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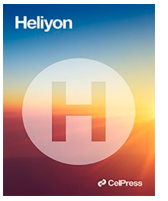

Research article

Microalbuminuria and lipid variations in adolescents diagnosed with type 1 diabetes

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ABSTRACT

Objective: This study investigates the prevalence of lipid abnormalities among adolescents diagnosed with Type 1 Diabetes Mellitus (T1DM) and explores potential associations with microalbuminuria and cardiovascular disease (CVD) risk factors.

Research Design and Methods: A retrospective study analyzed lipid profiles, microalbuminuria, and CVD risk in adolescents with T1DM. Six hundred individuals were assessed for lipid levels, BMI, and microalbuminuria.

Results: Dyslipidemia prevalence was 59.7 %, with 22.7 % exhibiting abnormal total cholesterol (TC) and triglycerides (TG), and 15.8 % with elevated TC alone. A2 microalbuminuria was found in 59.2 %, with 14.6 % showing A3. Females had higher A2 prevalence and mild eGFR decrease ($P = 0.02$). Lipid levels correlated significantly with microalbuminuria (TC: $r = 0.761$; TG: $r = 0.572$, $P = 0.03$ and 0.04, respectively). The prevalence of high total cholesterol (TC) + high triglycerides (TG), as well as the high TG alone, was considerably higher in patients belonging to the A2 Microalbuminuria group. AIP, HbA1c, and UACR showed a strong positive correlation ($r = 0.542$, $P = 0.04$; $r = 0.621$, $P = 0.02$).

Conclusion: Our study highlights the prevalence of elevated or borderline lipid levels among adolescents with Type 1 Diabetes Mellitus (T1DM), indicating a heightened risk of dyslipidemia in this population. Particularly concerning is the significantly increased incidence of dyslipidemia among young individuals with T1DM, with females exhibiting a notable susceptibility to cardiovascular disease (CVD) due to dyslipidemia's impact on the Atherogenic Index of Plasma (AIP). Furthermore, Microalbuminuria, specifically type A2 and A3, was prevalent among our study participants, with females showing a significantly higher occurrence of A2 microalbuminuria compared to males. The association between microalbuminuria and dyslipidemia, especially the combination of high total cholesterol (TC) and high triglycerides (TG), emphasizes the importance of comprehensive screening protocols for both microalbuminuria and dyslipidemia in managing the cardiovascular risk profile of individuals with T1DM.

1. Introduction

Our defense system is highly developed. It protects the body from dangerous external dangers and cancerous cells. In TIDM, the immune system unintentionally targets the beta-cells that make insulin in the pancreas; this can happen over a few weeks, months, or

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years. Because of this, insulin must be replaced by a pump or repeated shots. Without insulin, glucose levels in the blood continue increasing and may have detrimental effects, such as ketosis and sudden cardiac mortality [1]. 387 million people globally are estimated to have diabetes mellitus (DM), of which 5–10 % have T1DM [2,3]. The prevalence of TIDM in Saudi Arabia is estimated to be 109.5 per 100,000 people, with an incidence rate rising by 3 % annually [4,5]. Microvascular complications and cardiovascular disease (CVD) have an increased tendency to occur in diabetic individuals [5,6]. Subjects with TIDM frequently have lipid abnormalities, which are connected to glycemic regulation [6]. In adult type 1 diabetic patients, the link between dyslipidemia and the risk of CVD is well established, and using lipid-lowering medications has been linked to a decrease in cardiovascular illness [6]. 66.5 % of type 2 diabetes patients in Saudi Arabia have been found to have dyslipidemia [7]. There is currently no published study that provides a good understanding of the occurrence of dyslipidemia in young individuals with TIDM.

