Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Lipoprotein(a) in Pediatric Type 1 Diabetes: The Role of Pubertal Maturation Beyond Glycemic Control – A retrospective cross-sectional study

Anna Wołoszyn-Durkiewicz
ania0212@gumed.edu.pl
Gdańsk Medical University
Patrycja Rozwadowska-Kunecka
Gdańsk Medical University
Mateusz Okonek
Gdańsk Medical University
Gabriela Gawlak
Gdańsk Medical University
Maciej Banach
Medical University of Lodz
Małgorzata Myśliwiec
Gdańsk Medical University

Research Article

Keywords: Type 1 diabetes, Lipoprotein(a), Puberty, Tanner stage, Cardiovascular risk

Posted Date: November 13th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11561944/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Lipoprotein(a) in Pediatric Type 1 Diabetes: The Role of Pubertal Maturation Beyond Glycemic Control – A retrospective cross-sectional study

Anna Wołoszyn-Durkiewicz[a,b]*, Patrycja Rozwadowska-Kunecka[a]*(†), Mateusz Okonek[b,c], Gabriela Gawlak[c], Maciej Banach[d,e,f], Małgorzata Myśliwiec[a,b]

[a]Department of Pediatrics, Diabetology and Endocrinology, University Clinical Center in Gdańsk, Gdańsk, Poland

[b]Department of Pediatrics, Diabetology and Endocrinology, Faculty of Medicine, Medical University of Gdańsk, Gdańsk, Poland

[c]Student Scientific Circle of Pediatrics, Diabetology and Endocrinology, Faculty of Medicine, Medical University of Gdańsk, Gdańsk, Poland

[d] Department of Preventive Cardiology and Lipidology, Medical University of Lodz, Lodz, Poland

[e] Faculty of Medicine, the John Paul II Catholic University of Lublin, Lublin, Poland

[f] Ciccarone Center for the Prevention of Cardiovascular Disease, Johns Hopkins University School of Medicine, Baltimore, MD, USA

The study was conducted on Department of Pediatrics, Diabetology and Endocrinology, University Clinical Center in Gdańsk, Gdańsk, Poland

*** Correspondence:**
Anna Wołoszyn-Durkiewicz
anna.woloszyn-durkiewicz@gumed.edu.pl

(†) Anna Wołoszyn-Durkiewicz and Patrycja Rozwadowska-Kunecka have contributed equally to this work.

Abstract

Background and Aims: Children and adolescents with type 1 diabetes (T1D) are at increased lifetime risk of cardiovascular disease (CVD). Lipoprotein(a) [Lp(a)] is an inherited CVD risk factor, but data in pediatric T1D are limited. We assessed Lp(a) concentrations, the prevalence of elevated Lp(a), and their associations with clinical characteristics, lipid profile, and pubertal maturation.

Methods: This retrospective, cross-sectional study included 516 children and adolescents (0–18 years) with T1D. Serum Lp(a) was measured by particle-enhanced immunoturbidimetric assay. Elevated Lp(a) was defined as ≥50 mg/dL. Associations with clinical variables, lipid parameters, and Tanner stage were evaluated using non-parametric tests and multivariable analysis.

Results: Median Lp(a) concentration was 8.0 mg/dL, and elevated Lp(a) was found in 66 patients (12.8%). Lp(a) was not associated with diabetes duration, HbA1c, new-onset diabetes, or diabetic ketoacidosis. Weak positive correlations were observed with LDL-C (r_s=0.259, p<0.001) and non-HDL-C (r_s=0.264, p<0.001). Lp(a) increased across Tanner stages, and the prevalence of elevated Lp(a) rose from 7.0% in stage 1 to 19.8% in stage 5. Tanner stage remained independently associated with Lp(a) after adjustment for sex, HbA1c, and LDL-C.

Conclusions: Elevated Lp(a) was common in pediatric T1D and increased with pubertal maturation. These findings suggest that pubertal stage should be considered when interpreting Lp(a) concentrations. Longitudinal studies are needed to determine the clinical value of Lp(a) in cardiovascular risk assessment.

Keywords: Type 1 diabetes, Lipoprotein(a), Puberty, Tanner stage, Cardiovascular risk

1. Introduction

Type 1 diabetes (T1D) is associated with an increased lifetime risk of cardiovascular disease (CVD), and reduced life expectancy, particularly when disease onset occurs early in childhood. In a large Swedish registry, diagnosis of T1D before 10 years of age was associated with an estimated loss of 17.7 life-years in women and 14.2 life-years in men, and age at onset was an important determinant of survival and cardiovascular outcomes [1]. CVD remains a major contributor to excess morbidity and mortality in T1D [2]. Standard risk assessment in children with T1D is largely based on glycemic control and regular screening for diabetes-related complications and CVD risk factors, including blood pressure measurement, conventional lipid profile assessment, albuminuria screening, and retinal examination [3]. However, these markers may not fully identify children who carry additional genetically determined cardiovascular risk. However, routine assessment does not include lipoprotein(a) [Lp(a)] measurement; therefore, children with elevated additional inherited Lp(a)-related cardiovascular risk may remain unidentified.

Lp(a) is a predominantly genetically determined lipoprotein with proatherogenic and prothrombotic properties. Elevated Lp(a) is recognized as an independent cardiovascular risk factor [4,5], but its role in pediatric T1D remains insufficiently characterized. This is clinically relevant because children with T1D and elevated Lp(a) may represent a subgroup requiring more careful CVD risk assessment beyond routine clinical evaluation.

Although Lp(a) is often regarded as relatively stable from early life, available pediatric data suggest that its concentrations may change during development [6]. However, emerging evidence indicates that levels reached at the age of 18 months or later reflect those in adulthood and are strongly linked to parental levels [7]. Puberty is characterized by marked endocrine and metabolic changes, including alterations in insulin sensitivity, body composition [8], and lipid metabolism [9]. However, evidence directly linking Tanner stage with Lp(a) remains scarce and is largely derived from older general-population pediatric studies [10], whereas recent pediatric

T1D data are still limited and focus mainly on longitudinal Lp(a) variability rather than pubertal maturation specifically [11].

Thus, the study aimed to assess the distribution of Lp(a) concentrations and the prevalence of elevated Lp(a) in children and adolescents with T1D. We further investigated whether Lp(a) concentrations are associated with diabetes-related factors, conventional lipid parameters, family history of cardiovascular disease, sex, age, and pubertal maturation assessed by Tanner stage.

2. Material and methods

2.1. *Study design*

This was a retrospective, single-center, cross-sectional study conducted at the Department of Pediatrics, Diabetology and Endocrinology, Medical University of Gdansk. Medical records of consecutive children with T1D hospitalized between January 2023 and March 2026 were reviewed. For patients with multiple hospitalizations during the study period, the analysis was based on a single hospitalization record in which Lp(a) concentration was measured. All the data were anonymized prior to analysis. The Bioethics Committee at the Medical University of Gdansk approved the study (Resolution No. KB/241/2026). Due to the retrospective design of the study, the requirement for informed consent was waived. The study was conducted in accordance with the principles of the Declaration of Helsinki.

2.2. *Study group and data collection*

The study group consisted of 516 children and adolescents aged 0 to 18 years. Inclusion criteria comprised: a diagnosis of T1D according to the International Society for Pediatric and

Adolescent Diabetes (ISPAD) criteria [12], age between 0 and 18 years, and available serum Lp(a) measurements. Exclusion criteria for T1D patients comprised: incomplete medical records, diabetes other than T1D, concomitant diagnosis of familial hypercholesterolemia or use of lipid-lowering treatment, uncontrolled chronic diseases other than diabetes, cardiovascular events (such as stroke, myocardial infarction), surgery or trauma within the preceding 6 months or severe infections. Individuals meeting these criteria were considered eligible for inclusion in the study. Patients with diabetic ketoacidosis (DKA), (*n*= 90, 17.44%) were not excluded from the primary analysis in order to evaluate its potential effect on Lp(a) concentration, however, this subgroup was not included in regression modeling to avoid confounding by acute metabolic status.

