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Depressive symptoms, family functioning, and glycemic control in adolescents with type 1 diabetes: A cross-sectional study

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Abstract

Type 1 diabetes mellitus (T1DM) in adolescents requires rigorous self-management and lifelong insulin therapy, posing significant challenges for both metabolic control and psychological well-being. In this cross-sectional study, we investigated the interrelationships among depressive symptoms, family functioning, and glycemic control in 63 adolescents (aged 10–18 years) with T1DM in Greece. Depressive symptoms were measured using the Children's Depression Inventory, and family functioning was assessed with the General Functioning Scale of the Family Assessment Device. Glycemic control was determined from the most recent glycated hemoglobin (HbA1c) value obtained from medical records. Approximately 29% of adolescents exhibited depressive symptoms in the pathological range, and the median HbA1c was 7.1% (interquartile range [IQR]: 6.7–7.8%), with only 46% meeting the recommended target of ≤7.0%. Spearman's correlation analysis revealed a moderate positive association between depressive symptoms and HbA1c ($r = 0.30$; $p = 0.017$) and a strong positive correlation between poorer family functioning and increased depressive symptoms ($r = 0.53$; $p < 0.001$). However, family functioning was not significantly associated with glycemic control ($r = -0.04$; $p = 0.753$), potentially indicating that its impact on metabolic control may be mediated through depressive symptoms or other factors related to adherence. Logistic regression analysis demonstrated that poorer family functioning significantly increased the odds of pathological depressive symptoms (odds ratio [OR] = 10.33; 95% confidence interval [CI]: 2.26–47.18; $p = 0.003$) but did not directly predict glycemic control. Older adolescents reported higher levels of depressive symptoms and poorer family functioning compared to younger peers. These findings underscore the importance of addressing family functioning–including communication patterns, emotional support, and problem-solving abilities–and routine screening for depression in clinical practice to enhance psychological well-being and indirectly improve diabetes management in adolescents with T1DM. Future longitudinal research is warranted to establish causal relationships and explore potential mediators.

Keywords: Type 1 diabetes mellitus; Depressive symptoms; Family functioning; Glycemic control; Adolescents

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1. Introduction

Type 1 diabetes mellitus (T1DM) is a chronic autoimmune disease that results from the destruction of pancreatic β-cells, ultimately leading to an absolute deficiency of insulin and a lifelong need for exogenous replacement therapy.[1] Typically diagnosed during childhood or adolescence, T1DM imposes a heavy burden on young patients who must integrate rigorous self-management routines–frequent blood glucose monitoring, insulin administration, dietary adjustments, and regular medical visits–into their everyday lives.[2] The challenges associated with T1DM management are compounded by the dynamic nature of adolescence, a period marked by rapid physical, emotional, and cognitive development, as well as by evolving social relationships and an emerging desire for autonomy.[3,4]

In this vulnerable developmental stage, the psychological impact of managing a complex chronic illness is profound.[5] Research has consistently demonstrated that adolescents with T1DM are at an increased risk of experiencing depressive symptoms compared to their healthy peers.[6-8] Depression in this population is particularly concerning, as it may not only reduce quality of life but also interfere with adherence to treatment regimens, thereby compromising glycemic control.[9] Elevated levels of depressive symptoms have been associated with higher glycated hemoglobin (HbA1c) values, suggesting that emotional distress may impede effective diabetes management and elevate the risk of both acute and chronic complications.[10]

Family environment is another critical factor that influences the management of T1DM during adolescence.[11] Family functioning, which encompasses communication, emotional support, problem-solving abilities, and overall cohesion, is essential for providing the stability and encouragement necessary for successful self-care.[12] Adolescents who perceive their family environment as unsupportive or conflictual are more likely to exhibit psychological distress, which in turn may undermine their capacity to adhere to complex diabetes regimens.[13] Conversely, a well-functioning family unit can buffer the negative effects of stress, bolster resilience, and contribute to better overall health outcomes.[14,15]