Studies in both clinical and laboratory settings have shown that dyslipidemia may play a part in the emergence of microalbuminuria and diabetic nephropathy [8]. Lipid levels are related to mesangial, tubulointerstitial, and glomerular alterations in the kidney [8]. Treatment of hyperlipidemia with statins has been linked to decreased kidney damage in diabetes-related animal models [8]. Raised cholesterol levels may play a role in the development and progression of renal diseases, according to cross-sectional studies conducted on patients [8], and dyslipidemia can be treated to lower albumin excretion [8]. Higher cholesterol levels were found in the Institute for Renal Research participants in the UK who progressed to microalbuminuria compared to those who did not [9,10]. Triglycerides (TG) have also become a reliable indicator of renal complications' onset and worsening [10,11]. These findings suggest that measuring plasma lipids can enhance albumin excretion's prognostic value in identifying individuals who are at risk for diabetic nephropathy and cardiovascular disease. The existing research on the correlation between lipid abnormalities and the risk of developing microalbuminuria or CVD is inadequate, particularly when it comes to young persons in Saudi Arabia who have TIDM. The primary goals of the present investigation were to determine the frequency of lipid abnormalities and their correlation with the likelihood of microalbuminuria and the likelihood of developing cardiovascular disease (risk factors) in a substantial cohort of young individuals with TIDM.

2. Methods

The endocrinology and diabetes unit at the King Fahad Hospital in Medina, Saudi Arabia, conducted this research. For TIDM patients (aged between 13 and 16 years), electronic data were examined from January 2021 to December 2022. The General Office of Health Affairs' Institutional Review Board (IRB) in Madinah provided its ethical approval (approval IRB22-046). This study was retrospective and descriptive, involving 600 consecutive cases. The patients were selected from a group of newly diagnosed and untreated diabetic outpatients at the King Fahad Hospital in Madinah's endocrinology and diabetes center. Samples obtained within one month of diagnosis were removed to rule out lipid abnormalities linked to untreated diabetes. Patients receiving statin therapy were additionally eliminated from the study. A database of data that could be analyzed was created because all patient information had been completely recorded in the patient files. Age, gender, lab results (Fasting Blood glucose (FBG), HbA1C, Total cholesterol (TC), high-density lipoprotein (HDL-C), low-density lipoprotein (LDL-C), and triglycerides (TG), Serum creatinine, albumin), urine analysis (creatinine, albumin levels), data was obtained for two positive tests over 3 or more months, liver function test data (Aspartate transaminase (AST), Alanine transaminase (ALT)) were all examined.

- Lipid levels were classified as:
  1. Serum TC was categorized as follows: normal $<$5.17 mmol/L, borderline 5.17–6.20 mmol/L, and high $\geq$6.21 mmol/L.
  2. TG: normal $<$1.70 mmol/L, borderline high 1.70–2.25 mmol/L, and high 2.26–5.64 mmol/L
  3. LDL-C: normal level $<$2.59 mmol/L, above optimal 2.59–3.35 mmol/L, borderline high 3.36–4.13 mmol/L, high 4.14–4.90 mmol/L, and very high $\geq$4.91 mmol/L (The value was measured according to Friedewald formula, LDL-C (mmol/L) = TC - HDL-C - TG/2.2).
  4. HDL-C: high $\geq$1.55 mmol/L and low $<$1.03 mmol/L [12].
  5. Dyslipidemias can alter the levels of total cholesterol (TC), triglycerides (TG), low-density lipoprotein (LDL) cholesterol, or high-density lipoprotein (HDL) cholesterol. These changes can occur throughout childhood or adolescence either alone or in combination, and can continue into adulthood [13].

1. AIP was evaluated as Atherogenic Index of Plasma = log (TG/HDL-C). An AIP value of less than 0.11 is a value of low risk; the values between the range 0.11–0.21 are values of intermediate risk but the values above 0.21 are values of high-risk of CVD [14].

- The method to estimate Microalbuminuria is to determine the urinary Albumin/Creatinine Ratio (UACR) in a spot urine sample. UACR is measured by dividing albumin concentration in milligrams by creatinine concentration in grams and categorizing it into:
  1. A1 = UACR can be calculated as $<$30 mg/g (normal)
  2. A2 = UACR 30–300 mg/g (microalbuminuria)
  3. A3 = UACR $>$300 mg/g (Severe microalbuminuria) [15,16].

