Original Research

Saturated and *Cis*- and *Trans*-Unsaturated Fatty Acids Intake in Rural and Urban Costa Rican Adolescents

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Key words: adolescents, *trans* fatty acids, saturated fatty acids, rural vs. urban, dietary intake

Objective: The purpose of this study is to determine whether intake of saturated fatty acids and *cis*- and *trans*-unsaturated fatty acids is associated with an urban compared to a rural lifestyle, and whether these associations are responsible for differences in plasma lipid concentrations.

Methods: Two hundred seventy-five adolescents, aged 12 to 19 years, living in rural and urban areas of San José, Costa Rica, were included in the study. All participants completed three-day food records, provided a fasting blood sample, and carried out a modified Harvard Step Test.

Results: Compared to rural, urban adolescents reported higher intakes of energy-adjusted individual and total saturated fatty acids, total n-3, total n-6 ($p < 0.05$). Compared to rural, urban adolescents had higher intake of 18:1 (3.65 vs. 3.25, $p = 0.0001$) and 18:2 (0.62 vs. 0.80, $p = 0.001$) *trans* fatty acids, as well as lower intake of carbohydrate ($p < 0.05$). Palm shortening was the main source of saturated fat (32%), and partially hydrogenated soybean oil used for cooking was the main source of n-3 fatty acids (33%), n-6 fatty acids (33%) and *trans* fatty acids (34%). Compared to rural, urban adolescents had lower systolic and diastolic blood pressure and higher plasma HDL cholesterol concentration (44 vs. 40 mg/dL, $p < 0.0001$), but were more likely to be sedentary (68% vs. 57%, $p < 0.0001$). Among environmental factors, higher carbohydrate intake was a significant determinant of a lower HDL cholesterol (β coeff $= -1.45$, $p = 0.04$), while lauric and myristic fatty acids correlated with increased LDL cholesterol (β coeff $= 3.6, 1.7$, $p < 0.05$).

Conclusions: A diet containing less carbohydrate and less saturated fatty acids contributes to a more beneficial lipid profile in Costa Rican adolescents, but a trend towards high *trans* fatty acids intake, particularly in the urban area is worrisome given the well-known adverse effects of *trans* fatty acids.

INTRODUCTION

Coronary heart disease (CHD) is the main cause of death in most Latin American countries, including Costa Rica [1]. Adolescents make up a significant proportion—on average 21%—of the general population in these countries. Also, the extent of atherosclerotic change in early years is correlated with the presence of CHD factors in adults [2,3]. Eating habits associated with CHD risk are acquired early in life and may accelerate the development of this pathology [2,3]. Therefore, developing a healthy diet in adolescents may contribute to reducing the risk of CHD in adulthood [4].

The fatty acid composition of the diet is associated with CHD risk. Some prospective cohort studies [5,6], but not all [7,8] have found a significant positive association between saturated fat intake and risk of CHD. In the Nurses' Health Study [9], replacing five percent of energy from saturated fat with *cis*-unsaturated fats was associated with a 42 percent reduction in CHD. Similarly, *trans* fatty acid intake is associated with increased risk of CHD, and replacing two percent of the energy from *trans* fatty acids with non-hydrogenated unsaturated fats reduced the risk of CHD by 53 percent [9]. As expected, no association between *trans* fatty acid intake and CHD has been found in European countries were intake of *trans* fatty acids is low [10,11]. Using adipose biomarkers of intake, 18:2 *trans* fatty acids showed the highest association with CHD in population based case-control study in Costa Rica [12,13]. In contrast, both *cis* n-6 fatty acids (primarily linoleic

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acid, 18:2n-6) and *cis* n-3 fatty acids reduce the risk of CHD [14]. A synergistic relation between linoleic acid and alpha-linolenic acid intake has been suggested by Djoussé *et al.* [15], showing that the combined intake of these fatty acids may be associated with a greater reduction in the prevalence of CHD.

