Research Article

Al-Iraqia Medical College Journal (AIMCJ)
ISSN (Online): 3104-4565
ISSN (Print): 3104-4557

Association of Adipokines and Pro-Inflammatory Cytokines with Glycemic Control in Pediatric Type 1 DM

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ARTICLE INFO
Received: 06 / 03 / 2026
Revised: 31/ 03/ 2026
Accepted: 01/ 04/ 2026
Publish online: 15 /4 / 2026

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CITATION
Zahraa Ali H. Al-Tameemi. Association of Adipokines and Pro-Inflammatory Cytokines with Glycemic Control in Pediatric Type 1 Diabetes. *AIMCJ*. 2026;3(1) 100-111.

DOI: https://doi.org/10.58564/AIMCJ3.1.2026.258

Abstract

This research sought to assess the relationships among circulating adipokines, pro-inflammatory cytokines, and glycemic control in pediatric patients with type 1 diabetes mellitus (T1D).

A case-control analysis was conducted from April 12, 2025, to February 1, 2026, in pediatric and endocrine clinics in Thi-Qar. The study included 150 participants: 100 children with type 1 diabetes and 50 healthy controls matched by age and sex. Clinical and demographic information was documented, and fasting blood samples were gathered for biochemical analysis. Glycemic indicators, lipid profiles, adipokines (adiponectin, leptin, resistin, visfatin), and inflammatory cytokines (TNF-α, IL-6, IL-1β, CRP) were assessed using automated analyzers and ELISA techniques under controlled laboratory conditions.

Hemoglobin A1c (HbA1c) levels were significantly elevated in T1D patients compared to controls ($p<0.001$), indicating insufficient glycemic control. Children with diabetes showed notably higher fasting glucose levels and adverse lipid profiles, including elevated cholesterol, triglycerides, and low-density lipoprotein cholesterol (LDL-C), along with decreased high-density lipoprotein cholesterol (HDL-C). Additionally, adiponectin concentrations were markedly lower in the T1D group ($p<0.001$), while proinflammatory markers increased substantially, including leptin ($p<0.001$) and TNF-α ($p<0.001$). These markers showed significant positive correlations with HbA1c ($P<0.001$), indicating a robust association between systemic inflammation and glycemic dysregulation.

Pediatric type 1 diabetes is linked to an imbalance of adipokines and increased pro-inflammatory cytokines, which are associated with inadequate glycemic control. Persistent high blood sugar can activate inflammatory pathways and disrupt adipose tissue, leading to metabolic issues and immune system activation that worsen disease progression.

Keywords: Type 1 diabetes; Adipokines; Pro-inflammatory cytokines; Glycemic control; Pediatric diabetes.

AIMCJ.(2026),3;(1):100-111
https://doi.org/10.58564/AIMCJ3.1.2026.258

Introduction

Type 1 diabetes mellitus (T1D) is an enduring autoimmune metabolic condition that is defined by the autoimmune destruction of pancreatic **β-cells**, causing absolute insulin deficiency and chronic hyperglycemia. It is among the most prevalent endocrine diseases among children and adolescents around the globe. Pediatric T1D is a growing global disease, especially in developing and middle-income countries over the past few decades. This increasing prevalence is a major issue in public health because of the metabolic comorbidities of chronic hyperglycemia, such as cardiovascular disease, nephropathy, neuropathy, and retinopathy (1,2). Poor glycemic regulation in children in the early phases of the disease can enhance the development of these complications in adulthood; therefore, it is important to detect metabolic and inflammatory biomarkers early in the disease to monitor and control it (3).

The pathogenesis of T1D is complex, involving a combination of genetic predisposition, environmental precipitation, and immune dysregulation. The destruction of insulin-producing β-cells in pancreatic islets, an autoimmune process, is primarily used to diagnose the disease. This is facilitated by autoreactive T cells and inflammatory cytokines, which promote progressive β-cell apoptosis and loss of insulin secretion (4,5). As insulin deficiency develops, glucose uptake by peripheral tissues is impaired, leading to persistent hyperglycemia and metabolic disruptions. The most popular biomarker to assess the role of long-term glycemic control in diabetic patients, glycated hemoglobin (HbA1c), is The indicator of average blood glucose levels during the last two to three months (6).

