

Triglyceride to HDL-C Ratio and Increased Arterial Stiffness in Children, Adolescents, and Young Adults

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KEY WORDS

arterial stiffness, dyslipidemia, pediatrics

ABBREVIATIONS

Alx—augmentation index

BP—blood pressure

BrachD—brachial artery distensibility

CRP—high-sensitivity C-reactive protein

CV—cardiovascular

DBP—diastolic BP

HDL-C—high-density lipoprotein cholesterol

HR—heart rate

LDL-C—low-density lipoprotein cholesterol

MAP—mean arterial pressure

PWV—carotid-femoral pulse wave velocity

T2DM—type 2 diabetes mellitus

TG—triglycerides

TG/HDL-C—triglyceride to HDL-cholesterol ratio

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WHAT'S KNOWN ON THIS SUBJECT: The triglyceride to high-density lipoprotein cholesterol ratio (TG/HDL-C) estimates atherogenic small, dense low-density lipoprotein cholesterol and predicts arterial stiffness and hard cardiovascular events in adults. Whether TG/HDL-C predicts intermediate noninvasive end points (arterial stiffness) in youth is not known.



WHAT THIS STUDY ADDS: This study is the first to document stiffer vessels in youth with higher cardiovascular risk factor-adjusted TG/HDL-C, with the effect especially strong in obese subjects. Evaluating TG/HDL-C may be helpful in identifying young subjects at risk for obesity-related atherosclerosis.

abstract



BACKGROUND AND OBJECTIVE: Lipid levels are linked to early atherosclerosis. Risk stratification may be improved by using triglyceride to high-density lipoprotein cholesterol ratio (TG/HDL-C), which relates to arterial stiffness in adults. We tested whether TG/HDL-C was an independent predictor of arterial stiffness in youth.

METHODS: Subjects 10 to 26 years old (mean 18.9 years, 39% male, 56% non-Caucasian, $n = 893$) had laboratory, anthropometric, blood pressure, and arterial stiffness data collected (brachial distensibility, augmentation index, carotid-femoral pulse-wave velocity). Subjects were stratified into tertiles of TG/HDL-C (low, $n = 227$; mid, $n = 288$; high, $n = 379$).

RESULTS: There was a progressive rise in cardiovascular (CV) risk factors and arterial stiffness across TG/HDL-C ratio. The high TG/HDL-C ratio group had the stiffest vessels (all $P < .03$ by analysis of variance). TG/HDL-C as a continuous variable was an independent determinant of brachial distensibility in CV risk factor adjusted model and for carotid-femoral pulse-wave velocity in obese subjects, with trend for higher augmentation index.

CONCLUSIONS: TG/HDL-C, an estimate of small, dense low-density lipoprotein cholesterol, is an independent determinant of arterial stiffness in adolescents and young adults, especially in obese youth. These data suggest that use of TG/HDL-C may be helpful in identifying young adults requiring aggressive intervention to prevent atherosclerotic CV diseases. *Pediatrics* 2013;131:1–9

Cholesterol levels were first identified as a cardiovascular (CV) risk factor in 1959 in the Framingham Heart Study.¹ Since then, lipid parameters have been linked to early atherosclerosis on autopsy,² increased carotid intima-media thickness,³ and arterial stiffness.⁴ Risk stratification may be improved by testing for apolipoprotein B⁵ or use of lipid ratios, such as non-high-density lipoprotein (HDL)-cholesterol. Triglyceride (TG) to HDL-cholesterol ratio (TG/HDL-C) may be a better predictor of small, dense low-density lipoprotein (LDL),⁶ an atherogenic lipoprotein particle that strongly predicts coronary heart disease.⁷ In adults with low total LDL cholesterol (LDL-C), higher TG and lower HDL-cholesterol (HDL-C) were found to predict coronary heart disease.⁸ Data on adults show a relationship among TG, HDL-C, and arterial stiffness.^{9,10} TG/HDL-C does correlate to LDL particle size in youth,¹¹ but correlations to vascular damage are lacking. Therefore, we explored TG/HDL-C as an independent predictor of arterial stiffness in children, adolescents, and young adults.

METHODS

Study Population

Analyses were performed on pooled data from 2 studies from Cincinnati by using the same techniques.^{12,13} One compared CV structure in children, adolescents, and young adults with type 2 diabetes mellitus (T2DM) with nondiabetic controls (total $n = 784$, subjects included in these analyses, $n = 513$).¹² The other was a longitudinal school-based study exploring development of insulin resistance in healthy adolescents and young adults (total $n = 439$, subjects included in these analyses, $n = 380$).¹³ Subjects with diabetes, pregnant female subjects, and individuals with chronic disease or taking medication affecting carbohydrate metabolism were excluded from both studies. All subjects had nondiabetic level fasting

glucose (school study and lean subjects from T2DM study) or normal oral glucose tolerance (obese subjects from T2DM study) test per American Diabetes Association guidelines.¹⁴ Written informed consent was obtained from subjects ≥ 18 years old or the parent or guardian if < 18 years old. Written assent was obtained for subjects < 18 years old according to the institutional review board at Cincinnati Children's Hospital.

Data Collection

After a 10-hour fast, participants had questionnaire, anthropometric, blood pressure (BP), laboratory, and arterial stiffness data collected. Trained personnel obtained height using a calibrated stadiometer (Veeder-Rood, Elizabethtown, NC; RoadRod, Quick Medical, North Bend, WA; or Accustat, Genentech, South San Francisco, CA). Weight was measured by using a calibrated digital scale (Health-O-Meter; Sunbeam Products, Boca Raton, FL or SECA 770; SECA, Hanover, MD). The averages of 2 height and weight measurements were used. BMI was calculated as kg/m^2 . The average of 3 resting measures of systolic BP, diastolic BP (DBP), and mean arterial pressure (MAP) were obtained with a validated oscillometric device (DynaPulse Pathway; PulseMetric, Inc, San Diego, CA) by using the method of pulse wave form analysis.¹⁵