In an attempt to reduce the saturated content of the diet in Costa Rica, soybean oil has been replacing palm oil the last decade [16]. In 2001, the national average intake of soybean oil was four times higher than that reported in 1991 (21.1 g/d and 5.0 g/d, respectively), while palm oil intake decreased 65 percent in relation to 1991 (10.8 g/d and 31.5 g/d, respectively) [17]. Although this was expected to have a positive effect because of increased n-3 and n-6 fatty acids, recent studies show that soybean oil used for cooking in Costa Rica is partially hydrogenated [13], resulting in a lower proportion of alpha-linolenic acid and a higher proportion of *trans* fatty acids, than soybean oil that is not partially hydrogenated.

For the past 20 years, mortality rates for cardiovascular disease and myocardial infarction in Costa Rica have been higher in urban than in rural areas [18]. This epidemiological profile could be explained—at least in part—by establishing if the determination of CHD risk factors between both areas differs from an early age. We hypothesize that adolescents living in the urban area will have a more adverse fatty acid intake (high saturated and *trans* fatty acids, and low polyunsaturated fatty acids) and plasma lipid profile, than those living in the rural area. We will also examine whether dietary fatty acids explain the plasma lipid rural-urban differences.

MATERIALS AND METHODS

Study Population

Adolescents aged 12 to 19 years from San José, Costa Rica, were included in the study, as previously described [19]. Adolescents were recruited from five urban and five rural public high schools. The schools were chosen from a list of all the public high schools in San José using a proportional-size probability formula. Both parents and students gave their written consent to participate in the study according to the rules provided by the Bioethics Committee of the Costa Rican Institute for Research and Education on Nutrition and Health (INCIENSA).

Dietary Assessment

Dietary intake was determined using three-day food records [20]. The three days included one weekend day and the next or previous two weekdays (Sunday, Monday and Tuesday or Thursday, Friday and Saturday). The adolescents used a series of photographs of foods usually consumed in Costa Rica to estimate portion size while keeping the food record [21]. Food models and fresh foods were used to verify serving size.

In order to determine the contribution of the different foods to the total selected fatty acids intake, each food was classified into one of 23 possible food groups. These include: meat, fish, pork, chicken, organ meat, eggs, cold cuts, breads, breakfast cereals, margarines, palm oil shortening, butter, partially hydrogenated soybean oil, other oils (canola oil, sunflower oil, corn oil, and olive oil), rice, legumes, milk (1% and 2% fat), cheese, other dairy products (including cream cheese, sour cream, whipping cream, ice cream, butter, and *lactocrema*, a mixture of butter and margarine), fruits, vegetables, chocolates and candies, and other foods (including soups, pastas, sauces, condiments, nuts, and coconut).

Energy intake and total fat were calculated using the Food Processor® for Windows version 6.0 (Esha Research, Salem, Oregon), which was modified to include the nutritional value of 60 food preparations commonly consumed in Costa Rica. Fatty acid intake was estimated using a fatty acid content database (thirty-nine *cis* fatty acids and ten *trans* fatty acids isomers) for Costa Rican foods provided by Campos, H. (unpublished data, Campos Laboratory, 2002). For this study, 33 foods—mostly those sold at the schools' cafeterias—were analyzed for fatty acid content and incorporated into our database. In the database, the fatty acid content was expressed in grams per 100 grams of total fat. The *cis-trans* isomer content of foods was estimated using gas chromatography, as previously described by Baylin *et al.* [22]. To calculate fatty acid intake of each adolescent, the following formula was used: (grams of total fat in the amount of food consumed $\times$ grams of fatty acids per 100 grams of total fat)/100. The total fat content of each food was obtained with Food Processor® for Windows version 6.0 (Esha Research, Salem, Oregon). Table 1 shows the *trans* fatty acid content of the foods that contributed over 80 percent of total *trans* fatty acids to the Costa Rican adolescents' diet.

Anthropometric Measurements, Blood Pressure and Physical Activity

Weight, height, blood pressure, and fitness scores were determined using the previously described methodology [23]. Fitness score was determined using the Harvard Step Test modified by Bush *et al.* [24]. Each adolescent stepped up and down on a platform 33 cm high, at a rate of 30 steps per minute for 4 minutes. Upon completion of the test, the heart rate was counted for a 30-second period, starting exactly 1, 2 and 3 minutes after completion. These results were then added up and classified in scores—according to what Bush *et al.* propose [24]—to determine the cardiovascular fitness score of each adolescent. Scores ranged from 1 to 5. Adolescents who scored above 3 were considered sedentary.