Over the past few years, increasing attention has been given to the roles of inflammatory mediators and adipose tissue-derived hormones in the pathophysiology of diabetes. Adipose tissue is no longer viewed as a passive energy storage organ; it is now considered an active endocrine gland that produces a broad array of bioactive molecules, referred to as adipokines. These molecules control metabolic homeostasis and immune and inflammatory signaling pathways. Adiponectin, leptin, resistin, and visfatin are among the most widely investigated adipokines implicated in glucose metabolism and insulin sensitivity (7,8). Adiponectin usually displays anti-inflammatory and insulin-sensitizing properties, whereas leptin, resistin, and visfatin are typically associated with inflammatory processes and metabolic imbalances (9).
Changes in adipokine secretion can contribute to the development of metabolic disturbances and inflammation observed in patients with diabetes. Saying that lower levels of adiponectin have been linked to impaired glucose regulation and enhanced inflammatory processes. On the contrary, elevated leptin and resistin have been associated with insulin resistance, immune activation, and endothelial dysfunction (10). These adipokines communicate with immune cells and inflammatory pathways, suggesting that, in the pathogenesis of diabetes, metabolic and immune processes are closely linked (11). Besides adipokines, pro-inflammatory cytokines also play a central role in the autoimmune and inflammatory mechanisms of T1D.

AIMCJ.(2026),3;(1):100-111
https://doi.org/10.58564/AIMCJ3.1.2026.258

Tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and interleukin-1 beta (IL-1β) are the cytokines that have been known to mediate B-cell damage and systemic inflammation.
These cytokines may trigger intracellular signaling pathways that favor oxidative stress, apoptosis, and immune-mediated pancreatic tissue destruction (12). Moreover, chronic hyperglycemia per se may augment inflammatory responses by producing advanced glycation end products (AGEs) and reactive oxygen species, thereby increasing cytokine release and metabolic impairment (13).

The interaction between adipokines, inflammatory cytokines, and glycemic control is a significant field of research in pediatric diabetes. Despite studies investigating the inflammatory nature of T1D, analyses of adipokines and cytokines in relation to glycemic control have been relatively limited, especially in pediatric populations (14).

Knowledge of these relationships could provide insights into the processes that mediate the association between metabolic dysregulation and immune activation in children with diabetes. Additionally, detecting specific biomarkers associated with inadequate glycemic control can enhance disease monitoring and inform targeted therapeutic interventions (15).

Thus, the current research proposal was to explore the relationships among circulating adipokines, pro-inflammatory cytokines, and glycemic control in children with type 1 diabetes mellitus. This study aims to provide a clearer understanding of the metabolic-inflammatory interactions in pediatric T1D and their possible clinical implications by comparing biomarker levels between diabetic children and healthy controls and examining their relationships with glycemic indicators.

Material and Methods:

Study design and setting:

The case-control study was conducted to investigate the correlation between adipokines, pro-inflammatory cytokines, and glycemic management in children diagnosed with type 1 diabetes mellitus (T1D). The research took place between 12 April 2025 and 1 February 2026, within the pediatric departments and outpatient endocrine clinic of designated hospitals and medical centers in Thi-Qar directorate.

Study population:

The study population comprised 150 individuals: 100 children with type 1 diabetes mellitus and 50 apparently healthy children serving as the control group. The control group was selected from children attending routine health checkups and compared with the patient group based on age and sex to minimize potential confounding variables. The diagnosis of Type 1 diabetes mellitus in the patient population was determined using the American Diabetes Association (ADA) standards, including persistent hyperglycemia, reliance on insulin, and a medical history indicating that a specialist physician diagnosed the patient with this condition.
The children participating in the study were within the pediatric age group and had no prior history of any chronic metabolic, autoimmune, or inflammatory conditions. Participants with acute infections or endocrine disorders unrelated to diabetes and those who had been exposed to medications that could influence inflammatory markers or lipid metabolism were excluded from the study. Healthy controls were screened to reduce the risk of diabetes,

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https://doi.org/10.58564/AIMCJ3.1.2026.258

autoimmune diseases, or other chronic medical conditions. Demographic and clinical information were collected through structured questionnaires and medical records following enrollment.

The recorded variables included age, sex, body mass index (BMI), duration of diabetes, and insulin dosage. The BMI was calculated using the standard formula (weight in kilograms divided by height in meters squared) (16,17).

Venous blood samples (5 mL) were collected after an 8-hour overnight fast. Samples were centrifuged at 3000 rpm for 10 minutes to obtain serum, which was then stored at-20 °C until analysis.

Glycemic and Lipid Profiles: Fasting blood glucose (FBG), HbA1c, and lipid parameters (total cholesterol, triglycerides, HDL-C, and LDL-C) were measured using enzymatic colorimetric methods with kits from Biolabo (France) (18-20).