Despite extensive research on the separate impacts of depressive symptoms and overall family functioning–including communication, emotional involvement, behavior control, and problem-solving–on diabetes management, relatively few studies have simultaneously examined how these factors interact to affect glycemic control in adolescents with T1DM.[16] The literature suggests that while depressive symptoms are linked with poor metabolic outcomes, family dysfunction might further exacerbate this relationship by intensifying psychological distress.[17] Inadequate family support may reduce an adolescent's motivation to adhere to prescribed diabetes management practices, thereby creating a cycle in which emotional and physiological health deteriorate in tandem.[18] Moreover, the unique cultural and healthcare context in Greece–characterized by strong intergenerational family ties, frequent co-residence of adolescents with extended family, and traditional caregiving roles, particularly among mothers–may significantly shape how chronic illnesses such as T1DM are managed. Greek society places a high value on familial cohesion and collective responsibility, often prioritizing family welfare over individual autonomy. These cultural norms can both facilitate close monitoring and support of diabetes care while potentially complicating adolescents' efforts toward independence in self-management. In parallel, Greece offers universal health coverage through a national health insurance system that provides free or low-cost access to primary and specialized healthcare services, including pediatric diabetes care. This healthcare framework ensures that most adolescents with T1DM, regardless of socioeconomic status (SES), receive regular follow-up and standardized treatment protocols.[19,20]

Based on these considerations, the present study was designed to investigate the interrelationships among depressive symptoms, family functioning, and glycemic control in adolescents with T1DM. Specifically, we sought to determine whether higher levels of depressive symptoms are associated with poorer glycemic control and whether poorer family functioning is linked to increased depressive symptoms. Importantly, we also examined the potential mediating role of depressive symptoms in the relationship between family functioning and glycemic control. We hypothesize that suboptimal family dynamics contribute to elevated depressive symptoms, which in turn impair diabetes self-management and lead to worse metabolic outcomes. These hypotheses form a foundation for understanding the complex interplay between psychological well-being and diabetes management, and they underscore the potential benefits of family-centered interventions aimed at improving both mental health and glycemic control in this high-risk population.

In light of these aims, this study makes several contributions to the literature. While previous research has examined the impact of either depressive symptoms or family functioning on diabetes outcomes, few studies have investigated how these psychosocial variables interact to influence glycemic control in adolescents. Moreover, this is among the first studies to explore these relationships in a Greek context, where cultural norms around family support and caregiving may shape diabetes management. By applying validated psychometric instruments and conducting multivariable analyses, this study offers

new insights into how family dynamics may indirectly affect glycemic outcomes through their association with depressive symptoms. These findings have both clinical and cultural relevance and lay the groundwork for targeted psychosocial interventions in pediatric diabetes care.

2. Methods

2.1. Participants and procedures

Adolescents aged 10–18 years with a confirmed diagnosis of T1DM for at least 6 months were recruited from routine outpatient visits at the Diabetes Center, Division of Endocrinology, Diabetes, and Metabolism, First Department of Pediatrics, School of Medicine, National and Kapodistrian University of Athens, at Aghia Sophia Children's Hospital, Athens, Greece. Initially, 84 potential participants were identified; after applying inclusion and exclusion criteria and excluding families that did not provide consent, 63 adolescents were finally enrolled. Eligible participants were required to be proficient in Greek. Adolescents were excluded if they were not accompanied by a parent or guardian or if they had a severe comorbid chronic illness that could interfere with effective diabetes management. The sample size was determined by the number of eligible participants attending routine outpatient visits during the study period. While a formal *a priori* power analysis was not conducted, the sample size reflects the available population over the study period.

