






# Dietary inflammatory index scores are associated with atherogenic risk in Brazilian schoolchildren

Lara Gomes Suhett<sup>1,\*</sup> , Sarah A Vieira Ribeiro<sup>1</sup>, Helen Hermana M Hermsdorff<sup>1</sup>, Mariane A Silva<sup>1</sup> , Nitin Shivappa<sup>2,3,4</sup>, James R Hébert<sup>2,3,4</sup>  and Juliana F Novaes<sup>1</sup>

<sup>1</sup>Department of Nutrition and Health, Universidade Federal de Viçosa (UFV), Av. P.H. Rolfs s/n, Campus Universitário, CEP, Viçosa, MG 36570-000, Brazil; <sup>2</sup>Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, Columbia, SC, USA; <sup>3</sup>Statewide Cancer Prevention and Control Program (CPCP), Arnold School of Public Health, University of South Carolina, Columbia, SC, USA; <sup>4</sup>Department of Nutrition, Connecting Health Innovations (CHI), Columbia, SC, USA

Submitted 19 December 2020: Final revision received 14 April 2021: Accepted 20 April 2021: First published online 27 April 2021

## Abstract

**Objective:** To investigate the association between the Children's Dietary Inflammatory Index (C-DII<sup>TM</sup>) scores and atherogenic risk in Brazilian schoolchildren.

**Design:** A cross-sectional representative study. Three 24-h dietary recalls were performed to evaluate food consumption and to calculate C-DII scores. Blood samples were collected for the lipid profile analysis (serum total cholesterol (TC), HDL-cholesterol, LDL-cholesterol, VLDL-cholesterol and triglycerides (TAG)) and to determine atherogenic indexes (Castelli risk indexes I and II, lipoprotein combined index (LCI), and atherogenic index of plasma and atherogenic coefficient (AC)). A semi-structured questionnaire was used to obtain sociodemographic characteristics and screen time. Body fat was assessed by dual-energy X-ray absorptiometry. We compared the distributions of outcomes by C-DII categories using multivariable linear regression.

**Setting:** Viçosa, Minas Gerais, Brazil.

**Participants:** Three hundred seventy-eight children between the ages of 8 and 9 years.

**Results:** The mean C-DII score was  $0.60 \pm 0.94$ , and the prevalence of dyslipidaemia was 70%. Children with hypercholesterolaemia and hypertriglyceridaemia had higher C-DII scores. The C-DII was directly associated with atherogenic risk. Every 1 SD of C-DII was associated with a 0.07 (0.01, 0.13), 1.94 (0.20, 3.67), 0.06 (0.002, 0.12) and 0.12 (0.02, 0.22) units higher TC:HDL cholesterol ratio, LCI, AC and accumulation of altered dyslipidaemia markers (high TC + high LDL-cholesterol + high TAG + low HDL-cholesterol), respectively.

**Conclusions:** Dietary inflammatory potential, as estimated by the C-DII, is directly associated with atherogenic risk in Brazilian schoolchildren. This results reinforce the importance of effective nutritional policies to promote healthy eating habits and improve children's lipid profiles.

## Keywords

Inflammation  
Child  
CVD

Atherosclerosis  
Nutritional epidemiology

Dyslipidaemias are disorders characterised by the presence of high total cholesterol (TC), high LDL-cholesterol, low HDL-cholesterol and high triglycerides (TAG)<sup>(1)</sup>. The increasing prevalence of dyslipidaemia in childhood<sup>(2–4)</sup> is considered a major public health concern worldwide, especially due to its vital role in the pathogenesis of atherosclerosis and the development of CVD<sup>(1,5)</sup> through their effect on inflammatory process<sup>(5,6)</sup>.

In this context, the diet is an important moderator of systemic inflammation<sup>(7)</sup> and has been identified as a

modifiable risk factor for managing dyslipidaemia and preventing atherosclerotic disease<sup>(1,8,9)</sup>. Furthermore, studies in adults have shown the association of a pro-inflammatory diet with unfavourable lipoprotein profile<sup>(10,11)</sup> and sub-clinical atherosclerosis<sup>(12)</sup>.

A validated tool for assessing the inflammatory potential of diet in paediatric populations<sup>(13)</sup>, the Children's Dietary Inflammatory Index (C-DII<sup>TM</sup>), has been directly associated with cardiometabolic risk and inflammation in children and adolescents<sup>(13–15)</sup>. Moreover, we recently demonstrated the

\*Corresponding author. Email [nutrilarasuhett@gmail.com](mailto:nutrilarasuhett@gmail.com)

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association between C-DII with anti- and pro-inflammatory adipokines in our sample from the Schoolchildren Health Assessment Survey<sup>(15)</sup>.

In a study with adolescents, it was identified a direct association between C-DII with dyslipidaemia in overweight individuals (12–18 years), but not with isolated markers of lipid profile, reinforcing the need for further studies<sup>(16)</sup>. The effects of diet-related inflammation on lipid profile and atherosclerosis risk remain poorly explored at young ages<sup>(16–18)</sup>, and to date, no studies with children have evaluated these associations using the new C-DII. Therefore, we aimed to investigate the relationship of the C-DII with atherogenic risk in Brazilian schoolchildren. We hypothesise that the C-DII scores are directly associated with atherogenic risk.