Demographic, clinical, and laboratory data were extracted from electronic medical records. The collected variables included sex, age, duration of diabetes, age at T1D onset, anthropometric measurements, including body mass index (BMI), Tanner stage, the presence of DKA during hospitalization, and family history (up to second-degree relatives) of CVD, venous thromboembolism (VTE), diabetes, dyslipidemia, obesity, and hypertension. Positive CVD family history was defined as a family history of myocardial infarction, stroke, or venous thromboembolism in first- or second-degree relatives.

2.3. Laboratory measurements

Laboratory tests included glycated hemoglobin (HbA1c) and lipid profile parameters: total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C)**,** remnant cholesterol (RC), and triglycerides (TG). RC refers to the fraction of cholesterol contained in triglyceride-rich lipoproteins, such as very-low-density lipoprotein cholesterol (VLDL-C) and intermediate-density lipoprotein (IDL-C). The RC parameter was calculated as the difference between the total cholesterol concentration and the

combined concentrations of HDL and LDL cholesterol. Serum Lp(a) concentrations were measured using a particle-enhanced immunoturbidimetric assay with the Alinity c Lp(a) Reagent Kit on an Alinity c analyzer (Abbott Laboratories, Abbott Park, IL, USA). Lp(a) levels ≥50 mg/dL were considered elevated.

Lp(a) measurements were carried out during hospitalization after overnight fasting. All laboratory measurements were performed in the hospital's central laboratory. In patients hospitalized due to DKA, Lp(a) was measured 2–3 days after DKA resolution.

2.4. *Statistical analysis*

All analyses were performed in STATA, version 19.5 Basic Edition (StataCorp LLC College Station, TX, USA). A two-tailed p-value < 0.05 was considered statistically significant. The number of available observations varied between analyses because of missing data.

For continuous variables, descriptive statistics included mean, standard deviation (SD), median, interquartile range (IQR), and minimum and maximum values. Categorical variables were presented as frequencies and percentages. The Shapiro –Wilk test was used to assess the normality of continuous variable distributions.

As the data deviated from normality, the non-parametric Mann–Whitney U test was applied. For comparisons involving more than two groups, the Kruskal–Wallis test was used, followed by post-hoc pairwise comparisons using Dunn's test where appropriate. Effect size for the Kruskal–Wallis test was assessed using epsilon-squared (ε^2). Categorical variables were compared between groups using the chi-square test. To assess linear trends across ordered categories (Tanner stages), the Cochran–Armitage test was applied for categorical outcomes (prevalence of elevated Lp(a)), while Cuzick's non-parametric test was used for continuous outcomes (Lp(a) concentrations). Effect size for non-parametric trend tests was calculated as $r = z/\sqrt{N}$.

Due to the right-skewed distribution of Lp(a), non-parametric methods were used for group comparisons and correlation analyses. Correlations were assessed using Spearman's rank correlation coefficient. Age-related correlations were assessed in the entire study cohort. Correlations involving diabetes duration and HbA1c were restricted to patients with established T1D, as these variables more accurately reflect disease course and chronic metabolic control in this subgroup. Correlations between Lp(a) and lipid profile parameters were assessed after excluding patients with DKA to minimize the potential confounding effect of acute metabolic decompensation on lipid parameters. As a sensitivity check, analyses were repeated using log-transformed Lp(a), with unchanged results. To account for multiple testing, the false discovery rate (FDR) was controlled using the Benjamini–Hochberg procedure. FDR-adjusted *p*-values are reported as p_{adj}, with $p_{adj} < 0.05$ considered statistically significant. For post-hoc pairwise comparisons following Dunn's test, FDR correction was applied within the family of pairwise comparisons. To assess the stability of the correlation estimates and account for potential leverage effects after outlier exclusion, the 95% confidence intervals for the correlation coefficients were validated using bootstrap resampling with 10,000 replications.

To evaluate the association between age and Lp(a) levels, simple linear regression was performed using log-transformed Lp(a) (ln[Lp(a)]) due to its skewed distribution. Age was included as a continuous variable. Regression coefficients were back-transformed to report the percentage change in Lp(a) per 1-year increase in age, computed as $\left(e^{\beta} - 1\right) \times 100\%$ alongside 95% confidence intervals. Model linearity and homoscedasticity were confirmed using Ramsey's RESET test (F [3,416] = 0.08, p=0.968) and the Breusch–Pagan test (χ^2 [1] = 0.80, p=0.372), respectively. Despite residual skewness ($p < 0.001$, D'Agostino skewness test), statistical inference was based on the asymptotic normality of OLS estimators given the large sample size (n=421).

Due to the right-skewed distribution of Lp(a) levels, multivariable generalized linear modeling (GLM) with gamma distribution and log link function was applied to evaluate the association between pubertal development, assessed by Tanner stages, and Lp(a) levels. The model was adjusted for sex, metabolic control (HbA1c), and LDL-C concentrations. LDL-C was specifically selected as the primary lipid covariate due to its significant correlation with Lp(a) in univariate analysis and its biological relationship with Lp(a) metabolism. To ensure data robustness, we restricted the analysis to patients aged >5 years and excluded individuals with diabetic ketoacidosis (DKA) or extreme HbA1c outliers (>14%), resulting in a final study group of 340 individuals. We did not include chronological age and BMI z-score in the final model due to evidence of multicollinearity with Tanner stages, reflecting the close relationship between chronological age, somatic growth, and pubertal maturation. This approach was used to avoid overadjustment and ensure model stability. Multicollinearity among the included predictors was assessed using variance inflation factors (VIF) and pairwise correlation matrices. Results were expressed as exponentiated coefficients [exp(β)] with 95% confidence intervals.

The overall effect of Tanner stage was assessed using a Wald chi–square test. Potential interaction between age and Tanner stage was evaluated by including an interaction term in the model and assessed with a Wald F test. Adjusted mean Lp(a) concentrations across Tanner stages were estimated using predictive margins derived from the fitted models. Model specification was assessed using the Pregibon link test. Model fit was evaluated using deviance and Pearson chi-square statistics. Deviance and Anscombe residuals were visually inspected to assess residual patterns and potential violations of model assumptions.

4. Results

4.1. Clinical characteristics of patients

The detailed clinical characteristics of the study group are presented in **Table 1**. The study group included 516 children and adolescents, with a median age of 13 years (IQR: 8–15). Females accounted for 43.6% of the cohort (*n*=225). The cohort was predominantly of participants of Polish origin (*n*=502, 97.3%), with a small proportion of patients of Ukrainian (*n*=12, 2.3%) and Belarusian (*n*=2, 0.4%) origin. The median duration of diabetes was of 4.5 years (IQR: 0.02–9.50). Elevated Lp(a), defined as ≥50 mg/dL, was observed in 66 patients with T1D (12.79%). The Lp(a) levels showed a markedly right-skewed distribution (skewness=2.81), with most observations clustered at the lower end of the scale. The median Lp(a) concentration was 8.0 mg/dL (IQR: 0.04–0.19), and 75% (*n*=387) of the participants had Lp(a) levels below 19.0 mg/dL. Markedly elevated Lp(a) levels (180–235 mg/dL) were observed in a small subset of patients (*n*=3, 0.58%), with the maximum recorded value of 235 mg/dL occurring in a single individual. The maximum recorded value reached 2.35 mg/dL, indicating a subset of pediatric patients with markedly elevated Lp(a) levels. The distribution of Lp(a) concentrations is shown in **Figure 1**.

When stratified by clinical status, the median HbA1c level in the established T1D subgroup was 7.5% (IQR: 6.8–8.7%). In contrast, patients with new-onset T1D had a higher median HbA1c level of 12.1% (IQR: 10.1–13.7%), contributing to an overall cohort median of 8.10% (IQR: 7.10–10.85%). A positive family history for venous thromboembolism (VTE) was reported in 21 participants (4.14%), whereas a family history of myocardial infarction was reported in 107 individuals (21.10%).

