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Lipids and lipoprotein ratios: The contribution to carotid intima media thickness in adolescents and young adults with type 2 diabetes mellitus

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Abstract

Background—Dyslipidemia is common among adolescents with type 2 diabetes (T2D).

Objective—To assess whether the lipoprotein ratios LDL/HDL or TG/HDL (low density lipoprotein cholesterol/ high density lipoprotein cholesterol or triglycerides/HDL) or non-HDL cholesterol are more useful than the traditional lipid panel to predict increased arterial thickness in adolescents and young adults T2D. .

Methods—We evaluated 244 T2D adolescents and young adults in a cross sectional study (mean age 18 years, 56% African American, 65% female). Demographics, anthropometrics, and laboratory data were collected. Arterial thickness was assessed using carotid intima media thickness (IMT). Bivariate correlations and general linear models were used to determine the independent contributions of the various lipid parameters to carotid IMT.

Results—Bivariate correlations revealed LDL/HDL ratio was the strongest predictor carotid IMT ($p < 0.02$). After adjustment for potential covariates LDL/HDL was no longer significant. HDL cholesterol was the only lipid to independently (negatively) contribute to carotid IMT. Other risk factors that were independently associated with carotid IMT included age, race, sex and body mass index z score and hemoglobin A1C. Together these cardiovascular risk factors explained less than 20% of the variance in carotid IMT.

Conclusions—HDL cholesterol is the only lipid to independently associate with carotid IMT. Lipoprotein ratios and non-HDL did not provide additional information. The low variance in carotid IMT explained by traditional risk factors suggests nontraditional risk factors may be important to assess to better understand the contributors to early stage atherosclerosis in adolescents and young adults with T2D.

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Keywords

type 2 diabetes; lipids; lipoproteins; adolescents; pediatrics; carotid intima media thickness; vascular disease

Introduction

Dyslipidemia is common in adults with type 2 diabetes (1-3) and contributes to the increased risk to develop cardiovascular disease in the setting of type 2 diabetes. (4). Lipid abnormalities often include high plasma triglycerides (TG), low levels of high density lipoprotein (HDL) cholesterol and increased small dense low density lipoprotein (LDL) particles, termed diabetic dyslipidemia (5). Recent data suggests that non-HDL cholesterol (6; 7) and/or lipoprotein ratios including LDL/HDL or TG/HDL (8; 9) may be able to better predict cardiovascular disease risk than the traditional lipid profile.

Dyslipidemia is also common in youth with type 2 diabetes (3; 10). Whether non-HDL cholesterol or lipoprotein ratios are more useful than the traditional lipid profile to predict early arterial thickness as measured by carotid intima media thickness (IMT) in adolescents and young adults with type 2 diabetes is not known.

Methods

Participants were recruited from the Diabetes Clinic at Cincinnati Children's Hospital Medical Center, local physician offices, college campuses, and health fairs as part of a cross sectional study which was designed to evaluate cardiovascular structure and function in adolescents and young adults with type 2 diabetes, as previously described (11).

Eligibility criteria for the study included: age greater than 11 years with a diagnosis of type 2 diabetes given by a health care provider. All individuals had no evidence of another specific type of diabetes (type 1 diabetes) and were non-insulin dependent. For 210 participants islet cell antibody was also available and showed no evidence of glutamic acid decarboxylase, islet cell antigen 512, and insulin autoantibodies. Pregnant females were excluded from this study.

Prior to enrollment in the study, written informed consent was obtained from subjects 18 years old or the parent or guardian with written assent for subjects <18 years old according to the guidelines established by the Institutional Review Board at Cincinnati Children's Hospital Medical Center and in accordance with the Declaration of Helsinki.

Participants were seen in-person study visit where demographic, anthropometric, and fasting blood (>10 hour) was drawn. Height and weight were obtained as previously described (11). Body mass index (BMI) was calculated as weight (kilograms) divided by height (meters) squared. Pubertal staging (breast staging for females and testicular staging for males) was obtained from self-report data. Blood pressure (BP) was obtained manually with sphygmomanometer (Baum Desktop Model with V-Lok cuffs, Copiague, New York, USA) according to the Fourth Report (12) with the average of three measurements used in the analysis. Duration of type 2 diabetes was measured from the date of diagnosis to the date of study.

