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MANUSCRIPT

Interaction effect between breakfast skipping and sedentary behavior in the dietary inflammatory potential in Brazilian schoolchildren

hort title: C-DII, breakfast skipping, and sedentary behavior

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Highlights

- Studies investigating possible determinants of C-DII are scarce;
- Breakfast skipping was associated with higher C-DII scores;

- Sedentary behavior accentuates adverse effects of breakfast skipping on C-DII;
- Interventions encouraging healthy eating and lifestyle behaviors are required.

Abstract

Objective: Missed nutrients from skipped meals affect the diet quality. However, breakfast skipping potential to affect the inflammatory potential of diet as indicated by Children´s Dietary Inflammatory Index (C-DII^{TM}) score remain unknown. We aimed to evaluate the association between breakfast skipping and C-DII score; and to investigate the presence of interaction with sociodemographic factors and sedentary behavior. **Research Methods & Procedures:** This representative cross-sectional study enrolled 378 children aged 8 and 9 years of age from Viçosa, Minas Gerais, Brazil (2015). We collected sociodemographic data (sex, age, race, and household per capita income) and screen time using a semi-structured questionnaire. Dietary intake and breakfast skipping were evaluated by three 24-hour dietary recalls from which energy-adjusted C-DII scores were calculated. We performed linear regression models to test the associations and interactions. **Results:** The prevalence of breakfast skipping and sedentary behavior were 20.1% and 47.6%, respectively. The mean ± SD of C-DII score was 0.60 ± 0.94 and ranged from -2.16 (most anti-inflammatory diet) to 2.75 (most pro-inflammatory diet). Breakfast skipping was associated with a higher intake of lipids, monounsaturated fat, and polyunsaturated fat, and lower carbohydrate, calcium, and magnesium intake ($P<0.05$). After adjustment, breakfast skippers had higher C-DII scores ($\beta= 0.33$, 95% CI: 0.12 to 0.54). This association was more pronounced in children with sedentary behavior ($\beta= 0.53$, 95% CI: 0.24 to 0.82). **Conclusions:** Breakfast skipping was associated with a more pro-inflammatory diet in schoolchildren, and there was significant interaction with sedentary behavior. Early childhood interventions encouraging eating breakfast habit and engage in physical activity may help reduce the dietary inflammatory potential and prevent related-cardiometabolic disorders.

Keywords: Child, Breakfast skipping, Children's Dietary Inflammatory Index, Food intake, Sedentary lifestyle, Nutritional Epidemiology.

Introduction

Epidemiological studies have shown the central role of diet quality in the early development of childhood obesity and associated comorbidities [1-3] through inflammation and antioxidant

mechanisms [4,5]. The Children's Dietary Inflammatory Index (C-DII™) is a novel method of estimating the children's diet quality based on anti- and pro-inflammatory properties of specific nutrients. The C-DII classifies the diet from maximal anti-inflammatory to maximal pro-inflammatory [6], and higher positive scores are directly related to inflammation and cardiometabolic risk early in life [6-9]. However, studies evaluating the possible determinants of C-DII are scarce [10], while the effect of unhealthy nutritional behaviors such as breakfast skipping on the dietary inflammatory potential among children remain unknown.

Regular breakfast consumption is highly recommended in childhood as part of a healthy lifestyle providing adequate nutrients intake and superior diet quality [11-17]. Although breakfast is recognized as one of the most important meals of the day contributing to better overall health and well-being [18,19], breakfast skipping prevalence in children and adolescents is rising worldwide, ranging from 10% to 30% [20]. Moreover, breakfast skipping has been considered an important public health issue due to its association with the increased risk of chronic diseases in pediatric populations [20-23].

Besides breakfast consumption, other factors also can influence diet quality. Sociodemographic characteristics [10, 24-27] as income, race, and level of education, and lifestyle behaviors, such as screen time [10,28-30], can affect food choices, access to healthy food [31], and meal skipping [28, 32-35]. Furthermore, these factors can interact with each other to influence diet quality.