Table 1.

Figure 1.

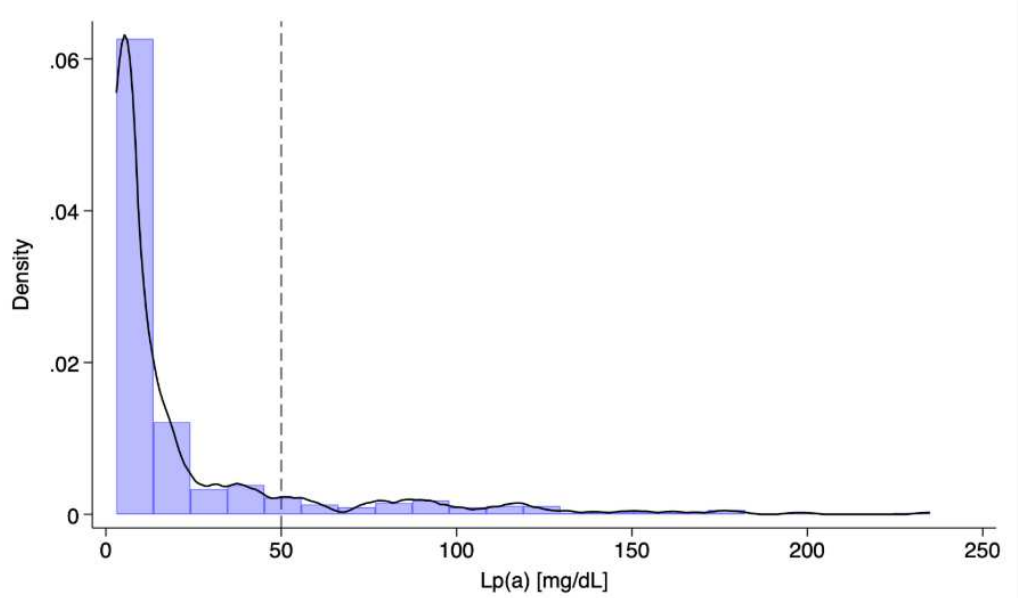


***Figure 1*. Distribution of serum lipoprotein(a) [Lp(a)] concentrations in the study cohort (*n*=516).** The histogram displays the density distribution of Lp(a) concentrations, and the solid line represents the kernel density estimate. The dashed vertical line indicates the threshold for elevated Lp(a) concentration (50 mg/dL), observed in 66 patients (12.79%).

4.2 T1D-related Characteristics

To evaluate whether T1D-related clinical characteristics were associated with Lp(a) concentrations, we performed subgroup and correlation analyses. We found no significant difference in Lp(a) concentrations between patients with established T1D and those with new-onset T1D [*n*=359, 8.0 mg/dL (IQR: 0.04–0.18) vs. *n*=157, 7.0 mg/dL (IQR: 0.04–0.21), respectively; *p*=0.903]. Similarly, Lp(a) concentrations did not differ significantly between patients without and with DKA during hospitalization [no DKA: *n*=426, 8.0 mg/dL (IQR: 0.04–0.19); DKA: *n*=90, 7.0 mg/dL (IQR: 0.04–0.20); *p*=0.605]. Given that diabetes duration and HbA1c more accurately reflect disease course and chronic metabolic control in patients with established T1D, correlation analyses involving these variables were restricted to this subgroup. Diabetes duration was not significantly correlated with Lp(a) concentration (r_s < 0.01, 95% bootstrap CI: −0.106 to 0.094, *p*=0.910, *n*=359, p_{adj}=0.910). Similarly, HbA1c was not

significantly correlated with Lp(a) concentration (r_s=0.083, 95% bootstrap CI: −0.022 to 0.187, p=0.123, p_{adj}=0.164, n=351).

4.3 Age

Spearman's rank correlation showed a statistically significant, albeit weak, positive association between age and Lp(a) concentration (r_s=0.13, 95% bootstrapped CI: 0.038 to 0.212, p=0.005, n=516). After FDR correction, this association was of borderline statistical significance (p_{adj}=0.009). In the univariable regression analysis excluding patients with DKA (n=421), continuous age was significantly associated with Lp(a) levels. Back-transformed estimates showed a 3.05% increase in Lp(a) per 1-year increase in age (95% CI: 0.43% to 5.67%, p=0.022).

Figure 2.

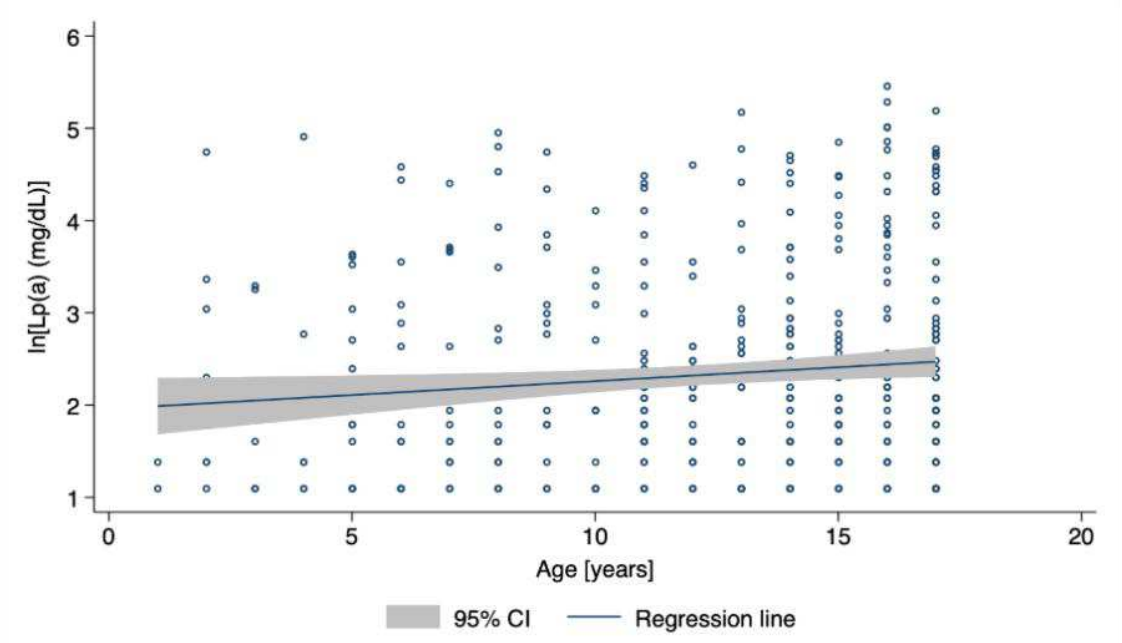


Figure 2. Scatter plot with linear regression line and 95% confidence interval showing the relationship between age and natural log-transformed lipoprotein(a) levels (lnLp(a)) in patients without DKA (n=421, p=0.021, R^2=0.013).

4.4 Sex

We found no statistically significant difference in Lp(a) concentrations between males and females (p=0.126). Median Lp(a) levels were comparable between males [*n*=291, 7.0 mg/dL (IQR: 0.04–0.19)] and females [*n*=225, 8.0 mg/dL (IQR: 0.04–0.20)].

4.5 Tanner stages

We compared Lp(a) concentrations across the five Tanner stages in 486 participants with available Tanner staging data. Lp(a) concentrations differed significantly across pubertal maturation stages (χ^2 (4) =14.21, p=0.007), indicating a non-uniform distribution across the Tanner spectrum, although the effect size was small (ε^2=0.02; **Figure 3**). Cuzick's non–parametric test for trend further supported a significant upward trend in Lp(a) concentrations across Tanner stages (z=3.34, p<0.001), with a small effect size (r=0.15).