Fasting plasma lipid profiles were carried out in a laboratory which is National Heart, Lung and Blood Institute/ Centers for Disease Control and Prevention standardized. The LDL cholesterol concentration was estimated using the Friedewald equation. Fasting plasma glucose was measured using a Hitachi model 704 glucose analyzer (Roche Hitachi,

Indianapolis, Indiana, USA). Glycosylated hemoglobin A1C (hemoglobin A1C) was measured in red blood cells using high performance liquid chromatography methods.

On the day of the study visit carotid ultrasound studies were performed by a single research vascular technologist. Both the right and left carotid arteries were evaluated with high-resolution B-mode ultrasonography using a GE Vivid 7 ultrasound imaging system (GE Medical Systems, Wauwatosa, Wisconsin, USA) with a 7.5MHz high-resolution linear array transducer. For each subject, the carotid wall and segments were examined independently from continuous angles to identify the thickest carotid IMT. Three segments were identified: the common artery, the bulb (bifurcation), and the internal carotid artery with the average value from the right and left side used in the analyses.

Multiple digital image loops were digitally transmitted using the Camtronics Medical System (Hartland, Wisconsin, USA) for offline reading. A trace technique was employed to measure the maximum carotid thickness from the leading edge. All images were read by a single research-trained vascular technician. Carotid IMT was measured from the leading edge (lumen-intima) to the leading edge (medial-adventitia). This technique has been found to be more reproducible than point-to-point measurements (coefficient of variation for repeat readings, 5.3 to 8% for trace vs. 8.4 to 11.6% for point to point for the three carotid segments (13).

All analyses were performed with Statistical Analysis Software (SAS®, version 9.2, Cary, North Carolina, USA). Data are mean $\pm$ standard deviation. Variance stabilizing procedures were applied as needed and non-normally distributed variables were log transformed (i.e. triglycerides). Bivariate correlations were used to assess the relationship between lipid parameters (independent variable) and carotid segments (dependent variable). Specific lipids of interest included LDL cholesterol, HDL cholesterol, TG, and non-HDL cholesterol. Non-HDL cholesterol was included as it is thought to be a more powerful predictor of coronary heart disease mortality and nonfatal coronary events than LDL cholesterol in patients with diabetes (6; 14-16). Lipoprotein ratios included TG/HDL representing small dense LDL particles (8) and LDL/HDL. .

Next, step wise general linear models were constructed to elucidate the independent determinants of three carotid segments. Initial models included lipids and were adjusted for age, race and sex. Final models incorporated additional covariates that were found to be significantly associated ($p < 0.05$) with one or more of the carotid segments in bivariate associations and included age, race, sex, BMI z-score, BP, glucose, hemoglobin A1c, and duration of type 2 diabetes. P values of < 0.05 were deemed significant.

Results

The study population consisted of 244 obese (BMI 37 ± 9 kg/m²) adolescents and young adults who were a mean age of 18.1 ± 3.1 (age range 10-23) years. See Table 1. Less than 10% of participants were $<$ age 14 years. Fifty six percent were female and 65% African American. The majority of participants ($>90\%$) were pubertal tanner stage 4 or 5. The mean hemoglobin A1C was $8.1 \pm 2.9\%$. The average duration of type 2 diabetes was 3.2 ± 2.6 years.

Of the 244 adolescents and young adults, 30 were treating their diabetes with insulin alone, 94 were taking oral agents alone (with $>97\%$ using a form of Glucophage) and 82 were on a combination of insulin and oral anti-diabetes therapies. For 27 participants no medication was reported suggesting their diabetes was treated with diet alone. Twenty five participants were on an angiotensin-converting-enzyme (ACE) inhibitor (possibly for BP lowering or treatment of microalbuminuria) and 5 were on lipid lowering drugs.

The lipid distributions and percentage of subjects with abnormal lipid values based on adolescent and young adult reference ranges (4; 17; 18) are shown in Table 2. The most common lipid abnormality present in this cohort was an elevated TG/HDL ratio representing increased small dense LDL particles (8).

Bivariate associations between each of the traditional lipid parameters and the lipoprotein ratios and carotid segments were evaluated using Pearson correlation coefficients (Supplement Table 1). With the exception of TG, each of the lipid parameters was associated with different segments of the carotid artery with the most correlations seen in the internal and common carotid segments. LDL cholesterol was significantly associated with the common carotid artery while non HDL cholesterol and TG/ HDL ratio were significantly associated with the internal and common carotid artery, $p < 0.05$. HDL cholesterol and LDL/ HDL demonstrated correlations with all 3 segments but LDL/HDL ratio found to be most strongly associated with the common, internal and bulb segments, $p < 0.02$.