2. The calculation of estimated glomerular filtration rate (eGFR) by Cockcroft and Gault formula:=[140 - age (years) $\times$ Body Wt. (Kg)]/[Serum Cr (mg/dL) $\times$ 72] $\times$ [0.85 if female]

- **The children's BMI:** Body mass index (BMI) and BMI Z-score: The participant's standing height was measured using a portable stadiometer, with measurements recorded to the nearest centimeter. Weight was assessed using an electronic scale, with measurements recorded in kilograms. The BMI was calculated by dividing the weight by the square of the height in meters. The height, weight, and BMI values were converted into Z scores using the World Health Organization (WHO) Child Growth Standards. Patients were classified into several categories based on their BMI Z-score. Those with Z-scores between -2 and $+0.99$ were classified as

underweight or normal weight. Patients with Z-scores between 1 and 1.99 were classified as overweight, while those with Z-scores between 2 and 2.99 were classified as obese. Patients with a Z-score of 3 or above were classified as extremely obese [17]. Also, the Centers for Disease Control and Prevention (CDC) recommends BMI categorization for children and teens between age 2 and 20, Percentile Range [18].

1. Underweight <5 %
2. Healthy weight 5 %–85 %
3. At risk of overweight 85 %–95 %
4. Overweight >95 %

Data analysis: The necessary data was exported to Excel and entered into GraphPad Prism 7 after that (GraphPad Software, CA, USA). Before statistical research, outliers in the data were checked. Data were examined using descriptive statistics (For all continuous variables, means and standard deviations are expressed; for scale or nominal data, frequencies and percentages are expressed). The differences in lab findings between study groupings were analyzed using a One-way ANOVA, and Pearson correlation was used to determine associations between the relevant variables. If statistical analyses were significant, the *P* value 0.05 or 0.001 thresholds of probability were used to ascertain this.

3. Results

Table 1 displays the general characteristics of the study group. The age and period of diabetes were comparable in the 345 females (57.5 %) and 255 males (42.5 %) individuals. There were significant differences in glycemic control between males vs females (FGB = 10.5 ± 2.8 vs 12.5 ± 2.7, $P < 0.001$, respectively) and HbA1c (7.9 ± 3.4 vs 9.9 ± 3.7, $P < 0.001$, respectively) (Table 1). Males had higher amounts of TC than females ($P < 0.001$), whereas females had higher levels of TG ($P < 0.001$). Furthermore, it was revealed that females exhibited significantly greater TG/HDL-C ratio and AIP levels compared to males ($P < 0.001$). In addition, females had a substantially greater BMI and percentile range compared to males ($P < 0.001$). Females had elevated urine albumin levels (41.5 ± 7.5 mg/mmol) compared to males, resulting in an increase in the UACR to 37.7 ± 6.5 along with a mild decrease in eGFR (Table 1).

3.1. Prevalence of dyslipidemia according to gender

Both genders showed a high frequency of elevated and borderline lipid levels, with a notable disparity in the occurrence of lipid

Table 1
T1DM patients' baseline characteristics.

