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Dietary Intake and Cardiometabolic Risk in Ethnically Diverse Urban Schoolchildren

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Abstract

Dietary factors vary widely among ethnic groups. However, the effect of specific nutrients on cardiometabolic risk is not well understood, especially in children. Four dietary factors known to influence cardiometabolic risk (ie, carbohydrate, saturated, monounsaturated, and polyunsaturated fat intake) were assessed by the Block Kids 2004 Food Frequency Questionnaire in a cross-sectional sample of racially diverse fourth- through eighth-grade students (n=148) in a Boston-area school district studied between January and April 2010. Fasting total cholesterol, low-density lipoprotein, high-density lipoprotein (HDL) cholesterol, triglyceride, C-reactive protein (CRP), and interleukin-6 (IL-6) levels, and body mass index *z* scores were measured. Differences in

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dietary factors and cardiometabolic risk factors were examined among the following racial/ethnic groups: white (39%), Hispanic (32%), black (8%), Asian (10%), and multiracial/other (11%). In bivariate analyses, total, saturated, and polyunsaturated fat intakes differed by race/ethnicity ($P<0.05$), with white and black children reporting saturated fat intakes above the recommended level. Forty-seven percent of children had at least one suboptimal cardiometabolic risk factor. HDL cholesterol, triglyceride, and IL-6 concentrations differed by race/ethnicity ($P<0.05$, $P<0.01$, and $P<0.01$, respectively), with Hispanics having low HDL cholesterol levels and high triglyceride levels, whereas Asians had high IL-6 levels. In multivariate analyses controlling for demographic characteristics, none of the dietary factors examined explained racial/ethnic differences in lipid profiles or inflammatory markers. Body mass index *z* score was associated with lower HDL cholesterol, higher triglyceride, higher CRP, and higher IL-6 levels ($P<0.0001$). Further research is warranted to determine the influence of dietary recommendations at a young age among different racial/ethnic groups on cardiometabolic health.

Keywords

Cardiometabolic risk; Dietary fat; Children; Ethnically diverse

Research has demonstrated that the development of cardiovascular disease (CVD) begins early in life and is progressive throughout the life span.[1] Racial and ethnic differences in dietary factors that may influence CVD risk in children are of special importance because of the premature mortality from CVD experienced by adult minority populations, most notably African-American and Latino populations, the two largest minority groups in the United States.[2]

Ethnic differences in risk factors, such as dietary fat intake,[3] obesity, and dyslipidemia,[4,5] are associated with the development of CVD and appear to be evident in childhood. Abnormal concentrations of serum lipids, in particular total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides are risk factors for CVD.[6] Data from the third National Health and Nutrition Examination Survey (NHANES III) indicated that non-Hispanic black children and adolescents had significantly higher total cholesterol, LDL cholesterol, and HDL cholesterol levels compared with non-Hispanic white and Mexican-American children and adolescents.[7] In addition, elevated concentrations of C-reactive protein (CRP) and the proinflammatory cytokine interleukin-6 (IL-6) have also been shown to contribute to the development of CVD in adults[8] and children.[9]

However, few studies have evaluated racial/ethnic-specific dietary factors that may influence schoolchildren's heart disease risk. Previous research suggests that dietary factors may play a role in lipid levels, although these patterns may be influenced by body fat content.[10] The potential role of diet early in the disease process and the identification of ethnic differences in macronutrient composition of children's diets by previous researchers[10,11] suggest that unfavorable lipid profiles observed in children may be due to differences in dietary patterns. Dietary macronutrient intakes are strongly linked to blood lipid levels; diets high in saturated fat increase total and LDL cholesterol,[12] whereas diets high in mono- and polyunsaturated

fats increase HDL cholesterol, and diets high in refined carbohydrates increase triglyceride concentrations in adults.[13] Thus, the aim of this study was to investigate racial/ethnic differences on the intake of specific dietary factors (ie, carbohydrate and saturated, monounsaturated, and poly-unsaturated fat intake), and assess whether these dietary factors were associated with increased cardiometabolic risk, independent of body mass index (BMI) *z* score, in a group of diverse urban schoolchildren. It is hypothesized that dietary saturated fat and carbohydrate intake will negatively affect triglyceride and LDL cholesterol levels, whereas monounsaturated and polyunsaturated fat intake will independently have a positive influence on HDL cholesterol level and inflammatory markers.