In multivariate regression models that adjusted for age, race, sex, LDL/HDL ratio was not associated with any of the 3 carotid segments (Table 3a). HDL cholesterol was the only lipid to independently contribute to the prediction of internal carotid IMT. In fully adjusted models (Table 3b) that included age, race, sex, BMI z-score, BP, glucose, hemoglobin A1C, and duration of type 2 diabetes, again HDL cholesterol was the only lipid to independently contribute to the prediction of carotid IMT. For all carotid segments, less than 20% of the variance in carotid IMT was explained by traditional cardiovascular risk factors and hemoglobin A1C.

Discussion

In this study we sought to establish the relationship between the traditional lipid panel, non HDL cholesterol and lipoprotein ratios with carotid IMT in adolescents and young adults with type 2 diabetes. Low HDL cholesterol was found to be the only lipid parameter to independently associate with increased carotid IMT.

Adult studies have investigated the effects of lipids on carotid IMT. Taniwaki et al found that total cholesterol and HDL cholesterol independently contributed to carotid IMT (19), while Hayashai et al found small dense LDL particles to be important in determining carotid IMT in type 2 diabetes adults (20). However, in both of these studies, lipoprotein ratios such as LDL/HDL were not included in the analyses. Only one study conducted by Katakami et al combined conventional lipid measurements (LDL, TG, and HDL cholesterol), non HDL cholesterol and lipoprotein ratios to detect subclinical atherosclerosis as measured by carotid IMT. They found HDL cholesterol, TC/HDL and LDL/HDL to all be significant independent determinants of carotid IMT ($p < 0.0001$) after adjustment for conventional risk factors.

Our group has previously published data on the relationship between the traditional lipid profile and carotid IMT in adolescents and young adults with type 2 diabetes (11; 13). These prior publications provide carotid IMT data on age, race and sex matched lean and obese controls (11; 13). The current study sought to build on our prior work by examining whether non-HDL cholesterol or specific lipoprotein ratios were stronger predictors of carotid IMT over the traditional lipid profile.

Lipoprotein ratios and non-HDL cholesterol were not superior. While adult studies have demonstrated HDL cholesterol independently contributes to increased carotid IMT, these studies have also shown an independent role for lipoprotein ratios (9; 19). Discordance among our work and adult studies may be due to the relatively short duration of dyslipidemia exposure in our cohort. Lipid abnormalities likely contribute to atherosclerosis

over time and potentially become more important as adolescents progress to early adulthood. This hypothesis is supported by longitudinal studies such as the Bogalusa and Muscatine Heart Studies, which have shown that childhood lipids are an important risk factor for the development of future carotid IMT (21; 22). Another potential explanation for our findings is that in this rather young cohort with type 2 diabetes, other cardiovascular risk factors including obesity and hemoglobin A1C are more important than lipids.

We demonstrate less than 20% of the variance in carotid IMT is explained by traditional cardiovascular risk factors and hemoglobin A1C. A large part of the variance in carotid IMT remains unexplained. These findings suggest exploration of nontraditional risk factors may be important to assess when evaluating carotid IMT in adolescents and young adults. Nontraditional risk factors include inflammatory biomarkers such as C reactive protein (CRP), serum amyloid A (SAA) and interleukin-6 (IL-6) and adipocyte derived cytokines such as adiponectin and leptin. These inflammatory markers and cytokines, along with apolipoproteins and their ratios, have been shown to be independent predictors of cardiovascular disease in adults (23-26).

This study has limitations. First, 34 participants did not have islet cell antibody data available. Instead, for this group we used provider documentation of diagnosis, obesity status, and non-insulin dependency to confirm the diagnosis of type 2 diabetes. While this could have resulted in erroneous classification, it is unlikely given this is the typical scheme for diagnosis in clinical practice. Additionally, we did not stratify our cohort by race and sex, though we recognize race and gender differences in lipids exist (27-30). Stratifying the cohort would have limited our power to detect associations, therefore, adjustments for race and gender were considered in the regression models. Pubertal tanner staging was self-reported and not confirmed by a physician. Since less than 10% of the cohort was under age 14 years we suspect the majority of participants were pubertal, as reported. Finally, this was a cross sectional study; therefore, only associations can be drawn between lipids and carotid IMT. Longitudinal and intervention studies are required to establish causality.