## Methods

### *Participants and study design*

This cross-sectional representative study was carried out with participants from the Schoolchildren Health Assessment Survey (*Pesquisa de Avaliação da Saúde do Escolar*, in portuguese). Data collection was conducted in 2015 at the Universidade Federal de Viçosa by trained nutritionists.

The sample size calculation and the sampling process have been described previously<sup>(19,20)</sup>. In brief, we recruited randomly 378 schoolchildren between the ages of 8 and 9 years from a total 1464 children in the same age group enrolled in one of the urban primary schools of Viçosa, Minas Gerais, Brazil.

Children were not included in the study when they used medications regularly or had a clinically diagnosed health condition that could interfere with nutritional status, body composition, lipid profile, blood pressure and/or glucose metabolism; whose parents did not sign informed consent form; or parents and guardian that, after three attempts, could not be reached.

### *Food intake and children's dietary inflammatory index computation*

To assess children's food intake, we performed 24-h dietary recalls, completed by both mother/guardian and the child, across three non-consecutive days, including one weekend day. To enhance data reliability, the interviewers were previously trained. Moreover, we also used household utensils and a photograph album with food and beverage serving sizes to help the participants estimate the sizes of portions consumed<sup>(21)</sup>.

The common household units for each food consumed were converted into g, mg or ml to evaluate daily energy (kcal) and nutrients intake. The food composition analysis was conducted in the software Dietpro<sup>®</sup> 5i, version 5.8 using the Brazilian Food Composition Table<sup>(20)</sup> and the USDA Food Composition Database<sup>(22,23)</sup>.

We calculated the C-DII scores to determine the inflammatory potential of diet according to the recent method proposed for paediatric populations<sup>(13)</sup>. This index characterises the child's diet on a continuum scale from maximally anti- to pro-inflammatory. Briefly, the Pesquisa de Avaliação da Saúde do Escolar dietary data were related to a representative world database that provides a global estimate mean along with the standard deviation for each nutrient considered in the C-DII definition<sup>(13)</sup>. First, we created a Z-score to express the individual exposure of the child relative to the 'standard global mean'. Second, these Z-scores were converted to a centred proportion to avoid the effect of 'right skewing' (i.e. with values from 0 to 1), multiplied by 2 and then subtracting 1. As a result, we achieved a symmetrical distribution ranging from –1 (anti-inflammatory) to +1 (pro-inflammatory) and centred on 0 (null). Next, the scores were multiplied by the 'overall food parameter-specific inflammatory effect score'. Finally, we summed each food parameter-specific C-DII scores to obtain the overall individual C-DII score<sup>(13)</sup>. To minimise the energy intake difference among people, the energy-adjusted C-DII was used by converting all food to per 1000 kcal consumption.

For the C-DII calculation, we included sixteen of the twenty-five possible food parameters<sup>(13)</sup>, as follows: carbohydrate, protein, total fat, SFA, MUFA, PUFA, fibre, Fe, Zn, Mg, vitamin C, vitamin B<sub>1</sub>, vitamin B<sub>2</sub>, vitamin B<sub>3</sub>, vitamin B<sub>6</sub> and vitamin D. Higher C-DII scores represent a more pro-inflammatory diet.

### *Lipid profile and atherogenic risk*

The children's blood samples were collected at the Laboratory of Clinical Analysis of the Health Division of the Universidade Federal de Viçosa by venepuncture in the antecubital vein after 12 h of fasting. Bloods were packed in 1.5 ml microtubes and stored at –80°C until the lipid profile analysis was completed.

We evaluated serum TC, LDL-cholesterol, HDL-cholesterol, VLDL-cholesterol and TAG using an automated equipment (BioSystems 200 Mindray<sup>®</sup> model), according to the manufacturer recommendations (Bioclin<sup>®</sup> kits). Children with at least one of the following altered lipids were classified with dyslipidaemia: TC ≥ 170 mmol/l, HDL-cholesterol < 45 mmol/l, LDL-cholesterol ≥ 110 mmol/l and TAG ≥ 75 mmol/l<sup>(1)</sup>.

Moreover, we calculated atherogenic indexes<sup>(24)</sup> such as the Castelli risk index I (TC/HDL-cholesterol), Castelli index risk II (LDL-cholesterol/HDL-cholesterol), lipoprotein combine index (LCI), atherogenic index of plasma and atherogenic coefficient (AC). LCI was calculated using the formula: (TC × TAG × LDL-cholesterol)/HDL-cholesterol. Atherogenic index of plasma is the base 10 log of the TAG/HDL-cholesterol. AC is the ratio of (TC – HDL-cholesterol)/HDL-cholesterol<sup>(24–26)</sup>. Furthermore, we evaluated the accumulation of altered dyslipidaemia



markers (high TC + high LDL-cholesterol + high TAG + low HDL-cholesterol), which contribute to the initiation and progression of endothelial dysfunction increasing the atherosclerosis risk<sup>(27,28)</sup>.

### **Sociodemographic characteristics and screen time**

A semi-structured questionnaire was administered to parents and guardians to obtain sociodemographic characteristics and data on screen time. The collected data included: sex, age (years) and race (White, Brown and Black), household's per capita income (US\$) and screen time (h/d).