Considering that breakfast skipping is a common unhealthy habit in childhood, affecting negatively diet quality with potential adverse health outcomes [7-9], we aimed to evaluate the association between breakfast skipping and the C-DII score; and to investigate the presence of interaction with sociodemographic factors and sedentary behavior. Our hypothesis is that these factors interact with each other to influence diet quality and can help us to identify target high-risk groups for nutrition interventions.

Material and Methods

Population and study design

This is a representative cross-sectional study with participants from the Schoolchildren Health Assessment Survey (*Pesquisa de Avaliação da Saúde do Escolar*, PASE – in Portuguese) in the city of Viçosa, Minas Gerais State, Brazil. Registered dietitians collected all data at the *Universidade Federal de Viçosa* (UFV) between May to December in 2015.

The sample size calculation and the sampling process were published in detail elsewhere [36,37]. Briefly, we recruited a random sample of 378 schoolchildren aged 8 and 9 years from the total 1,464 children of the same age range enrolled in all urban primary schools (n=24) of Viçosa, Minas

Gerais, Brazil. The following prevalence were considered in the sample size calculation: 50% with multiple outcomes for cardiometabolic risk factors, 95% confidence interval, 5% for tolerable error, 10% for losses, and 10% for confounding factors. Additionally, each school sample met the proportionality of the total number of students enrolled by to age and sex.

The non-inclusion criteria were children in regular use of medications or with some clinical health alteration that could interfere with the nutritional status, body composition, lipid profile, blood pressure, and/or glucose metabolism; children whose parent or guardian did not sign the informed consent form after three attempts. Once enrolled, no loss of participants occurred during data collection.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki. All procedures involving research study participants were approved by the Human Research Ethics Committee of the *Universidade Federal de Viçosa* (UFV) (663.171 / 2014). All parents and guardians signed the written informed consent.

Food intake assessment and Children's Dietary Inflammatory Index (C-DII) computation

Food intake was assessed by three non-consecutive days 24-hour dietary recalls (24HR), including one weekend day. Trained interviewers administered the 24HR with the mother/guardian and the child at the same time, using household utensils and a photograph album with food serving sizes and drinks to facilitate the report of portion sizes [(38)]. Household measures reported in the 24HR were converted to g, mg, or ml to obtain energy (kcal) and nutrients consumed. Daily calories and nutrients intake were estimated using the software Dietpro® 5i, version 5.8, the Brazilian Food Composition Table [(39)], and USDA Food Composition Database [(40)].

We calculated the C-DII scores using the validated method for pediatric populations proposed by Khan et al. [(6)]. The C-DII was validated with NHANES dataset (2005–2010) restricting the sample to 3300 children aged 6-14 years who had complete dietary data, demographics, and blood results, including CRP. The index was able to predict CRP concentrations indicating that it may be an interesting tool for the evaluation of the quality and inflammatory properties of the children's diet [(6)].

Complete information of food intake analysis and C-DII calculation in PASE study can be found elsewhere [(8,9)]. In summary, C-DII was designed based on a large literature review of 1943 articles. The review aimed to identify the "inflammatory effect scores" derived from the associations found between dietary compounds and six important inflammatory markers. In addition, it was created a world dietary database to represent the diversity of child´s diet using the data of 6 to 14 years old children from 16 different countries. Next, PASE dietary data was related to this regionally

representative world database that provides a robust global estimate mean and standard deviation for all the parameters included in C-DII calculation. Then, a z-score and centered percentiles for each food parameters were calculated, and then multiplied by the respective "overall food parameter-specific inflammatory effect score" derived from the literature review to obtain the "food parameter-specific C-DII score". Finally, all the "food parameter-specific C-DII score" were summed to have the "overall C-DII score" for each child. We adjusted the C-DII per 1000 kcal consumed to reduce the influence of energy intake among children in association analysis.

To calculate C-DII scores in our sample, we used the following 16 food parameters: carbohydrate, protein, total fat, saturated fatty acid, monounsaturated fatty acid, polyunsaturated fatty acid, fiber, iron, zinc, magnesium, and vitamins C, B1, B2, B3, B6, and D. A higher C-DII score indicates a more pro-inflammatory diet.

