgetfulness, embarrassment in public settings, inconvenience, emotional stress, denial, and body image concerns as common reasons for missed insulin doses [6,23]. However, the present study did not directly assess these potential mechanisms; therefore, the observed higher

frequency of insulin omission among young adults should be interpreted as an association rather than evidence of these underlying mechanisms. Over time, these behaviors may become fixed and contribute to cumulative metabolic harm in adulthood.

Adults in the current study revealed a higher burden of both chronic diabetes-related complications and psychological comorbidities. Retinopathy, neuropathy, and macrovascular disease were more common among adults, possibly related to longer disease duration and cumulative exposure to hyperglycemia. Importantly, age and diabetes duration were highly correlated in this sample; therefore, the higher burden of complications among young adults cannot be attributed independently to age in the absence of adjusted analysis. In parallel, anxiety, depression, and sleep disorders were also more prevalent, suggesting that the long-term burden of T1DM extends beyond metabolic complications to include psychosocial distress. A review and recent national Saudi survey reported high rates of depression and anxiety symptoms among individuals with T1DM, and effective strategies to reduce psychological distress include structured diabetes self-management education, motivational interviewing, peer-support programs, multidisciplinary care, ongoing family support, and well-planned transition from pediatric to adult care [7,10].

The strengths of this study include the direct comparison of adolescents and adults within the same regional healthcare setting, the assessment of anthropometric, behavioral, glycemic, and complication-related variables, and the generation of clinically relevant age-specific findings from a Saudi population where data remain limited. These strengths enhance the regional applicability of the results and support future service planning. Several limitations should be considered. The cross-sectional design precludes causal inference. Several limitations should be considered. The cross-sectional design precludes causal inference. Some variables, including insulin omission and monitoring frequency, were self-reported and may be subject to recall or social desirability bias. The single-region setting may limit generalizability. Validated measures for psychological distress and eating behaviors were not used. Moreover, multivariable adjustment was not performed; therefore, the observed age-group differences represent unadjusted associations, and confounding by diabetes duration and other clinical or socioeconomic factors cannot be excluded. Finally, the broad age categories may encompass developmental heterogeneity, particularly among adolescents, which should be considered when interpreting age-group differences.

In conclusion, this study determines two contrasting but clinically important phenotypes in T1DM. Adolescents appear particularly at risk of poor glycemic control despite greater use of monitoring devices, while young adults demonstrate the greater burden of insulin omission, obesity, psychological comorbidity, and complications. The results support the implementation of age-specific multidisciplinary interventions rather than a uniform care model for all individuals with T1DM

Funding

No external funding was received.

Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

- [1] American Diabetes Association Professional Practice Committee. "Diagnosis and classification of diabetes: Standards of Care in Diabetes—2025." *Diabetes Care*, vol. 48, suppl. 1, 2025, pp. S27-S49. <https://doi.org/10.2337/dc25-S002>
- [2] Magliano D.J. and Boyko E.J., editors. *IDF Diabetes Atlas*. 10th ed. Brussels: International Diabetes Federation, 2021. <https://www.ncbi.nlm.nih.gov/books/NBK581934/>
- [3] Ogle G.D. *et al.* "Global estimates of incidence of type 1 diabetes in children and adolescents: results from the International Diabetes Federation Atlas, 10th edition." *Diabetes Research and Clinical Practice*, vol. 183, 2022, pp. 109083. <https://doi.org/10.1016/j.diabres.2021.109083>
- [4] Gong B. *et al.* "Global, regional, and national burden of type 1 diabetes in adolescents and young adults." *Pediatric Research*, vol. 97, no. 2, 2025, pp. 568-576. <https://doi.org/10.1038/s41390-024-03107-5>
- [5] Lan Y.Y. *et al.* "Age-based challenges to type 1 diabetes management in the pediatric population." *Frontiers in Pediatrics*, vol. 12, 2024, pp. 1434276. <https://doi.org/10.3389/fped.2024.1434276>
- [6] Dabas H. *et al.* "Insulin adherence in adolescents with type 1 diabetes mellitus." *Indian Journal of Endocrinology and Metabolism*, vol. 27, no. 5, 2023, pp. 394-397. https://doi.org/10.4103/ijem.ijem_294_22
- [7] Khadilkar A. and Oza C. "Glycaemic control in youth and young adults: challenges and solutions." *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, vol. 15, 2022, pp. 121-129. <https://doi.org/10.2147/DMSO.S304347>
- [8] Alshareef M. *et al.* "Recurrent diabetic ketoacidosis in Saudi patients with type 1 diabetes mellitus: a retrospective study from a tertiary hospital." *Annals of Saudi Medicine*, vol. 45, no. 5, 2025, pp. 353-360. <https://doi.org/10.5144/0256-4947.2025.28.08.1200>
- [9] Elhabashy S.A. *et al.* "Uncontrolled type 1 diabetes among Egyptian adolescents; risk determinants and clinical outcomes." *Diabetes Epidemiology and Management*, vol. 6, 2022, pp. 100051. <https://doi.org/10.1016/j.deman.2022.100051>
- [10] Alguwaihes A.M. "Gender differences in type 1 diabetes management and mental health burden: findings from a national survey in Saudi Arabia." *Journal of Clinical Medicine*, vol. 14, no. 16, 2025, pp. 5777. <https://doi.org/10.3390/jcm14165777>
- [11] Buchberger B. *et al.* "Symptoms of depression and anxiety in youth with type 1 diabetes: a systematic review and meta-analysis." *Psychoneuroendocrinology*, vol. 70, 2016, pp. 70-84. <https://doi.org/10.1016/j.psyneuen.2016.04.019>
- [12] Soliman D. *et al.* "Transition from pediatric to adult care in type 1 diabetes mellitus: a longitudinal analysis of age at transfer and gap in care." *BMJ Open Diabetes Research & Care*, vol. 10, no. 6, 2022, pp. e002937. <https://doi.org/10.1136/bmjdr-2022-002937>
- [13] Malik F.S. *et al.* "Trends in glycemic control among youth and young adults with diabetes: the SEARCH for Diabetes in Youth Study." *Diabetes Care*, vol. 45, no. 2, 2022, pp. 285-294. <https://doi.org/10.2337/dc21-0507>