### **Anthropometry and body composition**

The children's anthropometric measurements were performed by a trained member of the research group. The children wore light clothes and were barefoot. Weight was measured using a digital electronic scale with a capacity of 150 kg and a sensitivity of 100 g (Tanita<sup>®</sup> Ironman Model BC 553; Tanita Corporation of America Inc.). The height was evaluated using a vertical stadiometer divided in cm and subdivided in mm (Altarexata<sup>®</sup>). We obtained height-for-age and BMI-for-age Z-scores using the WHO Anthro Plus software<sup>(29)</sup>.

We assessed the children's body fat by dual-energy X-ray absorptiometry (Lunar Prodigy Advance; GE Medical Systems Lunar). The child was fasted during the exam wearing only light clothing and remained in supine position on the scanning bed until the end of the equipment evaluation.

### **Data analyses**

#### *Exposure*

Children's Dietary Inflammatory Index (C-DII) scores were expressed in quintiles.

#### *Outcome*

Lipid profile (TC, HDL-cholesterol, LDL-cholesterol, VLDL-cholesterol and TAG), atherogenic indexes (Castelli risk indexes I and II, LCI, atherogenic index of plasma and AC) and accumulation of altered dyslipidaemia markers (high TC + high LDL-cholesterol + high TAG + low HDL-cholesterol), were all fit as continuous variables.

#### *Covariates*

Child's age, sex, race, screen time, the household's per capita income and body fat (%).

### **Statistical analyses**

The normality of the variables was assessed by the Kolmogorov–Smirnov test. Comparisons of mean and standard deviation between groups were verified by Student's *t* test, and Pearson's  $\chi^2$  test was used to evaluate the relationships between categorical variables. We evaluated

the distribution of dietary intake using mean and standard deviation (SD) according to C-DII categories from multivariable linear regression. Then, we compared the distributions of outcomes (lipid profile, atherogenic indexes and accumulation of altered dyslipidaemia markers) by C-DII categories (exposure), using mean differences and 95 % CI from unadjusted and multivariable linear regression models adjusted by age, sex, race, screen time, per capita income and body fat (%). All the possible confounders included in the analysis were chosen after a literature review. The robust estimates of the variance were specified in all models, which are consistent with heteroscedasticity and non-normality<sup>(30)</sup>.

Analyses were performed using the software Stata<sup>®</sup> version 14 (StataCorp LP) and Statistical Package for the Social Science<sup>®</sup> software version 21 (SPSS Inc.). The significance level was 0.05 for all hypothesis tests.

## **Results**

In our sample, 52.12 % were girls and 68.52 % were Non-White children. The prevalence of dyslipidaemia was 70 %. The means  $\pm$  SD of serum TC, HDL-cholesterol, LDL-cholesterol and TAG were  $152.29 \pm 26.40$  mmol/l,  $50.07 \pm 9.99$  mmol/l,  $86.96 \pm 23.38$  mmol/l and  $78.83 \pm 35.41$  mmol/l, respectively (data not shown). The children with dyslipidaemia had higher BMI-for-age ( $0.59 \pm 1.45$ ) and body fat ( $25.61 \pm 10.44$ ) compared with those with normal lipid profile ( $-0.01 \pm 1.19$  and  $21.01 \pm 8.40$ , respectively). The mean  $\pm$  SD of C-DII score was  $0.60 \pm 0.94$  and ranged from  $-2.16$  (maximum anti-inflammatory diet) to  $2.75$  (maximum pro-inflammatory diet) (Table 1). Furthermore, children with hypercholesterolaemia and hypertriglyceridaemia reported consuming a more pro-inflammatory diet (Fig. 1).

Table 2 shows the association of food intake with C-DII after adjustment for potentially confounding factors. The C-DII was inversely associated with energy intake and the consumption of carbohydrate, protein, PUFA, fruits, vegetables, whole grains, rice and beans, and dairy products. Conversely, C-DII was directly associated with total fat, MUFA, saturated fat and unhealthy food groups intake as crackers and chips, processed meat, fast-food and fried snacks, industrial juices and soft drinks, and sugar.

The C-DII was directly associated with atherogenic indexes, regardless of child's age, sex, race, per capita income, screen time and body fat (%). Compared with first, the fifth quintiles of C-DII were related to  $0.17$  (95 % CI  $-0.01, 0.35$ ),  $5.34$  (95 % CI  $0.43, 10.25$ ) and  $0.16$  (95 % CI  $-0.02, 0.34$ ) units higher TC/HDL-cholesterol ratio, LCI and AC, respectively. Every 1 SD of C-DII was associated with a  $0.07$  (95 % CI  $0.01, 0.13$ ),  $1.94$  (95 % CI  $0.20, 3.67$ ) and  $0.06$  (95 % CI  $0.002, 0.12$ ) units higher TC/HDL-c ratio, LCI and

**Table 1** Characteristics of participants according to the presence or absence of dyslipidaemia, Viçosa, Minas Gerais, Brazil, 2015