Parameter	Total (n = 600)	Males (n = 255, 42.5 %)	Females (n = 345, 57.5 %)	*P*-value
Age (years)	15.5 ± 1.4	15 ± 1.5	15.5 ± 1.6	>0.05
Duration from first assessment (years)	6.8 ± 1.7	6.5 ± 1.4	6.7 ± 1.2	>0.05
FBG (3.89–5.50 mmol/L)	10.8 ± 2.1	10.5 ± 2.8	12.5 ± 2.7	**<0.001****
HbA1c (4.3–6.0 %)	7.8 ± 3.6	7.9 ± 3.4	9.9 ± 3.7	**<0.001****
LDL-C (2.59–4.11 mmol/L)	4.5 ± 1.2	4.7 ± 1.1	4.6 ± 1.3	>0.05
HDL-C (1.04–1.55 mmol/L)	1.1 ± 0.45	1.02 ± 0.38	1.01 ± 0.35	>0.05
Total cholesterol (TC) (5.2–6.2 mmol/L)	5.9 ± 1.8	6.9 ± 1.3	6.1 ± 1.2	**<0.001****
Triglycerides (TG) (1.7–2.2 mmol/L)	3.1 ± 1.4	3.2 ± 1.2	4.1 ± 1.4	**<0.001****
TG/HDL-C (<5)	2.9 ± 0.51	2.7 ± 0.51	3.7 ± 0.61	**<0.001****
§AIP (<0.11)	0.4 ± 0.1	0.4 ± 0.2	0.5 ± 0.2	**<0.001****
Serum creatinine (0.4–0.9 mg/dL for 13–16 years)	0.9 ± 0.13	0.6 ± 0.19	1.1 ± 0.11	**0.02***
Serum Albumin (3.4–5.4 g/dL)	3.3 ± 0.23	3.0 ± 0.21	2.5 ± 0.11	**0.03***
Urine Albumin (<30 mg/dL)	35.5 ± 7.1	37.5 ± 8.1	41.5 ± 7.5	**<0.001****
Urine Creatinine (0.5–1.0 mg/dL)	1.4 ± 0.83	1.3 ± 0.53	1.1 ± 0.61	**<0.001****
§§UACR (Albumin/Creatinine Ratio)	25.5 ± 6.1	28.9 ± 5.2	37.7 ± 6.5	**<0.001****
§§§eGFR (mL/minute)	96 ± 10.9	127 ± 13.7	75 ± 11.1	**<0.001****
Weight (Kg)	50 ± 7.10	43 ± 5.11	56 ± 8.15	**<0.001****
BMI (kg/m^2)	22.2 ± 3.10	19.6 ± 1.11	24.9 ± 4.15	**<0.001****
BMI Z-scores	0.6 ± 0.2	−0.1 ± 0.1	1.1 ± 0.1	**<0.001****
§§§Percentile: %	71.9 ± 12.13	44.8 ± 11.13	87.1 ± 11.10	**<0.001****
AST (10–35 IU/L)	32.5 ± 13.10	30.6 ± 11.11	33.1 ± 10.11	>0.05
ALT (9–41 IU/L)	23.9 ± 11.12	22.7 ± 13.11	25.1 ± 12.05	>0.05

Data were expressed as mean ± SD for continuous variables. P ≤ 0.05* or 0.001** for females vs. males.
LDL-C value was measured.
FBG=Fasting blood glucose, HbA1c = hemoglobin A1c, HDL-C = high density lipoprotein, and LDL-C = low-density lipoprotein, hs-CRP = high-sensitivity C-reactive protein, AIP= Atherogenic Index of Plasma, BMI = body mass index, AST = Aspartate transaminase, ALT = Alanine transaminase, ALP= Alkaline phosphatase, eGFR = estimated glomerular filtration rate.
§AIP >0.21, high risk of CVD.
§§A2 = UACR 30–300 mg/g (microalbuminuria) was noticed in females.
§§§eGFR = 60–89 is considered a mildly decreased in females.
§§§§Percentile Range = >85 % is considered as Overweight in females.

abnormalities (all P < 0.05). In the study population of 600 adolescents, the average occurrence of lipid abnormalities was as follows: high LDL-C was observed in 20.5 % of the population, low HDL-C in 39.2 %, high total cholesterol in 22.7 %, and high TG in 24.7 %. Additionally, borderline LDL-C was found in 40 % of the population, borderline total cholesterol in 58.2 %, and borderline TG in 56.7 % (Table 2). Among the current study population, the occurrence of dyslipidemia was 59.7 %. Among the research population of 600 individuals, 22.7 % exhibited dyslipidemia characterized by abnormal levels of total cholesterol (TC) and triglycerides (TG). Additionally, 15.8 % of the population showed dyslipidemia characterized by abnormal levels of TC alone. These two forms of dyslipidemia were shown to be the most frequent in the study population (Table 2).

3.2. Prevalence of microalbuminuria according to gender

A total of 600 individuals, including 255 males (42.5 %) and 345 females (57.5 %), were enrolled in the research. Microalbuminuria type A2, with a UACR ranging from 3 to 29 mg/mmol, was seen in 59.2 % of the participants in the research. Additionally, type A3 microalbuminuria, characterized by a UACR greater than 30 mg/mmol, was found in 14.6 % of the study population. Females exhibited a substantially greater occurrence of A2 microalbuminuria compared to males (155 males vs 200 females, $P = 0.02$, Table 3). Regarding the occurrence of A3 severe microalbuminuria, there was a notable disparity between male and female numbers (36 vs 52), with a P-value of 0.05, as shown in Table 3.