Sociodemographic and behavioral factors

Sociodemographic characteristics were collected through a semi-structured questionnaire administered to parents or guardians. The child's sex, age (years), race (white, brown, black), and household´s per capita income (US$) were obtained.

Regarding the behavioral factors, we considered breakfast the first meal that the child consumed and/or drank within the first two hours after waking up [18,41], evaluated by 24HR. Breakfast skipping was considered when the children did not have at least one breakfast from the three 24HR. Moreover, we evaluated the sedentary behavior by time engaged in screen-based recreation (video games, computer, television, mobile phone, or tablet). Children with sedentary behavior were those who exceeded two hours/day of screen time [42].

Statistical analyses

Exposure. Breakfast skipping.

Outcome. C-DII as a continuous variable.

Covariates. Sociodemographic (child's sex, age, race, and household's per capita income) and behavioral (screen time >2h/day – sedentary behavior) factors. Household´s per capita income was modeled as continuous variable.

We performed the Kolmogorov-Smirnov test to verify the normality of the data. Descriptive analysis of individual data was performed. Frequency measurements were used for qualitative variables and mean ± standard deviation (SD) for quantitative variables. Pearson's chi-square test was used to evaluate the relationships between categorical variables and Student's t test for group comparisons of quantitative variables. The associations of breakfast skipping with daily nutrients

intake and C-DII scores were evaluated through a multivariable linear regression model. The interaction between breakfast skipping and sociodemographic factors (sex, age, race, and household per capita income) and sedentary behavior were tested by including an interaction term in the adjusted linear regression model. For example, the moderating effect of the sedentary behavior in the breakfast skipping - C-DII relation was tested by adding the interaction term "sedentary behavior*breakfast skipping" as a predictor of the C-DII. In the case of a significant interaction, the breakfast skipping - C-DII relation was tested stratified by the categories of the interaction variable. The potential confounders were included in the adjusted model after a literature review. Robust estimates of the variance were specified in all models, which are consistent with heteroscedasticity [43]. We performed the analyses in the Stata® version 14 (StataCorp LP, College Station, TX, USA). The significance level was 5% for all hypothesis tests.

Results

In our sample, 47.9% were boys, 68.5% were non-White, 47.6% had sedentary behavior, and 20.1% skipped breakfast (Table 1). The mean ± SD of per capita income was US$ 242.28 ± 276.61. The mean ± SD of C-DII score was 0.60 ± 0.94 and ranged from -2.16 (most anti-inflammatory diet) to 2.75 (most pro-inflammatory diet). Additionally, C-DII scores were higher in breakfast skippers (0.88 ± 0.80), compared to breakfast consumers (0.52 ± 0.96; P=0.003) (Figure 1).

Table 2 shows the association between breakfast skipping and daily nutrients intake after adjustment for potentially confounding factors. Breakfast skipping was associated to a higher intake of lipids (β = 2.15, 95% CI: 0.78 to 3.53), monounsaturated fat (β = 0.77, 95% CI: 0.21 to 1.33), and polyunsaturated fat (β = 0.93, 95% CI: 0.32 to 1.53), and lower intake of carbohydrate (β = -5.63, 95% CI: -9.26 to -1.99), calcium (β = -39.20, 95% CI: -73.97 to -4.43), and magnesium (β = -11.11, 95% CI: -17.06 to -5.16).

Moreover, children skipping breakfast had higher C-DII scores (β= 0.31, 95% CI= 0.11 to 0.52), regardless of child's sex, age, race, household per capita income, and sedentary behavior (Table 3). Sedentary behavior was a significant interaction factor (P=0.015), and the association between breakfast skipping and C-DII was more pronounced among those with this behavior (β= 0.53, 95% CI: 0.24 to 0.82 versus β= 0.02, 95% CI: -0.26 to 0.31) (Table 3 and Figure 2). However, there was no statistical interaction between breakfast skipping and sociodemographic factors (sex, age, race, and household per capita income) in relation to C-DII scores (Table 3).