Conclusion

HDL cholesterol was the only lipid parameter to be independently associated with carotid IMT in our cohort of adolescents and young adults with type 2 diabetes. Lipoprotein ratios and non-HDL cholesterol did not provide any additional information to predict an increase in carotid IMT. These findings suggest that the contributions of lipids likely develop overtime. Finally, given only a small proportion of the variability in carotid IMT is explained by traditional cardiovascular risk factors, our findings suggest nontraditional risk factors may be important to assess in order to better understand what contributes to early stage atherosclerosis in adolescents and young adults with type 2 diabetes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

TG	triglycerides
LDL	low density lipoproteins
HDL	high density lipoproteins
IMT	carotid intima media thickness
BMI	body mass index
BP	blood pressure
ACE inhibitor	angiotensin-converting-enzyme inhibitor
CRP	c reactive protein
SAA	serum amyloid A
IL6	interleukin-6

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Highlights

- HDL-C is the only lipid to independently associate with carotid IMT
- Lipoprotein ratios and non-HDL did not add to the prediction of carotid IMT
- Less than 20% of the variance in carotid IMT is explained by traditional CV risk factors
- Nontraditional risk factors may be important to understand early atherosclerosis

Table 1

Characteristics of the Study Population (n=244)

Variable	Mean $\pm$ Standard Deviation
Age (years) range 10-23 years	18.1 $\pm$ 3.1
Race- African American n (%)	136 (56%)
Sex- Female n (%)	159 (65%)
Weight (kg)	106 $\pm$ 29
Body Mass Index (kg/m ²)	37 $\pm$ 9
Pubertal Tanner Stage 4 or 5 n (%)	23 (9.4%)
Systolic blood pressure (mmHg)	121 $\pm$ 12
Diastolic blood pressure (mmHg)	67 $\pm$ 13
Hemoglobin A1c (%)	8.1 $\pm$ 2.9
Duration of type 2 diabetes (years)	3.2 $\pm$ 2.6
Common Carotid IMT (mm)	0.52 $\pm$ 0.08
Bulb Carotid IMT (mm)	0.47 $\pm$ 0.08
Internal Carotid IMT (mm)	0.39 $\pm$ 0.08

Data are number (percent) or mean $\pm$ standard deviation.

IMT= intima media thickness

Table 2

Lipids in the Study Population (n=244)

Variable	Mean $\pm$ Standard Deviation	Percent with abnormal lipid values	Recommended lipid values (4; 17; 18)
Triglycerides (mg/dl)	139 $\pm$ 89	34%	<150
LDL cholesterol (mg/dl)	107 $\pm$ 33	53%	<100
HDL cholesterol (mg/dl)	44 $\pm$ 11	41%	>40
Non HDL cholesterol (mg/dl)	135 $\pm$ 40	50%	<130
Triglycerides/HDL cholesterol	3.5 $\pm$ 3.0	65%	<2
LDL/HDL cholesterol	2.5 $\pm$ 0.9	28%	<3

LDL- low density lipoproteins; HDL-high density lipoproteins

Table 3a

Partially adjusted general linear models for prediction of carotid intima media thickness

	Common IMT	Bulb IMT	Internal IMT
Age (years)	0.013	0.012	0.021
Race (Females)	−0.086		
Race (African Americans)		0.036	
HDL cholesterol (mg/dl)			−0.005
<i>Model R²</i>	<i>0.12</i>	<i>0.06</i>	<i>0.15</i>

Table 3b

Fully adjusted general linear models for prediction of carotid intima media thickness

	Common IMT	Bulb IMT	Internal IMT
Age (years)	0.015	0.019	0.021
Sex (Females)	-0.076		
Race (African Americans)		0.037	
BMI z score (mg/m ²)	0.067	0.099	
Hemoglobin A1c (%)	0.013		
HDL cholesterol (mg/dl)			-0.005
Model R²	0.19	0.13	0.15

HDL- high density lipoproteins. IMT-intima media thickness.

3a. Models adjusted for age, race, sex.

3b. Models adjusted for age, race, sex, BMIz, blood pressure, glucose, hemoglobin A1c, and duration of type 2 diabetes.

Results are given for the significant coefficients ($p < 0.05$) remaining in the final step-wise regression models.