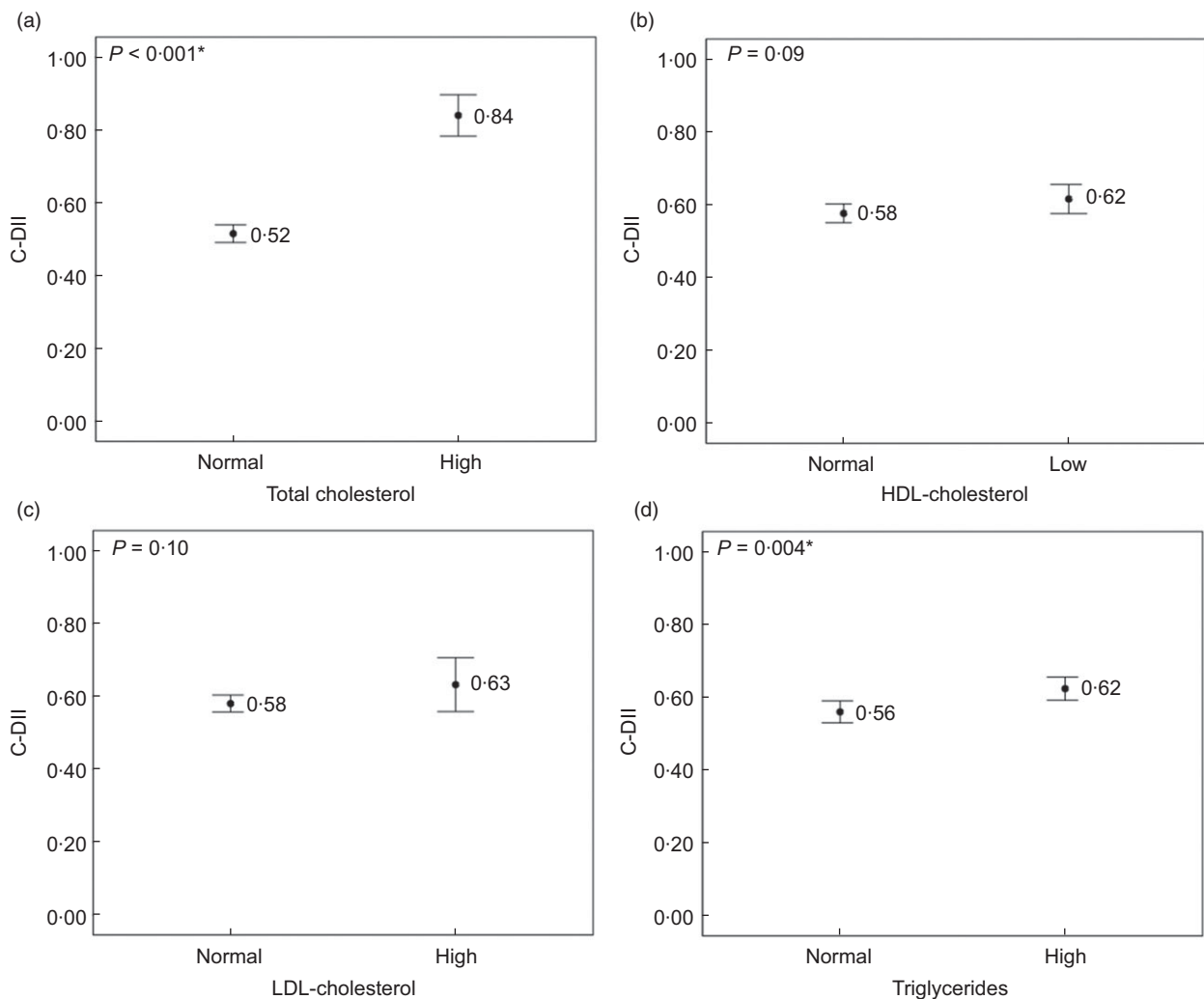
Characteristics	Dyslipidaemia						P
	Total (n 378)		No (n 115)		Yes (n 263)		
	Mean	SD	Mean	SD	Mean	SD	
Age (years)	8.51	0.50	8.45	0.50	8.54	0.50	0.10
Sex (girls)‡	52.12		27.40		72.60		0.18
Race (non-white)‡	68.52		30.10		69.90		0.84
Per capita income (US\$)†	242.28	276.61	231.04	255.16	247.20	285.82	0.60
Screen time (h/d)	3.53	1.46	3.31	1.42	3.63	1.46	0.05
Height-for-age (Z-score)	0.54	1.03	0.48	0.91	0.57	1.08	0.50
BMI-for-age (Z-score)	0.40	1.40	-0.01	1.19	0.59	1.45	<0.001*
Body fat (%)	24.21	10.08	21.01	8.40	25.61	10.44	<0.001*
C-DII	0.60	0.94	0.47	1.01	0.65	0.90	0.10

C-DII, Children's Dietary Inflammatory Index; SD, standard deviation.

\* $P < 0.05$ .

†Approximate exchange rates of real (R\$) to dollar (US\$) at the time of this study (US\$1.00 = R\$ 3.22).

‡Student's *t* test for continuous variables and ‡Pearson's  $\chi^2$  test for categorical variables.