The same sample processing and laboratory (Cincinnati Children's Hospital laboratory) were used for both studies. Fasting plasma glucose was measured by using a Hitachi model 704 glucose analyzer (Roche Hitachi, Indianapolis, IN) with intra-assay and inter-assay coefficients of variation of 1.2% and 1.6%.¹⁶ Plasma insulin was measured by radioimmunoassay using an anti-insulin serum raised in guinea pigs,¹²⁵I-labeled insulin (Linco, St. Louis, MO), and a double antibody method to separate bound from free tracer with

a sensitivity of 2 pmol and intra- and interassay coefficients of variation of 5% and 8%.¹⁷ High-sensitivity C-reactive protein (CRP) was measured by using a high-sensitivity enzyme-linked immunosorbent assay.¹⁸ Lipid profiles were performed at a National Heart, Lung, and Blood Institute–Centers for Disease Control and Prevention standardized laboratory. LDL-C was calculated by using the Friedewald equation.¹⁹ TG/HDL-C was calculated. Subjects were stratified by TG/HDL-C (low, $n = 227$; mid, $n = 288$; high, $n = 379$) based on the race-specific tertiles for lean subjects with BMI < 85 th percentile (whites: low = 0.83 to < 1.28 , mid = 1.28 to < 1.92 , high = > 1.92 ; blacks: low = 0.78 to < 0.90 , mid = 0.90 to < 1.40 , high = > 1.40).

Arterial Stiffness Measurements

The averages of 3 recordings of vascular function collected after 5 minutes of rest were used. Brachial artery distensibility (BrachD) was measured by a DynaPulse Pathway instrument (Pulse Metric, Inc., San Diego, CA).²⁰ This device derives brachial artery pressure curves from arterial pressure signals obtained from a standard cuff sphygmomanometer assuming a straight tube brachial artery and T-tube aortic system.²⁰ Our coefficients of variability were $< 9\%$.¹²

A SphygmoCor SCOR-PVx System (Atcor Medical, Sydney, Australia) was used for heart rate (HR), carotid-femoral pulse wave velocity (PWV), and augmentation index (Alx), an arterial stiffness measure that measures wave reflections.²¹ Electrocardiogram-gated pressure wave data were obtained with a tonometer placed on the artery. PWV is the difference in carotid-to-femoral path length (measured directly) divided by the difference in the electrocardiogram R-wave to foot of the pressure wave. For Alx, the pressure waves were calibrated by using MAP and DBP obtained in the same arm. A validated generalized transfer function was used to calculate central aortic pressure and Alx.²² Alx

was adjusted to an HR of 75 beats per minute. Coefficients of variability are <7% for PWV and intraclass correlation coefficients are 0.7 to 0.9 for Alx.¹²

Statistical Analysis

Analyses were performed with Statistical Analyses Software (SAS, version 9.2, SAS, Inc., Cary, NC). Average values for demographic, anthropometric, and laboratory data were obtained by TG/HDL-C. One-way analysis of variance was performed (χ^2 analyses for categorical variables) to determine if differences in mean levels of variables existed by TG/HDL-C tertiles. Least square means were calculated to adjust for differences in sample size among tertiles to allow for category-by-category comparisons in mean levels. Variance stabilizing measures were performed as needed. General linear models were constructed by using significant covariates from correlation analyses to determine if TG/HDL-C was an independent determinant of arterial stiffness. The full model contained TG/HDL-C, age, demographics, anthropometrics, MAP, HR (except for Alx), LDL-C, CRP, glucose, and insulin. Height was added for Alx to control for distance of wave reflection sites from the heart related to height. Significance of each covariate was assessed. Nonsignificant terms were removed until remaining covariates or interactions (effect modifiers) were significant ($P < .05$).

RESULTS

The population consisted of 893 subjects aged 10 to 26 years (mean 18.9 years, 39% male, 56% non-Caucasian, mostly African American). TG/HDL-C tertile groups did not differ by age but there were fewer non-Caucasian subjects in the low tertile and more male subjects in the high tertile (Table 1). There was a progressive increase in BMI and BMI z-score (data not shown) across TG/HDL-C tertiles, with similar patterns for BP, LDL-C, glucose, insulin, and CRP. The

prevalence of obesity was high (37.6% with BMI ≥ 95 th% for age and sex). Prevalence of hypertension was 5.3% for systolic BP and 3.0% for DBP. Elevated LDL-C (≥ 160 mg/dL) was present in 1.6% of subjects, 42.0% had elevated TG/HDL-C, and 16.5% had strong family history of CV disease (data not shown). Elevated CRP (≥ 1 mg/L) was found in 4.6% of lean (BMI <85th%) and 30% of obese subjects (BMI ≥ 95 th%). Impaired fasting glucose (≥ 100 mg/dL) was found in 1.8% of lean and 5.6% of obese subjects. Defining abnormal arterial stiffness as >90 th% for Alx and PWV or <10 th% for BrachD for our healthy lean subjects, 33% had an abnormality in 1 measure (11% high Alx; 32% low BrachD; 24% high PWV), 13% had abnormality in 2 measures, and 3% had abnormality in all 3 measures. The prevalence of abnormalities in BrachD and PWV were significantly higher in the high TG/HDL-C tertile (P for $\chi^2 < .0001$ for both).

When stratified by tertiles (Table 1), arterial stiffness increased across TG/HDL-C tertile groups with significantly higher PWV and lower BrachD. For Alx, only the

high and low tertiles differed. There are no published normal values for TG/HDL-C; however, using lipid tables from the National Institutes of Health Pediatric CV Risk Reduction Initiative²³ to calculate TG/HDL-C for youth 10 to 19 years old produces low, mid, and high levels of ≤ 2 , >2 to <3.25 , and ≥ 3.25 . Data from the Healthy study, a slightly younger cohort ($n = 6365$, age 11.8 years), would estimate high TG/HDL-C as 3.14.²⁴ Most of our subjects had TG/HDL-C below the high-tertile cut point from these studies, suggesting that vascular change may be occurring at much lower levels than expected based on the normative distribution for TG/HDL-C in American youth.