Table 1. *Trans* Fatty Acids (G/100 g Food) in Selected Foods Included in the Costa Rican Adolescents' Diet[1]

Food	C14:1*t*	C16:1*t*	Total C18:1*t*	Total C18:2*t*	C20:1*t*	C20:2*t*
Partially hydrogenated soybean oil	0.000	0.000	6.854	11.096	1.024	0.349
Palm shortening	0.000	0.000	0.545	0.922	0.000	0.000
Margarine	0.000	0.003	6.319	0.516	0.000	0.000
Milk 2%	0.000	0.013	0.087	0.222	0.000	0.000
Fresh cheese	0.000	0.138	0.984	0.185	0.000	0.000
Cream cheese	0.007	0.253	1.442	0.263	0.000	0.000
Sour cream	0.002	0.126	0.737	0.169	0.000	0.000
Ice cream and ice cream bars	0.000	0.011	0.371	0.000	0.000	0.000
Butter	0.001	0.365	2.720	0.402	0.000	0.000
Red meat	0.000	0.073	0.608	0.106	0.000	0.000
Cold cuts	0.000	0.021	0.215	0.078	0.003	0.000
Cookies	0.000	0.005	0.046	0.023	0.000	0.000
Crackers	0.000	0.000	0.006	0.237	0.000	0.000
Crème-filled cookies	0.000	0.000	1.027	0.174	0.000	0.000
Chocolate cookies	0.000	0.000	1.161	0.138	0.000	0.000
White bread	0.000	0.000	0.041	0.015	0.000	0.000
Hamburger	0.000	0.089	1.033	0.163	0.000	0.000
Cheeseburger	0.000	0.050	0.536	0.107	0.000	0.000
Empanada[2]	0.000	0.014	0.065	0.086	0.000	0.000
Extruded corn snacks	0.000	0.000	0.291	0.001	0.000	0.000

[1] The *trans* fatty acids in this table were defined as follows: 16:1 = 16:1 (n-7t); 18:1 = 18:1 (n-7t) + 18:1 (n-9t) + 18:1 (n-12t); 18:2 = 18:2 (n-6tt) + 18:2 (n-6ct); 20:1 = 20:1 (n-9t) and 20:2 (20:2 n-6t).

[2] Empanada is a deep-fried corn dough pastry turnover filled with meat, diced potatoes, or bean puree.

Biochemical Analyses

Serum triacylglycerol, cholesterol, and HDL cholesterol concentrations were measured using enzymatic reagents (Randox, England) and an automatic analyzer ASCA (LSI Instruments). LDL cholesterol was calculated with the Friedwald's *et al.* equation [25]. Intra-assay and inter-assay coefficients of variation for total serum cholesterol were, respectively, 2.5 and 2.9 percent, and 6 and 7 percent, respectively, for HDL cholesterol. The coefficient of variation for triglycerides was less than 4 percent for these analyses.

Statistical Data

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS Inc., version 10.0 for Windows, Chicago, Illinois). Variables were checked for outliers and normality, and where necessary, transformed using the natural logarithm. Fatty acid intakes were adjusted for total energy intake by regressing the transformed variable on total energy intake as described by Willett [26]. An analysis of variance was performed using GLM procedure in SPSS to determine whether dietary intakes vary across by gender and concentrations of urbanization. The significance of the differences between male and female means and urban and rural means was assessed using the Tukey multiple comparison test. The Stepwise multiple regression procedure was used to identify those variables associated with LDL cholesterol, HDL cholesterol and triglyceride concentrations at $p < 0.05$. Three multivariate models were examined; in each one, we included area, gender, age, cardiovascular fitness score, and energy intake to control for the effects of these variables.

RESULTS

Of the 300 selected adolescents, those whose parents did not provide written consent to participate in the study and those with missing serum samples were excluded ($n = 25$). The final sample of 275 adolescents consisted of 131 boys and 144 girls.