METHODS

Participants

A cross-sectional design was used to assess dietary intake of 148 students participating in the 2009–2010 Fitness and Metabolic Health study. That study enrolled subjects from eight public elementary/middle schools (fourth through eighth grade) in Somerville, MA, between January and April 2010. Somerville is a racially and ethnically diverse community within the greater Boston metro area. In the study population, 74.3% of students received free (60.1%) or reduced-price (14.2%) lunch. Schoolchildren were recruited for the study through presentations, flyers, and announcements in the schools and received a gift card to a local retailer for their participation. Informed written consent was obtained from the parents and assent was obtained from the children. The protocol was reviewed and approved by the Tufts University Institutional Review Board. The original sample included 162 children. Underweight participants (n=6) and those who reported implausible intake (<500 or >5,000 kcal)[14] (n=8) were excluded from these analyses.

Anthropometrics and Pubertal Status

Height and weight were measured by trained research assistants in triplicate with light clothing and without shoes. Height was taken using a portable stadiometer (Model 214, Seca Weighing and Measuring Systems) with the head in the Frankfurt plane made with a right angle height procedure[15] and recorded to the closest one-eighth inch. Weight was measured on a portable balance beam scale (Healthometer) and recorded to the closest 0.25 lb. BMI was calculated and then converted to a *z* score as recommended by the Centers for Disease Control and Prevention sex-specific growth charts[16] and used for the analyses.

Pubertal status was assessed by asking the female participants whether they had reached menarche (yes/no) and male participants if their voice had changed (yes/no).[17] Answering yes was considered a marker for late puberty.

Race/Ethnicity and Socioeconomic Status (SES)

Child race/ethnicity was determined by parental report based on Centers for Disease Control and Prevention guidelines: white/Caucasian, Mexican/Mexican American, other Hispanic/Latino, black/African American, Asian/Asian American/Asian Indian, Native American/American Indian, and multiracial/multiethnic/other,[18] and consolidated into five groups: white, Hispanic, black, Asian, and multiracial/other. Participant eligibility for free or

reduced-price lunch (<185% of federal household income level) under the National School Lunch Program, provided by the Somerville Public School District, was coded as a binary variable and used as an indicator of SES.

Dietary Intake Assessment

Dietary data were collected using the validated Block Kid 2004 Food Frequency Questionnaire (FFQ) (NutritionQuest).[19] The FFQ was pilot-tested in a focus group with children in the community of interest before the study took place. A registered dietitian and a trained graduate student administered the FFQ before and after school during the study months. The 8-page FFQ asked about frequency and quantity of 78 foods eaten during the past week and took approximately 20 to 30 minutes to complete. Children were also provided with a separate portion size picture attachment to improve portion size estimation. The collected dietary data were quantified by NutritionQuest as daily intake in grams (or milliliters for liquids) and further summarized into daily intakes of energy and nutrients using an algorithm from NutritionQuest. Macronutrient intake, including total, saturated, monounsaturated, and polyunsaturated fats and carbohydrate intake, was analyzed according to the adequate dietary ranges.[20]