In multivariable analyses, TG/HDL-C as a continuous variable was not an independent predictor of Alx (Table 2), but using TG/HDL-C tertile as a categorical variable produced a trend for higher Alx in the high versus low tertiles ($P \leq .059$, data not shown). Alx was influenced by age, female gender, non-white race, MAP, and fasting glucose ($R^2 = 0.23$, $P \leq .0001$). TG/HDL-C was a significant independent determinant

TABLE 1 CV Risk Factors and Arterial Stiffness Parameters Stratified by Tertiles of TG/HDL-C

Variable	Low ($n = 227$) Mean (SD)	Mid ($n = 288$) Mean (SD)	High ($n = 378$) Mean (SD)	ANOVA ^a
Age, y	18.7 (3.5)	19.0 (3.1)	19.0 (3.2)	NS
Race, n (% non-Caucasian)	107 (47.1)	169 (58.7)	220 (58.2)	L<M & H
Gender, n (% male)	78 (34.4)	102 (35.4)	165 (43.7)	L & M>H
Height, cm	167.1 (10.5)	167.8 (10.2)	168.8 (10.3)	NS
Weight, kg	65.1 (17.7)	78.7 (26.0)	90.9 (26.9)	L<M<H
BMI, kg/m ²	23.2 (5.6)	27.8 (8.6)	31.9 (9.2)	L<M<H
Systolic BP, mm Hg	110.1 (12.4)	112.3 (11.6)	116.2 (12.4)	L<M<H
DBP, mm Hg	63.9 (11.6)	65.4 (11.6)	67.7 (11.0)	L & M<H
MAP, mm Hg	79.1 (7.6)	81.4 (7.9)	83.7 (8.8)	L<M<H
HR, beats/min	62.5 (9.6)	64.1 (10.1)	64.4 (10.0)	L<H
Total cholesterol, mg/dL	156.0 (30.0)	162.7 (30.2)	171.8 (31.9)	L<M<H
LDL-C, mg/dL	82.4 (23.1)	94.4 (25.0)	104.0 (28.0)	L<M<H
HDL-C, mg/dL	63.6 (13.9)	54.1 (10.3)	44.9 (8.5)	L>M>H
TG	50.4 (14.1)	70.7 (18.7)	115.8 (50.7)	L<M<H
TG/HDL-C	0.8 (0.2)	1.3 (0.3)	2.7 (1.6)	L<M<H
Glucose, mg/dL	87.4 (6.1)	89.5 (7.0)	90.9 (7.3)	L<M<H
Insulin, μ U/mL	12.0(6.1)	15.4 (8.6)	19.7 (12.1)	L<M<H
High-sensitivity CRP, mg/L	1.02 (1.35)	1.87 (2.13)	2.57 (2.60)	L<M<H
Alx, %	-1.16 (12.11)	0.60 (11.04)	1.72 (11.11)	L<H
BrachD, %/mm Hg	6.76 (1.23)	6.37 (1.26)	5.89 (1.23)	L>M>H
PWV, m/s	5.60 (0.90)	5.84 (0.87)	6.13 (1.09)	L<M<H

ANOVA, analysis of variance.

^a All model P for χ^2 or ANOVA $\leq .0001$; all P for comparison of least square means $\leq .05$; L = low, M = mid, H = high TG/HDL-C tertile.

TABLE 2 Multivariable Models for Independent Determinants of Arterial Stiffness (Beta-Coefficients [SE] and Total Variance Explained)

Variable	Alx (higher = stiffer)	BrachD (lower = stiffer)	PWV (higher = stiffer)
Intercept	-43.5 (22.3)	2.16 (0.68)	-6.38 (0.30)
log TG/HDL-C		-0.018 (0.014)*	-0.46 (0.060)*
Age	0.39 (0.12)		0.12 (0.0082)
Female	4.25 (0.89)	0.087 (0.012)	
Non-white race	1.39 (0.72)		0.29 (0.053)
Height	-0.32 (0.044)		
BMI z-score		-0.070 (0.0065)	0.16 (0.028)
Log TG/HDL-C * BMI z-score		-0.018 (0.0086)	0.1 (0.037)
MAP	0.045 (0.045)	0.0035 (0.0079)	0.034 (0.0036)
HR		-0.018 (0.00063)	0.01 (0.0026)
Fasting glucose	11.73 (4.64)		
R ²	0.23	0.36	0.48

BrachD and PWV transformed to normal distribution. All models have $P \leq .0001$ and unless indicated with asterisk, all parameters have $P \leq .05$.

of BrachD ($R^2 = 0.36$, $P \leq .001$) and PWV ($R^2 = 0.48$, $P \leq .001$) even after adjustment for demographics, MAP, and HR. This was strongest in overweight and obese subjects (TG/HDL-C by BMI z-score interaction was significant). To better visualize the interaction, we stratified by BMI z-score (lean ≤ 1 or overweight/obese > 1). Plotting the regression (Figs 1, 2, and 3) showed no relationship between Alx and TG/HDL-C but a decline in BrachD for all subjects with the increase in PWV evident predominantly in the nonlean subjects.

Analyses were repeated by using TG or HDL-C alone (data not shown). There

were no differences in the results for Alx, as no lipid variables were independent determinants. Use of TG alone failed to reveal a difference between the mid- and high-tertile groups for BrachD and PWV by analysis of variance, as was seen using TG/HDL-C (Table 1). HDL alone failed to delineate between mid- and high-tertile group for PWV but results for BrachD were similar for TG/HDL-C (low $>$ mid $>$ high). Multivariable analyses with HDL-C alone explained slightly less of the variance in BrachD (R^2 0.363 vs 0.364), suggesting TG/HDL-C may be a more robust lipid variable

for explaining differences in arterial stiffness.

DISCUSSION

We show that TG/HDL-C is a significant determinant of arterial distensibility (BrachD) and pulse propagation (PWV) in apparently healthy adolescents and young adults. There is a trend for influence on measures incorporating wave reflections (Alx). TG/HDL-C may be especially helpful in predicting increased arterial stiffness in young individuals who have developed obesity. These data suggest that using the TG/HDL-C may be helpful for identifying young adults requiring aggressive intervention to prevent atherosclerotic CV diseases.