3.3. Prevalence of dyslipidemia parameters and microalbuminuria groups

The prevalence of high total cholesterol (TC) + high triglycerides (TG), as well as the high TG alone, was considerably higher in patients belonging to the A2 Microalbuminuria group compared to other groups ($P < 0.05$). However, the occurrence of high TC was significantly higher in patients belonging to the A3 severe Microalbuminuria group compared to other groups ($P < 0.05$, Table 4).

3.4. Correlation between HbA1c, lipid parameters, and UACR

Except for LDL-C and HDL-C, there was a significant relationship between mean lipid levels (total cholesterol, r = 0.761; TG, r = 0.572, $P = 0.03$ and 0.04, respectively) and UACR. AIP values were shown to have a significant positive correlation with UACR (r = 0.542, $P = 0.04$), and HbA1c levels were also found to be significantly correlated with UACR (r = 0.621, $P = 0.02$) (Table 5).

Table 2
Prevalence of dyslipidemia according to gender (n = 600).

Parameter	Total (n = 600)	Males (n = 255, 42.5 %)	Females (n = 345, 57.5 %)
LDL-C (2.59–4.11 mmol/L)	4.5 ± 1.2	4.7 ± 1.1	4.6 ± 1.3
Normal level <2.59 mmol/L	237(39.5 %)	100	137
Borderline high 3.36–4.13 mmol/L	240(40 %)	**100**	**140**[a]
High >4.90 mmol/L	123(20.5 %)	55	68
HDL-C (1.04–1.55 mmol/L)	1.1 ± 0.45	1.2 ± 0.45	1.1 ± 0.35
Low <1.03	235(39.2 %	118	117
Normal >1.55	365(60.8 %)	183	182
Total cholesterol (5.2–6.2 mmol/L)	5.9 ± 1.8	**6.9 ± 1.3**[a]	**6.1 ± 12**
Normal <5.2 mmol/L	115(19.2 %)	50	65
Borderline 5.2–6.2 mmol/L	349(58.2 %)	**187**[a]	**162**
High ≥6.2 mmol/L	136(22.7 %)	**89**[a]	**47**
Triglycerides (TG) (1.7–2.2 mmol/L)	3.1 ± 1.4	**3.2 ± 1.2**	**4.1 ± 1.4**[a]
Normal <1.7 mmol/L	112(18.7 %)	59	53
Borderline 1.7–2.2 mmol/L	340(56.7 %)	**152**	**188**[a]
High ≥5.6 mmol/L	148(24.7 %)	**61**	**87**[a]
AIP (<0.11)	0.4 ± 0.1	**0.4 ± 0.2**	**0.5 ± 0.2**[a]
Low risk <0.11	105(17.5 %)	53	52
Intermediate risk 0.11–0.21	310(51.7 %)	**120**	**190**[a]
High risk >0.21	185(30.8 %)	90	95
Lipid abnormalities (n = 600)			
YES	358(59.7 %)	**163**	**195**[a]
NO	242(40.3 %)	92	150
TC + TG + LDL-C + HDL-C	22(3.7 %)	10	12
TC + TG	136(22.7 %)	**53**	**83**[a]
TC + LDL-C	15(2.5)	9	6
TG	95(15.8 %)	**34**	**61**[a]
TC	70(11.7 %)	**47**[a]	**23**
TG + HDL-C	20(3.3 %)	10	10

Data were expressed as numbers (%) prevalence of parameters levels and Coexistence of lipid abnormalities, and the mean ± SD for continuous variables.

[a] P ≤ 0.05, ≤0.001for women vs. men.

Table 3
Prevalence of Microalbuminuria according to gender (n = 600).

Parameter	Total (n = 600)	Males (n = 255, 42.5 %)	Females (n = 345, 57.5 %)	*P*- value
Urine Albumin (<30 mg/dL)	35.5 ± 7.1	37.5 ± 8.1	41.5 ± 7.5	**<0.001****
Urine Creatinine (0.8–1.8 mg/dL in men and 0.6–1.6 mg/dL in women)	1.4 ± 0.83	1.3 ± 0.53	1.1 ± 0.61	**<0.001****
UACR	25.5 ± 6.1	28.9 ± 5.2	37.7 ± 6.5	**<0.001****
A1 = UACR <30 mg/g (normal)	157(26.2 %)	64	93	>0.05
§A2 = UACR 30–300 mg/g (Microalbuminuria)	355(59.2 %)	155	200	**0.02***
§A3 = UACR >300 mg/g (Severe Microalbuminuria)	88(14.6 %)	36	52	**0.05***

Data were expressed as mean ± SD for continuous variables and numbers (%) prevalence of ACR categories. P ≤ 0.05* or 0.001** for women vs. men.
§A2 Microalbuminuria in 155 males vs 200 females*.
§A3 severe Microalbuminuria in 36 males vs 52 females*.

