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Review

Lipid Profile in Children and Adolescents with Type 1 Diabetes Mellitus: A Systematic Review and Meta-analysis

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ABSTRACT

This study aimed to compare fasting lipid profiles in children and adolescents with type 1 diabetes mellitus and healthy controls. This systematic review and meta-analysis followed Preferred Reporting Items for Systematic reviews and Meta-Analyses 2020 guidelines and was registered in PROSPERO (CRD42024600840). A systematic search was conducted in PubMed, Scopus, SpringerLink, EBSCOhost, and Google Scholar. Eligible studies were observational and included children and adolescents aged 5-19 years with type 1 diabetes mellitus. Search terms combined "Lipid profile", "Dyslipidemia", "Cholesterol", "HDL", "LDL", "Triglycerides", "Child", "Adolescent", "Pediatric", "Young people", "Type 1 Diabetes", and "Insulin Dependent Diabetes". Study quality was assessed with the Newcastle-Ottawa Scale, and data were synthesized using RevMan 5.4. Eleven studies were included with a total of 1,529 participants. Compared with the controls, children and adolescents with type 1 diabetes mellitus showed higher total cholesterol [mean difference (MD)=14.3 mg/dL; 95% confidence interval (CI): 8.4-20.4], low-density lipoprotein-cholesterol (MD=11.0 mg/dL; 95% CI: 7.0-14.8), and high-density lipoprotein cholesterol (MD=2.66 mg/dL; 95% CI: 0.1-5.2). Triglycerides were slightly increased but not significantly (MD=8.6 mg/dL; 95% CI: -0.4-21.3). This meta-analysis reveals lipid alterations in pediatric type 1 diabetes mellitus. Routine lipid screening and timely interventions are warranted in order to guide preventive care for cardiovascular disease risk.

Keywords: Type 1 diabetes mellitus, pediatric, lipid profile, dyslipidemia, meta-analysis

Introduction

Type 1 diabetes mellitus (T1DM) is one of the most common chronic endocrine disorders in children and adolescents. Its global incidence has been increasing steadily over the last three decades, with an estimated annual rise of approximately 3% worldwide (1). The International Diabetes Federation reported that, in 2021, there were approximately 1.5 million individuals under the age of 20 living with T1DM worldwide, with the highest incidence peaks occurring between the ages of 5-9 and 10-14 years (2,3). Although the disease is characterized primarily by autoimmune-mediated β-cell destruction and insulin deficiency, its long-term morbidity is driven largely by chronic complications, particularly cardiovascular disease (CVD) (4).

Dyslipidemia is a well-recognized and modifiable risk factor for CVD in T1DM, contributing to accelerated atherosclerosis and increased cardiovascular morbidity later in life (5). The American Diabetes Association (ADA) defines dyslipidemia in children as elevated total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), triglycerides

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(TG), or decreased high-density lipoprotein-cholesterol (HDL-C). For children with T1DM, ADA recommends obtaining an initial fasting lipid profile soon after diagnosis in children aged ≥2 years, with repeat screening at ages 9-11 years when initial results are normal. The recommended LDL-C target for children with T1DM is <100 mg/dL (6). Multiple factors contribute to lipid abnormalities in T1DM, including chronic hyperglycemia, insulin deficiency, increased free fatty acid flux, altered apolipoprotein metabolism, and the presence of obesity or insulin resistance in a subset of patients (7).

The prevalence of dyslipidemia in pediatric T1DM varies widely among studies—ranging from approximately 29% to over 70%, highlighting variability related to glycemic control, disease duration, pubertal status, and geographic or ethnic differences (8-10). While clinical guidelines recommend routine lipid screening in all children with T1DM starting at age 10 years or soon after diagnosis if there is a family history of dyslipidemia or premature CVD, real-world adherence to screening protocols remains suboptimal (11). Moreover, there has been limited synthesis of the contemporary evidence in describing lipid profile abnormalities in this population.

Given the critical role of dyslipidemia in the pathogenesis of CVD and its potential reversibility with timely intervention, understanding the characteristics of lipid profiles in children and adolescents with T1DM is essential for optimizing early detection and management strategies. Therefore, this systematic review and meta-analysis aimed to compare fasting lipid profiles, namely TC, TG, HDL-C, and LDL-C, in children and adolescents with T1DM and healthy controls.

Methods

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 guidelines. The review protocol was registered on the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42024600840.

Eligibility Criteria

Types of Studies

All published observational studies which evaluated lipid profiles in pediatric T1DM were included. Only original studies published in full-text and written in either English or Indonesian were considered. This study excluded interventional trials, reviews, conference abstracts, editorials, letters, case reports, and/or animal studies.

Participants

The eligible studies included children and adolescents aged 5-19 years diagnosed with T1DM based on their medical records or laboratory findings. The lower age limit of 5 years was selected to align with the first epidemiological peak of T1DM incidence. This study excluded studies involving adults without clearly separated pediatric data, those participants with type 2 diabetes or other endocrine/metabolic disorders, individuals on lipid-lowering therapy, congenital anomalies and those with significant comorbidities such as CVD, renal failure, or genetic dyslipidemia. Only those studies reporting at least 8-hour fasting lipid profiles were included in order to ensure standardization and the comparability of lipid measurements.