Biochemical Analysis

Phlebotomy was conducted at school before school hours after a 12-hour overnight fast during late winter (January to March 2010). Participants were asked whether they had consumed any beverages or foods before the morning blood draw. Blood was drawn, in private, by a trained phlebotomist from the antecubital vein. All samples were centrifuged, aliquotted, and stored at −80°C until analysis. The determination of total cholesterol, triglyceride, HDL cholesterol, and LDL cholesterol concentrations were simultaneously performed on the Hitachi 917 analyzer (Roche Diagnostics) using reagents and calibrators from Roche Diagnostics. Cholesterol was measured enzymatically. Triglyceride levels were measured enzymatically with correction for endogenous glycerol. The concentration of HDL cholesterol was determined using a direct enzymatic colorimetric assay. LDL cholesterol concentration was determined by a homogenous direct method from Roche Diagnostics. All blood lipid levels were analyzed by the Clinical and Epidemiologic Research Laboratory at Boston Children’s Hospital. The criteria for assessing CVD risk were suboptimal levels of LDL cholesterol ≥110 mg/dL (≥2.86 mmol/L); HDL cholesterol <40 mg/dL (<1.04 mmol/L); or triglycerides ≥75 mg/dL (≥0.85 mmol/L) or ≥90 mg/dL (≥1.02 mmol/L) for children aged 0 to 9 years or 10 to 19 years, respectively.[21]

Serum IL-6 concentration was measured by a quantitative enzyme-linked immunosorbent assay (Quantikine High Sensitivity Human IL-6, R&D Systems, Inc). Serum CRP level was measured via a latex-enhanced turbidimetric immunoassay (Immulite 1000 High Sensitivity CRP, Diagnostic Products Corporation). CRP and IL-6 were measured through the Boston Obesity and Nutrition Research Center within the Nutrition Evaluation Laboratory at the Human Nutrition Research Center on Aging at Tufts University.

Statistical Analysis

All statistical analyses were performed with SPSS (version 17.0, 2008, IBM Corp). To address the influence of outlying values, nutrient data were Winsorized to the first and 99th percentiles, which did not alter results of any statistical significance testing. To determine racial/ethnic differences in relevant anthropometrics, lipid and inflammation measures, and select macronutrient intakes, analysis of variance with post hoc Bonferonni adjustments and nonparametric Kruskall-Wallis tests were conducted. The values for HDL cholesterol, triglycerides, CRP, and IL-6 were log-transformed to normality for statistical analyses.

Initially, descriptive analyses were conducted comparing all five ethnic groups. To investigate the relationships between dietary factors and race/ethnicity on cardiometabolic parameters, linear regressions were performed for LDL cholesterol, HDL cholesterol, triglycerides, CRP, and IL-6. All equations were controlled for confounding factors, such as BMI *z* score, age, sex, puberty, and SES. Interaction terms between race/ethnicity and dietary factors were then examined. To refine the model, nonsignificant interaction terms were removed ($P>0.05$). A P value of 0.05 was used to determine statistical significance.

RESULTS AND DISCUSSION

The sample was composed of 148 schoolchildren aged 9 to 15 years (59% girls). More than 60% of participants were from racial/ethnic minorities (32% Hispanic, 8% black, 10% Asian, and 11% multiracial). A majority of the Hispanic children were from El Salvador, Puerto Rico, and Guatemala. Age, BMI *z* score, total energy, and select dietary macronutrients known to affect cardiovascular health are summarized in Table 1**.** BMI *z* score and SES differed between racial/ethnic groups. More than 70% of Hispanic children were overweight or obese, followed by 50% of black children and 50% of multiracial children, 46% of white children, and 33% of Asian children ($P<0.05$). In comparison with white children, Hispanic children had higher BMI *z* scores ($P<0.05$); however, there were no significant differences between other groups for BMI *z* score. Free and reduced-price lunch status, a proxy for SES, differed by racial/ethnic groups ($P<0.001$), with 100% of Hispanic and multiracial children qualifying for free/reduced-price lunch (data not shown).

Average intakes of total fat and saturated fat for all children were slightly lower than those reported for children aged 9 to 15 years in NHANES III.[22] Ethnic differences in total, saturated, and polyunsaturated fat intakes were apparent in this sample ($P<0.05$), but not for carbohydrates. Children of all ethnic groups studied were within the recommended ranges for total fat,[20] with black children reporting the highest total and polyunsaturated fat intakes. White and black children had the highest saturated fat intakes (11.0% and 10.4%, respectively), with percentages exceeding the current recommendations, which is consistent with intake reported in NHANES.[22] Energy intake was notably lower in this study (mean 1,469±806 kcal) compared with NHANES III data (2,195±188 kcal), which may reflect the different data collection methodology. NHANES III data were collected using a single multiple-pass, 24-hour recall, whereas data for this study were collected by FFQ. The high prevalence of overweight and obesity in this sample may have contributed to underreporting, which has been shown to increase with increasing BMI in children.[23]