- [14] McLarty R.P. *et al.* "Glycemic control, associated factors, acute complications of Type 1 Diabetes Mellitus in children, adolescents and young adults in Tanzania." *Endocrinology, Diabetes & Metabolism*, vol. 4, no. 2, 2021, p. e00200. <https://doi.org/10.1002/edm2.200>
- [15] Petitti D.B. *et al.* "Glycemic control in youth with diabetes: the SEARCH for Diabetes in Youth Study." *The Journal of Pediatrics*, vol. 155, no. 5, 2009, pp. 668-672.e1-3. <https://doi.org/10.1016/j.jpeds.2009.05.025>
- [16] Azar S. *et al.* "Barriers to type 1 diabetes adherence in adolescents." *Journal of Clinical Medicine*, vol. 13, no. 19, 2024, p. 5669. <https://doi.org/10.3390/jcm13195669>
- [17] Hölzen L. *et al.* "Hypoglycemia unawareness: a review on pathophysiology and clinical implications." *Biomedicines*, vol. 12, no. 2, 2024, p. 391. <https://doi.org/10.3390/biomedicines12020391>
- [18] Laffel L.M. *et al.* "Effect of continuous glucose monitoring on glycemic control in adolescents and young adults with type 1 diabetes: a randomized clinical trial." *JAMA*, vol. 323, no. 23, 2020, pp. 2388-2396. <https://doi.org/10.1001/jama.2020.6940>
- [19] Agarwal S. and Cappola A.R. "Continuous glucose monitoring in adolescent, young adult, and older patients with type 1 diabetes." *JAMA*, vol. 323, no. 23, 2020, pp. 2384-2385. <https://doi.org/10.1001/jama.2020.7058>
- [20] Chauhan R. *et al.* "Global prevalence and clinical correlates of obesity in children and adolescents with type 1 diabetes: a systematic review and meta-analysis." *Discover Public Health*, vol. 23, 2026, p. 396. <https://doi.org/10.1186/s12982-026-01660-4>
- [21] Dean Y.E. *et al.* "Association between type 1 diabetes mellitus and eating disorders: a systematic review and meta-analysis." *Endocrinology, Diabetes & Metabolism*, vol. 7, no. 3, 2024, p. e00473. <https://doi.org/10.1002/edm2.473>
- [22] Vidyasagar S. *et al.* "Perceived comfort with weight, body shape and eating pattern of young adults with type 1 diabetes and associations with clinical and psychological parameters in a clinical setting." *Journal of Eating Disorders*, vol. 12, no. 1, 2024, pp. 106. <https://doi.org/10.1186/s40337-024-01059-z>
- [23] Alsaidan A.A. *et al.* "Assessment of adherence to insulin injections among diabetic patients on basal-bolus regimen in primary and secondary healthcare centers in Al-Jouf Region of Saudi Arabia: a descriptive analysis." *Journal of Clinical Medicine*, vol. 12, no. 10, 2023, pp. 3474. <https://doi.org/10.3390/jcm12103474>