In adults, small, dense LDL²⁵ and TG/HDL-C²⁶ predicted burden of coronary artery disease found on cardiac catheterization. Furthermore, higher TG/HDL-C was associated with abnormal HR recovery in a large cohort of 4963 healthy adults and presence of both of these abnormalities predicted increased mortality.²⁷ Small, dense LDL also predicted preclinical change as measured by carotid intima-media thickness independently of CV risk factors,^{28,29} whereas TG/HDL-C independently predicted carotid intima-media thickness progression.³⁰ No other studies specifically examined the relationship between TG/HDL-C and arterial stiffness; however, some publications examined related lipid measures. Non-HDL-C was also found to be correlated with leg arterial compliance but only in healthy women, not men.³¹ In addition, TG, total cholesterol, and LDL-C were found to be correlated with PWV, but none were independent predictors in a study of hypertensive adults.¹⁰ Furthermore, a small case-control study found higher PWV in subjects with metabolic syndrome, which is defined by a high TG and low HDL-C phenotype,³² and HDL-C remained an independent predictor of

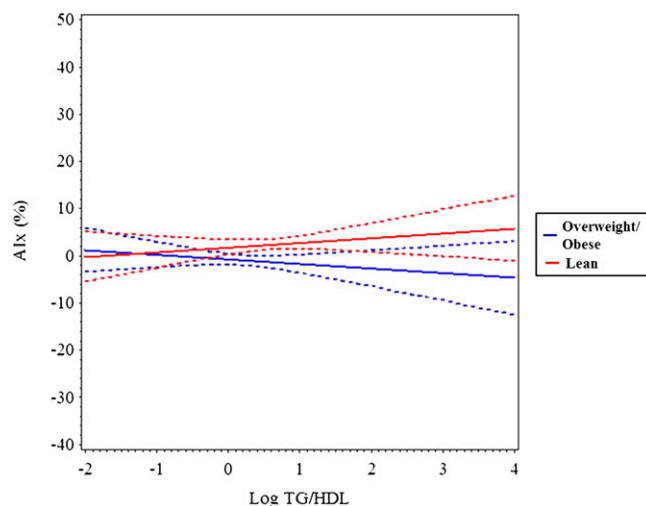


FIGURE 1

Mean Alx (solid line) and 95% confidence interval (dashed lines) by log TG/HDL-C stratified by BMI z-score group (lean = black, overweight/obese = gray). There is no significant increase across TG/HDL-C ratio regardless of BMI.

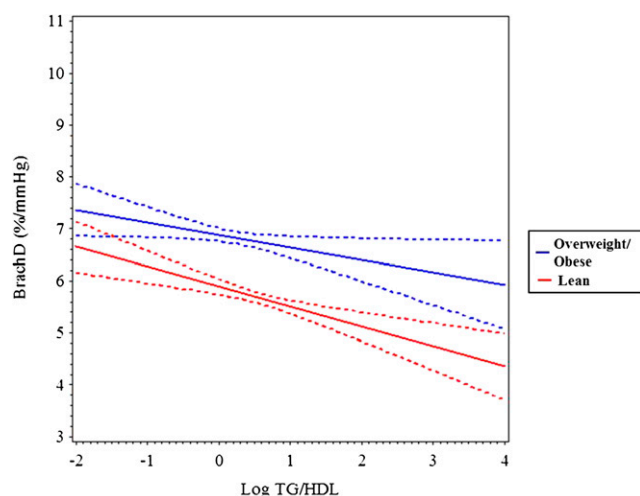


FIGURE 2

Mean BrachD (solid line) and 95% confidence interval (dashed lines) by log TG/HDL-C stratified by BMI z-score group (lean = black, overweight/obese = gray). The decline in BrachD by TG/HDL-C is steeper in the obese group ($P \leq .04$).

PWV after correction for other CV risk factors.⁹ For Alx, 1 investigator found a relationship between higher TG and Alx, but this relationship was independent only in men.³³ Another small study found no relationship between low HDL-C and Alx in healthy adults,³⁴ but a larger cohort demonstrated that low HDL-C in youth correlated with Alx measured 18 years later, albeit in a high-risk population with type 1 diabetes.³⁵ Clearly, more study is needed to determine the importance of TG/HDL-C as a reflection of

small, dense LDL in determining arterial health, as the atherogenicity of TG (TG was associated with coronary heart disease)³⁶ and the cardioprotective effects of HDL-C (low HDL-C predicted incident heart disease)⁹ may also play a role in the utility of using the ratio to predict vascular health.

Similar to the gaps in knowledge found in the literature regarding adults, few data are available relating TG/HDL-C to vascular measures in youth. The Pathobiological Determinants of Atherosclerosis

in Youth study demonstrated a relationship between low HDL-C and extent of fatty streaks and raised lesions in the thoracic and abdominal aorta and the right coronary artery.² Low HDL-C measured in youth also predicted thicker carotid intima-media thickness in adulthood in a combined longitudinal cohort of children from the Young Finns study, Bogalusa Heart Study, and Childhood Determinants study from Australia.³⁷ The Bogalusa Heart Study also found that elevated non-HDL-C and total/HDL-C cholesterol ratio measured at age 5 to 17 years predicted thicker carotid intima-media thickness 16 to 19 years later with odds ratios of 2.60 and 1.78 respectively.³⁸ Recent data from the Young Finns study found apolipoprotein B and non-HDL-C in young adulthood predicted PWV 6 years later.³⁹ Similarly, 2 small studies of obese youth found that TG was an independent predictor of carotid thickness,^{40,41} and a larger community-based study of healthy youth found low HDL-C was an independent predictor,⁴² especially if the metabolic syndrome was present.⁴³ A few studies have examined the relationship of PWV to TG and HDL-C but the only study examining the ratio included only cardiac (left ventricular mass)⁴⁴ and not vascular outcomes. Interestingly, a relationship between TG/HDL-C and left ventricular mass was found to be independent of other CV risk factors.⁴⁴ None of the pediatric studies examining vascular measures performed multivariable analysis to determine the independent contribution of these lipid parameters to arterial stiffness. Three found higher PWV in subjects with higher TG and lower HDL-C levels.⁴⁵⁻⁴⁷ One found higher PWV only with higher TG but not lower HDL-C,⁴⁸ and 1 found no relation between PWV and TG.⁴⁹ Other studies examined either carotid PWV,⁵⁰ or brachial-ankle PWV,^{51,52} parameters that differ substantially from carotid-femoral PWV measured in this study. One study also found high TG and low