Table 4
Prevalence of Dyslipidemia Parameters and Microalbuminuria groups (n = 600).

Parameter	A1 = UACR <30 mg/g (normal)	§A2 = UACR 30–300 mg/g (Microalbuminuria)	A3 = UACR >300 mg/g (Severe Microalbuminuria)	*P*-value
Lipid abnormalities (n = 600)				
YES	358(59.7 %)			
NO	242(40.3 %)			
TC + TG + LDL-C + HDL-C	0	12(3.7 %)	10(3.7 %)	>0.05
TC + TG	9	97(22.7 %)	30(22.7 %)	**0.02***
TC + LDL-C	2	5(2.5)	8(2.5)	>0.05
TG	3	70(15.8 %)	22(15.8 %)	**0.03***
TC	6	24(11.7 %)	40(11.7 %)	**0.03***
TG + HDL-C	0	10(3.3 %)	10(3.3 %)	>0.05

Data were expressed as numbers (%) for prevalence of dyslipidemia parameters according to Microalbuminuria groups. P ≤ 0.05* or 0.001**.

4. Discussion and conclusion

The purpose of the current retrospective research was to determine the prevalence of dyslipidemia among adolescent patients with TIDM and its associated complications in the Saudi population. According to the research, TIDM patients in Saudi Arabia frequently have dyslipidemia, which increases their risk of developing CVD and microalbuminuria. The present study reveals that the prevalence of dyslipidemia of 59.7 % of the study population. Also, our study indicates that total cholesterol values were higher in males than in females, while TG levels were higher in females. In addition, females were found to have significantly higher TG/HDL-C ratios and AIP values than men. Compared to females, males had a significantly higher prevalence of cholesterol dyslipidemia. Contrarily, triglyceride dyslipidemia was considerably more prevalent in females than in males. Furthermore, high triglyceride and high cholesterol dyslipidemia were considerably more common in females than in males. With a frequency of 72.5 % or higher dyslipidemia is a frequent complication in diabetic patients [19]. In 129 young people with TIDM, a cross-sectional study by Abed et al. [20], found a prevalence of dyslipidemia of 64 %. In Saudi Arabia, TIDM affects 35,000 infants and is on the rise. In terms of incidence rate, Saudi Arabia ranks eighth in the globe with 33.5 cases per 100,000 people [19,21]. According to Alzahrani et al. [22], the prevalence of dyslipidemia among Saudi citizens is 33 %. The 60 children and adolescents were examined by Mona et al. [23], who also concluded other findings. According to their research, high LDL-C and low HDL-C dyslipidemia were the most common types, with rates of 65 %

Table 5
Pearson's Correlation Coefficient between HbA1c, BMI, Lipids levels, and UACR.

Parameter	UACR	
	r	P
HbA1c	**0.621**	**0.02***
LDL-C (mmol/L)	0.321	>0.05
HDL-C (mmol/L)	−0.323	>0.05
Total cholesterol (mmol/L)	**0.761**	**0.03***
Triglycerides (TG) (mmol/L)	**0.572**	**0.04***
BMI	0.341	>0.05
AIP	**0.542**	**0.04***

P-values were achieved from Pearson's correlation; Starred values show a significant level *P ≤ 0.05, LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol, UACR: Urinary Albumin/Creatinine Ratio, BMI: body mass index and AIP: Atherogenic Index of Plasma.

and 28.2 % in diabetic patients and controls, respectively [23]. In Brazil, Homma et al. [19], retrospective cross-sectional research included 239 young TIDM patients. They found overall rates of dyslipidemia in males and females of 61.8 % and 81.7 %, respectively [19]. Due to the retrospective nature of the study and the undetermined status of statin therapy, this difference from our findings. Comparatively to males, more females than males had total dyslipidemia, according to Bulut et al. [24], Increasing estrogen impact in girls may result in a tendency for weight gain, according to research [24], explaining that females reach puberty earlier than males in the same age group. Diabetes metabolic control is more challenging and more likely to result in poor metabolic control in these situations because of the altered psychological and hormonal balance, as well as adaptation challenges during puberty [24].