The general characteristics of the studied population are shown in Table 2. When compared to rural, urban adolescents had a more beneficial profile for some risk factors, but not all. For example, urban adolescents had lower systolic and diastolic blood pressure and higher HDL cholesterol concentrations yet, they were more sedentary. Urban adolescents consumed less dietary fiber, folate, and carbohydrate, but more total energy, total fat, protein and cholesterol. Likewise, urban adolescents consumed more total saturated fatty acids, *trans* fatty acids, n-3 and n-6 fatty acids (Table 3).

The main *trans* fatty acids consumed were 18:1 and 18:2, representing 77.1% and 19.3% of the total *trans* fatty acids consumed, respectively. Of these *trans* fatty acids, the most frequently consumed isomers were 18:1n-7t and 18:2tc (data not shown).

Consumption of milk, dairy products, fast foods, vegetables, breads, bakery foods, meats, sausages, eggs, fish, and partially hydrogenated soy oil was significantly higher ($p = 0.000$) in urban adolescents than among their rural counterparts (data not

Table 2. General Characteristics and Dietary Intake in Rural and Urban Costa Rican Adolescents Aged 12–18 Years[1,2]

Parameter	Male (n = 144)		Female (n = 131)		Main effect p value	
	Rural (n = 69)	Urban (n = 75)	Rural (n = 62)	Urban (n = 69)	Area	Gender
Age	15.3 ± 1.7	15.5 ± 1.5	15.3 ± 1.8	15.3 ± 1.4	0.5848	0.7124
Weight (kg)	55.8 ± 11.0	58.5 ± 11.5	52.9 ± 8.4	53.2 ± 7.5	0.1823	0.0009
Height (cm)	163.6 ± 9.2	165.9 ± 9.2	155.1 ± 5.9	157.8 ± 5.7	0.0088	0.0000
BMI (Kg/m^2)	20.7 ± 1.0	20.8 ± 1.0	21.7 ± 0.9	21.1 ± 0.8	0.5054	0.0482
Systolic pressure (mmHg)	113.9 ± 2.5	112.1 ± 2.3	111.2 ± 1.9	106.0 ± 2.3	0.0089	0.0010
Diastolic pressure (mmHg)	67.1 ± 1.8	66.4 ± 2.1	66.7 ± 1.4	63.2 ± 1.8	0.0275	0.0565
Sedentarism (%)[3,4]	42.7 ± 29.8	53.7 ± 24.8	71.8 ± 25.7	81.7 ± 19.0	0.0008	0.0000
Total cholesterol (mg/dL)	143.8 ± 22.2	151.1 ± 20.6	162.2 ± 23.5	162.4 ± 22.1	0.1459	0.0000
HDL cholesterol (mg/dL)	38.9 ± 7.4	42.7 ± 7.0	41.6 ± 5.2	46.2 ± 6.3	0.0000	0.0001
LDL cholesterol (mg/dL)	82.5 ± 21.4	86.3 ± 19.9	96.8 ± 22.4	93.3 ± 21.0	0.9163	0.0000
Serum triacylglycerol (mg/dL)	101.8 ± 5.6	104.0 ± 6.1	115.8 ± 5.5	106.9 ± 5.7	0.3820	0.0083
Energy intake (Kcal)	2258.7 ± 139.4	2442.0 ± 134.5	1792.4 ± 102.9	2070.5 ± 80.8	0.0061	0.0000
Carbohydrate (% of energy)	66.4 ± 11.2	60.2 ± 15.5	65.2 ± 12.7	62.3 ± 13.3	0.0001	0.6612
Protein (% of energy)	11.5 ± 3.5	12.7 ± 3.4	11.8 ± 2.9	11.8 ± 3.4	0.0281	0.3798
Total fat (% of energy)	29.8 ± 6.6	32.5 ± 6.8	31.0 ± 6.4	33.7 ± 6.0	0.0000	0.0812
Saturated (% of energy)	10.6 ± 3.2	12.4 ± 3.7	10.8 ± 3.1	11.8 ± 3.2	0.0000	0.3112
Monounsaturated (% of energy)	7.2 ± 3.0	9.3 ± 3.2	8.3 ± 3.1	9.6 ± 2.9	0.0000	0.5604
Polyunsaturated (% of energy)	5.4 ± 3.2	6.6 ± 3.0	5.2 ± 3.0	5.6 ± 2.6	0.0192	0.9362
Dietary fiber (g/d)	27.4 ± 5.4	17.5 ± 3.3	22.0 ± 3.5	17.1 ± 2.1	0.0000	0.0430
Cholesterol (mg/d)	185.6 ± 33.0	231.9 ± 22.8	161.0 ± 23.0	195.6 ± 22.6	0.0180	0.0786
Vitamin E (mg/d)	7.8 ± 2.1	7.6 ± 1.9	7.3 ± 1.9	7.2 ± 1.6	0.8178	0.3285
Folate (mg/d)	304.6 ± 26.7	244.3 ± 25.7	242.7 ± 22.3	225.3 ± 17.6	0.0146	0.0106