**Fig. 1** Children's Dietary Inflammatory Index (C-DII) score according to the presence or absence of dyslipidaemia in schoolchildren from Viçosa, Minas Gerais, Brazil, 2015. Values are mean (95 % CI). Student's *t* test ( $P < 0.05^*$ ) adjusted for child's age, sex, race, per capita income, screen time and body fat

**Table 2** Distribution of nutrients and food groups intake according to Children's Dietary Inflammatory Index (C-DII) in schoolchildren from Viçosa, Minas Gerais, Brazil, 2015

Dietary intake	C-DII (quintiles)										<i>P</i> <sub>trend</sub> †
	Q1 (-2.16 to -0.19) (n 75)		Q2 (-0.20 to 0.41) (n 76)		Q3 (0.42 to 0.86) (n 76)		Q4 (0.87 to 1.41) (n 76)		Q5 (1.42 to 2.75) (n 75)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Energy (kcal)	1500.48	356.74	1481.12	438.58	1424.70	519.99	1304.22	467.57	1275.28	398.42	<0.001*
Macronutrients (% EI)											
Carbohydrate	60.78	6.29	59.78	6.28	59.22	6.07	58.11	5.90	57.56	5.64	<0.001*
Protein	15.25	2.93	14.61	2.70	13.53	2.78	12.91	2.66	13.04	2.92	<0.001*
Total fat	26.70	5.52	26.49	4.92	27.80	4.79	29.34	4.78	29.49	4.94	<0.001*
MUFA	8.23	1.85	8.25	1.93	8.63	2.03	9.32	1.94	9.73	2.12	<0.001*
PUFA	6.04	1.90	5.50	1.74	5.87	2.07	5.53	1.97	4.70	1.78	<0.001*
Saturated fat	8.94	2.17	8.89	2.25	9.16	2.12	9.78	2.40	9.96	2.16	0.001*
Food groups (% EI)											
Fruits and vegetables	12.44	7.59	9.14	7.94	8.13	6.01	6.50	4.39	6.31	6.35	<0.001*
Fruits and natural juices	7.42	6.56	4.87	5.58	4.11	4.64	3.00	3.34	2.68	2.86	<0.001*
Red, yellow and green veggies	0.69	0.60	0.78	1.53	0.54	0.88	0.34	0.49	0.36	0.97	0.01*
Whole grains	0.93	3.13	0.44	1.44	0.32	1.08	0.16	0.63	0.32	1.00	0.004*
Dairy products	11.46	6.25	9.45	5.78	9.37	5.78	9.45	6.65	7.68	6.16	<0.001*
Meat, fish and eggs	12.78	5.90	12.16	6.55	11.61	5.93	12.36	6.38	10.89	6.37	0.29
Rice and beans	16.01	7.70	14.96	7.77	13.33	6.59	14.44	7.75	13.56	7.78	0.001*
Crackers and chips	6.61	6.55	8.90	9.51	8.00	8.16	9.82	8.37	11.18	9.60	0.003*
Processed meat	3.10	3.77	3.15	3.82	4.00	4.21	4.38	4.39	4.90	4.70	0.01*
Fast-food and fried snacks	3.82	4.90	5.91	6.61	6.27	7.90	6.88	8.85	8.12	10.11	<0.001*
Industrial juices and soft drinks	3.23	3.13	4.85	3.77	4.88	3.30	5.15	3.89	5.23	5.00	<0.001*
Added sugar	15.98	6.12	17.05	5.70	18.51	7.41	19.21	6.74	19.97	7.42	<0.001*

EI, energy intake; MUFA, monounsaturated fat; PUFA, polyunsaturated fat; sd, standard deviation.

\**P* < 0.05.

†From linear regression models with a variable representing ordinal C-DII categories introduced as continuous. Robust estimates of variance were specified in all models. Adjusted for child's age, sex, race, per capita income, screen time and body fat.

AC, respectively (Table 3). Additionally, a pro-inflammatory diet was associated with the accumulation of altered dyslipidaemia markers (high TC + high LDL-cholesterol + high TAG + low HDL-cholesterol). Children with the most pro-inflammatory diet (fifth quintile) had 0.32 (95 % CI 0.01, 0.63) unit higher accumulation of altered dyslipidaemia markers than children with the most anti-inflammatory diet (first quintile) (Fig. 2). Every 1 sd of C-DII was associated with a 0.12 (95 % CI 0.02, 0.22) unit higher accumulation of altered dyslipidaemia markers.

## Discussion

Our cross-sectional study supports the hypothesis that a pro-inflammatory diet is associated with a higher atherogenic risk in schoolchildren.

The findings showed a direct association between C-DII and atherogenic indexes, but not individual parameters. Previous studies with paediatric population<sup>(16,18)</sup> also found no significant associations between the pro-inflammatory diet and isolated traditional markers of lipid profile, corroborating with our results. However, the atherogenic indexes are good indicators of CVD risk because these consider the balance between atherogenic and protective lipoproteins, thus, increasing their predictive capacity

compared with isolated traditional markers<sup>(24,31)</sup>. In this context, the assessment of atherogenic indexes, also obtained at young ages, should be encouraged in paediatric clinical practice as interesting complementary methods of screening and monitoring cardiometabolic risk<sup>(32,33)</sup>.