Discussion

In this cross-sectional study, breakfast skipping was associated with higher C-DII scores and this association was more evident among children with sedentary behavior. Our findings demonstrated that breakfast skipping might contribute to more pro-inflammatory dietary intake, as indicated by higher C-DII scores.

Other studies observed similar results regarding the relationship between breakfast skipping and the quality of the diet evaluated by the adherence to the Mediterranean diet [16], Healthy Eating Index (HEI) [13,17], and Breakfast Quality Index (BQI) [15] in pediatric populations. The children who skipped breakfast consumed less healthy foods such as fruits, dairy, and high-fiber foods, diminishing the nutrients intake and diet quality [11-17]. Furthermore, breakfast skipping has been related to appetite dysregulation [48] and an increase in eating energy-dense foods (e.g., fast food) [28,33], which altogether, may explain our results in relation to a higher fat intake and poorer-diet quality. In addition, a pro-inflammatory diet is associated with inflammation and cardiometabolic risk in children and adolescents [6-9, 49]. Previous findings in our sample showed direct associations of C-DII scores with pro-inflammatory adipokines (chemerin) and atherogenic risk, and inverse association with anti-inflammatory adipokine (adiponectin) in Brazilian children [8-9]. Therefore, encouraging breakfast consumption from the first stages of life may reduce the dietary inflammatory potential and impact beneficially on health.

We also observed that the association between breakfast skipping and C-DII scores was more pronounced in children with sedentary behavior. This result is aligned with the literature that reports a direct association of excessive screen time with unhealthy eating habits [29,30], with a more pro-inflammatory diet [10], as well as negatively affects breakfast consumption among children [32,33,50]. There is evidence that unhealthy nutritional and lifestyle behaviors tend to cluster in children, revealing that poor dietary habits coincide with a sedentary pattern for instance, whereas a healthy diet is associated with higher physical activity [51]. Additionally, screen may interfere in physiological signs of satiety and hunger, which leads to unhealthy food choices with higher intake of low-nutrients and high-energy density food [28]. Thus, sedentary behavior may accentuate the adverse effects of breakfast skipping on diet quality. Once unhealthy lifestyle behaviors are likely to persist into adulthood [52], it is recommended that children limit recreational screen time to less than 2 hours per day [42]. Public health policies designed to increase diet quality should target schoolchildren with unhealthy lifestyle profiles aiming to make simple behavioral changes such as consuming breakfast and reducing daily screen time.

Besides, we showed that breakfast skipping was directly associated with fat intake and inversely with carbohydrate, calcium, and magnesium, in accordance with previous investigations [12-15,44]. Complementing these results, we recently demonstrated that C-DII scores were inversely

associated with dietary antioxidants [8] and directly associated with fat and unhealthy food groups intake [9]. Nutrients have a key role on children's optimal growth and development [45], while missed nutrients from skipped meals can affect the diet quality [11-17] leading to cardiometabolic alterations [20,21,23]. Calcium intake, for example, an essential mineral for bone health [46,47], was inversely associated with adiposity and subclinical inflammation in schoolchildren [53]. Considering that breakfast is a fundamental meal for meeting nutrient daily recommendations [18,19], urgent actions are necessary to stimulate breakfast consumption and help children to adopt healthier eating habits.

One limitation of our study was the cross-sectional design that limits causal inference. Second, the lack of standardized definition and assessment method for breakfast skipping make it difficult to compare these results with other studies. Third, despite the calculation of the C-DII considered 16 of the total 25 food parameters available in the definition, our C-DII scores were similar to other pediatric study [10,49]. Finally, although C-DII was validated in NHANES sample [6], the studies evaluating the inflammatory potential of diet using this new index specific for children are still scarce. Therefore, more research validating the index with other inflammation markers in different populations are necessary to consolidate its use in pediatric clinical practice.