Mean blood lipid values for each ethnic group are summarized in Table 2. Nearly 20% of children had elevated LDL cholesterol levels, 17.6% had low HDL cholesterol levels, and 33.8% had elevated triglyceride levels. HDL cholesterol and triglyceride levels differed between racial/ethnic groups ($P<0.05$ and $P<0.01$, respectively). Of the inflammatory markers, only IL-6 was different between groups ($P<0.05$). Table 3 shows the results of the possible influence of dietary factors and race/ethnicity, independent of BMI *z* score, on blood lipid levels for LDL cholesterol, HDL cholesterol, triglycerides, CRP, and IL-6. BMI *z* score, but none of the measured dietary factors, was associated with HDL cholesterol, triglycerides, CRP, and IL-6 ($P<0.001$), which is consistent with other studies.[10] None of the interaction terms between race/ethnicity and dietary factors were significant, suggesting that racial/ethnic differences in the measured dietary factors were not strong indicators of cardiometabolic risk (data not shown). Higher triglyceride and lower HDL cholesterol levels did not appear to be explained by racial/ethnic differences in dietary fat and carbohydrate intake. Lower total cholesterol and LDL cholesterol level were not explained by racial/ethnic differences in saturated fat intake, a finding consistent with earlier studies.[11,13] Although it was hypothesized that ethnic differences in macronutrient intakes would account for differences in serum lipid levels, differences in dietary intake were not associated with these cardiometabolic risk factors. The lack of influence of diet on serum lipid levels is consistent with previous studies. Several researchers[24] have described the relation between macronutrients and lipid concentrations as being “weak and inconsistent,” with numerous studies finding no association, particularly when body fat is controlled for.[10]

Finally, racial/ethnic differences in dietary intakes were not significantly associated with the inflammatory markers CRP or IL-6. However, BMI *z* score was positively associated with CRP and IL-6, which is consistent with previous studies, which have shown increased subclinical inflammation in obese children.[9,25] Unlike previous research,[9] our study did not identify a relationship between saturated and polyunsaturated fat intake and subclinical inflammation independent of BMI *z* score, possibly due to the large proportion of children who had high saturated fat intakes. However, regardless of any effect on body weight, dietary fat intake in children is of interest because there is a relationship in adults between dietary fat and atherosclerotic heart disease independent of BMI. The atherosclerotic process begins in childhood[26] and early experiences with food can shape long-term eating patterns.

Our study was limited by its cross-sectional nature. The modest sample size of some of the racial/ethnic groups may have been insufficient to detect weak associations. Dietary macronutrient intakes were examined with blood lipid levels and inflammatory markers, instead of micronutrients or food groups, which could better assess dietary quality. However, previous studies support analyses of dietary macronutrient intakes with blood lipid levels,[9] because previous studies have shown marked ethnic differences in children.[11] Moreover, dietary assessment is particularly challenging in children, due to challenges of memory, estimation in portion sizes, and misreporting.[27,28] All self-reported dietary assessment methods (eg, 24 hour-recalls, FFQs, food records, and check lists) tend to underreport energy and nutrient intake.[29] In our study, the FFQ was chosen because of its use in other similar populations, ease of implementation in a school-based setting, and relatively low cost. Inaccurately reported intake has important implications in studies that deal with

assessing the role of diet in childhood obesity and related health risk factors. However, the accuracy of data collection in this study was strengthened by the use of a validated[19] FFQ.