Current studies with adults have shown the association between a pro-inflammatory diet and an increased risk of dyslipidaemia<sup>(10)</sup>, elevated TAG/HDL-cholesterol ratio and apoB<sup>(11)</sup>, as well as the development of CVD and increased mortality<sup>(12,34–36)</sup>. Though results do exist in adults, the investigations regarding the impacts of dietary inflammatory potential on children's lipid profiles are limited<sup>(17,18)</sup>; to date, no studies have been found evaluating the relationship between C-DII and atherogenic indexes. Taken together, more research conducted in children is needed to clarify this issue.

We also observed a positive association of the C-DII with the accumulation of lipid abnormalities characterising a dyslipidaemia pattern. This result suggests a potential role of diet in the early occurrence of CVD through inflammatory modulation mechanisms. The adherence to an anti-inflammatory diet with a higher intake of nutrients and antioxidant compounds sources as fruits and vegetables may improve lipid profile<sup>(37,38)</sup> and reduce inflammation<sup>(39,40)</sup> and atherosclerosis risk<sup>(36)</sup>. In contrast, a poor-quality diet that includes excessive intake of pro-inflammatory food

**Table 3** Crude and adjusted analyses of the association of the Children's Dietary Inflammatory Index (C-DII) with lipid profile and atherogenic indexes in schoolchildren from Viçosa, Minas Gerais, Brazil, 2015

Markers	C-DII (quintiles)					Per 1 sd§	P <sub>trend  </sub>
	Q1 (-2.16 to -0.19) (n 75)	Q2 (-0.20 to 0.41) (n 76)	Q3 (0.42 to 0.86) (n 76)	Q4 (0.87 to 1.41) (n 76)	Q5 (1.42 to 2.75) (n 75)		
TC (mmol/l)							
Mean	148.35	152.95	151.29	154.17	154.91		
SD	25.11	27.08	22.14	31.10	26.19		
Unadjusted difference (95 % CI)†	Reference	4.60 (-3.75, 12.95)	2.94 (-4.64, 10.52)	5.64 (-3.41, 14.69)	6.56 (-1.68, 14.80)	1.63 (-0.92, 4.19)	0.21
Adjusted difference (95 % CI)‡	Reference	4.86 (-3.17, 12.91)	3.98 (-3.57, 11.53)	6.37 (-2.69, 15.44)	8.09 (0.05, 16.13)	2.17 (-0.35, 4.68)	0.10
LDL-c (mmol/l)							
Mean	85.46	91.00	83.91	89.31	85.12		
SD	21.70	26.09	18.36	27.99	21.41		
Unadjusted difference (95 % CI)†	Reference	5.54 (-2.14, 13.21)	-1.55 (-7.98, 4.88)	3.85 (-4.22, 11.92)	-0.34 (-7.26, 6.58)	-0.36 (-2.58, 1.85)	0.75
Adjusted difference (95 % CI)‡	Reference	6.21 (-0.99, 13.42)	0.53 (-5.77, 6.85)	5.68 (-2.35, 13.72)	2.09 (-4.54, 8.73)	0.7 (-1.44, 2.85)	0.62
HDL-c (mmol/l)							
Mean	50.64	49.91	50.22	49.15	50.43		
SD	9.26	10.19	9.35	10.90	10.44		
Unadjusted difference (95 % CI)†	Reference	-0.73 (-3.85, 2.38)	-0.42 (3.39, 2.56)	-1.48 (-4.71, 1.75)	-0.21 (-3.38, 2.95)	-0.48 (-1.45, 0.49)	0.33
Adjusted difference (95 % CI)‡	Reference	-0.34 (-3.51, 2.81)	-0.11 (-3.19, 2.95)	-1.14 (-4.40, 2.12)	0.27 (-2.87, 3.40)	-0.38 (-1.37, 0.60)	0.49
VLDL-c (mmol/l)							
Mean	15.14	15.27	15.62	16.17	16.69		
SD	6.16	6.92	7.87	7.04	7.40		
Unadjusted difference (95 % CI)†	Reference	0.13 (-1.97, 2.22)	0.48 (-1.78, 2.74)	0.76 (-1.38, 2.90)	1.54 (-0.64, 3.73)	0.46 (-0.29, 1.21)	0.23
Adjusted difference (95 % CI)‡	Reference	-0.08 (-2.01, 1.85)	0.42 (-1.82, 2.66)	0.61 (-1.48, 2.71)	1.79 (-0.26, 3.84)	0.53 (-0.16, 1.22)	0.13
TAG (mmol/l)							
Mean	75.71	76.34	78.12	80.86	83.44		
SD	30.82	34.60	39.34	35.20	37.01		
Unadjusted difference (95 % CI)†	Reference	0.63 (-9.84, 11.21)	2.41 (-8.89, 13.71)	4.87 (-5.73, 15.46)	7.73 (-3.20, 18.67)	2.46 (-1.31, 6.24)	0.20
Adjusted difference (95 % CI)‡	Reference	-0.17 (-9.77, 9.42)	2.49 (-8.69, 13.68)	4.58 (-5.61, 14.77)	9.30 (-0.91, 19.51)	2.94 (-0.46, 6.34)	0.09
TC/HDL-c							
Mean	2.99	3.14	3.08	3.22	3.15		
SD	0.55	0.65	0.58	0.71	0.63		
Unadjusted difference (95 % CI)†	Reference	0.15 (-0.04, 0.34)	0.09 (-0.08, 0.27)	0.23 (0.02, 0.43)	0.16 (-0.03, 0.35)	0.07 (0.01, 0.13)	0.03*
Adjusted difference (95 % CI)‡	Reference	0.14 (-0.05, 0.32)	0.10 (-0.08, 0.28)	0.22 (0.02, 0.43)	0.17 (-0.01, 0.35)	0.07 (0.01, 0.13)	0.02*
LDL-c/HDL-c							
Mean	1.73	1.89	1.72	1.89	1.75		
SD	0.49	0.62	0.44	0.69	0.55		
Unadjusted difference (95 % CI)†	Reference	0.16 (-0.04, 0.34)	0.01 (-0.16, 0.13)	0.13 (-0.06, 0.33)	0.02 (-0.15, 0.18)	0.01 (-0.04, 0.06)	0.69
Adjusted difference (95 % CI)‡	Reference	0.16 (-0.01, 0.33)	0.02 (-0.13, 0.17)	0.16 (-0.05, 0.36)	0.05 (-0.11, 0.21)	0.03 (-0.03, 0.08)	0.38
AIP							
Mean	0.35	0.36	0.36	0.44	0.45		
SD	0.45	0.50	0.52	0.52	0.46		
Unadjusted difference (95 % CI)†	Reference	0.01 (-0.14, 0.17)	0.01 (-0.14, 0.17)	0.01 (-0.10, 0.24)	0.01 (-0.05, 0.24)	0.04 (-0.01, 0.08)	0.14
Adjusted difference (95 % CI)‡	Reference	0.00 (-0.15, 0.14)	0.00 (-0.15, 0.16)	0.01 (-0.10, 0.22)	0.10 (-0.04, 0.24)	0.04 (-0.01, 0.08)	0.09
LCI							
Mean	20.74	24.71	21.68	27.10	24.52		
SD	13.90	21.31	17.18	23.63	19.11		