Post-hoc pairwise comparisons using Dunn's test showed higher Lp(a) concentrations in Tanner stage 3 compared with Tanner stage 1 (p=0.011) and in Tanner stage 5 compared with Tanner stages 1 (p<0.001) and 2 (p=0.009). After FDR correction for multiple comparisons, the differences between Tanner stages 1 and 3 (p_{adj}=0.038), 1 and 5 (p_{adj}=0.005), and 2 and 5 (p_{adj}=0.038) remained statistically significant.

To evaluate the relationship between Tanner stage and the prevalence of elevated Lp(a), we performed a Pearson chi-square test of independence. The prevalence of elevated Lp(a) increased with pubertal maturation, from 7.0% in Tanner stage 1 to 19.8% in Tanner stage 5. This association was statistically significant (χ^2=13.11, df=4, p=0.011; ***Figure 4***). The Cochran–Armitage test further demonstrated a significant linear increase in the prevalence of elevated Lp(a) across the stages (z=3.39, p<0.001).

Figure 3.

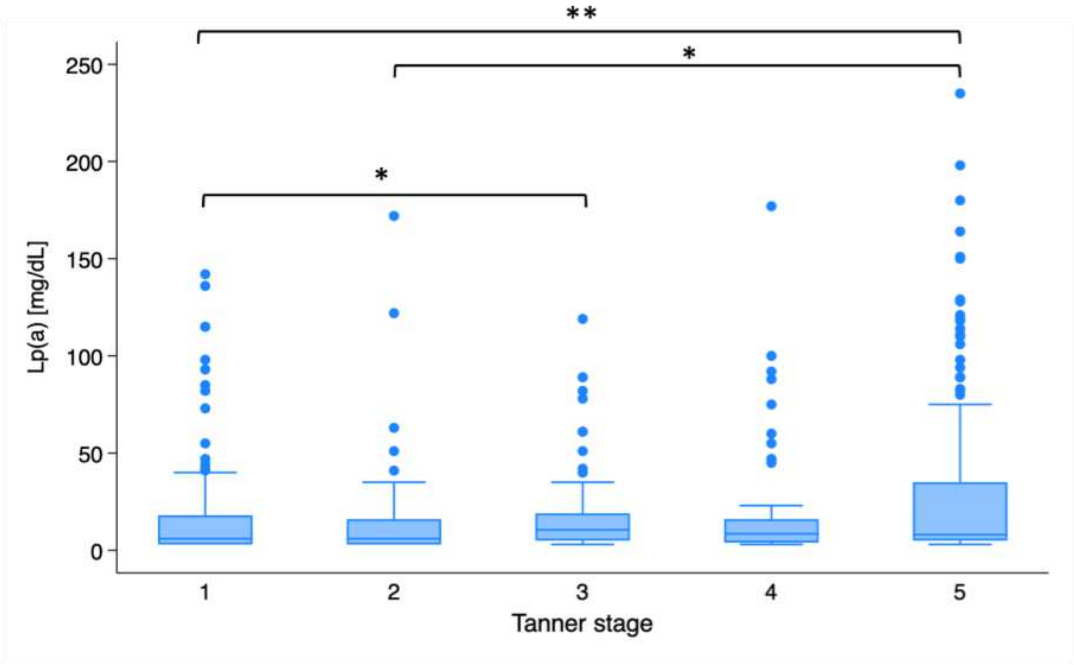


Figure 3. **Distribution of serum lipoprotein(a) [Lp(a)] concentrations across Tanner stages 1–5.** Boxplots represent the median, interquartile range, and whiskers extending to 1.5 × IQR. Individual points indicate outliers. Brackets indicate significant post-hoc Dunn's pairwise comparisons after FDR correction. Statistical significance is denoted as p_{adj}<0.05 (*) and p_{adj}<0.01 (**). The numbers of participants in Tanner stages 1–5 were n=142 (29.22%), 51 (10.49%), 62 (12.76%), 64 (13.17%), and 167 (34.36%), respectively.

Table 2.

Table 2. Post-hoc pairwise comparisons of lipoprotein(a) [Lp(a)] concentrations across Tanner stages. Pairwise comparisons were performed using Dunn's test following a significant Kruskal–Wallis test. The false discovery rate was controlled using the Benjamini–Hochberg procedure. Adjusted p-values are reported as p_{adj}. Statistically significant results are shown in bold.

Comparison	unadjusted *p*	FDR-adjusted *p*
Tanner 1 vs 2	0.493	0.493
Tanner 1 vs 3	**0.011**	**0.038**
Tanner 1 vs 4	0.154	0.219
Tanner 1 vs 5	**<0.001**	**0.005**
Tanner 2 vs 3	**0.032**	0.081
Tanner 2 vs 4	0.202	0.252
Tanner 2 vs 5	**0.009**	**0.038**
Tanner 3 vs 4	0.140	0.219
Tanner 3 vs 5	0.430	0.477
Tanner 4 vs 5	0.068	0.136

Figure 4.

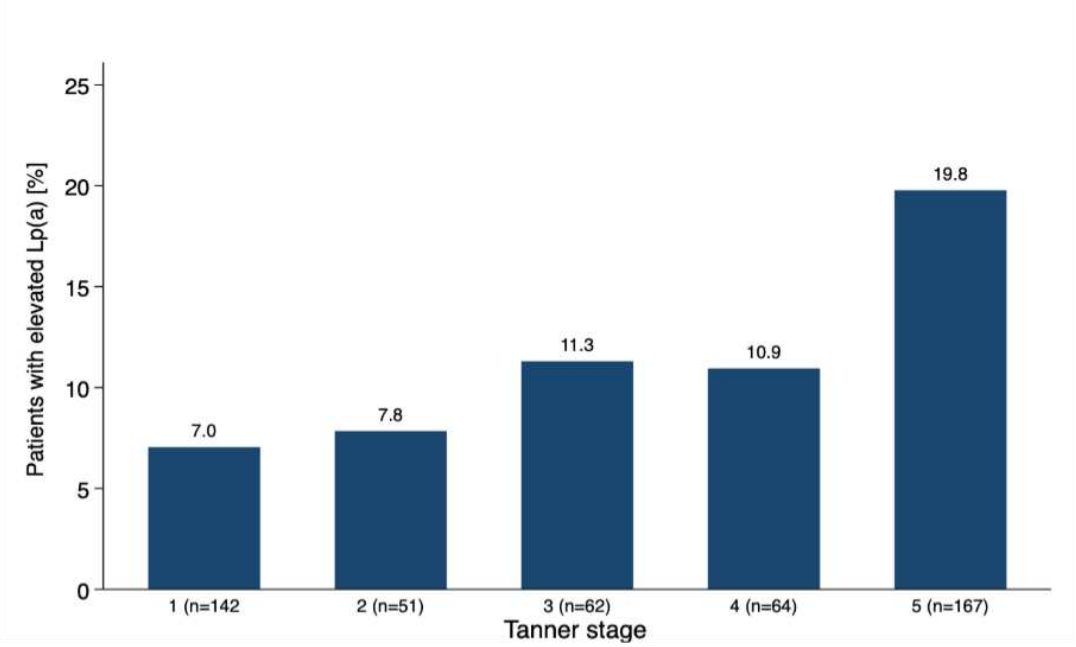


Figure 4. **Prevalence of elevated lipoprotein(a) [Lp(a)] concentrations across Tanner stages.** Bars represent the percentage of patients with T1D with elevated Lp(a), defined as Lp(a) ≥50 mg/dL, within each Tanner stage. Values above the bars represent percentages of participants in each Tanner stage. Pearson's chi-square test was used to assess differences across stages. The Cochran–Armitage test for trend showed a significant linear increase in the prevalence of elevated Lp(a) with advancing pubertal maturation (z=3.39, p <0.001).