Adipokine Quantification: Serum adiponectin, leptin, resistin, and visfatin were quantified using sandwich ELISA kits from Elabscience (China). These kits were selected for their high sensitivity and specificity in pediatric samples.

Inflammatory Markers: High-sensitivity ELISA kits from Elabscience were used to measure circulating levels of TNF-α, IL-6, and IL-1β. C-reactive protein (CRP) was analyzed using the hs-CRP immunoturbidimetric assay.

Procedure Standardization: All measurements were performed on automated clinical chemistry analyzers and microplate readers at 450 nm. Assays were conducted in duplicate to minimize intra-assay variation, following the manufacturer's strictly defined procedures.

Statistical Analysis:

Statistical Package for the Social Sciences (SPSS) version 26 was used to analyze the collected data. Continuous variables were represented as mean ± standard deviation (SD), whereas categorical variables were presented with frequencies and percentages. The Kolmogorov-Smirnov test was utilized to evaluate the normality of the data distribution. The independent-samples t-test was used to compare the means of normally distributed variables between T1D and healthy controls. The Pearson correlation coefficient (r) was used to assess the relationships among adipokines, inflammatory cytokines, and indicators of glycemic control, such as HbA1c. Any p-value lower than 0.05 was deemed statistically significant for all assessments.

Results:

Table 1 presents the sociodemographic and clinical characteristics of pediatric participants included in the study. The analysis demonstrated no statistically significant differences between children with type 1 diabetes (T1D) and healthy controls regarding age ($p = 0.621$), gender distribution ($p = 0.987$), or BMI ($p = 0.573$), indicating that the groups were well matched for these baseline variables. The patients with T1D had an average of 4.6 ± 2.3 years of diabetes, and the daily insulin dose was 0.82 ± 0.21 U/kg. There was a notable difference in the family history of diabetes, where patients with T1D had a higher family history of diabetes than controls ($p = 0.041$).

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Table 1: Sociodemographic and Clinical Characteristics of Pediatric Type 1 Diabetes Patients and Healthy Controls

Variable	T1D Patients (n=100) Mean±SD	Controls (n=50) Mean±SD	P-value
Age (years)	11.2 ± 3.4	10.9 ± 3.1	0.621
Gender (Male/Female)	54 / 46	27 / 23	0.987
BMI (kg/m²)	19.8 ± 3.2	20.1 ± 3.4	0.573
Duration of diabetes (years)	4.6 ± 2.3	—	—
Family history of diabetes (%)	38 (38%)	11 (22%)	**0.041**
Insulin therapy (daily dose U/kg)	0.82 ± 0.21	—	—
HbA1c (%)	9.1 ± 1.8	5.2 ± 0.6	**<0.001**

**Statistical analysis was done using the Mann-Whitney test*

Table 2: Comparison of Glycemic and Lipid Profile Parameters Between Pediatric Type 1 Diabetes Patients and Healthy Controls

Parameter	T1D Patients (n=100) Mean±SD	Controls (n=50) Mean±SD	P-value
Fasting Blood Glucose (mg/dL)	214.6 ± 52.8	88.4 ± 10.7	**<0.001**
HbA1c (%)	9.1 ± 1.8	5.2 ± 0.6	**<0.001**
Total Cholesterol (mg/dL)	185.3 ± 34.7	162.5 ± 29.4	**0.002**
Triglycerides (mg/dL)	148.2 ± 41.6	112.3 ± 30.1	**<0.001**
HDL-C (mg/dL)	42.1 ± 8.7	51.6 ± 9.3	**<0.001**
LDL-C (mg/dL)	109.4 ± 27.8	93.2 ± 22.5	**0.004**

**Statistical analysis was done using the Paired T-test test*
#Statistical analysis was done using the Wilcoxon signed rank test

Moreover, glycemic control indices were significantly different between groups, with diabetic children exhibiting fairly high HbA1c levels ($p < 0.001$), indicating poor glycemic control in pediatric patients with T1D.

Table 2 shows the differences in glycemic control and lipid profiles between healthy children and patients with T1D. The results showed markedly elevated fasting blood glucose levels in T1D patients when compared to the control group ($p < 0.001$). Additionally, HbA1c levels were significantly higher in patients with diabetes than in healthy individuals, indicating that the T1D group had inadequate long-term glycemic control ($p < 0.001$). Regarding lipid profile parameters, total cholesterol levels were significantly higher in T1D patients than in controls ($p = 0.002$). Tri-glyceride concentrations were notably higher in the diabetic cohort ($p < 0.001$). Conversely, levels of high-density lipoprotein cholesterol (HDL-C) were markedly lower in T1D patients than in healthy subjects ($p < 0.001$).