CVD continues to be a major source of illness and death worldwide, with atherosclerosis being the predominant underlying cause [25]. In 2017, CVD caused an estimated 17.8 million deaths worldwide, with almost three-quarters occurring in low-income and middle-income nations [26]. Dyslipidemia is a well-established factor that increases the risk of atherosclerotic cardiovascular disease (ASCVD) and associated disorders globally. Various measurements were used to assess the risk of atherosclerotic cardiovascular disease (ASCVD) caused by dyslipidemia. Clinicians commonly utilize many measures like the low-density lipoprotein (LDL-C) to high-density lipoprotein (HDL-C) ratio, triglycerides (TGs), and the combination index of HDL-C lipoprotein (LCI) for therapeutic purposes [25]. In addition, the Atherogenic Index of Plasma (AIP) has been recently established as a suitable marker. The Atherogenic Index of Plasma (AIP) is a mathematical conversion of the ratio of triglycerides (TGs) to high-density lipoprotein (HDL) cholesterol. It is often regarded as a more accurate indicator of cardiovascular disease (CVD) risk. Cai et al. (2017) identified it as a distinct risk factor for cardiovascular disease (CVD) [27–29]. Furthermore, epidemiological studies have assessed a significant correlation between AIP and risk factors for cardiovascular disease, such as hypertension, obesity, and diabetes mellitus [30,31]. According to AIP values in our study subjects, young women have a moderate risk of CVD which is another significant finding of the current research. Pérez and colleagues [32] suggested that T1DM affects cardiovascular risk more significantly in females than in males, despite having well-controlled blood glucose levels, women with T1DM also have an elevated atherogenic profile than males. Furthermore, they found no association between the lipid profile and obesity/overweight with impaired metabolic control in female patients, suggesting that in adolescent T1DM patients, being female can be a risk factor for dyslipidemia which increases the risk of CVD. In line with our findings, T1DM patients have a high prevalence of dyslipidemia and a 4–10-fold increased risk of cardiovascular disease [33,34]. Patients with T1DM exhibit a variety of qualitative and functional atherogenic lipoprotein abnormalities [35], and dyslipidemia is found to be prevalent in 72.5 % of these patients, which increases their risk of vascular complications [36]. Patients with T1DM are at higher risk for developing atherosclerosis earlier, which would increase morbidity and mortality [36]. T1DM and dyslipidemia together raise the risk of CVD. High levels of TG, total cholesterol (TC), and low HDL-C are positively correlated with inadequate glycemic management, increasing the risk of diabetic complications [37]. The high level of HbA1c in the study's participants (poor glycemic control) with TC and TG dyslipidemia was another crucial result. Higher mean HbA1c was significantly associated with dyslipidemia, according to Abed et al. [20], who also supported our findings. Young males and females with type 1 diabetes and HbA1c levels of 7 % or higher are therefore at significant risk of developing CVD. The incidence of adverse cardiovascular events may be decreased in this situation by implementing quick and strict preventive measures. Similar to this, [38] Soliman and Ibrahim [37] conducted a retrospective analysis of 806 T1DM patients and found that poor glycemic control was significantly correlated with higher levels of dyslipidemia (TG, TC, LDL-C), a longer duration of diabetes, and older age.