[1] Values are means ± SD.

[2] Dietary nutrients are adjusted for total energy intake.

[3] Sedentarism was determined using a Harvard step test modified by Bush *et al.* (24). Adolescents with a cardiovascular fitness score above 3 were considered sedentary.

[4] p-values of the coefficients of a logistic regression.

Table 3. Intake of Individual Polyunsaturated Fatty Acids in Rural and Urban Costa Rican Adolescents Aged 12–18 Years[1,2]

Fatty acid (g/day)	Male (n = 144)		Female (n = 131)		Main effect p value	
	Rural (n = 75)	Urban (n = 69)	Rural (n = 69)	Urban (n = 62)	Area	Gender
Palmitic acid	15.3 ± 2.33	16.8 ± 1.87	14.6 ± 2.84	15.5 ± 2.01	0.0231	0.0891
Lauric acid	0.31 ± 0.07	0.43 ± 0.08	0.41 ± 0.08	0.49 ± 0.06	0.0113	0.1096
Myristic acid	1.25 ± 0.09	1.65 ± 0.08	1.53 ± 0.04	1.75 ± 0.21	0.0020	0.5913
Stearic acid	4.32 ± 1.32	5.28 ± 1.10	4.12 ± 1.15	5.53 ± 1.11	0.0001	0.2265
Total saturated fatty acids	21.10 ± 3.28	26.38 ± 2.59	19.03 ± 3.35	24.76 ± 3.26	0.0462	0.2817
∝-linolenic acid	0.79 ± 0.24	0.78 ± 0.21	0.88 ± 0.34	0.83 ± 0.23	0.1821	0.4932
Eicosapentaenoic acid	0.05 ± 0.01	0.06 ± 0.02	0.07 ± 0.02	0.07 ± 0.01	0.4903	0.1035
Docosahexaenoic acid	0.05 ± 0.02	0.06 ± 0.03	0.07 ± 0.03	0.07 ± 0.03	0.5800	0.4315
Total n-3 fatty acids	1.02 ± 0.24	1.09 ± 0.27	1.05 ± 0.76	1.15 ± 0.67	0.0424	0.8069
Linoleic acid	7.63 ± 2.02	8.89 ± 1.77	8.36 ± 1.76	8.63 ± 1.88	0.0867	0.7063
y-linolenic	0.05 ± 0.02	0.04 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.4758	0.9312
Arachidonic acid	0.17 ± 0.13	0.21 ± 0.15	0.13 ± 0.09	0.17 ± 0.13	0.3617	0.7315
Total n-6 fatty acids	7.98 ± 2.04	9.26 ± 1.77	8.61 ± 1.75	9.00 ± 1.88	0.0413	0.7342
Trans 16:1	0.07 ± 0.01	0.10 ± 0.03	0.08 ± 0.02	0.10 ± 0.01	0.0001	0.2198
Trans 18:1	3.14 ± 0.44	3.66 ± 0.78	3.36 ± 0.15	3.64 ± 0.28	0.0001	0.3037
Trans 18:2	0.57 ± 0.69	0.83 ± 0.59	0.66 ± 0.16	0.76 ± 0.12	0.0010	0.5869
Total *trans* fatty acids	4.04 ± 0.78	4.96 ± 0.82	4.35 ± 0.67	4.75 ± 0.68	0.0001	0.4185

[1] Values are means ± SD.