4.6 Lipid Status

The correlations between Lp(a) concentration and lipid profile were assessed exclusively in the subgroup of patients without DKA to minimize the potential confounding effect of acute DKA on lipid parameters. Lp(a) concentration showed weak but statistically significant positive correlations with atherogenic lipid parameters, including LDL-C, TC, non-HDL-C, RC, and TG. These associations remained statistically significant after adjusting for multiple comparisons using the FDR procedure with p_{adj}<0.001 for LDL-C, TC, and non-HDL cholesterol, and p_{adj}=0.026 for TG. Conversely, no significant correlation was observed between Lp(a) and HDL-C or RC. Detailed correlation coefficients, 95% bootstrap confidence intervals, and FDR-adjusted p-values are presented in **Table 3**

Table 3.

Table 3. Correlations between Lp(a) concentration and lipid profile parameters. Correlations were assessed using Spearman's rank correlation coefficient in patients without DKA. Confidence intervals were estimated using bootstrap resampling with 10,000 replications. FDR-adjusted *p*-values were calculated using the Benjamini–Hochberg procedure. Statistically significant results are shown in bold. The model was restricted to patients without DKA and with extreme HbA1c outliers excluded.

Lipid parameter	*n*	r_s	95% bootstrap CI	*p*	p_{adj}
LDL-C	411	0.259	0.169 to 0.350	**<0.001**	**<0.001**
TC	421	0.249	0.157 to 0.341	**<0.001**	**<0.001**
non-HDL-C	299	0.264	0.158 to 0.370	**<0.001**	**<0.001**
TG	421	0.117	0.023 to 0.210	**0.016**	**0.024**
HDL-C	421	0.016	−0.079 to 0.111	0.743	0.743
RC	371	0.059	−0.044 to 0.162	0.254	0.305

CI, confidence interval; DKA, diabetic ketoacidosis; FDR, false discovery rate; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; Lp(a), lipoprotein(a); non-HDL-C, non-high-density lipoprotein cholesterol; TC, total cholesterol; TG, triglycerides

4.7 Family history

Family history data were available for 507 participants. Lp(a) concentrations were comparable between patients with and without a positive family history of cardiovascular disease (CVD) (Mann-Whitney U rank-sum test, p=0.802). Similarly, subgroup analyses of specific CVD-related family history events, including premature myocardial infarction (p= 0.896), stroke (p=0.689), and thromboembolic events (p=0.663), showed no significant differences in Lp(a) concentrations**.** The prevalence of elevated Lp(a) also did not differ according to CVD family history (χ^2 (1) =0.11, p=0.736), with comparable rates in patients with and without a positive CVD family history (13.6% vs. 12.5%, respectively).

4.8 Multivariable predictors of serum Lp(a) in the pediatric T1D population.

To identify independent predictors of Lp(a) concentration, we fitted a multivariable GLM using a gamma distribution and log link function (n=340). The model included Tanner stage, sex, HbA1c, and LDL-C as predictors and was restricted to patients without DKA and aged >5 years**.**

In the adjusted model, LDL-C was independently associated with Lp(a) concentration, indicating that each 1 mg/dL increase in LDL-C was associated with an approximately 1.5% higher Lp(a) concentration**.** In the inverse adjusted GLM, each 1 mg/dL increase in Lp(a) was associated with a 0.23 mg/dL increase in measured total LDL-C (95% CI: 0.15–0.32, p<0.001). After applying the Dahlén modification ($LDL\text{-}C_{corr}=LDL\text{-}C-0.3\times Lp(a)$)[13]**,** the median LDL-C significantly decreased from 102.0 mg/dL (IQR: 84.0–121.0) to 95.3 mg/dL (IQR: 80.1–112.7) (p<0.001).

Pubertal maturation also remained independently associated with Lp(a), with a statistically significant overall effect of Tanner stage (Wald $\chi^2(4)=9.87$, $p=0.043$)**.** Compared with Tanner stage 1, Tanner stage 3 and 5 were associated with higher Lp(a) concentrations. No independent association was observed for sex and HbA1c. Full model estimates, including exponentiated coefficients, 95% confidence intervals, and *p*-values, are presented in **Table 4**. Predictive margins indicated that adjusted Lp(a) concentrations varied across Tanner stages, with the highest predicted values observed in Tanner stages 3 and 5. The predicted mean Lp(a) concentration was 14.3 mg/dL in Tanner stage 1, 12.3 mg/dL in Tanner stage 2, 26.2 mg/dL in Tanner stage 3, 19.6 mg/dL in Tanner stage 4, and 26.3 mg/dL in Tanner stage 5. This corresponded to an approximately 84% higher predicted Lp(a) concentration in Tanner stage 5 compared with Tanner stage 1. Furthermore, we did not observe a significant interaction between age and Tanner stage ($F=0.98$, $p=0.417$).

Model diagnostics supported adequate model specification and fit. Multicollinearity among the included predictors was low, with weak pairwise correlations between predictors (maximum $r=0.14$) and variance inflation factors below commonly accepted thresholds (mean VIF=1.38, all individual values <2.0). The Pregibon link test showed no evidence of model misspecification ($p=0.947$ for the squared predictor), and the deviance-based dispersion

parameter was acceptable (deviance/df =1.29). Visual inspection of deviance and Anscombe residuals did not reveal systematic residual patterns.

Table 4.

Table 4. Multivariable predictors of serum Lp(a) concentration using a gamma log-link regression model. Data were analyzed using a generalized linear model with a gamma distribution and log link function due to the right-skewed distribution of Lp(a). Results are presented as exponentiated coefficients [exp(β)], interpreted as mean ratios with 95% confidence intervals. The model was adjusted for Tanner stage, sex, HbA1c, and LDL-C, and was restricted to patients aged >5 years without DKA and with extreme HbA1c outliers (>14%) excluded (*n*=340).

Variable	exp (b)	95% CI	p-value
Puberty			
Tanner stage 1	Reference	_	
Tanner stage 2	0.862	0.484 to 1.538	0.616
Tanner stage 3	1.836	1.069 to 3.154	**0.028**
Tanner stage 4	1.369	0.832 to 2.254	0.216
Tanner stage 5	1.843	1.228 to 2.767	**0.003**
Sex			
Male	Reference	_	_
Female	1.182	0.882 to 1.585	0.262
Metabolic control			
HbA1c, per 1% increase	0.999	0.920 to 1.086	0.989
Lipid parameter			
LDL-C, per 1 mg/dL increase	1.015	1.010 to 1.021	**<0.001**

CI, confidence interval; DKA, diabetic ketoacidosis; GLM, generalized linear model; HbA1c, glycated hemoglobin; LDL-C, low-density lipoprotein cholesterol; Lp(a), lipoprotein(a)

Figure 5.

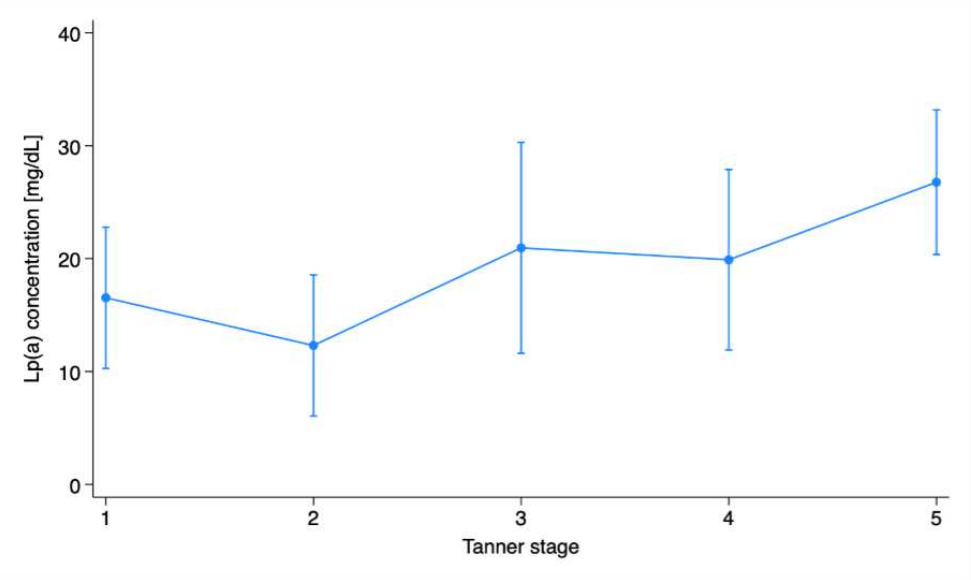


Figure 5. **Predicted Lp(a) concentrations across Tanner stages derived from the multivariable GLM.** Points represent predictive margins, and error bars indicate 95% confidence intervals. The model was adjusted for sex, HbA1c, and LDL-C and was restricted to patients without DKA aged >5 years, with extreme HbA1c outliers (>14%) excluded. The number of participants across Tanner stages in the model population was: stage 1, *n*=59; stage 2, *n*=33; stage 3, *n*=42; stage 4, *n*=54; and stage 5, *n*=152.