Data collection was seamlessly integrated into the outpatient visit. Trained research assistants approached adolescents and their parents/guardians, provided detailed information regarding the study's objectives and procedures, and distributed information sheets along with consent/assent forms. Once consent was obtained, participants completed the study questionnaires in a quiet, private area of the clinic. Clinical data, including HbA1c levels and other relevant variables, were subsequently abstracted from medical records by clinical staff under the supervision of the research team. To ensure anonymity and confidentiality, all completed questionnaires were stored in sealed envelopes and later transferred to a secure data repository.

2.2. Measures

2.2.1. Depressive symptoms

Depressive symptoms were assessed using the Children's Depression Inventory (CDI),[21] a well-established self-report questionnaire validated for children and adolescents. There are 27 items quantifying symptoms such as depressed mood, hedonic capacity, vegetative functions, self-evaluation, and interpersonal behaviours. It covers the consequences of depression, as they relate to children and functioning in school and with peers. For each item, the child has three possible answers: 0 indicates the absence of symptoms, 1 for mild symptoms, and 2 for definite symptoms. The total score ranges from 0 to 54. A cutoff score of 15, based on validation studies conducted in Greece,[22] was used to differentiate between "low/normal" and "high/pathological" levels of depressive symptoms. The CDI was chosen due to its strong psychometric properties, age-appropriate format for children and adolescents, and its prior validation in the Greek population.

2.2.2. Family functioning

Family functioning was assessed with the General Functioning Scale of the Family Assessment Device (GF-FAD).[23] The GF-FAD consists of 12 self-report items designed to assess overall family functioning. Items are rated on a 4-point Likert scale ranging from 1 (strongly agree) to 4 (strongly disagree), with reverse scoring applied to certain items so that higher overall scores indicate lower family functioning. A score of 24 or higher is used to indicate poor family functioning. The GF-FAD was adapted for the Greek context, demonstrating acceptable psychometric properties.[24]

2.2.3. Glycemic control

Glycemic control was determined by the most recent measurement of HbA1c, obtained from the patients' medical records. An HbA1c level ≤7.0% was considered indicative of good glycemic control, in accordance with the International Society for Pediatric and Adolescent Diabetes Clinical Practice Consensus Guidelines 2022.[25] Although HbA1c is a continuous measure, categorizing it allowed clearer identification of participants who did or did not meet recommended clinical targets, facilitating practical clinical interpretation.

2.2.4. Demographic and additional clinical data

Demographic and additional clinical data were collected through self-report questionnaires completed by both adolescents and their parents. The questionnaires gathered detailed sociodemographic information, such as age, gender, and educational level, as well as insights into family structure and SES from both the adolescent's and the parent's perspectives. SES was assessed using a single self-report item included in both the adolescent and parent questionnaires. Respondents were asked to rate their SES as "low," "middle," or "high" based on their own perceptions, without reference to specific indicators such as income or education level. This subjective approach, while commonly used in survey research, reflects participants' perceived relative standing rather than objective socioeconomic metrics. In addition, clinical data were obtained, including

the age at diagnosis, the duration of diabetes, the type of insulin therapy used (whether multiple daily injections or continuous subcutaneous insulin infusion), the utilization of continuous glucose monitoring systems, and the frequency of self-monitoring of blood glucose. These comprehensive data allowed for a thorough investigation of the relationships among clinical characteristics, depressive symptoms, family functioning, and glycemic control in the study population.