[2] Dietary nutrients are adjusted for energy intake.

shown). The reverse was true for fruits, roots and tubers, rice, legumes, bananas, plantains and palm shortening. There were no differences in food intake by gender.

The food sources of saturated and unsaturated fatty acids in the adolescents' diet are shown in Tables 4 and 5. Palm shortening, margarine, dairy and bakery products were the major sources of saturated fat in the adolescents' diet. Dairy was the major contributor of lauric (65%), myristic (67%) and

Table 4. Food Sources of Saturated Fatty Acids in Costa Rican Adolescents' Diet[1]

Lauric acid (12:0)	Myristic acid (14:0)	Palmitic acid (16:0)	Stearic acid (18:0)	Total saturated fat
Dairy (65%)	Dairy (67%)	Palm shortening (33%)	Dairy (24%)	Palm shortening (32%)
Milk (13%)[2]	Milk (21%)	Dairy (19%)	Milk (8%)	Dairy (22%)
Cheese (10%)	Cheese (14%)	Milk (7%)	Cheese (6%)	Milk (8%)
Other (42%)[3]	Other (32%)	Cheese (4%)	Other (10%)	Cheese (6%)
Bakery (22%)	Bakery (9%)[5]	Other (9%)	Red meat (22%)	Other (10%)
Margarine (7%)	Red meat (8%)[6]	Bakery (10%)	Palm shortening (19%)	Margarine (12%)
Snacks (2%)	Cold cuts (4%)	Red meat (9%)	Cold cuts (12%)	Bakery (10%)
Breads (1%)	Palm shortening (4%)	Margarine (8%)	Bakery (6%)	Snacks (5%)
Others (3%)[4]	Margarine (3%)	Cold cuts (7%)	Margarine (6%)	Red meat (5%)
	Breads (1%)	Breads (5%)	Breads (4%)	Cold cuts (4%)
	Snacks (1%)	Snacks (4%)	Chicken (2%)	Chicken (3%)
	Others (3%)	Chicken (2%)	Organ meat (1%)	Others (7%)
		Others (3%)	Others (4%)	

[1] Numbers in parentheses indicate percentage of a given fatty acid contributed by each food/food group.
[2] Mostly 1 and 2% fat milk.
[3] Includes cream cheese, sour cream, whipping cream, ice cream, butter and *lactocrema*, a mixture of butter and margarine.
[4] Includes foods that contributed less than 1% of fat.
[5] Includes cookies, cakes, doughnuts, and puff pastries.
[6] Red meat refers to beef and pork.

Table 5. Estimated Main Food Sources of Dietary N-3, N-6 and *Trans*-Fatty Acids for Costa Rican Adolescents[1]

n-3 fatty acids	n-6 fatty acids	*trans* fatty acids
Partially hydrogenated soybean oil (33%)	Partially hydrogenated soybean oil (33%)	Partially hydrogenated soybean oil (34%)
Legumes (9%)	Palm shortening (12%)	Dairy (21%)
Vegetables (8%)	Breads (9%)	Milk (9%)
Dairy (7%)	Cold cuts (8%)	Cheese (5%)
Milk (2%)[2]	Red meats (6%)	Other (7%)
Cheese (2%)	Bakery (5%)	Bakery (11%)
Other (3%)[3]	Other oils (5%)	Red meat (10%)
Red meat (6%)[4]	Vegetables (2%)	Margarine (9%)
Fruits (5%)	Dairy (2%)	Palm shortening (5%)
Cold cuts (5%)	Legumes (1%)	Cold cuts (4%)
Breads (5%)	Fruits (1%)	Breads (3%)
Bakery (3)[5]	Others (4%)	Others (4%)
Palm shortening (2%)		
Fish (2%)		
Other oils (1%)[6]		
Others (5%)[7]		

[1] Numbers in parentheses indicate percentage of a given fatty acid contributed by each food/food group.
[2] Mostly 1 and 2% fat milk.
[3] Includes cream cheese, sour cream, whipping cream, ice cream, butter and *lactocrema*, a mixture of butter and margarine.
[4] Red meat refers to beef and pork.
[5] Includes cookies, cakes, doughnuts, and puff pastries.
[6] Includes corn oil, canola oil and sunflower oil.
[7] Includes foods that contributed less than 1% of fat.

stearic fatty acids (24%), while palm shortening was the main contributor of palmitic acid (33%). Partially hydrogenated soybean oil was the main contributor of n-3 fatty acids (33%), n-6 fatty acids (33%) and *trans* fatty acids (34%). About 35% of the total *trans* fatty acids consumed came from naturally occurring sources (meats, 14%; milk, 9%; other dairy products, 7%, and cheese, 5%).