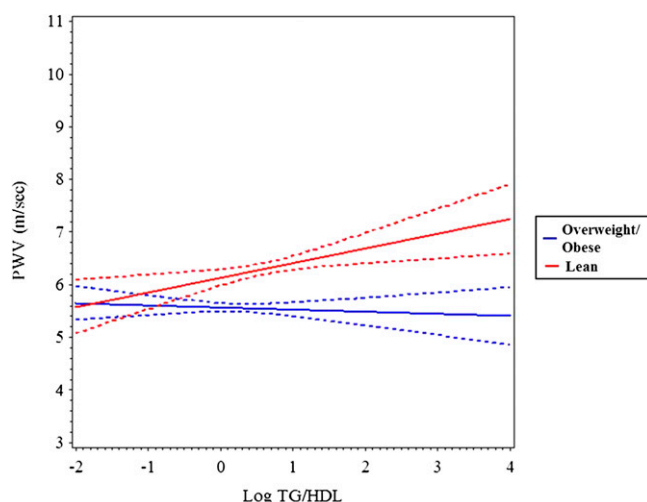


FIGURE 3

Mean PWV (solid line) and 95% confidence interval (dashed lines) by log TG/HDL-C stratified by BMI z-score group (lean = black, overweight/obese = gray). The increase in PWV by TG/HDL-C is higher in the obese group ($P \leq .006$).

HDL-C correlated with Alx,⁴⁶ whereas another found low HDL-C but not high TG correlated with Alx.⁴⁸ The only study in youth that examined BrachD found no relationship with TG or HDL-C; however, the authors used a wall-tracker technique that differs from the device used in this study.⁵³ Our data are the first to systematically study TG/HDL-C in relation to 3 distinct measures of arterial stiffness in a healthy adolescent and young adult population. Our data also suggest that measures of distensibility (BrachD) and pulse propagation (PWV) may be more effective in identifying target organ damage related to dyslipidemia than measures of wave reflection (Alx). The usefulness of a marker of CV risk can be demonstrated by reduction in risk with modification of the risk factor. Although no studies have directly linked reduction in small, dense LDL to improvement in arterial stiffness, inferences from the existing literature can be made. For instance, LDL particle size was improved with treatment with statins.⁵⁴ Although LDL particle size was not measured, a meta-analysis of the effect of statin therapy on PWV found improvement in arterial stiffness in most studies.⁵⁵ Conversely, 1 study used a treatment that was effective in lowering TG level but did not change LDL particle size and no change in distensibility was found.⁵⁶ Data in children are even more sparse, but in 1 study, diet and exercise were shown to drop TG levels in children followed over 2 years,⁵⁷ although no assessment of vascular function was performed. When a statin was used to lower TG and raise HDL-C levels in children with familial hypercholesterolemia, an increase in brachial flow-mediated dilation, a measure of endothelial function, was seen,⁵⁸ whereas a study of the use of plant stanols, which did not change TG or HDL-C levels, failed to show improved flow-mediated dilation in children with familial hypercholesterolemia.⁵⁹ To date, no investigations have studied diet or drug

therapy for TG and HDL-C by using arterial stiffness as an end point in children. Our data linking TG/HDL-C to vascular target organ damage in children are limited by our cross-sectional design. A longitudinal study design could provide a more robust argument that worsening of arterial stiffness over time is related to small, dense LDL as estimated by TG/HDL. Furthermore, an interventional study demonstrating improvement in arterial stiffness with treatment of elevated TG/HDL-C in both adults and children would provide evidence for the effect of this lipid pattern on arterial stiffness. Pooling data from 2 different studies was performed to increase the power to detect differences in this young cohort with a limited lifetime exposure to dyslipidemia. This approach may lead to selection bias, however, as 1 study recruited students from a school-based population and 1 included targeted diabetic youth and matched them to obese and lean controls. However, obesity, insulin resistance, and diabetes are increasing in prevalence in the United States, and these are the populations most likely to demonstrate the abnormal TG/HDL-C pattern⁶⁰ and, conversely, youth with high TG/HDL-C are more likely to be insulin resistant.^{61,62} Therefore, we do believe our analyses are relevant. Another limitation is that these data may have limited clinical applicability, as many pediatric practitioners do not have access to the types of devices used in our study to measure arterial stiffness; however, increasingly, large pediatric hospitals are acquiring expertise with these measures and more normative data are being published. Our cohort was predominantly female and African American because of the race and gender breakdown of the parent studies from which subjects were recruited. This may limit generalizability to other populations, although we did

correct for race and gender in our multivariable models. Also of note is that the relationship between TG/HDL-C and insulin resistance, another risk factor for increased arterial stiffness in youth,¹³ may differ by race in obese youth.⁶¹ Another limitation is that we were not able to measure other lipoprotein parameters that could contribute to increased vascular stiffness or for which TG/HDL-C might be a marker, such as small, dense LDL, Lipoprotein(a), oxidized LDL, lipid peroxidation products, and lipoprotein-associated phospholipase-A2. Furthermore, although TG/HDL-C is related to small, dense LDL,⁶ there is controversy as to whether increased arterial stiffness is related directly to the level of small, dense LDL, or if it is more closely associated with elevated levels of TG-rich lipoprotein remnants, elevated LDL particle numbers,⁶³ or the obesity-related inflammation seen in the metabolic syndrome.

CONCLUSIONS

The report of the National Institutes of Health–appointed expert panel on Integrated Guidelines for CV Health and Risk Reduction in Children and Adolescents has confirmed the importance of screening for dyslipidemias in youth, including hypertriglyceridemia.²³ However, this comprehensive review of the evidence identified many gaps in the knowledge base, especially with regard to the utility of targeting specific lipid abnormalities in an effort to improve intermediate markers of future CV disease. Whether TG/HDL-C provides incremental data compared with plasma TG alone is still controversial,⁶⁴ but it is easier to perform than advanced lipid testing and may prove useful in identifying subjects at high risk for accelerated vascular aging who need more aggressive, early therapy to improve long-term CV outcome. Future research should also

focus on the usefulness of noninvasive measures of arterial stiffness in stratifying CV risk in young patients.