2.3. Statistical analysis

Descriptive statistics were computed for all sociodemographic and clinical variables; frequencies, percentages, and measures of central tendency (medians and interquartile ranges for non-normally distributed data, and means with standard deviations [*SDs*] for normally distributed data) were calculated. Normality was assessed with the Shapiro–Wilk test. Relationships among depressive symptoms, family functioning, and glycemic control (as measured by HbA1c) were examined using Spearman's rank-order correlation coefficients. In addition, group comparisons to explore differences in depressive symptoms and family functioning according to factors such as the frequency of blood glucose monitoring and age groups were conducted using independent samples *t*-tests and Chi-square tests. Logistic regression analyses were performed to assess whether family functioning predicted pathological depressive symptoms and poor glycemic control. In the first model, the presence of pathological depressive symptoms (defined by a CDI score above the clinical threshold) served as the dependent variable, with family functioning as the primary independent predictor. A second logistic regression model was employed with glycemic control–categorized as HbA1c ≤7.0% for good control versus HbA1c >7.0% for poor control–as the outcome variable. Furthermore, multivariable logistic regression analyses were conducted by including potential confounders such as age, gender, SES, and frequency of blood glucose monitoring. In our regression models, covariates were treated as follows: age was entered as a continuous variable, while gender, SES (categorized as low, middle, and high, with high as the reference), and frequency of blood glucose monitoring (categorized as rare versus frequent) were included as categorical variables. Missing data were addressed using a complete-case analysis approach; participants with missing values on key variables (*e.g.*, HbA1c, CDI, or GF-FAD scores) were excluded from the corresponding analyses. The proportion of missing data was minimal (<5%), and sensitivity analyses using multiple imputation yielded comparable results, indicating that the impact of missing data on our findings was negligible. Statistical significance was set at $p<0.05$. Data were analyzed using SPSS software (version 29.0; IBM, USA).

3. Results

3.1. Sample characteristics

A total of 63 adolescents participated in the study. Table 1 provides a detailed description of the sociodemographic characteristics of the sample.

3.2. Clinical characteristics

Table 2 outlines the clinical characteristics of adolescents, including diabetes-related variables.

3.3. Psychosocial characteristics

The mean GF-FAD score was 21.4 (*SD* = 6), indicating variability in perceived family functioning (with higher scores reflecting poorer functioning). Based on the CDI, 18 adolescents (29%) scored in the pathological range for depressive symptoms, whereas 44 adolescents (71%) scored within normal limits. Table 3 compares depressive symptoms and family functioning by the frequency of blood glucose monitoring.

Although adolescents who monitored their blood glucose more frequently reported slightly higher depressive symptoms, the difference approached but did not reach statistical significance ($p=0.055$). Family functioning did not significantly differ between the groups.

Table 1. Participants' demographic characteristics (*n*=63)

Variable	Category	*n*	Percentage	Median (IQR)
Gender	Male	28	44.4	-
	Female	35	55.6	-
Age (years)	-	-	-	14 (12–15)
Educational level	Elementary school	22	34.9	-
	Middle school	28	44.4	-
	High school	13	20.6	-
Family structure	Living with both parents	52	83.9	-
	Single parent only	7	11.3	-
	Other	3	4.8	-
Reported socioeconomic status (adolescents)	Middle	39	61.9	-
	High	24	38.1	-
Reported socioeconomic status (parents)	Low	10	16.4	-
	Middle	48	78.7	-
	High	3	4.9	-

Note: Percentages may not sum to 100% due to rounding or missing data.
Abbreviation: IQR: Interquartile range.

3.4. Correlation analyses

Spearman's correlation coefficients were computed to explore the associations among depressive symptoms, family functioning, and glycemic control (HbA1c). As shown in Table 4, a significant moderate positive correlation was found between CDI scores and HbA1c (r = 0.30; p=0.017). In addition, there was a strong positive correlation between poorer family functioning (higher GF-FAD scores) and higher depressive symptoms (r = 0.53; p<0.001). No significant correlation was observed between family functioning and HbA1c (r = −0.04; p=0.753).