In the multivariate model using LDL cholesterol concentrations as a dependent variable and adjusting for area, gender, age, cardiovascular fitness score and energy intake, the increase of LDL cholesterol concentrations was associated to an increased intake of both lauric and palmitic acid, but the effect of lauric acid on LDL cholesterol concentrations was higher than that of palmitic acid (Table 6). For each one gram increase in lauric acid intake, LDL cholesterol concentrations increased 3.6 mg/dL; while, for each one gram increase in palmitic acid intake, LDL cholesterol concentrations increased 1.7 mg/dL.

Table 6. Regression Models with HDL Cholesterol, LDL Cholesterol and Triglyceride as Response Variables and Nutrient Intake as Explanatory Variables

Independent variables	Estimated coefficient	p value
LDL Cholesterol		
Area[1]	−2.526	0.583
Gender[2]	−3.457	0.436
Age	0.522	0.831
Cardiovascular fitness score[3]	−9.1206 E-02	0.025
Energy Intake	−2.782 E-04	0.809
Lauric acid[4]	3.583	0.002
Palmitic acid[4]	1.683	0.037
$R^2 = 0.173$		
HDL Cholesterol		
Area[1]	3.822	0.000
Gender[2]	−2.147	0.028
Age	4.258 E-02	0.754
Cardiovascular fitness score[3]	−1.735 E-02	0.045
Energy Intake	−3.631 E-04	0.623
Carbohydrates[4]	−1.485	0.042
$R^2 = 0.179$		
Triglyceride		
Area[1]	−5.238	0.072
Gender[2]	−2.825	0.526
Age	−2.121	0.216
Cardiovascular fitness score[3]	0.123	0.028
Energy Intake	4.325 E-03	0.065
Myristic acid[4]	3.915	0.027
$R^2 = 0.195$		

[1] Urban area = 1, Rural area = 0.

[2] Male = 1, Female = 0.

[3] Determined using a Harvard step test modified by Bush *et al.* [24].

[4] Adjusted for total energy intake.

Overall, higher HDL cholesterol concentrations were associated to a decrease in both the cardiovascular fitness score and the carbohydrate intake.

DISCUSSION

The results of this study demonstrate that urban dwellers are exposed since adolescence to sedentary lifestyles and higher intakes of saturated fat, cholesterol and *trans* fatty acids, in contrast to their rural counterparts. This could explain, at least in part, the larger prevalence of CHD in Costa Rican urban areas [18]. However, urban adolescent also consumed less carbohydrate, less folate, less fiber, and more polyunsaturated fat and this study cannot distinguish which of these factors or factors will be the most relevant for CHD. It is surprising that despite a general more adverse lifestyle pattern in the urban area, urban adolescents had lower diastolic and systolic blood pressure and higher HDL cholesterol, both important risk factors for CHD. Area of residence did not have an effect on total cholesterol and LDL cholesterol concentrations probably because in addition to increased saturated fatty acids, *trans* fatty acids and cholesterol intake in urban adolescents they also had increased intake of polyunsaturated fat which has opposite effects.

This study showed that the effect of lauric acid on LDL cholesterol concentrations in adolescents is stronger than the effect of palmitic acid, the most abundant fatty acids in the adolescents' diet. Because lauric acid intake is very low compared to palmitic acid intake (2% and 67% of the total saturated fat intake, respectively), it is possible that the attributable risk associated to lauric acid intake is low. Nonetheless, Kabagambe *et al.* [12] have suggested that a small increase in lauric acid intake could result in a significant increase in CHD risk for Costa Rican adults, presumably because saturated fatty acids have a stronger effect on populations with lower saturated fat intakes compared to those with high intakes [12]. For example, a 1% energy increase in lauric acid is associated with a 1.9-fold increase in the risk of non-fatal acute myocardial infarction [12].