CONCLUSIONS

Our study showed racial/ethnic differences in total, saturated, and polyunsaturated fat intake by children. Although none of the examined macronutrients explained racial/ethnic differences in lipid profiles or inflammatory markers, BMI *z* score was associated with many CVD risk factors. Further research is warranted to determine the extent to which diets high in saturated fat and low in unsaturated fat influence cardio-metabolic health in children, and to determine whether adhering to selected dietary recommendations is beneficial. In addition, the reported data on the diets and cardiometabolic risk factors in a diverse population of schoolchildren at high risk for obesity and cardiovascular disease adds to the body of knowledge on the topic and can be used to inform nutrition interventions and policy.

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Table 1

Anthropometric data and select dietary components by race/ethnicity among urban school-aged children (N=148) in a study to examine the effect of specific nutrients on cardiometabolic risk

Variable	White (n=57)	Hispanic (n=48)	Black (n=12)	Asian (n=15)	Multiracial (n=16)	*P* value
	←———*mean*[a]±*standard deviation*———→					
Age (y)	10.9±1.5	11.7±1.6	11.3±1.8	11.3±1.7	12.1±1.7	0.05
Body mass index *z* score	0.6±1.0	1.3±0.9[b]	0.5±1.2	0.7±1.1	1.0±0.9	0.01
Energy (kcal)	1,277±598	1,570±916	1,767±983	1,315±537	1,775±1027	0.07
Fat (g)[c]	50.7±7.8	46.1±11.4	55.7±17.4	47.5±6.6	45.8±7.5	0.02
Saturated fat (g)[c]	17.8±3.1	16.2±4.4	17.0±3.7	15.7±2.6	15.4±2.1	0.04
MUFA[d] (g)[c]	18.9±3.4	17.3±4.6	20.5±6.4	18.2±3.0	17.6±3.5	0.10
PUFA[e] (g)[c]	9.8±3.1	8.7±3.0	11.8±4.5	9.9±1.9	9.3±2.8	0.04
Carbohydrate (g)[c]	211.2±24.4	222.2±36.2	203.2±48.3	224.0±24.4	226.3±20.9	0.10

[a]Means compared using analysis of variance.

[b]Mean is significantly different from white, $P<0.01$ (based on analysis of variance with post hoc Bonferonni).

[c]Adjusted by total energy intake.

[d]MUFA=monounsaturated fatty acid.

[e]PUFA=polyunsaturated fatty acid.

Table 2

Cardiometabolic risk factors by race/ethnicity among urban school-aged children (N=148) in a study to examine the effect of specific nutrients on cardiometabolic risk

Risk factor	White (n=57)	Hispanic (n=48)	Black (n=12)	Asian (n=15)	Multiracial (n=16)	*P* value
	←———*mean±standard deviation*———→					
Total cholesterol (mg/dL)[bc]	166.4±26.8	159.6±28.5	169.4±37.6	169.3±24.2	148.3±19.4	0.11
High-density lipoprotein cholesterol (mg/dL)[cd]	53.8±12.8	47.0±12.4	53.6±13.0	53.1±13.7	49.7±10.5	0.04
Low-density lipoprotein cholesterol (mg/dL)[bc]	95.0±23.7	95.0±26.5	97.4±35.1	97.4±21.6	83.4±18.4	0.40
Triglyceride (mg/dL)[de]	75.0±31.1	100.4±63.4	66.8±29.3	82.3±38.7	58.3±35.6	0.009
C-reactive protein (mg/L)[df]	1.3±2.6	1.2±1.8	1.0±1.6	1.3±2.6	0.6±0.6	0.12
Interleukin-6 (pg/mL)[dg]	1.2±1.8	1.5±1.2	1.8±1.3	2.1±3.9	1.1±0.6	0.008

[b] Means compared with analysis of variance.

[c] Acceptable cholesterol concentrations:[21] total cholesterol: <170 mg/dL (<4.40 mmol/L), high-density lipoprotein cholesterol: >45 mg/dL (>1.04 mmol/L), low-density lipoprotein cholesterol <110 mg/dL (<2.86 mmol/L). To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.026. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.6. Cholesterol of 170 mg/dL=4.40 mmol/L.

[d] Medians compared with a nonparametric Kruskall-Wallis test.