5. Discussion

The present study provides insight into the distribution and clinical correlates of Lp(a) in a large pediatric cohort with T1D. Beyond confirming the markedly skewed distribution of Lp(a), our findings suggest that pubertal maturation, rather than chronological age alone, may be associated with higher Lp(a) concentrations**.** In contrast, parameters directly related to diabetes course or metabolic control, including diabetes duration, HbA1c, new-onset diabetes status, and DKA, were not associated with Lp(a).

The proportion of children with elevated Lp(a) in our cohort indicates that a clinically relevant subgroup of pediatric patients with T1D may carry an additional inherited cardiovascular risk factor. The prevalence of elevated Lp(a) in our cohort was broadly comparable to that reported in the general population in Poland and across Europe, where approximately 13% of individuals had Lp(a) >50 mg/dL [13,14]. This alignment suggests that type

1 diabetes per se does not inherently increase the overall prevalence or incidence of elevated Lp(a). However, in specific subcohorts at very high cardiovascular risk, the prevalence may be considerably higher, reaching up to 20% or more [14,15].

Although direct comparisons with previous studies are limited by differences in study populations, Lp(a) thresholds, and reporting units, our findings are broadly consistent with earlier reports. In children with newly diagnosed diabetes, Kanouse et al. reported elevated Lp(a) in 22.4% of participants using a threshold of ≥75 nmol/L; however, their cohort included both T1D and T2D [16]. In adults with T1D, elevated Lp(a) defined as >120 nmol/L, were reported in approximately 16% of patients [17]. Although mass and molar units of Lp(a) are not directly interchangeable, this finding suggests that elevated Lp(a) affects a clinically meaningful proportion of patients with T1D. Furthermore, the median Lp(a) concentration observed in our cohort was similar to that reported previously in pediatric T1D populations [18.]

A central finding of our study was the association between pubertal maturation and Lp(a) concentration. Chronological age showed only a weak positive correlation with Lp(a), whereas Tanner stage demonstrated a more consistent relationship, including a significant trend across pubertal development and an independent association in multivariable models**.** This suggests that biological maturation may be more informative than chronological age alone when interpreting Lp(a) levels in pediatric patients with T1D. Large pediatric studies have shown that serum lipid concentrations differ across pubertal stages and change during sexual maturation [5,8,9]. Although Lp(a) is largely genetically determined[5], it may not be entirely static during childhood and adolescence [19].

Previous studies directly examining Lp(a) in relation to pubertal maturation are scarce. In contrast to our findings, Cobbaert et al. in a study published in 1995, did not observe a significant association between Tanner stage and Lp(a) concentrations in Belgian schoolchildren. This discrepancy may reflect differences in study populations, as their cohort

represented the general pediatric population, whereas our study focused on children and adolescents with T1D. Longitudinal data further support the possibility that Lp(a) may not remain entirely stable during development. In particular, de Boer et al. reported a 22% increase in mean Lp(a) concentrations between childhood and adulthood among individuals not receiving lipid-lowering therapy[6]. Puberty itself is characterized by activation of the sex steroid and GH/IGF-1 axes, transient physiological insulin resistance, and changes in body composition [6-8]. In children with T1D, these developmental processes occur in the additional context of glycemic exposure, exogenous insulin treatment, and diabetes-related changes in lipid metabolism[9]. These factors may contribute to variability in Lp(a) concentrations, although the cross-sectional design of our study precludes conclusions regarding causality. Preliminary observations in youth with T1D also indicate that Lp(a) may vary during childhood and adolescence, although these findings require confirmation in peer-reviewed studies [11]. Together, these observations support the need for longitudinal studies to clarify whether pubertal maturation directly influences Lp(a) concentrations or whether Tanner stage reflects broader developmental processes associated with Lp(a) variability in pediatric T1D.

Another important issue is whether diabetes-related factors influence Lp(a) concentrations in pediatric T1D. In our cohort, diabetes duration, HbA1c, new-onset diabetes status, and DKA were not associated with Lp(a) concentrations, suggesting that these factors were not major determinants of Lp(a) levels in this population. Recent pediatric data remain limited. Kanouse et al. reported a positive correlation between 3-month Lp(a) values and HbA1c in children with newly diagnosed diabetes [16], while Mlinarič et al. found that poorer metabolic control was associated with a higher likelihood of elevated Lp(a) in children, adolescents, and young adults with T1D [20]. These findings differ from our results, as HbA1c was not associated with Lp(a) concentrations in our cohort. However, direct comparisons are limited by differences in cohort characteristics, diabetes duration, glycemic status, Lp(a)

thresholds, and assay methodology. Clinically, our findings indicate that children with well-controlled T1D may have elevated Lp(a), supporting the need to assess Lp(a) as a distinct cardiovascular risk marker rather than relying solely on HbA1c or diabetes history.

In contrast to diabetes-related variables, the conventional lipid profile showed a closer relationship with Lp(a). In unadjusted analyses, Lp(a) showed weak but significant positive associations with atherogenic lipid parameters, including LDL-C, TC, non-HDL-C, and TG, whereas no association was observed with HDL-C. Among these variables, LDL-C was included in the multivariable model and remained independently associated with Lp(a). Similar findings were reported by Foster et al., who observed a positive association between Lp(a) and LDL-C in a pediatric diabetes cohort[18]. However, pediatric studies specifically examining the relationship between Lp(a) and LDL-C in T1D remain limited. This relationship should be interpreted cautiously because cholesterol contained within Lp(a) particles contributes to conventionally measured or calculated LDL-C values, potentially introducing a degree of mathematical coupling between the two variables [21,22]. Because standard laboratory assays and formulas quantify total LDL-C inclusive of Lp(a)-bound cholesterol (~30% of total Lp(a) mass), markedly elevated Lp(a) levels artificially inflate reported LDL-C values. Applying the Dahlén modification prevents risk misclassification and overtreatment in pediatric patients with type 1 diabetes[13]. Nevertheless, the coexistence of elevated Lp(a) and a more atherogenic lipid parameters may help identify children with T1D who require more detailed cardiovascular risk assessment.

Interestingly, Lp(a) concentrations were not associated with reported family history of cardiovascular disease, myocardial infarction, stroke, or VTE events. This may reflect limitations of retrospective family history data, underreporting, the relatively young age of some relatives, incomplete knowledge of cardiovascular events in the family members. Current expert recommendations increasingly emphasize direct Lp(a) measurement or cascade testing

in selected pediatric populations rather than relying solely on reported family history [4,23,24]. Therefore, the absence of a positive family history should not be considered sufficient to exclude elevated Lp(a) in children with T1D.