Variables of Interest

The variables of interest included demographic characteristics and fasting lipid profile parameters, namely TC, TG, HDL-C, and LDL-C.

Outcomes of Interest

The outcomes were the fasting levels of TC, TG, HDL-C, and LDL-C. All outcomes were treated as continuous variables, measured in mg/dL, and extracted as means ± standard deviations.

Search Strategy and Study Selection

A systematic literature search was conducted using five electronic databases: PubMed, Scopus, SpringerLink, EBSCOhost, and Google Scholar, covering studies published within the last 10 years in order to ensure inclusion of the most recent and clinically relevant evidence. Keywords and Medical Subject Headings of ("Lipid profile" or "Dyslipidemia" or "Cholesterol" or "HDL" or "LDL" or "Triglycerides") and ("Child" or "Adolescent" or "Pediatric" or "Young people") and ("type 1 diabetes" or "insulin dependent diabetes") were applied, guided by a structured participant, intervention, comparator, outcomes, framework (Table I). Three independent reviewers performed the screening, removed duplications, and assessed full-text eligibility. Any discrepancies were resolved through discussion and consensus.

Data Collection Process

Data were independently extracted by three reviewers using a standardized data extraction form. The demographic characteristics and lipid profiles from all included studies were summarized in a table. Disagreements among the reviewers were resolved through discussion and consensus was reached.

Table I. PICO framework of the included studies evaluating lipid profiles in children and adolescents with type 1 diabetes mellitus	
Participants	Children and adolescents aged 5 to 19 years diagnosed with T1DM based on medical records or laboratory findings
Interventions	Fasting lipid profile parameters—total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) in children and adolescents with T1DM
Comparator	Fasting lipid profiles in healthy children and adolescents
Outcomes	The differences in fasting lipid profiles, including serum TC, TG, HDL-C, and LDL-C
PICO: Participant, intervention, comparator, outcomes, T1DM: Type 1 diabetes mellitus	

Summary Measures

The primary summary measures were analyzed as continuous variables and reported in mg/dL. When outcomes were measured consistently, the results are presented as mean differences (MDs). In cases involving different correction methods, standardized MDs are given. Statistical significance was assessed using p values and 95% confidence intervals.

Risk of Bias in Evaluation

The risk of bias and methodological quality of the included studies were assessed using the Newcastle-Ottawa Scale. Cross-sectional studies were evaluated based on sample representativeness, sample size, consideration of non-respondent, exposure and outcome assessment, comparability, and statistical methods. Each domain was scored 1 or 2 points depending on the level of rigor, with a maximum total score of 10. Based on the final score, studies were categorized as very good (9-10 points), good (7-8 points), satisfactory (5-6 points), or unsatisfactory (0-4 points).

For cohort studies, criteria included cohort representativeness, the selection of non-exposed cohorts, exposure ascertainment, the absence of baseline outcomes, comparability, outcome assessment, and follow-up adequacy. For case-control studies, assessments involved case definition, case and control selection, comparability, exposure ascertainment, and non-response rates. Both study types were rated on a star scale from 0 to 9, with higher scores indicating better quality. Studies were categorized as follows: good quality: 3-4 stars in the selection domain, 1-2 in comparability, and 2-3 in the outcome/exposure domain, fair quality: 2 stars in selection, 1-2 in comparability, and 2-3 in outcome/exposure, and poor quality: did not meet the above thresholds.

Statistical Analysis

Meta-analyses were performed using RevMan 5.4 software. Pooled effect estimates were calculated using a random-effects model (DerSimonian-Laird method) if heterogeneity was substantial (I^2>50%), or a fixed-effects model if heterogeneity was low. Statistical heterogeneity was assessed using the I^2 statistic and chi-squared test, with an I^2 value above 50% indicating moderate-to-high heterogeneity. Publication bias was evaluated qualitatively using funnel plots when at least 10 studies were available for a given outcome.

Results

PRISMA

A total of 2,361 studies were identified through the initial search across five electronic databases. Of these, 807 studies were excluded due to duplicate records, and 1,031 were excluded for other reasons. Abstract screenings were carried out and they resulted in the exclusion of 177 studies. Subsequently, some studies were excluded due to ineligibility according to certain criteria, including studies unrelated to the topic, the absence of a control group as a comparator, and that they did not involve pediatric populations. Finally, this current study included 11 studies for qualitative synthesis and 9 studies for quantitative synthesis. The study selection processes are illustrated in Figure 1.