Based on the UACR values, we also determined that total cholesterol and TG had a significant impact on albumin excretion over the duration of the study. In addition, we determined that microalbuminuria affected females and males who had a significant prevalence of dyslipidemia. A2 Microalbuminuria was more common in females than in males, and this difference was statistically significant ($P < 0.05$). Men and women differed significantly in terms of the frequency of A3 microalbuminuria (36 vs. 52, $P < 0.05$). In young individuals with T1DM, the association between microalbuminuria and dyslipidemia has not been thoroughly studied. Although associations with lipid abnormalities were found to be more prominent in individuals with macroalbuminuria, increased total cholesterol and/or TG have been associated with microalbuminuria in adult populations [38–40]. Data from the Oxford Regional Prospective Study indicated that the prevalence of microalbuminuria increased across tertiles of total cholesterol in pediatric populations with diabetes [40,41], and a recent German study revealed a predictive role for both LDL cholesterol and TG on the emergence of persistent microalbuminuria [42]. We investigated the relationships between lipid levels and the onset of microalbuminuria using UACR values in current research. High UACR values were closely related to higher levels of TG and TC. Overall, lipid levels were higher in those who developed microalbuminuria, which suggests it was probably associated with their worse glycemic control. Furthermore, given that microalbuminuria serves as an indicator of nephropathy progression in patients with diabetes, early detection, and intervention strategies are crucial for mitigating both microvascular and macrovascular complications in this vulnerable population. Therefore, implementing regular screening protocols and tailored intervention strategies targeting dyslipidemia and microalbuminuria are essential components of comprehensive care for adolescents with T1DM, aimed at reducing their risk of cardiovascular complications and improving long-term health outcomes.

limitations of the study, it's important to acknowledge that while this research marks a significant step forward in understanding the prevalence of dyslipidemia and its implications for cardiovascular disease (CVD) and microalbuminuria among adolescents with Type 1 Diabetes Mellitus (T1DM) in Saudi Arabia, several limitations temper the generalizability and depth of the findings.

Firstly, the study adopts a single-centered design, which inherently restricts the diversity and representativeness of the study population. A broader, multicenter approach would provide a more comprehensive understanding of the prevalence and correlates of dyslipidemia among adolescents with T1DM across different regions and healthcare settings in Saudi Arabia. Additionally, a retrospective study design, while valuable for analyzing existing data, may introduce biases and limitations in data collection, such as incomplete medical records or inconsistencies in diagnostic criteria over time. Secondly, the absence of information regarding patient statin medication status represents a notable gap in the study's analysis. Incorporating data on statin usage would not only enhance the

accuracy of lipid profile assessments but also enable a more nuanced exploration of the interplay between dyslipidemia, medication adherence, and cardiovascular outcomes in this population. Addressing these limitations through prospective, multicenter studies with comprehensive patient data collection, including medication histories and long-term follow-up assessments, would strengthen the validity and applicability of findings. Moreover, integrating qualitative research methods, such as patient interviews or focus groups, could provide valuable insights into the lived experiences and healthcare needs of adolescents with T1DM in Saudi Arabia, informing the development of tailored interventions and preventive strategies to mitigate the risk of cardiovascular complications in this vulnerable population.

5. Conclusion

In summary, the study underscores the significance of closely monitoring lipid levels, particularly in young individuals with Type 1 Diabetes Mellitus (T1DM), as variations were noted based on gender and body mass index (BMI), with higher levels observed in females. Moreover, the presence of persistently high or borderline lipid levels, accompanied by elevated atherogenic index of plasma (AIP), mild microalbuminuria, and slightly decreased estimated glomerular filtration rate (eGFR), especially in females, suggests a potential predisposition to cardiovascular disease (CVD) and diabetic nephropathy progression in this demographic.

These findings illuminate the prevalence of dyslipidemia within the Saudi Arabian population, signaling a heightened risk for CVD. Consequently, proactive screening for dyslipidemia and microalbuminuria among T1DM adolescents is imperative to identify individuals at early stages of complications, necessitating intensified monitoring and possibly additional therapeutic interventions.

Moving forward, further investigation into the intricate interplay between dyslipidemia, microalbuminuria, and T1DM is warranted. Moreover, the formulation and implementation of stringent preventive strategies targeting dyslipidemia and microalbuminuria could potentially mitigate the combined burden of diabetes and dyslipidemia within the Saudi populace, thereby contributing to a reduction in disease incidence and improved public health outcomes.

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Ethics approval statement

Ethical approval to perform the study was taken from The Institutional Review Board (IRB), General Directorate of Health Affairs in Madinah provided ethical approval (approval IRB22-046).

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Walaa Mohammedsaeed: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Data curation, Conceptualization. **Dalal Nasser Binjawhar:** Writing – review & editing, Writing – original draft, Validation, Resources, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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