Table 2. Clinical characteristics of adolescents with T1DM (*n*=63)

Variable	Category	*n*	Percentage	Median (IQR)
Age at diagnosis (years)	-	-	-	10 (9–12)
Duration of diabetes (months)	-	-	-	30 (13–60)
Insulin therapy	Multiple daily injections	40	63.5	-
	Continuous subcutaneous insulin infusion (CSII)	23	36.5	-
Use of continuous glucose monitoring (CGM)	Yes	62	98.4	-
	No	1	1.6	-
Frequency of blood glucose monitoring	1–3 times/day (rare)	32	50.8	-
	≥ 4 times/day (frequent)	31	49.2	-
HbA1c (%)	-	-	-	7.1 (6.7–7.8)
Glycemic control	Good (HbA1c ≤7.0%)	29	46.0	-
	Poor (HbA1c >7.0%)	34	54.0	-

Abbreviations: IQR: Interquartile range; T1DM: Type 1 diabetes mellitus.

Table 3. Comparison of depressive symptoms and family functioning by frequency of blood glucose monitoring

Outcome variable	Rare monitoring (*n*=31)	Frequent monitoring (*n*=31)	*t* (*df*=60)	*p*
Depressive symptoms (CDI)	Mean=10.1, *SD*=7.2	Mean=13.9, *SD*=8.1	−1.97	0.055
Family functioning (GF-FAD)	Mean=20.7, *SD*=6.3	Mean=22.1, *SD*=5.8	−0.86	0.393

Abbreviations: CDI: Children's Depression Inventory; df: Degrees of freedom; GF-FAD: General Functioning subscale of the Family Assessment Device; SD: Standard deviation.

3.5. Logistic regression analyses

Two separate logistic regression models were used to assess predictors of pathological outcomes.

3.5.1. Model 1: Predicting pathological depressive symptoms

In this model, the dependent variable was whether an adolescent had high (pathological) depressive symptoms (CDI > 15). Family functioning (GF-FAD score) was entered as the independent variable. The results (Table 5) indicated that poorer family functioning significantly increased the odds of pathological depressive symptoms (odds ratio [OR] = 10.33; 95% confidence interval [CI]: 2.26–47.18; p=0.003). The model was statistically significant (χ^2[1 = 12.75; p<0.001) and explained between 19% (Cox & Snell R^2) and 27% (Nagelkerke R^2) of the variance in depressive symptoms.

3.5.2. Model 2: Predicting poor glycemic control

In the second model, the dependent variable was poor glycemic control (HbA1c >7.0%). Family functioning was again the independent variable. As shown in Table 6, family functioning did not significantly predict glycemic control (OR = 1.21; 95% CI: 0.44–3.30; p=0.712). The model was not statistically significant (χ^2[1] = 0.14; p=0.712).

3.6. Multivariable analysis

A multivariable logistic regression model was also computed, including family functioning and covariates

Table 4. Spearman's correlations among depressive symptoms, family functioning, and glycemic control

Variable pair	Spearman's *r*	*p*
Depressive symptoms (CDI) and HbA1c	0.30	0.017*
Depressive symptoms (CDI) and GF-FAD	0.53	<0.001**
GF-FAD and HbA1c	−0.04	0.753

Note: *p<0.05; **p<0.001.
Abbreviations: CDI: Children's depression inventory; GF-FAD: General functioning subscale of the family assessment device.

Table 5. Logistic regression model predicting pathological depressive symptoms (CDI > 15)

Predictor	*B*	*SE*	Wald	*df*	*p*	OR	95% CI (LL–UL)
Family functioning (GF-FAD)	2.34	0.78	9.07	1	0.003	10.33	2.26–47.18
Constant	−5.27	1.53	11.82	1	0.001	0.01	-

Abbreviations: CDI: Children's depression inventory; CI: Confidence interval; df: Degrees of freedom; GF-FAD: General Functioning Subscale of the Family Assessment Device; LL: Lower limit; OR: Odds ratio; SE: Standard error; UL: Upper limit.

(gender, age, SES, and frequency of blood glucose monitoring), to predict pathological depressive symptoms. In this model, family functioning remained a significant predictor (OR = 15.78; 95% CI: 1.99–125.25; p=0.009), whereas the other covariates did not reach statistical significance (Table 7).