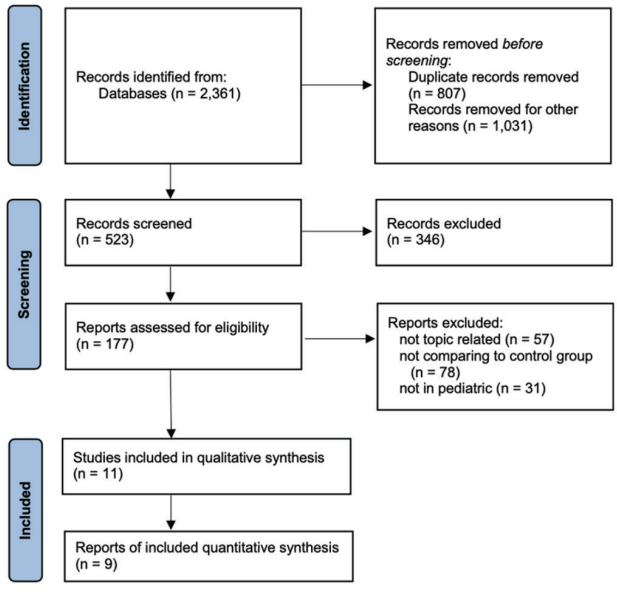

Figure 1. PRISMA 2020 flow diagram of included studies
PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses

Quality Assessment

For the cross-sectional studies, scores varied between 6 and 10 (out of 10). Two studies [Parthasarathy et al. (12) 2015 and Wu et al. (13) 2021] reached the maximum score and were rated as "Very good," while one [Prado et al. (14) 2017] was rated as "Good." The remaining three studies [Angelopoulou et al. (15) 2024; Zabeen et al. (16) 2018; and Trigona et al. (17) 2019] were considered "Satisfactory," mostly due to their less detailed reporting in certain domains. The cohort studies demonstrated consistently good quality, with scores ranging from 7-9 (out of 9). Two studies [Heier et al. (18) 2017 and Mona et al. (19) 2015] scored 7 and were rated as "Good," while one study [Pena et al. (20) 2016] achieved the highest score of 9. The case-control studies were both rated as "Good," each scoring 7 out of 9 [Alakkad et al. (21) 2020, and Alwasity et al. (22) 2022]. These studies showed solid design and comparability, although information on non-response rates was not consistently available. Taken together, the overall quality of the included studies was satisfactory to very good, with most falling into the good to very good range. Despite some variability in reporting, particularly in the cross-sectional designs, the available evidence was methodologically sound and provided a reliable foundation for the conclusions of this meta-analysis. The quality assessment of this study can be seen in Table II.

Characteristics of the Included Studies

This review included 11 observational studies published between 2015 and 2024, conducted across various geographic regions including Egypt, Iran, Greece, Norway, India, Australia, Germany, Switzerland, and the United Kingdom. The study designs consisted of cross-sectional (n=6), cohort (n=3), and case-control (n=2) methodologies. Sample sizes ranged from 43 to 404 participants, with total study populations involving both children and adolescents with T1DM and healthy controls. The age range of participants across these studies varied from 5-19 years.

Most studies defined T1DM diagnosis according to World Health Organization or ADA criteria, typically involving elevated HbA1c (≥6.5%), fasting blood glucose ≥126 mg/dL, or random plasma glucose ≥200 mg/dL in symptomatic individuals. All included studies enrolled children and adolescents with a confirmed diagnosis of T1DM for at least 6-12 months, with several studies requiring diabetes durations of ≥5 years. All lipid profile measurements were conducted in a fasting state (≥8 hours) to ensure comparability.

The inclusion criteria across the studies typically included children and adolescents aged 5-19 years, a confirmed diagnosis of T1DM, a diabetes duration of ≥6-12 months, the availability of fasting lipid measurements, and the absence of acute illness at the time of inclusion. The use of lipid-lowering medications or other systemic therapies, the presence of comorbid conditions affecting lipid metabolism (e.g., hypothyroidism, nephrotic syndrome, chronic renal or liver disease, Down syndrome), acute complications of diabetes [e.g., diabetic ketoacidosis, severe hypoglycemia], the presence of microvascular complications, the use of angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, or hormonal therapies, smoking, pregnancy, and/or obesity were exclusion criteria in some studies. The baseline characteristics of the included studies are presented in Table III.

Table II.I. Results of quality assessment using NOS for cross sectional studies

Cross sectional studies	Selection				Comparability	Outcomes		Total (max 10)	Assessment
	Representative of the sample	Sample size	Non respondents	Ascertainment of the exposure		Assessment of outcomes	Statistical test		
Parthasarathy et al. (12) 2015	*	*	*	**	**	**	*	10	Very good
Angelopoulou et al. (15) 2024	*	-	-	**	-	**	*	6	Satisfactory
Zabeen et al. (16) 2018	*	*	-	**	-	*	*	6	Satisfactory
Prado et al. (14) 2017	*	-	-	**	**	*	*	7	Good
Trigona et al. (17) 2019	*	*	-	**	-	*	*	6	Satisfactory
Wu et al. (13) 2021	*	*	*	**	**	**	*	10	Very good