Furthermore, low-density lipoprotein cholesterol (LDL-C) levels were notably elevated in the diabetic group compared to the control group ($p = 0.004$). Combined, these data demonstrate a clear trend of dyslipidemia and metabolic disorders associated with pediatric type 1 diabetes.

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https://doi.org/10.58564/AIMCJ3.1.2026.258

Table 3: Serum Levels of Adipokines in Pediatric Type 1 Diabetes Patients and Healthy Controls

Adipokine	T1D Patients (n=100) Mean±SD	Controls (n=50) Mean±SD	P-value
Adiponectin (µg/mL)	7.4 ± 2.3	10.2 ± 2.7	**<0.001**
Leptin (ng/mL)	15.8 ± 5.1	11.4 ± 4.2	**<0.001**
Resistin (ng/mL)	8.6 ± 2.4	6.3 ± 1.9	**<0.001**
Visfatin (ng/mL)	4.9 ± 1.5	3.6 ± 1.2	**<0.001**

**Statistical analysis was done using the Paired T-test test*
#Statistical analysis was done using the Wilcoxon signed rank test

Table 3 compares adipokine levels in pediatric patients with T1D and healthy controls. The serum adiponectin level in T1D patients was significantly lower compared to the control group ($p < 0.001$). In contrast, children with diabetes exhibited markedly elevated levels of pro-inflammatory and metabolically active adipokines. Serum leptin levels were notably elevated in the T1D group compared to the control group ($p< 0.001$). Similarly, resistin levels were significantly elevated in patients with T1D compared with healthy individuals ($p < 0.001$). A statistically significant increase in Visfatin concentration was observed in the diabetic group compared with the control group ($p < 0.001$). These findings indicate that pediatric T1D patients exhibit a clear imbalance in adipokine regulation, characterized by reduced levels of the anti-inflammatory adipokine adiponectin and elevated levels of pro-inflammatory adipokines, potentially leading to metabolic dysregulation and pro-inflammatory responses in T1D.

Table 4 summarizes the circulating levels of various pro-inflammatory cytokines in pediatric patients diagnosed with T1D and healthy controls. The findings demonstrated a significant increase in levels of inflammatory markers among diabetic children. The concentration of serum tumor necrosis factor-alpha ($p < 0.001$) was markedly higher in the T1D group than in the control group. Similarly, IL-6 concentrations were significantly higher in individuals with type 1 diabetes than in healthy individuals ($p < 0.001$). The concentration of interleukin-1 beta (IL-1β) was significantly higher in the diabetic group than in the control group ($p < 0.001$). In addition, CRP was markedly elevated in T1D patients when compared to the control group ($p < 0.001$). Collectively, these results indicate a pronounced inflammatory phenotype in pediatric type 1 diabetes, supporting the significance of ongoing immune activation and cytokine-mediated inflammation in the disease's pathophysiology and metabolic dysfunction.

Table 4: Serum Levels of Pro-Inflammatory Cytokines in Pediatric Type 1 Diabetes Patients and Healthy Controls

Cytokine	T1D Patients (n=100) Mean±SD	Controls (n=50) Mean±SD	P-value
TNF-α (pg/mL)	18.6 ± 6.2	10.7 ± 3.5	<0.001
IL-6 (pg/mL)	9.8 ± 3.1	4.5 ± 1.7	<0.001
IL-1β (pg/mL)	6.2 ± 2.0	3.1 ± 1.2	<0.001
CRP (mg/L)	4.9 ± 1.8	1.7 ± 0.9	<0.001

**Statistical analysis was done using the Paired T-test test*
#Statistical analysis was done using the Wilcoxon signed rank test

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Table 5. Correlation Between Adipokines, Inflammatory Cytokines, and Glycemic Control (HbA1c) in Pediatric Type 1 Diabetes Patients (n=100)

Biomarker	r value	P-value
Adiponectin	-0.41	<0.001
Leptin	0.36	0.002
Resistin	0.39	<0.001
Visfatin	0.33	0.004
TNF-α	0.45	<0.001
IL-6	0.42	<0.001
IL-1β	0.31	0.006
CRP	0.38	<0.001