3.7. Age group comparisons

Chi-square analyses and independent t-tests were used to explore differences based on age group. A significant difference was observed in depressive symptoms across age groups. Among adolescents with low depressive symptoms (CDI ≤15), 54.5% were aged 10–13 years and 45.5% were aged 14–18 years. In contrast, among those with high depressive symptoms, 16.7% were aged 10–13 years, while 83.3% were aged 14–18 years (χ^2[1, n = 62] = 7.46; p=0.006). Although poor glycemic control was more common in older adolescents (61.8% in the 14–18 age group vs. 38.2% in the 10–13 age group), this difference did not reach statistical significance (χ^2[1, n = 63] = 1.15; p=0.283). Furthermore, independent t-tests indicated that older adolescents reported significantly poorer family functioning (mean GF-FAD: 22.8 ± 6.0) compared with younger adolescents (mean GF-FAD: 19.2 ± 6.0; t[60] = −2.42; p=0.019).

Table 6. Logistic regression model predicting poor glycemic control (HbA1c >7.0%)

Predictor	*B*	*SE*	Wald	*df*	*p*	OR	95% CI (LL–UL)
Family functioning (GF-FAD)	0.19	0.51	0.14	1	0.712	1.21	0.44–3.30
Constant	−0.21	0.95	0.05	1	0.826	0.81	

Abbreviations: CI: Confidence interval; df: Degrees of freedom; GF-FAD: General functioning subscale of the Family Assessment Device; LL: Lower limit; OR: Odds ratio; SE: Standard error; UL: Upper limit.

Table 7. Multivariable logistic regression model predicting pathological depressive symptoms

Predictor	*B*	*SE*	Wald	*df*	*p*	OR	95% CI (LL–UL)
Family functioning (GF-FAD)	2.76	1.06	6.81	1	0.009	15.78	1.99–125.25
Gender	0.55	0.76	0.52	1	0.471	1.73	0.39–7.75
Age	1.47	0.83	3.13	1	0.077	4.34	0.85–22.10
Socioeconomic status (low vs. high)	−0.58	1.74	0.11	1	0.741	0.56	0.02–17.14
Socioeconomic status (middle vs. high)	−1.20	1.52	0.62	1	0.431	0.30	0.06–5.97
Frequency of blood glucose monitoring	1.02	0.76	1.80	1	0.180	2.78	0.62–12.42
Constant	−6.70	2.55	7.54	1	0.006	0.001	-

Abbreviations: CI: Confidence interval; df: Degrees of freedom; GF-FAD: General functioning subscale of the family assessment device; LL: Lower limit; OR: Odds ratio; SE: Standard error; UL: Upper limit.

4. Discussion

This cross-sectional study examined the interrelationships among depressive symptoms, family functioning, and glycemic control in a sample of 63 adolescents with T1DM. The findings suggest that a significant proportion of adolescents (approximately 29%) exhibit clinically significant depressive symptoms, which are moderately associated with poorer glycemic control, as indicated by higher HbA1c levels. Importantly, poor family functioning was strongly associated with elevated depressive symptoms and significantly predicted the presence of pathological depression, even when controlling for demographic and clinical factors.

Our results are consistent with previous studies reporting that depressive symptoms are prevalent in adolescents with T1DM.[6-8] The observed moderate positive correlation between depressive symptom severity and HbA1c underscores the impact of psychological distress on diabetes self-management.[26] Depressed adolescents may experience reduced motivation, energy, and cognitive functioning, all of which are essential for maintaining adherence to complex diabetes management regimens.[27] Consequently, these individuals are more likely to demonstrate poorer metabolic control, thereby increasing their risk for both acute and chronic complications.