*: One point, **: Two points, -: Zero points

Table II.II. Results of quality assessment using NOS for case control studies

Cross sectional studies	Selection					Outcomes			Total (Max 9)	Assessment
	Adequacy of case definition	Representativeness of the cases	Selection of controls	Definition of controls	Comparability	Ascertainment of exposure	Same method of ascertainment for cases and controls	Non-response rate		
Alakkad et al. (21) 2020	*	*	*	*	*	*	*	-	7	Good
Alwasity et al. (22) 2022	*	*	*	*	*	*	*	-	7	Good

*: One point, **: Two points, -: Zero points

Table II.III. Results of quality assessment using NOS for cohort study studies

Cohort studies	Selection					Outcomes			Total (Max 9)	Assessment
	Representative of exposed cohort	Selection of exposed cohort	Ascertainment of exposure	Outcome not present at the start of study	Comparability	Assessment of outcomes	Length of follow-up	Adequacy of follow-up		
Heier et al. (18) 2017	*	*	*	*	*	*	*	-	7	Good
Mona et al. (19) 2015	*	*	*	*	*	*	*	-	7	Good
Peña et al. (20) 2016	*	*	*	*	**	*	*	*	9	Good

*: One point, **: Two points, -: Zero points
NOS: Newcastle-Ottawa Scale

Table 3. Summary and baseline characteristics of the included studies

Author	Country, Year	Study design	Sample size			Sample age (years)	TC (mg/dL) [Mean ± SD]	
			T1DM	Control	Total		T1DM	Control
Alakkad et al. (21)	Egypt, 2020	Case control	50	25	75	9-19	164.88±39.54	152.22±30.55
Alwasity et al. (22)	Iran, 2022	Case control	52	52	104	6-18	175±55	136±34
Angelopoulou et al. (15)	Greece, 2024	Cross sectional	56	56	112	9-13	166.33±32.72	154.67±15.98
Heier et al. (18)	Norway, 2017	Cohort	293	111	404	8-18	178±31	166±27
Mona et al. (19)	Egypt, 2015	Cohort	N/A	N/A	60	9-16	N/A	N/A
Parthasarathy et al. (12)	India, 2015	Cross sectional	80	54	134	5-17	157±33.5	153.5±27.7
Peña et al. (20)	Australia, 2016	Cohort	77	33	110	10-18	170±42.53	158.54±26.29
Prado et al. (14)	Berlin, 2017	Cross sectional	42	20	62	10-15	164.73±38.28	160.09±39.83
Trigona et al. (17)	Switzerland, 2019	Cross sectional	32	42	74	6-17	170.39±17.70	160±11.87
Wu et al. (13)	London, 2021	Cross sectional	48	19	67	12-17	155.84±31.32	121.42±25.9
Zabeen et al. (16)	India, 2018	Cross sectional	N/A	N/A	422	10-18	N/A	N/A

Table 3. Continued

Author	TG (mg/dL) [Mean ± SD]		HDL (mg/dL) [Mean ± SD]		LDL (mg/dL) [Mean ± SD]		Results
	T1DM	Control	T1DM	Control	T1DM	Control	
Alakkad et al. (21)	85.85±49.50	82.50±42.22	49.78±17.98	47.28±11.33	98.60±35.80	91.55±26.70	Not significant
Alwasity et al. (22)	140±35	74±25	59±19	53±15	93±51	68±30	Lipid abnormalities (TC, TG, LDL) were significantly higher in diabetic patients than in the control group
Angelopoulou et al. (15)	53.33±16.74	58.33±20.54	NA	NA	89.00±31.20	83±15.98	The median TC was significantly higher in diabetic children compared to the control group
Heier et al. (18)	62±44.80	62±44.80	70±15	66±15	97±27	89±27	Reduced HDL function in children and young adults with T1DM compared to the control subjects (p<0.001)
Mona et al. (19)	N/A	N/A	N/A	N/A	N/A	N/A	Dyslipidemia was significantly more frequent among T1DM children and adolescents compared to the control subjects (39/60, 65% vs. 11/39, 28.2%, p<0.001). The most frequent type of dyslipidemia was high LDL and low HDL in the dyslipidemic group
Parthasarathy et al. (12)	71±26.5	71.5±30.5	48.2±13.1	53.1±11.9	95.3±27.7	84.5±26.4	Children and adolescents with T1DM had an abnormal lipid compared to the control group
Peña et al. (20)	36.73±34.02	33.64±13.53	63.03±12.76	58±13.53	92.80±34.80	81.20±20.10	Not significant
Prado et al. (14)	32.86±12.76	38.67±7.34	43.31±10.44	40.21±10.44	102.86±38.28	101.70±46.01	Not significant
Trigona et al. (17)	46.05±20.61	50.58±10.88	56.45±6.6	54.37±5.64	104.7±15.59	96.67±10.68	Not significant
Wu et al. (13)	78.82±27.45	53.14±37.19	57.23±10.82	49.88±16.24	89.32±27.84	67.28±14.69	T1DM showed higher levels of TC, LDL, TG compared with the control group
Zabeen et al. (16)	N/A	N/A	N/A	N/A	N/A	N/A	More than half (65%) of the children and adolescents with T1DM had dyslipidemia