**Table 3** Continued

Markers	C-DII (quintiles)					Per 1 SD§	P <sub>trend</sub>
	Q1 (-2.16 to -0.19) (n 75)	Q2 (-0.20 to 0.41) (n 76)	Q3 (0.42 to 0.86) (n 76)	Q4 (0.87 to 1.41) (n 76)	Q5 (1.42 to 2.75) (n 75)		
Unadjusted difference (95% CI)†	Reference	3.96 (-1.78, 9.72)	0.93 (-4.06, 5.93)	6.35 (0.10, 12.61)	3.77 (-1.59, 9.14)	1.37 (-0.58, 3.33)	0.17
Adjusted difference (95% CI)‡	Reference	3.98 (-1.28, 9.25)	1.84 (-3.23, 6.91)	7.07 (0.74, 13.39)	5.34 (0.43, 10.25)	1.94 (0.20, 3.67)	0.03*
AC	1.99	2.14	2.08	2.22	2.15		
SD	0.55	0.65	0.58	0.71	0.63		
Unadjusted difference (95% CI)†	Reference	0.15 (0.04, 0.34)	0.10 (-0.08, 0.28)	0.20 (-0.01, 0.41)	0.16 (-0.03, 0.35)	0.06 (0.00, 0.12)	0.05
Adjusted difference (95% CI)‡	Reference	0.13 (-0.06, 0.32)	0.09 (-0.09, 0.27)	0.18 (-0.03, 0.40)	0.16 (-0.02, 0.34)	0.06 (0.002, 0.12)	0.04*

95% CI, 95% confidence interval; SD, standard deviation; AC, atherogenic coefficient; AIP, atherogenic index of plasma; HDL-c, high-density lipoprotein cholesterol; LDL-c, low-density lipoprotein cholesterol; LDL-c/HDL-c, low-density lipoprotein cholesterol/high-density lipoprotein cholesterol ratio; TC, total cholesterol; TC/HDL-c, total cholesterol/high-density lipoprotein cholesterol ratio; TAG, triglycerides; VLDL-c, very-low-density lipoprotein cholesterol.

\*P < 0.05.

†From linear regression models with each lipid marker as a continuous outcome and C-DII as predictor. Robust estimates of variance were specified in all models.

‡From linear regression adjusted for child's age, sex, race, per capita income, screen time and body fat.

§From linear regression model with each lipid marker as continuous outcome and C-DII per 1 SD (continuous) as predictor.

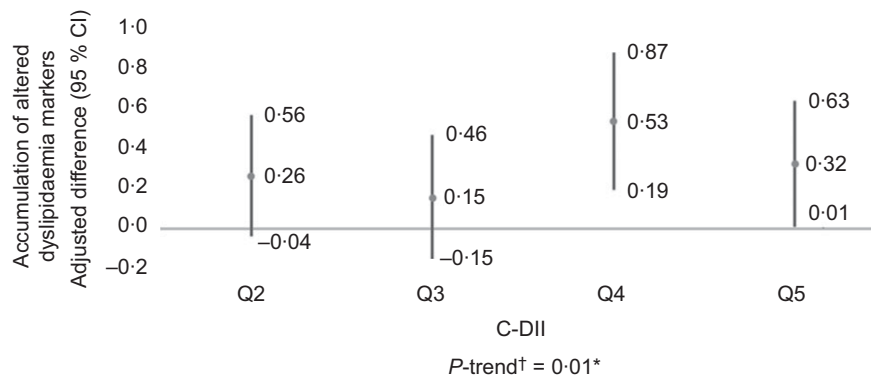
|| Test for linear trend when a variable representing ordinal C-DII categories were introduced as a continuous predictor in the linear regression.