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REFERENCES

- Dawber TRKW, Kannel WB, Revotskie N, Stokes J III, Kağan A, Gordon T. Some factors associated with the development of coronary heart disease: six years' follow-up experience in the Framingham study. *Am J Public Health Nations Health*. 1959;49:1349–1356
- Rainwater DL, McMahan CA, Malcom GT, et al; The PDAY Research Group. Lipid and apolipoprotein predictors of atherosclerosis in youth: apolipoprotein concentrations do not materially improve prediction of arterial lesions in PDAY subjects. *Arterioscler Thromb Vasc Biol*. 1999;19(3):753–761
- Heiss G, Sharrett AR, Barnes R, Chambless LE, Szklo M, Alzola C. Carotid atherosclerosis measured by B-mode ultrasound in populations: associations with cardiovascular risk factors in the ARIC study. *Am J Epidemiol*. 1991;134(3):250–256
- Brouwers MC, Reesink KD, van Greevenbroek MM, et al. Increased arterial stiffness in familial combined hyperlipidemia. *J Hypertens*. 2009;27(5):1009–1016
- Ramjee V, Sperling LS, Jacobson TA. Non-high-density lipoprotein cholesterol versus apolipoprotein B in cardiovascular risk stratification: do the math. *J Am Coll Cardiol*. 2011;58(5):457–463
- Tsimihodimos V, Gazi I, Kostara C, Tselepis AD, Elisaf M. Plasma lipoproteins and triacylglycerol are predictors of small, dense LDL particles. *Lipids*. 2007;42(5):403–409
- Onat A, Can G, Kaya H, Hergenç G. "Atherogenic index of plasma" (log₁₀ triglyceride/high-density lipoprotein-cholesterol) predicts high blood pressure, diabetes, and vascular events. *J Clin Lipidol*. 2010;4(2):89–98
- Blankstein R, Budoff MJ, Shaw LJ, et al. Predictors of coronary heart disease events among asymptomatic persons with low low-density lipoprotein cholesterol MESA (Multi-Ethnic Study of Atherosclerosis). *J Am Coll Cardiol*. 2011;58(4):364–374
- Roes SD, Alizadeh Dehnavi R, Westenberg JUM, et al. Assessment of aortic pulse wave velocity and cardiac diastolic function in subjects with and without the metabolic syndrome: HDL cholesterol is independently associated with cardiovascular function. *Diabetes Care*. 2008;31(7):1442–1444
- Legedz L, Bricca G, Lantelme P, et al. Insulin resistance and plasma triglyceride level are differently related to cardiac hypertrophy and arterial stiffening in hypertensive subjects. *Vasc Health Risk Manag*. 2006;2(4):485–490
- Stan S, Levy E, Delvin EE, et al. Distribution of LDL particle size in a population-based sample of children and adolescents and relationship with other cardiovascular risk factors. *Clin Chem*. 2005;51(7):1192–1200
- Urbina EM, Kimball TR, Khoury PR, Daniels SR, Dolan LM. Increased arterial stiffness is found in adolescents with obesity or obesity-related type 2 diabetes mellitus. *J Hypertens*. 2010;28(8):1692–1698
- Urbina E, Gao Z, Khoury P, Martin L, Dolan L. Insulin resistance and arterial stiffness in healthy adolescents and young adults. *Diabetologia*. 2012;55(3):625–631
- American Diabetes Association. Type 2 diabetes in children and adolescents. *Diabetes Care*. 2000;23(3):381–389
- Brinton TJ, Cotter B, Kailasam MT, et al. Development and validation of a non-invasive method to determine arterial pressure and vascular compliance. *Am J Cardiol*. 1997;80(3):323–330
- Goodman E, Daniels SR, Morrison JA, Huang B, Dolan LM. Contrasting prevalence of and demographic disparities in the World Health Organization and National Cholesterol Education Program Adult Treatment Panel III definitions of metabolic syndrome among adolescents. *J Pediatr*. 2004;145(4):445–451
- Martin LJ, Woo JG, Daniels SR, Goodman E, Dolan LM. The relationships of adiponectin with insulin and lipids are strengthened with increasing adiposity. *J Clin Endocrinol Metab*. 2005;90(7):4255–4259
- Kimberly MM, Vesper HW, Caudill SP, et al. Standardization of immunoassays for measurement of high-sensitivity C-reactive protein. Phase I: evaluation of secondary reference materials. *Clin Chem*. 2003;49(4):611–616
- Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*. 1972;18(6):499–502
- Urbina EM, Brinton TJ, Elkasabany A, Berenson GS. Brachial artery distensibility and relation to cardiovascular risk factors in healthy young adults (The Bogalusa Heart Study). *Am J Cardiol*. 2002;89(8):946–951
- Laurent S, Cockcroft J, Van Bortel L, et al; European Network for Non-invasive Investigation of Large Arteries. Expert consensus document on arterial stiffness: methodological issues and clinical applications. *Eur Heart J*. 2006;27(21):2588–2605
- O'Rourke MF, Gallagher DE. Pulse wave analysis. *J Hypertens*. 1996;14(5):S147–S157
- Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents. Summary Report. *Pediatrics*. 2011;128 Suppl 5:S213–S256
- Marcus MD, Baranowski T, DeBar LL, et. Severe obesity and selected risk factors in a sixth grade multiracial cohort: the HEALTHY study. *J Adolesc Health*. 2010;47:604–607
- März W, Scharnagl H, Winkler K, et al. Low-density lipoprotein triglycerides associated with low-grade systemic inflammation, adhesion molecules, and angiographic coronary artery disease: the Ludwigshafen Risk and Cardiovascular Health study. *Circulation*. 2004;110(19):3068–3074
- Ostfeld R, Mookherjee D, Spinelli M, et al. A triglyceride/high-density lipoprotein ratio \geq or = 3.5 is associated with an increased burden of coronary artery disease on cardiac catheterization. *J Cardiometab Syndr*. 2006;1(1):13–15
- Shishehbor MH, Hoogwerf BJ, Lauer MS. Association of triglyceride-to-HDL cholesterol ratio with heart rate recovery. *Diabetes Care*. 2004;27(4):936–941
- Norata GD, Raselli S, Grigore L, et al. Small dense LDL and VLDL predict common carotid artery IMT and elicit an inflammatory response in peripheral blood mononuclear and endothelial cells. *Atherosclerosis*. 2009;206(2):556–562
- Mora S, Szklo M, Otvos JD, et al. LDL particle subclasses, LDL particle size, and