TC: Total cholesterol, TG: Triglycerides, HDL: High-density lipoprotein, LDL: Low-density lipoprotein, SD: Standard deviation, T1DM: Type 1 diabetes mellitus, N/A: Not applicable

Meta-Analysis Results

Four lipid profile parameters were compared between T1DM and healthy children: TC, TG, HDL-C, and LDL-C. All four parameters were higher in T1DM children than in the control groups, with three showing statistical significance. TC levels were found to be significantly higher in T1DM children, with substantial heterogeneity observed [MD=14.31 (8.39, 20.43), p<0.00001; I^2=62%, p=0.007]. TG levels were also found to increase in T1DM children, but statistically insignificantly. These findings had the highest heterogeneity across all studies [MD=8.62 (-0.41, 21.25), p=0.18; I^2=94%, p=0.18]. In contrast, HDL-C were found to have significantly higher levels in T1DM children, with substantial heterogeneity observed [MD=2.66 (0.08, 5.23), p=0.04; I^2=56%, p=0.03]. LDL-C levels were found to be significantly higher in T1DM children, with the lowest heterogeneity across the studies [MD=10.99 (6.99, 14.76), p<0.00001; I^2=23%, p=0.24]. Forest plots are shown in Figures 2.1 to 2.4. Sensitivity analyses were performed in order to assess the influence of individual studies, and the overall findings remained robust. Funnel plots for each result are shown in Figures 2.5 to 2.8.

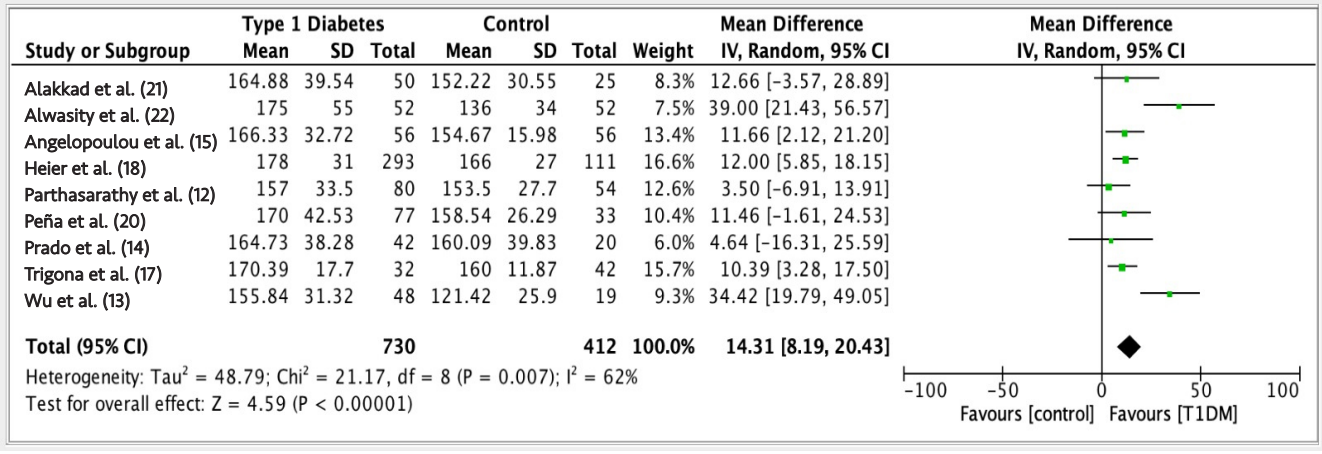

Figure 2.1. Meta-analysis forest plot of TC in children and adolescents with T1DM versus healthy controls
TC: Total cholesterol, SD: Standard deviation, T1DM: Type 1 diabetes mellitus, CI: Confidence interval