As strengths, this is a study with a representative sample composed exclusively by children, being relevant phase for investigation of eating habits. To the best of our knowledge, this is the first epidemiological study to evaluate the influence of the interaction between behavioral factors (breakfast skipping and sedentary behavior) in the child's dietary inflammatory status. Thus, we believe that this study can be a starting point for further research to confirm the relationship between these common unhealthy habits (breakfast skipping and screen time) in childhood and the pro-inflammatory diet, as well as to motivate the implementation of effective action in public health policy and practice.

In conclusion, breakfast skipping is associated with a more pro-inflammatory diet in schoolchildren, with emphasis among those with sedentary behavior. Early childhood interventions encouraging eating breakfast and engaging in physical activity may help reduce the inflammatory potential of diet and prevent related-cardiometabolic disorders. Future studies evaluating the determinants of diet quality using C-DII scores should be carried out to confirm our findings.

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Disclosure

Dr. James R. Hébert 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. The subject matter of this paper will not have any direct bearing on that work, nor has that activity exerted any influence on this project.

Author contribution

LGS, and MAS participated in the study design and data collection. LGS performed the statistical analysis and drafted the manuscript. JFN, LLJ, SAVR, and HHMH guided LGS in article writing, critical review, statistical analysis and data interpretation. NS and JRH obtained the C-DII score from the data delivered to it, obtained by LGS, member of the PASE research group. All authors have approved the final version of this article submitted.

Conflict of interests

None.

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Tables and Figures

Table 1. Characteristics of the study population according to breakfast skipping, Viçosa, Minas Gerais, Brazil, 2015.

Characteristics	**Total**	**Breakfast skipping (%)**		**P-value**
	(%)	**No**	**Yes**	
Sex (boys)	47.9	81.2	18.8	0.539
Age (8 years old)	48.4	80.9	19.1	0.645
Race (Non-white)	68.5	78.4	21.6	0.278
Household per capita income (US$) [1]				0.256
<96.9 (1st quartile)	24.6	86.0	14.0	
97.0-155.3 (2nd quartile)	24.9	73.4	26.6	

155.4 – 262.2 (3rd quartile)	25.7	79.4	20.6	
>262.3 (4th quartile)	24.9	80.9	19.1	
Sedentary behavior (Screen time >2h/day)	47.6	76.7	23.3	0.135
Breakfast skipping (yes)	20.1	-	-	-

[1]Approximate exchange rates of real (R$) to dollar (US$) at the time of this study (US$1.00 = R$ 3.22).
Pearson Chi-square test (*P < 0.05).