Family functioning emerged as a critical psychosocial factor in our study. The strong positive correlation between poor family functioning and higher depressive symptoms suggests that adolescents perceiving their family environment as unsupportive or conflict-ridden are at greater risk for developing depression. This finding aligns with studies suggesting that an optimal family environment–characterized by effective communication, emotional support, and cooperative problem solving–can act as a buffer against stress and promote better psychological outcomes.[12,14,15] However, due to the cross-sectional nature of our study, we cannot infer a causal direction. It is equally plausible that adolescents experiencing depressive symptoms may perceive their family environment more negatively, or that a third variable–such as illness severity, financial burden, or societal stressors–may underlie both poor family functioning and increased depressive symptoms. Future longitudinal and mediation-focused studies are warranted to clarify the directionality of these relationships and to explore potential confounders or shared underlying factors.

Interestingly, while family functioning was a robust predictor of depressive symptoms, it did not directly predict glycemic control. This may suggest that the influence of family functioning on metabolic outcomes is mediated through its impact on psychological well-being and self-management behaviors. For example, families that function poorly may contribute to the emergence of depressive symptoms, which in turn impede proper diabetes management, ultimately leading to elevated HbA1c levels. Alternatively, other unmeasured factors (such as individual self-efficacy or external social support) might play a more direct role in determining glycemic control.[28] Future studies employing mediation analyses could further elucidate these complex pathways and help identify targets for family-centered interventions.

Our subgroup analyses indicated that older adolescents (14–18 years) were more likely to report higher depressive symptoms and poorer family functioning compared with younger adolescents (10–13 years). This finding may be attributed to the increased pressures and responsibilities that come with mid-to-late adolescence. As adolescents mature, they are expected to take on greater responsibility for managing their diabetes.[29] However, this transition often occurs in the context of normative developmental challenges, such as the struggle for autonomy and identity formation, which may exacerbate emotional distress and strain family relationships.[30] In addition to the burden of self-care, older adolescents may also face heightened emotional and social challenges. As their social world expands and they seek greater independence, the visibility and constraints of diabetes management may reinforce feelings of difference or isolation. These experiences can further contribute to psychological distress and place added strain on the family, as both adolescents and caregivers adjust to evolving roles and expectations.[3] While the frequency of poor glycemic control was higher in the older group, the difference was not statistically significant. This might be due to the multifactorial nature of glycemic control, which can be influenced by several factors, including treatment adherence, duration of diabetes, and external support systems.[9]

The current findings have several important implications for clinical practice. First, routine screening for depressive symptoms should be integrated into diabetes care for adolescents. Early detection of psychological distress may facilitate timely intervention and ultimately improve adherence to diabetes management. Second, interventions that target family functioning could be particularly beneficial.[31,32] By enhancing communication, problem solving, and emotional support within the family unit, these interventions may reduce depressive symptoms and indirectly improve glycemic control.

Given the strong association between family functioning and depression, healthcare providers should consider including family-based assessments and interventions as part of a comprehensive approach to diabetes management. Educational programs for parents and caregivers may improve their understanding of the psychosocial challenges faced by adolescents with T1DM and help them develop supportive strategies. In addition, it is important to consider that poor family functioning may reflect not only adolescent distress but also psychosocial strain experienced by other family members. Caregivers of adolescents with T1DM may struggle with stress, anxiety, or depressive symptoms themselves, which could affect their ability to provide consistent support.[33] In this context, interventions should go beyond education to include psychological support for parents and caregivers, recognizing their emotional burden and promoting family-wide resilience. Future studies should assess parental mental health to better understand how caregiver distress interacts with adolescent outcomes.