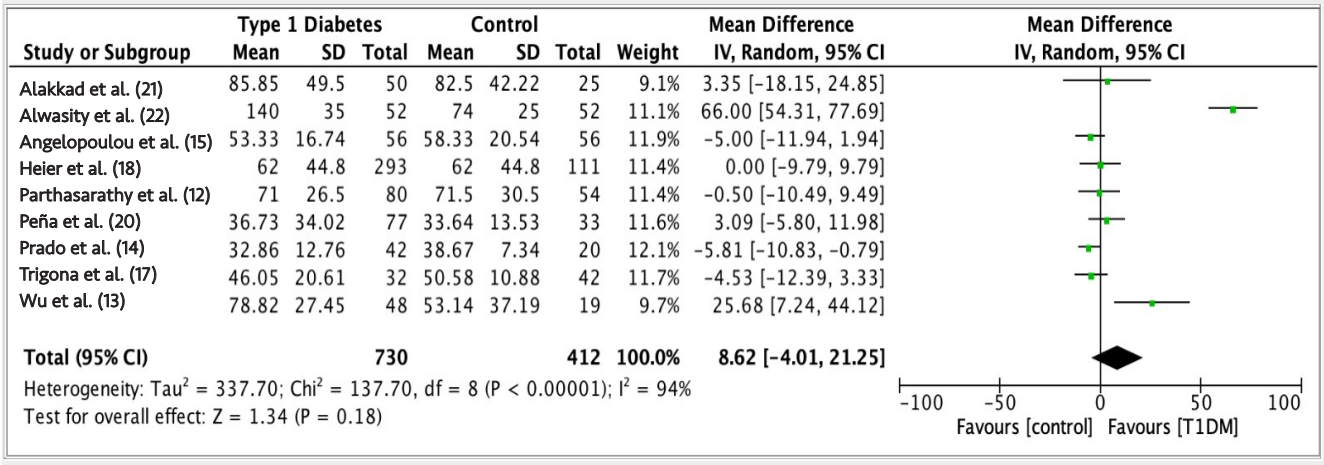

Figure 2.2. Meta-analysis forest plot of TG in children and adolescents with T1DM versus healthy controls
TG: Triglycerides, SD: Standard deviation, T1DM: Type 1 diabetes mellitus, CI: Confidence interval

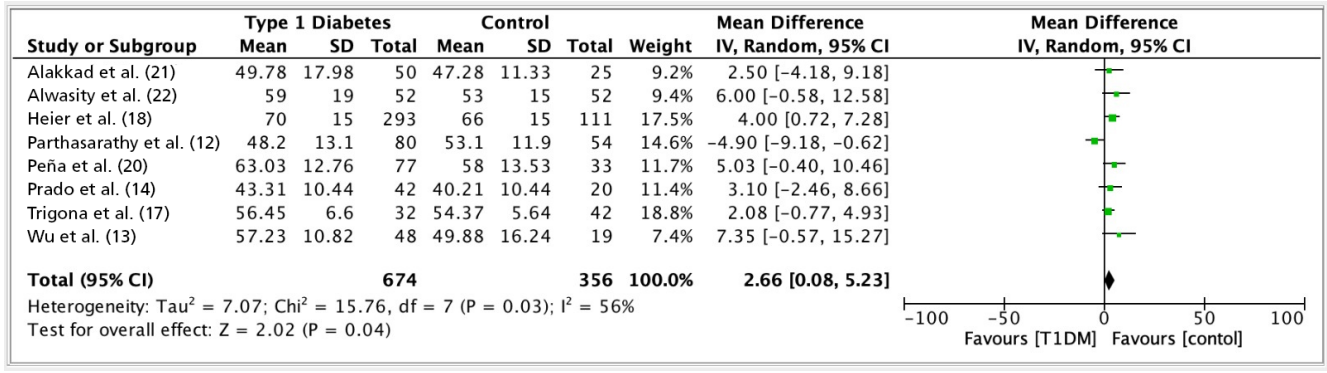

Figure 2.3. Meta-analysis forest plot of HDL-C in children and adolescents with T1DM versus healthy controls
HDL-C: High-density lipoprotein-cholesterol, SD: Standard deviation, T1DM: Type 1 diabetes mellitus, CI: Confidence interval

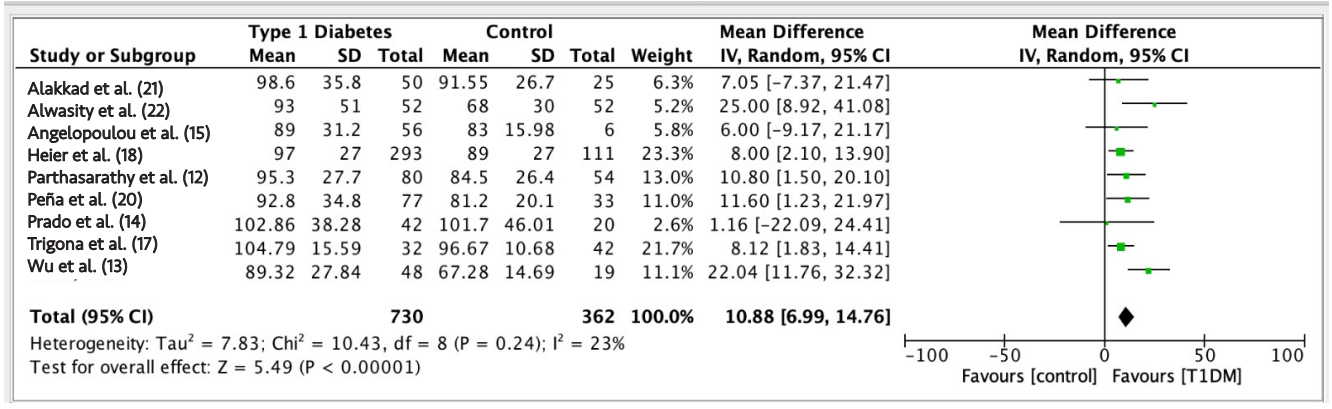

Figure 2.4. Meta-analysis forest plot of LDL-C in children and adolescents with T1DM versus healthy controls
LDL-C: Low-density lipoprotein-cholesterol, SD: Standard deviation, T1DM: Type 1 diabetes mellitus, CI: Confidence interval