**Statistical analysis was done using the Spearman correlation test*

Table 5 displays the correlation analysis of circulating adipokines, inflammatory cytokines, and glycemic control, assessed by HbA1c levels, in children with T1D. The analysis revealed a negative correlation between adiponectin levels and HbA1c, indicating a significant inverse relationship: lower adiponectin levels were associated with poorer glycemic control ($r = -0.41$, $p < 0.001$). In contrast, certain adipokines showed positive correlations with HbA1c, including leptin ($r = 0.36$, $p = 0.002$), resistin ($r = 0.39$, $p < 0.001$), and visfatin ($r = 0.33$, $p = 0.004$), suggesting their potential role in metabolic dysregulation and insulin resistance in pediatric diabetes. Moreover, inflammatory cytokines showed a strong and positive correlation with HbA1c levels. TNF- showed the highest correlation ($r = 0.45$, $p < 0.001$), followed by IL-6 ($r = 0.42$, $p < 0.001$), CRP ($r = 0.38$, $p < 0.001$), and lastly, IL-1β ($r = 0.31$, $p = 0.006$). Collectively, these results suggest a significant link between adipokine imbalance, systemic inflammation, and inadequate glycemic control in children with type 1 diabetes, highlighting the role of metabolic-inflammatory interactions in disease progression and glycemic dysregulation.

Discussion:

The study presented outlined the connection among adipokines, pro-inflammatory cytokines, and glycemic regulation in children with T1D. The sociodemographic analysis showed no statistically significant differences in age, gender distribution, or BMI between diabetic patients and healthy controls. Other studies on childhood diabetes have shown that when age and BMI are closely matched, the observed biochemical differences can be attributed to disease-induced metabolic and immunological changes rather than to demographic bias (21,22).

Conversely, the current findings indicated that a family history of diabetes was notably more prevalent in the T1D patients' group (38%) than in the control group. The observation confirms that genetic susceptibility is significant in the progression of autoimmune diabetes. In children, the genetic tendency toward type 2 diabetes is recognized to include immune-regulatory genes and HLA class II alleles that favor genetic elements contributing to pancreatic damage and immune-response activation (23).

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The assessment of glycemic markers revealed that the fasting blood glucose and HbA1c levels were markedly elevated in diabetic children compared to healthy peers. These findings correspond with the pathophysiology of T1D, characterized by autoimmune-mediated destruction of insulin-secreting β-cells. As insulin deficiency progresses, glucose uptake by peripheral tissues declines, leading to chronic hyperglycemia and inadequate glycemic control over time, as evidenced by rising HbA1c levels (24,25). Similar results were found in multiple studies involving children, indicating that HbA1c remains the most reliable indicator of ongoing glycemic instability and metabolic dysregulation in youth with T1D (20). Hyperglycemia in these individuals may persist, leading to oxidative stress and endothelial dysfunction, triggering systemic inflammation and metabolic complications (26).

The lipid profile findings in the present study indicated a significant rise in total cholesterol, triglycerides, and LDL-cholesterol in T1D patients. Still, there was a notable reduction in HDL cholesterol levels in T1D patients compared with controls. These alterations indicate the presence of dyslipidemia associated with diabetes (27,28). The influence of insulin deficiency on liver lipid metabolism may explain this trend. Insulin typically suppresses hepatic lipolysis and modulates lipoprotein lipase activity; in this context, insulin deficiency promotes triglyceride synthesis and impairs the clearance of circulating lipoproteins (29).

Additionally, persistent hyperglycemia can promote lipoprotein glycation, leading to reduced HDL function and increased LDL oxidation. Additional research has identified similar lipid abnormalities in pediatric T1D patients, while some have observed milder dyslipidemia, particularly in those with optimal glycemic control. This variation in research may be linked to differences in glycemic control, disease duration, adherence to insulin therapy, and lifestyle factors such as diet and exercise (30).

They also found significant alterations in circulating adipokines in diabetic children. Specifically, adiponectin concentration was notably lower in T1D patients than in healthy controls, potentially due to elevated HbA1c or longer disease duration, whereas leptin, resistin, and visfatin were significantly elevated. Adiponectin is recognized as an adipokine that reduces inflammation and enhances insulin sensitivity, exerting a protective influence on glucose metabolism. Reduced adiponectin levels in diabetic patients may reflect impaired adipose tissue function and increased inflammatory signaling (31).