parameters, such as sugar and dietary fats (e.g. ultra-processed foods), increases lipogenesis<sup>(41,42)</sup>, activates the NF-κB pathway<sup>(43,44)</sup> and may subsequently alter lipid profile in children<sup>(45,46)</sup>. Moreover, emerging evidence demonstrate that the pro-inflammatory diet is directly associated with the secretion of pro-inflammatory cytokines and expression of adhesion molecules<sup>(13,47,48)</sup> which contributes to vascular tissue inflammation, endothelial dysfunction<sup>(5,6)</sup> and carotid intima-media thickening<sup>(16)</sup>. Atherosclerosis is a chronic inflammatory disease<sup>(5,6)</sup> that often originates in childhood<sup>(49)</sup> and is related to future cardiovascular events<sup>(50)</sup>. Therefore, a diet rich in anti-inflammatory properties might benefit children's health and growth, preventing the early onset of the atherosclerotic process and subsequent heart diseases in adulthood.

Some strengths of this study should be pointed out. First, this is a representative study with the sample composed exclusively of children, an important group in which to investigate food consumption because eating habits are created in childhood. Second, we evaluated the association of C-DII and atherogenic risk using traditional lipoproteins as well as non-traditional atherogenic indexes. Furthermore, body composition was analysed with dual-energy X-ray absorptiometry, a gold-standard method for assessing body composition, and the models were adjusted by body fat (%). We highlight that, according to our knowledge, this is the first epidemiological study to evaluate the relationship of C-DII with atherogenic risk in children. Our study provides novel information to public health practice and a better understanding of the role of the inflammatory dietary factors in the early occurrence of dyslipidaemia and underlying atherosclerosis.

This study has some limitations. First, the application of 24-h dietary recalls may present memory bias; however, the interviewers were previously trained, and the 24-h dietary recalls were administered on three non-consecutive days, using food a photo album and standard measurement tools; and all are recognisably methodological strategies to guarantee better accuracy. Second, we calculated the C-DII score with sixteen of the total twenty-five food parameters included in the C-DII definition. Nevertheless, our C-DII scores were similar to previous paediatric studies<sup>(18,51)</sup>. Finally, the cross-sectional design makes it impossible to establish causal relationships. Thus, further longitudinal studies with paediatric population are required to confirm our findings and determine the long-term effects of dietary-related inflammation on lipid profile and cardiovascular risk.

We conclude that pro-inflammatory diet, as indicated by higher C-DII scores, is associated with higher atherogenic risk in Brazilian schoolchildren. These results reinforce the importance of effective nutritional policies to promote healthy eating habits, improve the children's lipid profile and prevent later CVD.



**Fig. 2** Association between the Children's Dietary Inflammatory Index (C-DII) and the accumulation of altered dyslipidaemia markers (high TC + high TAG + high LDL-cholesterol + low HDL-cholesterol) in schoolchildren from Viçosa, Minas Gerais, Brazil, 2015. Q, quintiles; Q1: reference. †From linear regression models with the number of altered dyslipidaemia markers as continuous outcome and a variable representing ordinal C-DII categories introduced as continuous predictor. Robust estimates of variance were specified in all the models. Adjusted for child's age, sex, race, per capita income, screen time and body fat. ( $P < 0.05^*$ )

### Acknowledgements

*Acknowledgements:* We thank BioClin (Belo Horizonte, MG, Brazil) for the lipid profile kits granted, the *Pesquisa de Avaliação da Saúde do Escolar* participants and parents.

*Financial support:* Our study was supported by Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG – CDS-APQ-02979-16), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq – 478910/2013-4 and 407547/2012-6) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES – code 001). H.H.M.H. has a Research Fellowship from CNPq (1D-level). The CNPq, FAPEMIG and CAPES had no role in the design, analysis or writing of this article. *Conflict of interest:* The authors declare no conflicts of interest. However, Dr James R. Hébert discloses that he owns controlling interest in Connecting Health Innovations LLC (CHI), a company that has licensed the right to his invention of the dietary inflammatory index (DII®) from the University of South Carolina in order to develop computer and smart phone applications for patient counseling and dietary intervention in clinical settings. Dr Nitin Shivappa is an employee of CHI. *Authorship:* L.G.S.: Conceptualisation; data analysis; investigation; writing – original draft; writing – review & editing. S.A.V.R.: Writing – review & editing, final approval of the version to be published. H.H.M.H.: Writing – review & editing, final approval of the version to be published. M.A.S.: Writing – review & editing, final approval of the version to be published. N.S.: Writing – review & editing, final approval of the version to be published. J.R.H.: Writing – review & editing, final approval of the version to be published. J.F.de.N.: Project administration, writing – review & editing, final approval of the version to be published. *Ethics of human subject participation:* This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving research participants were approved by the Human Research Ethics Committee of the Universidade Federal de

Viçosa (reference number 663.171/2014). Written informed consent was obtained from all parents.

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