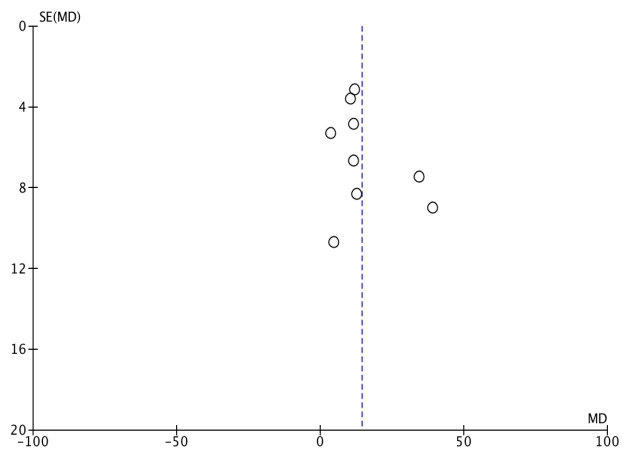

Figure 2.5. Funnel plot of TC in children and adolescents with T1DM versus healthy controls
TC: Total cholesterol, T1DM: Type 1 diabetes mellitus, MD: Mean difference

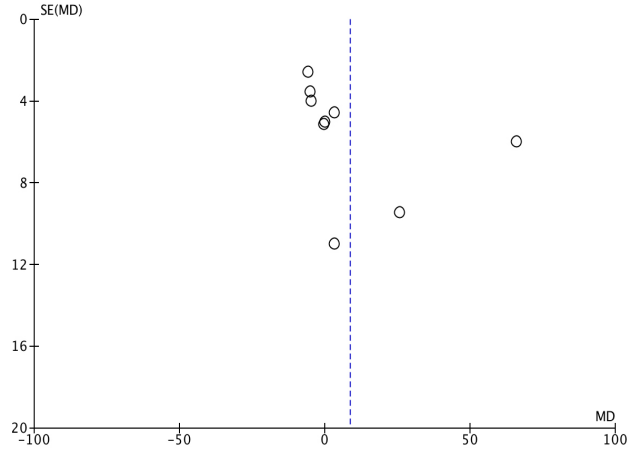

Figure 2.6. Funnel plot of TG in children and adolescents with T1DM versus healthy controls
TG: Triglycerides, T1DM: Type 1 diabetes mellitus, MD: Mean difference

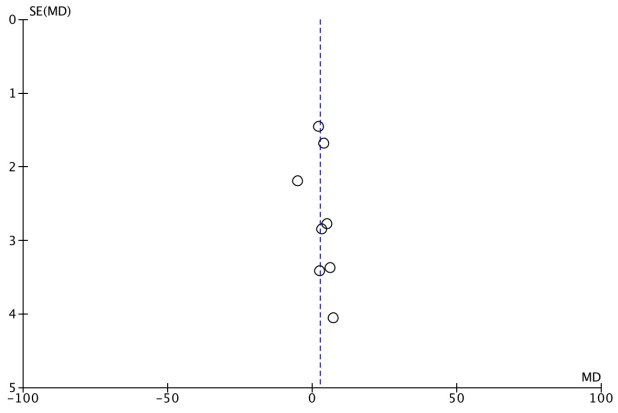

Figure 2.7. Funnel plot of HDL-C in children and adolescents with T1DM versus healthy controls
HDL-C: High-density lipoprotein-cholesterol, T1DM: Type 1 diabetes mellitus, MD: Mean difference

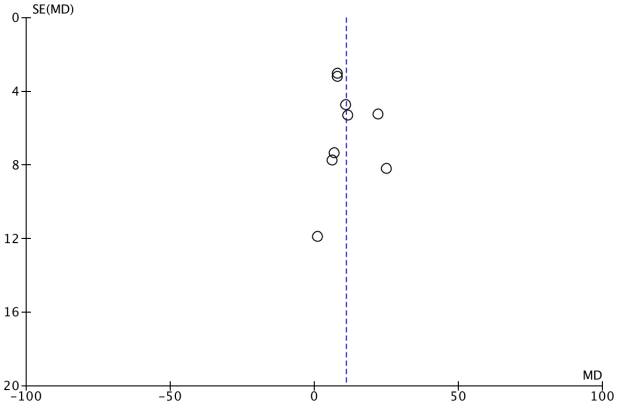

Figure 2.8. Funnel plot of LDL-C in children and adolescents with T1DM versus healthy controls
LDL-C: Low-density lipoprotein-cholesterol, T1DM: Type 1 diabetes mellitus, MD: Mean difference

Discussion

In this meta-analysis of the pediatric population with T1DM, we found that all four lipid parameters, namely TC, TG, HDL-C and LDL-C, were higher in pediatric T1DM patients compared with the control groups. Among these, TC, LDL-C and HDL-C were significantly elevated, while TG did not differ significantly and demonstrated the greatest between-study heterogeneity. These findings confirm that dyslipidemia in T1DM begins early in life, long before the onset of overt CVD, and so they support the importance of routine lipid monitoring from childhood (23,24).