Our findings may have valuable implications for cardiovascular risk stratification in pediatric T1D. Since Lp(a) concentrations were not associated with HbA1c or diabetes duration, selective testing based only on metabolic control could fail to identify some patients with elevated Lp(a). Current pediatric diabetes guidelines focus primarily on conventional lipid screening and LDL-C–based intervention thresholds, and do not specifically recommend universal Lp(a) testing in all children with T1D [3]. However, contemporary lipid consensus statements increasingly recognize Lp(a) as an inherited cardiovascular risk factor and recommend at least once-in-a-lifetime testing in adults, as well as selective testing or cascade screening in youth with ischemic stroke, premature ASCVD family history, familial hypercholesterolemia, or known elevated Lp(a) in relatives [4,24]. Lp(a) determination should be considered as early as possible, even in people under 18 years of age, for risk assessment, cascade screening, monitoring and lifestyle modification [25]. Our results support the potential value of Lp(a) assessment as an additional component of cardiovascular risk stratification in pediatric T1D, beyond standard lipid parameters, glycemic control, and reported family history. Early recognition may facilitate more individualized cardiovascular risk assessment, including reinforcement of healthy lifestyle behaviors, optimization of modifiable cardiovascular risk factors, and consideration of family cascade screening where appropriate.

The main strengths of this study include a well-characterized pediatric T1D cohort and the evaluation of Lp(a) within a broad clinical framework encompassing diabetes-related variables, lipid profile, family history, and pubertal maturation. The assessment of Tanner staging allowed us to evaluate biological maturation beyond chronological age alone, which is

particularly important in pediatric populations. The association between pubertal maturation and Lp(a) was observed across several analytical approaches, including correlation analyses, group comparisons, and multivariable modeling.

This study has several limitations. Its retrospective and single-center design limits causal inference and generalizability. In addition, the cross-sectional nature of the analysis does not allow conclusions about individual longitudinal changes in Lp(a) during puberty. Family history data were obtained retrospectively and may be affected by underreporting or incomplete knowledge of cardiovascular events among relatives. A further limitation concerns the measurement of Lp(a). In our study, Lp(a) was reported in mass units, whereas current recommendations emphasize the use of assays with minimized apo(a) isoform-related bias and reporting in molar units, preferably nmol/L[5,26]. Therefore, direct comparison with studies using nmol/L-based thresholds should be made with caution, and conversion between mass and molar units should not be performed using a fixed conversion factor [4].

Future longitudinal studies should evaluate Lp(a) trajectories from childhood through puberty in both children with T1D and healthy controls. Such studies should include repeated Lp(a) measurements using recommended assay methodology, and evaluation of Tanner staging, hormonal parameters, and long-term markers of vascular health. This would help determine whether puberty represents a true biological window of Lp(a) increase or whether the observed pattern reflects differences in patient characteristics, broader developmental changes, or measurement-related factors. Beyond research implications, these findings may also support the development of a risk-stratified model of care for children and adolescents with T1D and elevated Lp(a), including closer lipid and vascular monitoring, optimization of modifiable risk factors, and individualized follow-up.

6. Conclusions

In conclusion, our findings indicate that elevated Lp(a) affects a clinically meaningful proportion of children and adolescents with T1D and may identify patients with additional inherited cardiovascular risk not captured by HbA1c, diabetes duration, or standard clinical history. The association between Lp(a) and Tanner stage suggests that pubertal maturation may be an important developmental context for the expression of Lp(a)-related risk. These observations support the potential value of considering Lp(a) measurement in cardiovascular risk stratification of pediatric patients with T1D, particularly during adolescence. Longitudinal studies with repeated Lp(a) measurements, standardized assay methodology, genetic characterization, and long-term assessment of early vascular changes and diabetes-related complications are needed to confirm these findings and guide future risk-stratified care pathways.

Acknowledgments

The authors have no acknowledgements to declare.

Funding

This research received no external funding.

Disclosure of Interest

The authors declare no conflicts of interest.

Ethics Approval

The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Bioethics Committee of Medical University of Gdansk (Approval No. KB/241/2026). Owing to the retrospective design of the study and the use of anonymized routinely collected clinical data, the requirement for informed consent was waived by the Bioethics Committee.

Data Availability

The data underlying this article are available from the corresponding author upon reasonable request.

Author Contributions Statement

Conceptualization: **A.W.D., P.R.K.**

Methodology: **A.W.D, P.R.K.**

Investigation**: A.W.D, P.R.K., M.O., G.G.**

Data curation: **A.W.D, P.R.K, M.O., G.G**.

Formal analysis: **A.W.D., P.R.K., M.O., G.G, M.B., M.M.**

Writing: **A.W.D., P.R.K., M.O., G.G.**

Writing – review and editing: **A.W.D., P.R.K., M.O., G.G., M.B., M.M.**

Supervision: **M.B., M.M.**

All authors have read and approved the final version of the manuscript.

References

1.Rawshani A, Sattar N, Franzén S, Rawshani A, Hattersley AT, Svensson AM, et al. Excess mortality and cardiovascular disease in type 1 diabetes in relation to age at onset: a nationwide study of 27,195 young adults with diabetes. *Lancet* 2018;**392**:477. https://doi.org/10.1016/S0140-6736(18)31506-X

2. Eliasson B, Lyngfelt L, Strömblad SO, Franzén S, Eeg-Olofsson K. The significance of chronic kidney disease, heart failure and cardiovascular disease for mortality in type 1 diabetes: nationwide observational study. *Sci Rep* 2022;**12**:17950. https://doi.org/10.1038/s41598-022-22932-4

3. Donaghue KC, Marcovecchio ML, Wadwa RP, Chew EY, Wong TY, Calliari LE, et al. ISPAD Clinical Practice Consensus Guidelines 2018: Microvascular and macrovascular complications in children and adolescents. *Pediatr Diabetes* 2018;**19**:262–274. https://doi.org/10.1111/pedi.12742

4. Kronenberg F, Mora S, Stroes ESG, Ference BA, Arsenault BJ, Berglund L, et al. Lipoprotein(a) in atherosclerotic cardiovascular disease and aortic stenosis: A European Atherosclerosis Society consensus statement. *Eur Heart J* 2022;**43**:3925–3946. https://doi.org/10.1093/eurheartj/ehac361

5. Reyes-Soffer G, Ginsberg HN, Berglund L, Duell PB, Heffron SP, Kamstrup PR, et al. Lipoprotein(a): A Genetically Determined, Causal, and Prevalent Risk Factor for Atherosclerotic Cardiovascular Disease: A Scientific Statement From the American Heart Association. *Arterioscler Thromb Vasc Biol* 2021;**42**:e48. https://doi.org/10.1161/ATV.0000000000000147

6. de Boer LM, Hof MH, Wiegman A, Stroobants AK, Kastelein JJP, Hutten BA. Lipoprotein(a) levels from childhood to adulthood: Data in nearly 3,000 children who visited a pediatric lipid clinic. *Atherosclerosis* 2022;**349**:227–232. https://doi.org/10.1016/j.atherosclerosis.2022.03.004

7.Strandkjær N, Hansen MK, Nielsen ST, Frikke-Schmidt R, Tybjærg-Hansen A, Nordestgaard BG, et al. Lipoprotein(a) Levels at Birth and in Early Childhood: The COMPARE Study. *J Clin Endocrinol Metab* 2022;**107**:324–335. https://doi.org/10.1210/clinem/dgab734

8. Hannon TS, Janosky J, Arslanian SA. Longitudinal Study of Physiologic Insulin Resistance and Metabolic Changes of Puberty. *Pediatr Res* 2006;60:759–763. https://doi.org/10.1203/01.pdr.0000246097.73031.27

9. Schienkiewitz A, Truthmann J, Ernert A, Wiegand S, Schwab KO, Scheidt-Nave C. Age, maturation and serum lipid parameters: findings from the German Health Survey for Children and Adolescents. *BMC Public Health* 2019;**19**:1627. https://doi.org/10.1186/s12889-019-7901-z