- carotid atherosclerosis in the Multi-Ethnic Study of Atherosclerosis (MESA). *Atherosclerosis*. 2007;192(1):211–217
30. Maki KC, Davidson MH, Dicklin MR, Bell M, Witchger M, Feinstein SB. Predictors of anterior and posterior wall carotid intima media thickness progression in men and women at moderate risk of coronary heart disease. *J Clin Lipidol*. 2011;5(3):141–151
 31. Corti R, Fuster V, Fayad ZA, et al. Effects of aggressive versus conventional lipid-lowering therapy by simvastatin on human atherosclerotic lesions: a prospective, randomized, double-blind trial with high-resolution magnetic resonance imaging. *J Am Coll Cardiol*. 2005;46(1):106–112
 32. Grundy SM, Brewer HB Jr, Cleeman JI, Smith SC Jr, Lenfant C; American Heart Association; National Heart, Lung, and Blood Institute. Definition of metabolic syndrome: report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. *Circulation*. 2004;109(3):433–438
 33. Aznaouridis K, Vlachopoulos C, Dima I, Ioakeimidis N, Stefanadis C. Triglyceride level is associated with wave reflections and arterial stiffness in apparently healthy middle-aged men. *Heart*. 2007;93(5):613–614
 34. Alagóna C, Soro A, Ylitalo K, Salonen R, Salonen JT, Taskinen M-R. A low high density lipoprotein (HDL) level is associated with carotid artery intima-media thickness in asymptomatic members of low HDL families. *Atherosclerosis*. 2002;165(2):309–316
 35. Prince CT, Secrest AM, Mackey RH, Arena VC, Kingsley LA, Orchard TJ. Cardiovascular autonomic neuropathy, HDL cholesterol, and smoking correlate with arterial stiffness markers determined 18 years later in type 1 diabetes. *Diabetes Care*. 2010;33(3):652–657
 36. Frohlich J, Dobiášová M. Fractional esterification rate of cholesterol and ratio of triglycerides to HDL-cholesterol are powerful predictors of positive findings on coronary angiography. *Clin Chem*. 2003;49(11):1873–1880
 37. Magnussen CG, Venn A, Thomson R, et al. The association of pediatric low- and high-density lipoprotein cholesterol dyslipidemia classifications and change in dyslipidemia status with carotid intima-media thickness in adulthood evidence from the cardiovascular risk in Young Finns study, the Bogalusa Heart study, and the CDAH (Childhood Determinants of Adult Health) study. *J Am Coll Cardiol*. 2009;53(10):860–869
 38. Frontini MG, Srinivasan SR, Xu J, Tang R, Bond MG, Berenson GS. Usefulness of childhood non-high density lipoprotein cholesterol levels versus other lipoprotein measures in predicting adult subclinical atherosclerosis: the Bogalusa Heart Study. *Pediatrics*. 2008;121(5):924–929
 39. Koivisto T, Hutri-Kähönen N, Juonala M, et al. Apolipoprotein B is related to arterial pulse wave velocity in young adults: the Cardiovascular Risk in Young Finns Study. *Atherosclerosis*. 2011;214(1):220–224
 40. Wunsch R, de Sousa G, Reinehr T. Intima-media thickness in obesity: relation to hypertension and dyslipidaemia. *Arch Dis Child*. 2005;90(10):1097
 41. Fang J, Zhang JP, Luo CX, Yu XM, Lv LQ. Carotid intima-media thickness in childhood and adolescent obesity relations to abdominal obesity, high triglyceride level and insulin resistance. *Int J Med Sci*. 2010;7(5):278–283
 42. Ayer JG, Harmer JA, Nakhla S, et al. HDL-cholesterol, blood pressure, and asymmetric dimethylarginine are significantly associated with arterial wall thickness in children. *Arterioscler Thromb Vasc Biol*. 2009;29(6):943–949
 43. Juonala M, Viikari JS, Rönnemaa T, et al. Associations of dyslipidemias from childhood to adulthood with carotid intima-media thickness, elasticity, and brachial flow-mediated dilatation in adulthood: the Cardiovascular Risk in Young Finns Study. *Arterioscler Thromb Vasc Biol*. 2008;28(5):1012–1017
 44. Di Bonito P, Moio N, Scilla C, et al. Usefulness of the high triglyceride-to-HDL cholesterol ratio to identify cardiometabolic risk factors and preclinical signs of organ damage in outpatient children. *Diabetes Care*. 2012;35(1):158–162
 45. Gungor N, Thompson T, Sutton-Tyrrell K, Janosky J, Arslanian S. Early signs of cardiovascular disease in youth with obesity and type 2 diabetes. *Diabetes Care*. 2005;28(5):1219–1221
 46. Riggio S, Mandraffino G, Sardo MA, et al. Pulse wave velocity and augmentation index, but not intima-media thickness, are early indicators of vascular damage in hypercholesterolemic children. *Eur J Clin Invest*. 2010;40(3):250–257
 47. Sakuragi S, Abhayaratna K, Gravenmaker KJ, et al. Influence of adiposity and physical activity on arterial stiffness in healthy children: the lifestyle of our kids study. *Hypertension*. 2009;53(4):611–616
 48. Arnberg K, Larnkjær A, Michaelsen KF, Mølgaard C. Central adiposity and protein intake are associated with arterial stiffness in overweight children. *J Nutr*. 2012;142(5):878–885
 49. Koulsi A, Oldroyd J, McElduff P, Banerjee M, Vyas A, Cruickshank JK. Maternal and neonatal influences on, and reproducibility of, neonatal aortic pulse wave velocity. *Hypertension*. 2007;49(1):225–231
 50. Pandit D, Kinare A, Chiponkar S, Khadiiikar A, Khadiiikar V. Carotid arterial stiffness in overweight and obese Indian children. *J Pediatr Endocrinol Metab*. 2011;24(1-2):97–102
 51. Lee J-W, Lee D-C, Im J-A, Shim J-Y, Kim S-M, Lee H-R. Insulin resistance is associated with arterial stiffness independent of obesity in male adolescents. *Hypertens Res*. 2007;30(1):5–11
 52. Miyai N, Arita M, Miyashita K, Morioka I, Takeda S. The influence of obesity and metabolic risk variables on brachial-ankle pulse wave velocity in healthy adolescents. *J Hum Hypertens*. 2009;23(7):444–450
 53. Whincup PH, Gilg JA, Donald AE, et al. Arterial distensibility in adolescents: the influence of adiposity, the metabolic syndrome, and classic risk factors. *Circulation*. 2005;112(12):1789–1797
 54. Karalis DG, Ishisaka DY, Luo D, Ntanos F, Wun C-C. Effects of increasing doses of atorvastatin on the atherogenic lipid subclasses commonly associated with hypertriglyceridemia. *Am J Cardiol*. 2007;100(3):445–449
 55. Rizos EC, Agouridis AP, Elisaf MS. The effect of statin therapy on arterial stiffness by measuring pulse wave velocity: a systematic review. *Curr Vasc Pharmacol*. 2010;8(5):638–644
 56. Ambring A, Friberg P, Axelsen M, et al. Effects of a Mediterranean-inspired diet on blood lipids, vascular function and oxidative stress in healthy subjects. *Clin Sci (Lond)*. 2004;106(5):519–525
 57. de Ferranti SD, Crean S, Cotter J, Boyd D, Osganian SK. Hypertriglyceridemia in a pediatric referral practice: experience with 300 patients. *Clin Pediatr (Phila)*. 2011;50(4):297–307
 58. de Jongh S, Lilien MR, op't Roodt J, Stroes ES, Bakker HD, Kastelein JJ. Early statin therapy restores endothelial function in children with familial hypercholesterolemia. *J Am Coll Cardiol*. 2002;40(12):2117–2121
 59. Jakulj L, Vissers MN, Rodenburg J, Wiegman A, Trip MD, Kastelein JJ. Plant stanols do not restore endothelial function in pre-pubertal children with familial hypercholesterolemia despite reduction of low-density lipoprotein