Leptin, resistin, and visfatin, in contrast, are often associated with inflammatory and metabolic responses to stress. Elevated inflammatory signaling and changes in energy balance in diabetic individuals may lead to increased leptin levels. Resistin and visfatin have been linked to insulin resistance, endothelial dysfunction, and inflammatory activation, suggesting that these adipokines may contribute to metabolic disorders in childhood diabetes (32). However, other studies have reported the opposite, finding elevated rather than decreased adiponectin levels in T1D. These discrepancies may be ascribed to differences in patient age, disease duration, body fat distribution, and the metabolic compensatory responses during the early stages of diabetes (33). The inflammatory nature observed in the study also supports the notion that T1D is not just a metabolic disorder but rather a chronic inflammatory condition. Serum concentrations of

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TNF-alpha, IL-6, IL-1b, and CRP were significantly elevated in diabetic children compared to controls. These cytokines are crucial for immune activation and facilitate autoimmune damage to pancreatic β-cells. TNF-α and IL-1β can directly induce apoptosis in β-cells by activating nuclear factor-κB (NF-κB) and oxidative stress signaling pathways, leading to a gradual depletion of insulin release (34,35).

IL-6 also contributes to systemic inflammation and alters glucose metabolism. Elevated CRP levels indicate a generalized inflammatory response, often seen in chronic metabolic conditions. Many studies have confirmed the link between T1D and elevated levels of inflammatory cytokines, while other research has shown lower levels or no differences in cytokine levels among certain groups. Such discrepancies may arise from variations in disease stage, phases of insulin therapy, genetic factors, or the insensitivity of laboratory tests (36).

The analysis of correlation indicated that biomarkers and glycemic control are significantly related. A notable inverse correlation existed between adiponectin and a positive correlation with leptin, resistin, visfatin, inflammatory cytokines, and HbA1c levels. These findings suggest that reduced glycemic control is associated with a heightened inflammatory response and an imbalance in adipokines. Mechanistically, persistent hyperglycemia promotes the formation of advanced glycation end products (AGEs) and reactive oxygen species, which initiate inflammatory responses and cytokine production. At the same time, inflammatory cytokines may further impair insulin signaling pathways, creating a harmful cycle between metabolic dysfunction and inflammation (37).

The elevated R between systemic inflammatory markers and HbA1c (notably TNF-α ($r=0.45$, $p<0.001$) and IL-6 ($r=0.42$, $p<0.001$)) suggests that persistent hyperglycemia acts as the main catalyst for the systemic inflammatory increase seen in these pediatric patients. The present research supports the idea that inflammatory markers may serve as potential biomarkers for disease progression and metabolic complications of T1D in children (38).

Conclusion

The findings showed that type 1 diabetes in children is associated with significant alterations in adipokines and pro-inflammatory cytokines that are closely linked to inadequate glycemic control. Reduced adiponectin levels and elevated leptin, resistin, visfatin, and inflammatory cytokines signify a metabolic and inflammatory imbalance. Persistent hyperglycemia can promote oxidative stress and immune activation by overstimulating cytokine signaling and impairing adipose tissue function. These interactions may contribute to the progression of metabolic imbalance and inflammatory responses, suggesting the potential usefulness of these biomarkers for assessing disease severity and monitoring glycemic control in children with T1D.

Ethical Approval:

The Institutional Ethics Committee of the medical facility (Al-Habbobi Teaching Hospital, Nasiriya, Iraq) granted ethical approval for this study before the commencement of the research (1285, 10/04/2025). Additionally, the parents or legal guardians of the children involved in the study provided written informed consent after being informed of the research's purpose and procedures, including blood sample collection.

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https://doi.org/10.58564/AIMCJ3.1.2026.258

Conflict of Interest: None to declare

Funding: Nil

References:

1. Rasheed NW, Abbood YH, Abd-Alhussain SQ, Abu-Shana JH. Fibronectin as a nexus of inflammation and dysmetabolism in type 2 diabetes. *Al-Iraqia Medical College Journal*. 2025 Aug 15;2(2):49-59.
2. AbdulKareem NG, Jassim NA, Mohammed ZK, Alkabban M. linkage between the duration of diabetes mellitus type-2 with the biochemical measurements and the extent of chronic complications. *Journal of Bioscience and Applied Research.* 2024 Jun 1;10(2):235-46.
3. Popoviciu MS, Kaka N, Sethi Y, Patel N, Chopra H, Cavalu S. Type 1 diabetes mellitus and autoimmune diseases: a critical review of the association and the application of personalized medicine. *Journal of Personalized Medicine.* 2023 Feb 26;13(3):422.
4. Ilonen J, Lempainen J, Veijola R. The heterogeneous pathogenesis of type 1 diabetes mellitus. *Nature Reviews Endocrinology*. 2019 Nov;15(11):635-50.
5. Ogrotis I, Koufakis T, Kotsa K. Changes in the global epidemiology of type 1 diabetes in an evolving landscape of environmental factors: causes, challenges, and opportunities. *Medicina*. 2023 Mar 28;59(4):668.
6. Zorena K, Michalska M, Kurpas M, Jaskulak M, Murawska A, Rostami S. Environmental factors and the risk of developing type 1 diabetes—old disease and new data. *Biology*. 2022 Apr 16;11(4):608.
7. Burhans MS, Hagman DK, Kuzma JN, Schmidt KA, Kratz M. Contribution of adipose tissue inflammation to the development of type 2 diabetes mellitus. *Comprehensive physiology*. 2019 Jan 17;9(1):1-58.7.
8. Booth A, Magnuson A, Fouts J, Foster MT. Adipose tissue: an endocrine organ playing a role in metabolic regulation. *Hormone molecular biology and clinical investigation*. 2016 Apr 1;26(1):25-42.
9. Chait A, Den Hartigh LJ. Adipose tissue distribution, inflammation, and its metabolic consequences, including diabetes and cardiovascular disease. *Frontiers in cardiovascular medicine*. 2020 Feb 25;7:522637.
10. Zorena K, Jachimowicz-Duda O, Ślęzak D, Robakowska M, Mrugacz M. Adipokines and obesity. Potential link to metabolic disorders and chronic complications. *International journal of molecular sciences.* 2020 May 18;21(10):3570.
11. Unamuno X, Gómez-Ambrosi J, Rodríguez A, Becerril S, Frühbeck G, Catalán V. Adipokine dysregulation and adipose tissue inflammation in human obesity. *European journal of clinical investigation.* 2018 Sep;48(9):e12997.
12. Shao L, Feng B, Zhang Y, Zhou H, Ji W, Min W. The role of adipose-derived inflammatory cytokines in type 1 diabetes. *Adipocyte*. 2016 Jul 2;5(3):270-4.
13. Taylor EB. The complex role of adipokines in obesity, inflammation, and autoimmunity. *Clinical Science*. 2021 Mar;135(6):731-52.
14. Reinehr T, Karges B, Meissner T, Wiegand S, Stoffel-Wagner B, Holl RW, Woelfle J. Inflammatory markers in obese adolescents with type 2 diabetes and their relationship to hepatokines and adipokines. *The Journal of Pediatrics*. 2016 Jun 1;173:131-5.
15. Ullah A, Singla RK, Batool Z, Cao D, Shen B. Pro-and anti-inflammatory cytokines are the game-changers in childhood obesity-associated metabolic disorders (diabetes and

AIMCJ.(2026),3;(1):100-111
https://doi.org/10.58564/AIMCJ3.1.2026.258

non-alcoholic fatty liver diseases). *Reviews in Endocrine and Metabolic Disorders*. 2024 Aug;25(4):783-803.

16. Shaker AM, Nuaman BN. The Metabolic and Hepatic Impact of Central Obesity in MASLD Patients: Evidence from an Iraqi Cross-sectional Cohort. *Al-Iraqia Medical College Journal*. 2025 Dec 15;2(3):54-64.
17. Almusawi ZM, Haddad NI, Husein EA. Dectin-1 levels in obese and overweight women with polycystic ovary syndrome (PCOS). *International Journal of Pharmaceutical Research*. 2020;12(2):1095-102.
18. Ali I. T., Haddad N. I. A., Hussein E. A. Correlation of Serum Adiponectin and C-reactive protein with Other Biochemical Parameters in Iraqi Pregnant Women. *Chem. Methodol.,* 2022; 6(5): 357-365. doi: 10.22034/chemm.2022.328177.1435
19. Abu-Shana JH, Abdulkareem NG, Jasim AO, Abbood YH. Effect of diabetes mellitus type 2 on the correlation of vitamin D with lipid profile in Iraqi patients. *Iraqi Journal of Science*. 2024 Sep 30:4881-9.
20. Ali IT, Haddad NI, Hussein EA. Assessment of monocyte chemoattractant protein-1 (MCP-1) and other biochemical parameters in Iraqi pregnant women. *Iraqi Journal of Science.* 2022 Oct 30:4152-62.
21. Fatima N, Faisal SM, Zubair S, Ajmal M, Siddiqui SS, Moin S, Owais M. Role of pro-inflammatory cytokines and biochemical markers in the pathogenesis of type 1 diabetes: correlation with age and glycemic condition in diabetic human subjects. *PloS one*. 2016 Aug 30;11(8):e0161548.
22. Zhao X, Gang X, Liu Y, Sun C, Han Q, Wang G. Using metabolomic profiles as biomarkers for insulin resistance in childhood obesity: a systematic review. *Journal of Diabetes Research*. 2016;2016(1):8160545.
23. Alqahtani AA, Alzidany AM, Alenazi SM, Dhifallah T, Alotaibi BJ. Long-term complications of poor glycemic control in diabetic patients. *EC MICROBIOLOGY*. 2020;2:1-7.
24. Chang SC, Yang WC. Hyperglycemia, tumorigenesis, and chronic inflammation. *Critical reviews in oncology/hematology*. 2016 Dec 1;108:146-53..
25. Vijayakumar P, Nelson RG, Hanson RL, Knowler WC, Sinha M. HbA1c and the prediction of type 2 diabetes in children and adults. *Diabetes care*. 2017 Jan 1;40(1):16-21.
26. Ibfelt EH, Wibaek R, Vistisen D, Andersen GS, Jørgensen ME, Hulman A, Dabelea D, Birkebaek NH, Svensson J, Rønn PF. Trajectory and predictors of HbA1c in children and adolescents with type 1 diabetes—a Danish nationwide cohort study. *Pediatric Diabetes.* 2022 Sep;23(6):721-8.
27. Amor AJ, Castelblanco E, Hernández M, Giménez M, Granado-Casas M, Blanco J, Soldevila B, Esmatjes E, Conget I, Alonso N, Ortega E. Advanced lipoprotein profile disturbances in type 1 diabetes mellitus: a focus on LDL particles. *Cardiovascular diabetology.* 2020 Aug 9;19(1):126.
28. Salardi S, Maltoni G, Zucchini S, Iafusco D, Zanfardino A, Confetto S, Toni S, Zioutas M, Marigliano M, Cauvin V, Franceschi R. Whole lipid profile and not only HDL cholesterol is impaired in children with coexisting type 1 diabetes and untreated celiac disease. *Acta Diabetologica*. 2017 Oct;54(10):889-94.
29. Melin EO, Thulesius HO, Hillman M, Svensson R, Landin-Olsson M, Thunander M. Lower HDL-cholesterol, a known marker of cardiovascular risk, was associated with depression in type 1 diabetes: a