The finding of elevated TC and TG levels in this study was in line with previous studies (25). Indeed, a study by Fagundes Melo et al. (24) 2014 found TC and TG were the main altered lipid parameters. A positive correlation was found between TC and TG with respect to age and the duration of disease (10). The level was reported to increase according to the time of the disease. Poor glycemic control is the key.

The elevation of LDL-C was statistically significant with the lowest heterogeneity across studies. LDL-C is the primary atherogenic lipoprotein, and its elevation in childhood carries lifelong implications, as cumulative LDL-C exposure is a major determinant of premature coronary artery disease (26). Mechanistically, chronic hyperglycemia induces non-enzymatic glycation of apoB-containing lipoproteins, reducing their clearance through LDL-C receptors and leading to prolonged circulation times. In addition, hepatic alterations associated with relative insulin deficiency or fluctuating replacement, such as increased VLDL secretion, further augment LDL-C burden (27,28). These mechanisms explain the robustness of LDL-C elevation in pediatric T1DM despite insulin therapy. Recent cohort data from Brazilian children and adolescents further confirm the high prevalence of LDL-C abnormalities in T1DM, highlighting their relevance in diverse populations (24).

The finding of significantly elevated HDL-C levels in T1DM requires cautious interpretation. Although traditionally considered protective, there is evidence that higher HDL-C in T1DM does not necessarily confer cardiovascular benefit. Studies in adolescents have shown that, despite normal-to-high HDL-C levels, markers of vascular dysfunction, such as impaired flow-mediated dilation remain present, suggesting that HDL particles in T1DM may be dysfunctional (29).

Our results suggest that LDL-C remains the most reliable and clinically actionable lipid marker in pediatric T1DM. Although higher HDL-C levels are traditionally considered protective, their role in this population is less clear, and potential dysfunction may limit the expected benefits. Clinicians should therefore interpret elevated HDL-C with caution, while recognizing that further studies are needed in order to clarify its clinical significance. These findings reinforce the need for early and routine dyslipidemia screening and aggressive LDL-C reduction strategies in pediatric T1DM, in line with contemporary guidelines, while also highlighting the limitations of standard lipid panels in capturing the complexity of dyslipidemia in this group. Future research should employ advanced lipidomic approaches, including nuclear magnetic resonance-based lipid profiling, in order to characterize qualitative alterations in lipoprotein subclasses and particle functionality. Such

high-resolution techniques may help elucidate the true nature of dyslipidemia in pediatric T1DM, which cannot be fully captured by conventional fasting lipid panels.

Study Limitations

This systematic review and meta-analysis provides an up-to-date synthesis of the available studies examining lipid profiles in children and adolescents with T1DM. Several limitations should be acknowledged. First, substantial heterogeneity was observed, particularly in triglyceride outcomes, likely reflecting differences in study design, sample size, disease duration, glycemic control, and insulin regimens. Second, as most of the included studies were observational, causal relationships between T1DM and lipid abnormalities could not be established. Third, data on important confounding factors such as pubertal status, body mass index, and socioeconomic background, which may have influenced lipid outcomes, were inconsistently reported. Finally, hereditary dyslipidemias, which are often polygenic and inherited in an autosomal dominant manner, may also have contributed to the variability in lipid profiles but they were not captured in this analysis.

Future Studies

Future research should prioritize standardized reporting of lipid outcomes, stratified by age, pubertal status, glycemic control, and insulin therapy, in order to reduce heterogeneity and allow more precise comparisons. Longitudinal cohort studies are needed to clarify temporal relationships between glycemic control, lipid abnormalities, and vascular outcomes. Randomized controlled trials evaluating the impact of early lipid-lowering interventions, including statins or lifestyle modifications, in pediatric T1DM would provide critical evidence to guide clinical practice. Additionally, more detailed investigations into HDL functionality, beyond conventional concentration-based measurements, are warranted in order to determine whether the observed increases in HDL-C truly confer cardiovascular protection in this population.

Conclusion

Children and adolescents with T1DM exhibit early dyslipidemia, with significantly higher TC, LDL-C, and HDL-C compared to healthy controls. The early onset of these abnormalities highlights a potential increased risk of CVD. However, given the observational nature of the included studies and variability across populations, these findings should be interpreted with caution. While HDL-C was found to be elevated, its functional implications remain uncertain and requires further investigation. Overall, our results support the importance of early lipid screening and careful LDL-C monitoring in pediatric T1DM, but future studies are needed in order to clarify the role of HDL and to establish evidence-based preventive strategies.

Ethics

Informed Consent: Informed consent was not required for this study because it is a systematic review and meta-analysis based on previously published data.

Footnotes

Authorship Contributions

Concept: M.O., J.C., T.D., Design: M.O., J.C., T.D., Data Collection or Processing: M.O., J.C., T.D., Analysis or Interpretation: M.O., J.C., T.D., Literature Search: M.O., J.C., T.D., Writing: M.O., J.C., T.D.

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