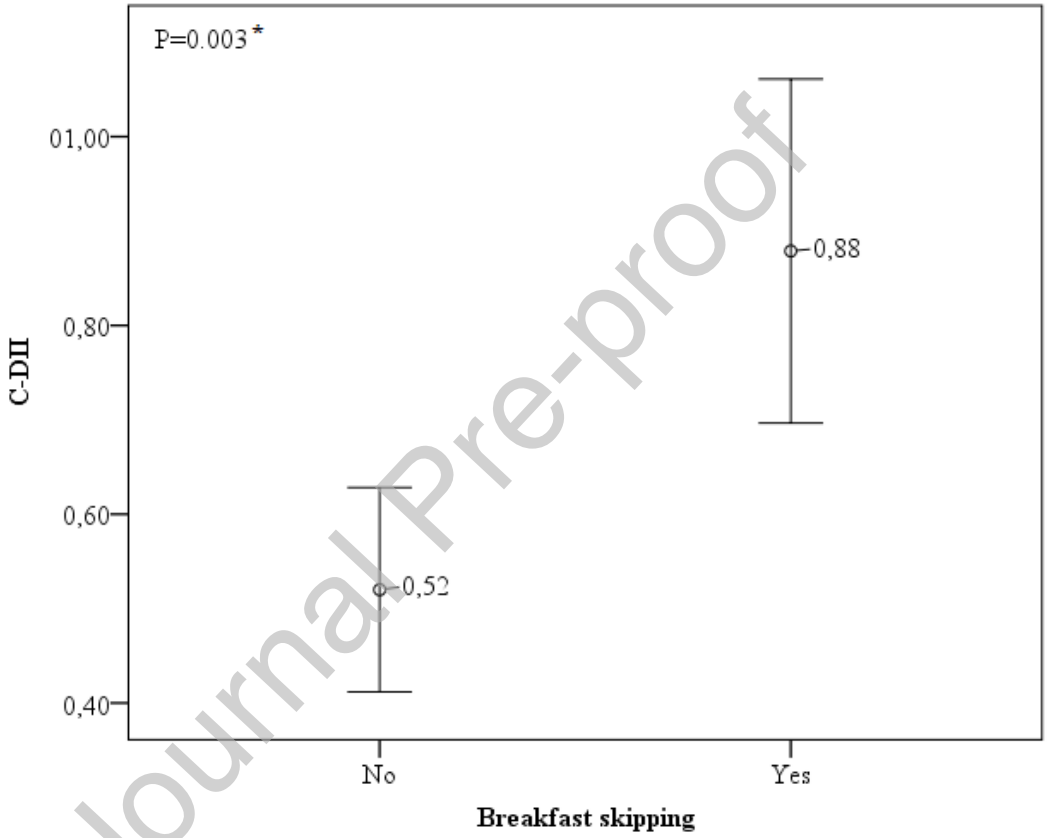

Figure 1. Children´s Dietary Inflammatory Index (C-DII) according to breakfast skipping in schoolchildren from Viçosa, Minas Gerais, Brazil, 2015. Data are mean and 95% CI. *P<0.05 from Student t test.

Table 2. Association between breakfast skipping and daily dietary intake in schoolchildren from Viçosa, Minas Gerais, Brazil, 2015.

Nutrients[1]	Breakfast skipping				Adjusted model		
	No		Yes				
	Mean	SD	Mean	SD	β	95% CI	P-value
Energy (kcal)	1417.71	442.24	1315.72	460.88	-89.71	-203.83 – 24.41	0.123
Macronutrients (g)							
Carbohydrate †	59.52	6.14	57.36	5.76	-5.63	-9.26 – -1.99	0.002*
Protein	13.92	2.88	13.65	3.11	-0.41	-2.32 – 1.49	0.671
Lipids †	27.58	5.10	29.46	4.99	2.15	0.78 – 3.53	0.002*
MUFA †	8.68	2.04	9.40	2.01	0.77	0.21 – 1.33	0.007*
PUFA †	5.36	1.82	6.18	2.25	0.93	0.32 – 1.53	0.003*
Saturated fat	9.30	2.15	9.50	2.63	0.22	-0.48 – 0.93	0.536
Fiber	9.98	3.44	9.45	3.68	-0.45	-1.37 – 0.46	0.329
Micronutrients							
Vitamin D (μg)	1.32	0.98	1.11	1.09	-0.21	-0.48 – 0.05	0.118
Calcium (mg) †	337.52	136.41	295.90	141.93	-39.20	-73.97 – -4.43	0.027*
Iron (mg)	4.85	2.16	4.61	1.32	-0.19	-0.56 – 0.17	0.304
Zinc (mg)	4.43	1.44	1.35	1.26	-0.03	-0.36 – 0.29	0.826
Magnesium (mg) †	112.5	33.11	100.66	19.66	-11.11	-17.06 – -5.16	<0.001*
B1 (mg)	0.68	0.21	0.68	0.23	0.001	-0.05 – 0.06	0.968
B2 (mg)	0.77	0.27	0.71	0.28	-0.06	-0.13 – 0.01	0.091
B3 (mg)	6.87	3.22	7.37	2.95	0.63	-0.08 – 1.35	0.085
B6 (mg)	0.60	0.22	0.58	0.26	-0.01	-0.07 – 0.05	0.742
C (mg)	54.03	126.54	52.76	125.35	1.55	-30.39 – 33.50	0.924

EI, energy intake; MUFA, monounsaturated fat; PUFA, polyunsaturated fat.
Values are mean ± SD (standard deviation).
[1] Nutrients adjusted for 1000 kcal.
† Significant difference of the mean nutrient's intake according to the groups of breakfast skipping (yes/no). Student t test (P<0.05).
From linear regression models (*P < 0.05). Adjusted for child's age, sex, race, household per capita income, and sedentary behavior.