Higher HDL cholesterol concentrations are positively associated with physical activity and inversely associated with carbohydrate intake [26]. Our data show that rural adolescents (typically more active, but with lower fat and higher carbohydrate intakes) had the lowest HDL cholesterol concentrations, a pattern that resembles that of Costa Rican rural adults [27]. HDL cholesterol decreases when dietary fat is decreased [28], because high-carbohydrate intake increases endogenous triglyceride synthesis and very low-density lipoprotein secretion [29]. Our results show that for each percentage point of increase in carbohydrate intake, serum HDL cholesterol concentrations decreased by 1.5 mg/dL.

Unsaturated fats, e.g. long-chain n-3 fatty acids, have been shown to lower the risk of CHD [26], so a low intake of n-3 fatty acids, particularly in the rural area that consumes 12 g of fish per day, is worrisome. Baylin *et al.* [30] have reported that alpha-linolenic acid is associated with a large and significant reduction in the risk of non-fatal acute myocardial infarction in Costa Rica, suggesting that increase consumption of vegetable oils would be beneficial. Partially hydrogenated soybean oil was the primary contributor of alpha-linolenic acid in the adolescents' diet; however, it is not wise to promote its consumption yet since it was also the primary source of *trans* fatty acids. Partially hydrogenated soybean oil intake is greater in urban areas than in rural areas, explaining the greater consumption of *trans* fatty acids in urban adolescents as opposed to rural adolescents, who primarily consume palm oil shortening. This suggests that the food industry's support is necessary to modify the manufacturing processes of soy oil in order to reduce its *trans* fatty acid content.

The intake of total *trans* fatty acids by urban and rural Costa Rican adolescents is very similar to that reported for adolescents in the U.S. (2.8% of total energy) and much greater than the recommended maximum intake (1% of total energy) [31–33]. In the diets of both groups of adolescents, the most frequently consumed isomer was 18:1, however the percentage of total *trans* fatty acids from meat and dairy products was higher in Costa Rica (36%) than in the U.S. (20–25%) [34].

It is well established that *trans* fatty acids increase the risk of MI [35]. Clinical studies show that 18:1 *trans* fatty acids (77% of adolescents' *trans* fatty acids intake) adversely affect the lipoprotein profile [36]. Specifically, 18:1 *trans* in subcutaneous fat are higher in patients with CHD than controls [37]. Some epidemiological studies [11,38,39] have found no association between 18:1 *trans* fatty acids in adipose tissue and the risk of myocardial infarction, but it has been proposed that the low-adipose tissue level of these fatty acids can explain the absence of association [13]. A study by Baylin *et al.* [13] show that 18:2 *trans* fatty acids isomers had the strongest association with CHD in Costa Rica, and the relative abundance of this isomer in adipose tissue is higher in Costa Rica than in other countries [13]. Similar results have been obtained when comparing red cell membrane fatty acids in patients with primary cardiac arrest and controls [40].

Trans fatty acids derived from meat and dairy products may also be associated with CHD [41,42]. A positive association between adipose tissue *trans* fatty acids found exclusively in animal products (16:1n-7*trans*) and non-fatal acute myocardial infarction was observed in Costa Rican adults [13]. Our data show that Costa Rican adolescents consume a considerable proportion of *trans* fatty acids from meat and dairy products which are also major sources of saturated fat. Therefore, strategies directed at reducing consumption of meat and high-fat dairy products will be beneficial for the reduction of total *trans* fatty acids as well.

CONCLUSIONS

A higher intake of saturated and *trans* fatty acids was associated with an urban compared to a rural lifestyle. Urban adolescents also had a higher intake of *cis*-n-3 and n-6 fatty acids because partially hydrogenated soybean oil was the main source of these fatty acids. Dairy and meat products were major contributors to both saturated fat and *trans* fatty acids. Because there was no consistent adverse pattern in urban adolescents, this study could not identify a clear rural-urban discriminating profile. However, this study provides novel information on *cis* and *trans* fatty acids in adolescents which show trends that are worrisome given the high overall content of *trans* fatty acids and low n-6 and n-3 fatty acids in specific areas of Costa Rica.

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