[e] Acceptable triglyceride concentrations:[21] For children aged 0–9 years: <75 mg/dL (<0.85 mmol/L), for children aged 10–19 years: <90 mg/dL (<1.02 mmol/L). To convert mg/dL triglyceride to mmol/L, multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 75 mg/dL=0.85 mmol/L.

[f] To convert mg/L C-reactive protein to nmol/L, multiply mg/L by 9.254. To convert nmol/L C-reactive protein to mg/L, multiply nmol/L by 0.105. C-reactive protein of 1.3 mg/L=12.38 nmol/L.

[g] To convert pg/mL interleukin-6 to pmol/L, multiply pg/mL by 0.131. To convert pmol/L interleukin-6 to pg/mL, multiply pmol/L by 7.63. Interleukin-6 of 1.2 pg/mL=9.12 pmol/L.

Table 3

Association of dietary intake, race/ethnicity, and cardiovascular disease risk markers in urban school-aged children (N=146) in a study to examine the effect of specific nutrients on cardiometabolic risk[a]

	Cardiovascular Disease Risk Marker									
	Low-Density Lipoprotein Cholesterol[b]		High-Density Lipoprotein Cholesterol[bc]		Triglyceride[cd]		C-Reactive Protein[c]		Interleukin-6[c]	
Variable	**β (95% CI)**	***P* value**	**β (95% CI)**	***P* value**	**β (95% CI)**	***P* value**	**β (95% CI)**	***P* value**	**β (95% CI)**	***P* value**
Saturated fat (% kcal)	−1.08 (−4.60, 2.44)	0.55	.01 (−.01, .02)	0.45	.004 (−.02, .03)	0.76	−.01 (−.10, .06)	0.72	.002 (−.04, .05)	0.92
Monounsaturated fatty acid (% kcal)	−1.73 (−6.42, 2.96)	0.47	.004 (−.01, .02)	0.64	−.002 (−.04, .03)	0.90	.07 (−.03, .18)	0.16	0.01 (−.05, .06)	0.83
Polyunsaturated fatty acid (% kcal)	−.83 (−4.63, 2.96)	0.67	.001 (−.01, .02)	0.88	−.01 (−.03, .02)	0.72	−.07 (−.15, .02)	0.11	.01 (−.04, .06)	0.63
Carbohydrate (% kcal)	−.55 (−2.14, 1.04)	0.50	.001 (−.01, .01)	0.68	.001 (−.01, .01)	0.92	.02 (−.02, .05)	0.40	.01 (−.01, .03)	0.45
Ethnicity										
White[e]	—	—	—	—	—	—	—	—	—	—
Hispanic	−11.6 (−23.9, 0.71)	0.07	.00 (−.05, .05)	0.98	.01 (−.09, .10)	0.89	.07 (−.20, .35)	0.60	.06 (−.10, .21)	0.48
Black	2.75 (−14.7, 20.2)	0.76	.01 (−.05, .08)	0.73	−.04 (−.18, .09)	0.52	.21 (−.18, .60)	0.28	.28 (.07, .50)	0.011
Asian	.56 (−14.4, 15.5)	0.94	.01 (−.5, .06)	0.82	.02 (−.93, .13)	0.81	.18 (−.15, .51)	0.29	.13 (−.05, .32)	0.16
Multiracial	−14.7 (−30.9, 1.50)	0.08	.02 (−.05, .08)	0.61	−.20 (−.32, −.08)	0.002	−.14 (−.49, .22)	0.40	−.03 (−.23, .17)	0.76
Body mass index *z* score	4.19 (−0.18, 8.56)	0.06	−.06 (−.07, −.04)	−0.0001	.09 (.05, .12)	−0.0001	.35 (.25, .44)	−0.0001	.12 (.06, .17)	−0.0001

[a] Adjusted for sex, age, pubertal status, and socioeconomic status.

[b] To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.026. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.6. Cholesterol of 170 mg/dL=4.40 mmol/L.

[c] Calculated with log-transformed variables.

[d] To convert mg/dL triglyceride to mmol/L, multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 75 mg/dL=0.85 mmol/L.

[e] Referent.

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