AIMCJ.(2026),3;(1):100-111
https://doi.org/10.58564/AIMCJ3.1.2026.258

cross-sectional study. *Lipids in health and disease*. 2019 Mar 18;18(1):65.

30. Rathsman B, Haas J, Persson M, Ludvigsson J, Svensson AM, Lind M, Andersson Franko M, Nyström T. LDL cholesterol level as a risk factor for retinopathy and nephropathy in children and adults with type 1 diabetes mellitus: a nationwide cohort study. *Journal of Internal Medicine.* 2021 Jun;289(6):873-86.
31. Cura–Esquivel I, Perales-Quintana MM, Torres-González L, Guzmán-Avilán K, Muñoz-Espinosa L, Cordero-Pérez P. Metabolic, inflammatory and adipokine differences on overweight/obese children with and without metabolic syndrome: A cross-sectional study. *PLoS One*. 2023 Mar 15;18(3):e0281381.
32. Wolf RM, Jaffe AE, Rodriguez S, Lei X, Sarver DC, Straub AT, Wong GW, Magge SN. Altered adipokines in obese adolescents: a cross-sectional and longitudinal analysis across the spectrum of glycemia. *American Journal of Physiology-Endocrinology and Metabolism*. 2021 Jun 1;320(6):E1044-52.
33. Mărginean CO, Meliț LE, Huțanu A, Ghiga DV, Săsăran MO. The adipokines and inflammatory status in the era of pediatric obesity. *Cytokine.* 2020 Feb 1;126:154925.
34. Cabrera SM, Henschel AM, Hessner MJ. Innate inflammation in type 1 diabetes. *Translational Research.* 2016 Jan 1;167(1):214-27.
35. Clark M, Kroger CJ, Tisch RM. Type 1 diabetes: a chronic anti-self-inflammatory response. *Frontiers in immunology*. 2017 Dec 22;8:1898..
36. Bennett JM, Reeves G, Billman GE, Sturmberg JP. Inflammation–nature's way to efficiently respond to all types of challenges: implications for understanding and managing "the epidemic" of chronic diseases. *Frontiers in medicine*. 2018 Nov 27;5:316.
37. Krhač M, Lovrenčić MV. Update on biomarkers of glycemic control. *World journal of diabetes*. 2019 Jan 15;10(1):1.
38. Lazar S, Reurean-Pintilei DV, Ionita I, Avram VF, Herascu A, Timar B. Glycemic variability and its association with traditional glycemic control biomarkers in patients with type 1 diabetes: a cross-sectional, multicenter study. *Journal of Clinical Medicine*. 2025 Apr 2;14(7):2434.