- cholesterol levels. *J Pediatr*. 2006;148(4):495–500
60. Musso C, Graffigna M, Soutelo J, et al. Cardiometabolic risk factors as apolipoprotein B, triglyceride/HDL-cholesterol ratio and C-reactive protein, in adolescents with and without obesity: cross-sectional study in middle class suburban children. *Pediatr Diabetes*. 2011;12(3 pt 2):229–234
 61. Giannini C, Santoro N, Caprio S, et al. The triglyceride-to-HDL cholesterol ratio: association with insulin resistance in obese youths of different ethnic backgrounds. *Diabetes Care*. 2011;34(8):1869–1874
 62. Quijada Z, Paoli M, Zerpa Y, et al. The triglyceride/HDL-cholesterol ratio as a marker of cardiovascular risk in obese children; association with traditional and emergent risk factors. *Pediatr Diabetes*. 2008;9(5):464–471
 63. Davidson MH, Ballantyne CM, Jacobson TA, et al. Clinical utility of inflammatory markers and advanced lipoprotein testing: advice from an expert panel of lipid specialists. *J Clin Lipidol*. 2011;5(5):338–367
 64. St-Pierre AC, Cantin B, Dagenais GR, Mauriège P, Després JP, Lamarche B. The triglyceride/high-density lipoprotein cholesterol ratio, the small dense low-density lipoprotein phenotype, and ischemic heart disease risk. *Metab Syndr Relat Disord*. 2004;2(1):57–64

(Continued from first page)

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Hutchinson et al. School-age Outcomes of Extremely Preterm or Extremely Low Birth Weight Children. *Pediatrics*. 2013;131(4):e1053–e1061

An error occurred in this article by Hutchinson et al, titled “School-age Outcomes of Extremely Preterm or Extremely Low Birth Weight Children” published in the April 2013 issue of *Pediatrics* (2013;131[4]:e1053–e1061; originally published online March 18, 2013; doi:10.1542/peds.2012-2311). On page e1053, under Abstract, on line 5 and 6 of the Methods paragraph, this reads: “A term/normal birth weight (T/NBW) cohort was recruited comprising 199 infants with birth weights <2500 g or gestational age <37 weeks.” This should have read: “A term/normal birth weight (T/NBW) cohort was recruited comprising 199 infants with birth weights \geq 2500 g or gestational age \geq 37 weeks.”

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Urbina et al. Triglyceride to HDL-C Ratio and Increased Arterial Stiffness in Children, Adolescents, and Young Adults. *Pediatrics*. 2013;131(4):e1082–e1090

An error occurred in the article by Urbina et al, titled “Triglyceride to HDL-C Ratio and Increased Arterial Stiffness in Children, Adolescents, and Young Adults” published in the April 2013 issue of *Pediatrics* (2013;131[4]:e1082–e1090; originally published online March 4, 2013; doi:10.1542/peds.2012-1726). On pages e1085 and e1086, the legends for Figs 1, 2, and 3 read: “log TG/HDL-C stratified by BMI z-score group (lean = black, overweight/obese = gray).” These should have read: “(lean = blue, overweight/obese = red).” Furthermore, the color-coded legends in the box on the right of the figures was incorrect. They should have had a blue line for the lean subjects and a red line for the obese subjects.

doi:10.1542/peds.2013-1865

Foster et al. Feasibility and Preliminary Outcomes of a Scalable, Community-based Treatment of Childhood Obesity. *Pediatrics*. 2012;130(4):652–659

An error occurred in this article by Foster et al, titled “Feasibility and Preliminary Outcomes of a Scalable, Community-based Treatment of Childhood Obesity” published in the October 2012 issue of *Pediatrics* (2012;130[4]:652–659; originally published online September 17, 2012; doi:10.1542/peds.2012-0344). On page 656, in Table 2, this reads: “BMI z score Change at 24 Weeks Overall ($n = 155$) -0.062 ± 0.003 ; <13 y ($n = 115$) -0.068 ± 0.003 ; \geq 13 y ($n = 40$) -0.042 ± 0.005 .” This should have read: “BMI z score Change at 24 Weeks Overall ($n = 155$) -0.09 ± 0.01 ; <13 y ($n = 115$) -0.10 ± 0.03 ; \geq 13 y ($n = 40$) -0.04 ± 0.05 .”

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Broder-Fingert et al. Racial and Ethnic Differences in Subspecialty Service Use by Children With Autism. *Pediatrics*. 2013;132(1):94–100

A production error occurred in the print version of the article by Broder-Fingert et al, titled “Racial and Ethnic Differences in Subspecialty Service Use by Children With Autism” published in the July 2013 issue of *Pediatrics* (2013;132[1]:94–100; originally published online June 17, 2013; doi: 10.1542/2012-3886). On page 97, under Table 4, this reads: “20.32.” This should have read: “0.32.”

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