Several limitations of the present study should be noted. The sample size was relatively small, which may limit the generalizability of the findings and the power to detect smaller effects. For instance, the wide CIs observed for some predictors in the present model of predicting pathological depressive symptoms and the multivariable analysis, particularly for socioeconomic status, suggest that the study may have been underpowered to detect small to moderate associations. The limited sample size contributed to reduced precision in these estimates, and larger studies are warranted to confirm these findings and provide more reliable effect size estimates. A further limitation of this study is the exclusive reliance on self-report measures (*i.e.*, the CDI and GF-FAD), which are subject to response bias and may not fully capture the complexity of depressive symptoms and family functioning. Future research should consider incorporating multi-informant data, including parental reports and clinician assessments, to enhance measurement accuracy and provide a more comprehensive understanding of these constructs. Moreover, the cross-sectional design precludes any inference of causality. Longitudinal studies are needed to determine the directionality of the observed relationships and to assess whether improvements in family functioning and reductions in depressive symptoms lead to better glycemic control over time. In addition, our study did not include serum biomarkers, as the focus was on psychosocial factors and self-reported outcomes rather than physiological disease mechanisms. Future studies may benefit from incorporating such biomarkers to explore biological moderators or mediators of psychological distress in T1DM. Similarly, we did not collect data on participants'

body mass index (BMI) or maternal history of gestational diabetes. Although these are clinically relevant variables, they were beyond the scope of our psychosocial focus. Future research could consider including such indicators to examine potential physiological or intergenerational risk pathways. Moreover, we did not directly assess diabetes self-care behaviors using validated instruments, such as the Summary of Diabetes Self-Care Activities (SDSCA).[34] Future studies should consider incorporating such measures to better capture the behavioral pathways linking psychological well-being and glycemic outcomes. Finally, potential mediators (*e.g.*, self-management skills, peer support) were not examined in this study and should be considered in future investigations.

Future research should build on these findings by addressing several key areas. Studies with larger and more diverse samples are needed to enhance the generalizability of the results. Longitudinal designs would allow for an exploration of causal relationships and a better understanding of the long-term impact of family functioning and depressive symptoms on glycemic control. It is also essential to investigate potential mediators and moderators, such as self-management skills and peer support, that may influence the relationship between family dynamics and metabolic outcomes. Moreover, future investigations should compare various dimensions of family functioning using comprehensive assessment tools to determine which aspects–such as communication or emotional support–most strongly predict depressive symptoms and glycemic control. Finally, randomized controlled trials evaluating family-based interventions will be critical to determine their efficacy in improving both psychosocial and metabolic outcomes in adolescents with T1DM.

5. Conclusion

This study demonstrates that depressive symptoms are prevalent among adolescents with T1DM and are significantly associated with poorer glycemic control. Moreover, poor family functioning is strongly linked to elevated depressive symptoms and independently predicts the risk of pathological depression. Although family functioning did not directly predict glycemic outcomes, its strong association with depressive symptoms underscores its indirect role in diabetes management. The findings of this study highlight the clinical importance of integrating routine screenings for family functioning into standard diabetes care for adolescents with T1DM. Identifying at-risk family dynamics early allows healthcare providers to deliver targeted, practical psychological interventions aimed at enhancing communication, problem-solving, and emotional support within families. Incorporating these screenings and interventions into existing diabetes care guidelines may help mitigate depressive symptoms, thereby indirectly improving glycemic control and overall patient well-being. However, these findings should be interpreted in the light of the study's limitations, including its cross-sectional design, small sample size, and reliance on self-report measures, which may introduce response bias. Future longitudinal research utilizing multi-informant assessments is warranted to confirm these associations and further elucidate the underlying mechanisms.

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Conflict of interest

The authors declare that they have no competing interests.

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Ethics approval and consent to participate

The study protocol was approved by the Scientific Council of Aghia Sophia Children's Hospital (Protocol No. 23101) and the Committee of Ethics and Deontology of the School of Medicine of the National and Kapodistrian University of Athens (Protocol No. 919). Informed consent was obtained from all participating families, and the study adhered to the ethical principles outlined in the Declaration of Helsinki.

Consent for publication

All participating families consented on the publication of their data.

Availability of data

The datasets used and/or analysed during the current study are available from the authors upon reasonable request.

Further disclosure

Part of or the entire set of findings were previously presented in Christina-Georgia Pouliezou's master's thesis, submitted to National and Kapodistrian University of Athens, 2025.

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