10. Cobbaert C, Deprost L, Mulder P, Rombaut K, Gijsels G, Kesteloot H. Pubertal serum lipoprotein (a) and its correlates in Belgian schoolchildren. *Int J Epidemiol* 1995;**24**:78–87. https://doi.org/10.1093/ije/24.1.78

11. Iafrate-Luterbacher F, Jimenez-Sanchez C, Anastasiadou ML, Prados J, Renström F, Brändle M, et al. Longitudinal variability of lipoprotein(a) in youth-onset type 1 diabetes: implications for cardiovascular risk stratification. *Cardiovasc Diabetol* 2026. doi:10.1186/s12933-026-03252-7. https://doi.org/10.1186/s12933-026-03252-7

12. Mayer-Davis EJ, Kahkoska AR, Jefferies C, Dabelea D, Balde N, Gong CX, et al. ISPAD Clinical Practice Consensus Guidelines 2018: Definition, epidemiology, and classification of diabetes in children and adolescents. *Pediatr Diabetes* 2018;**19**:7– https://doi.org/10.1111/pedi.12773

13. Saeedi R, Li M, Allard M, Frohlich J. Marked effects of extreme levels of lipoprotein(a) on estimation of low-density lipoprotein cholesterol. *Clin Biochem* 2014;**47**:1098–1099. https://doi.org/10.1016/j.clinbiochem.2014.04.023

14. Dyrbuś K, Mędrala Z, Konsek K, Nowowiejska-Wiewióra A, Trzeciak P, Skrzypek M, et al. Lipoprotein(a) and its impact on cardiovascular disease - the Polish perspective: design and first results of the Zabrze-Lipoprotein(a) Registry. *Arch Med Sci* 2024;**20**:1069–1076. https://doi.org/10.5114/aoms/188294

15. Burzyńska M, Jankowski P, Babicki M, Banach M, Chudzik M. Prevalence of hyperlipoproteinemia(a) in individuals of European ancestry treated at outpatient cardiology clinics: results from a cross-sectional STAR-Lp(a) study. *Pol Arch Intern Med* 2024;**134** (11):16860. https://doi.org/10.20452/pamw.16860

16. Kanouse A, Sohail R, Salemi P. Characterizing Lipoprotein(a) in Children With New-Onset Diabetes and Implications for Cardiovascular Risk Assessment. *J Endocr Soc* 2025;**9**(10):bvaf142. https://doi.org/10.1210/jendso/bvaf142

17. Littmann K, Wodaje T, Alvarsson M, Bottai M, Eriksson M, Parini P, et al. The association of lipoprotein(A) plasma levels with prevalence of cardiovascular disease and metabolic control status in patients with type 1 diabetes. *Diabetes Care* 2020;**43**:1851–1858. https://doi.org/10.2337/dc19-1398

18. Foster C, Rahman AKMF, Ashraf AP. Lipoprotein(a) Concentrations Correlate With LDL-C in Children With Type 1 and 2 Diabetes. *J Endocr Soc* 2021;**5** (11):bvab138.https://doi.org/10.1210/jendso/bvab138

19. Enkhmaa B, Berglund L. Non-genetic influences on lipoprotein(a) concentrations. *Atherosclerosis* 2022;**349**:53. https://doi.org/10.1016/j.atherosclerosis.2022.04.006

20. Mlinarič M, Schweiger DS, Plesnik E, Dovč K, Bratina N, Battelino T. Lipoprotein(a) in children, adolescents, and young adults with type 1 diabetes. *Atherosclerosis* 2021;**331**:e**119.** https://doi.org/10.1016/j.atherosclerosis.2021.06.351

21. Yeang C, Witztum JL, Tsimikas S. Novel method for quantification of lipoprotein(a)-cholesterol: implications for improving accuracy of LDL-C measurements. *J Lipid Res* 2021;**62**:100053. https://doi.org/10.1016/j.jlr.2021.100053

22. Fatica EM, Meeusen JW, Vasile VC, Jaffe AS, Donato LJ. Corrigendum to 'Measuring the contribution of Lp(a) cholesterol towards LDL-C interpretation' [Clin. Biochem. 86 (2020) 45-51]. *Clin Biochem* 2021;**88**:56–57. https://doi.org/10.1016/j.clinbiochem.2020.12.008

23. Annink ME, Janssen ES, Reeskamp LF. Effectiveness of cascade screening for elevated lipoprotein(a), an underdiagnosed family disorder. *Curr Opin Lipidol* 2024; 2024;**35**(6):290–296. https://doi.org/10.1097/MOL.0000000000000951

24. Kohn B, Ashraf AP, Wilson DP. Should Lipoprotein(a) be Measured in Youth? *J Pediatr.* 2021;**228**:285–289. https://doi.org/10.1016/j.jpeds.2020.08.042

25. Kronenberg F, Mora S, Stroes ESG. Consensus and guidelines on lipoprotein(a) - Seeing the forest through the trees. *Curr Opin Lipidol* 2022; 1;33(6):342-352. https://doi.org/10.1097/MOL.0000000000000855

Table 1. Clinical characteristics of the study group. Normally distributed variables are presented as mean ± SD, whereas non-normally distributed variables are presented as median (IQR). Categorical variables are presented as number (percentage). Elevated Lp(a) was defined as Lp(a) ≥ 50 mg/dL. The number of available observations is indicated where data were incomplete.

Variable	T1D (n=516)
Sex [females]	225 (43.60%)
Age [years]	13.74 (9.27-16.42)
New T1D diagnosis [*n*, (%)]	157 (30.43%)
DKA [*n*, (%)]	90 (17.44%)
T1D duration [years]	4.50 (0.02-9.50)
Age of T1D onset [years]	7.85 (4.71-11.44)
Body mass [kg]	50.60 (29.6-65.4)
Height [cm]	159.40 (135.00-172.00)
BMI [kg/m²]	19.04 (16.02-22.80)
BMI z-score (*n*=490)	0.12 (-0.72-0.87)
Obesity [*n*, (%)]	42 (8.14%)
Tanner (*n*=486), (n, %)	
1	142 (29.22%)
2	51 (10.49%)
3	62 (12.76%)
4	64 (13.17%)
5	167 (34.36%)
Overall T1D – HbA1c [%]	8.10 (7.10-10.85)
HbA1c in established T1D [%] (*n*=359)	7.50 (6.80-8.70)
HbA1c in new-onset T1D [%] (*n*=157)	12.10 (10.10-13.70)
Lp(a) [mg/dL]	8 (4-19)
Elevated Lp(a) ≥50 mg/dL [*n*, (%)]	66 (12.79%)
TC [mg/dL]	175.00 (153.00-201.00)
LDL-C [mg/dL]	103.00 (85.00-122.00)
HDL-C [mg/dL]	53.57 ±13.89
RC [mg/dl]	13 [9-19]
TG [mg/dL]	74.00 (53.00-113.00)
Non-HDL [mg/dL]	119.00 (99.00-146.00)
VTE event [*n*, (%)]	5 (0.97%)
Family history (*n*=507)	
VTE [*n*, (%)]	21 (4.14%)
MI [*n*, (%)]	107 (21.10%)
Stroke [*n*, (%)]	45 (8.88%)
Dyslipidemia [*n*, (%)]	176 (34.71%)
T1D [*n*, %]	106 (20.91%)
Non-T1D diabetes [*n*, (%)]	298 (58.78%)
Hypertension [*n*, (%)]	272 (53.65%)
Obesity [*n*, (%)]	166 (32.74%)

BMI, body mass index; DKA, diabetic ketoacidosis; HbA1c, glycated hemoglobin; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; Lp(a), lipoprotein(a); MI, myocardial infarction; non-HDL-C, non-high-density lipoprotein cholesterol, RC, remnant cholesterol; T1D, type 1 diabetes; TC, total cholesterol; TG, triglycerides; VTE, venous thromboembolism