Table 3. Association between breakfast skipping and the Children´s Dietary Inflammatory index (C-DII) in schoolchildren from Viçosa, Minas Gerais, Brazil, 2015.

Statistical models	C-DII		
	β	**95% CI**	**P-value**
Crude Linear Model			
Breakfast skipping			
No	Ref	-	-
Yes	0.36	0.15 – 0.57	0.001*
Adjusted Linear Model [1]			
Breakfast skipping			
No	Ref	-	-
Yes	0.33	0.12 – 0.54	0.002*
Adjusted Linear Model [2]			
Breakfast skipping			
No	Ref		
Yes	0.31	0.11 – 0.52	0.002*
Interaction [3]			
Breakfast skipping * Sex	-0.10	-0.52 – 0.31	0.621
Breakfast skipping * Age	-0.01	-0.51 – 0.31	0.637
Breakfast skipping * Race	0.13	-0.32 – 0.59	0.566
Breakfast skipping * Household per capita income	0.16	-0.03 – 0.37	0.101
Breakfast skipping * Sedentary behavior	0.50	0.01 – 0.90	0.015*

Ref: reference

From the linear regression models with the C-DII as continuous outcome and the breakfast skipping as predictor. Robust estimates of variance were specified in all the models.

[1] Adjusted for child's sex, age, race, household per capita income (model 1).

[2] Adjusted for model 1 + sedentary behavior.

[3] Exposure interactions with each variable tested in independent models adjusted for child's sex, age, race, household per capita income, and sedentary behavior.

(*P < 0.05).

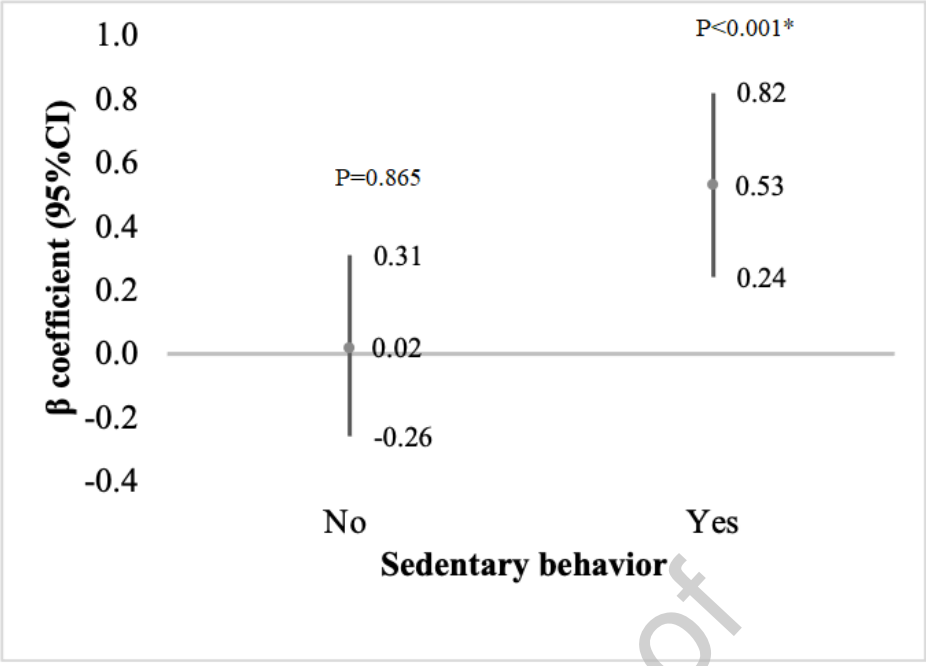

Figure 2. Linear regression models for the association between breakfast skipping and the Children´s Dietary Inflammatory index (C-DII) scores stratified by sedentary behavior in schoolchildren from Viçosa, Minas Gerais, Brazil, 2015. Adjusted for child's sex, age, race, and household per capita income ($^{*}P < 0.05$).