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ORIGINAL CONTRIBUTION

Adherence to the EAT-*Lancet* sustainable reference diet and cardiometabolic risk profile: cross-sectional results from the ELSA-Brasil cohort study

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Abstract

Purpose The EAT-*Lancet* Commission released a reference sustainable diet to improve human health and respect the planetary boundaries. The Planetary Health Diet Index (PHDI) was developed with the purpose of evaluate the adherence to this reference diet. The aim of the present study was to evaluate the association between adherence to the EAT-*Lancet* diet with cardiometabolic risk profile.

Methods We used the cross-sectional baseline data from 14,155 participants of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), a multicenter ongoing cohort study. Dietary data were collected using a 114-item validated food frequency questionnaire. The PHDI was used to assess the adherence to the EAT-*Lancet* diet. It consists of 16 components and the total score can range from 0 to 150 points. Linear, logistic and quasi-Poisson regression models were built to evaluate the associations between PHDI and the outcomes.

Results Individuals with higher adherence to EAT-*Lancet* diet (PHDI, 5th quintile) had lower values for systolic blood pressure (β − 0.84; 95% CI − 1.66: − 0.01), diastolic blood pressure (β − 0.70; 95% CI − 1.24: − 0.15), total cholesterol (β − 3.15; 95% CI − 5.30: − 1.01), LDL-c (β − 4.10; 95% CI − 5.97: − 2.23), and non-HDL-cholesterol (β − 2.57; 95% CI − 4.62: − 0.52). No association was observed for HDL-c, triglycerides and HOMA-IR.

Conclusions Our results indicate that higher adherence to the EAT-*Lancet* diet is associated with lower levels of blood pressure, total cholesterol, LDL-c, and non-HDL-c.

Keywords EAT-*Lancet* diet · Sustainable diet · Diet indexes · Cardiovascular diseases · Blood pressure · Lipid profile

Introduction

Cardiovascular disease (CVD) remains a major cause of death worldwide and its prevalence is still increasing globally [1]. Cardiometabolic risk factors such as high blood pressure (BP), high fasting plasma glucose, insulin resistance (HOMA-IR), high cholesterol and LDL-c, lower HDL-c and overweight and obesity are the largest drivers to the CVD global burden [2]. In addition, social and behavioral factors (e.g., smoking, alcohol consumption, physical

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inactivity and unhealthy dietary patterns) contribute to the CVD risk and the cardiometabolic risk as well [2].

The American Heart Association (AHA) stated that the adoption of healthy lifestyle behaviors (i.e., no smoking, regular physical activity practice, moderate alcohol consumption and a healthy dietary pattern) could provide a better cardiovascular health (CVH) and consequently decrease the CVD rates [3]. In this way, AHA developed the concepts of "ideal cardiovascular health" (ICH), a seven-metric score that includes cardiometabolic risk factors (BP, fasting plasma glucose, and total cholesterol) and behavioral factors (body mass index [BMI], smoking, physical activity level and a heathy dietary pattern) to assess the CVH [4].

According to some studies, a healthy dietary pattern should consider sustainability in addition to disease prevention, as the definition of a healthy diet also involves environmental factors [5, 6]. According to the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO), sustainable healthy diets are "dietary patterns that promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable" [7].

Early in 2019, the landmark EAT-*Lancet* Commission on "Healthy Diets from Sustainable Food Systems" proposed a balanced sustainable reference diet to guide the global population to follow a healthy and sustainable diet to promote human health within planetary boundaries. This sustainable reference diet consists predominantly of fruits, vegetables, whole grains, nuts, and legumes, includes only a low to moderate amount of seafood and poultry, and no or low amount of red meat, animal fats, added sugar, refined grains, and starchy vegetables. Besides that, the EAT-*Lancet* diet is nutritionally balanced, has a low environmental impact and it would be responsible for decrease around 11 million deaths per year in a global adoption scenario estimation [5, 8].

However, studies that assess the relationship between the adherence to the EAT-*Lancet* diet with cardiometabolic risk profile are scarce and as far as we know, only one study assessed this relationship [9]. Nonetheless, they used a binary score that not include all EAT-*Lancet* food groups and all intermediate values [10] Recently, the Planetary Health Diet Index (PHDI) [11] was proposed, a diet quality index that considers the EAT-*Lancet* characteristics, besides the proportionally scoring system, which allows a better distribution and a more refined and precise estimation [12]. Thus, in the present study, we aimed to evaluate the association between adherence to the EAT-*Lancet* diet evaluated by the PHDI with cardiometabolic risk profile and with CVH evaluated using the ICH score. To achieve this purpose, we used baseline data from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil).

Material and methods

Study design

The ELSA-Brasil is a multicenter and ongoing cohort study conducted in six Brazilian cities (São Paulo, Rio de Janeiro, Salvador, Porto Alegre, Belo Horizonte and Vitoria) from three major Brazilian regions (Northeast, Southeast, and South). The complete study design and data collection were previously described [13–16]. Briefly, all males and females active and retired employees from six universities in these cities who were aged between 35 and 74 years were eligible for the study. Exclusion criteria were as follow: current or recent (4 months prior to the first interview) pregnancy, intention to quit working at the institution in the near future, severe cognitive or communication impairments, and, if retired, residence outside of a study center. In the present study, we used baseline data that were collected between August 2008 and December 2010. The ELSA-Brasil was approved by the research ethics committees of all research centers. All participants volunteered and signed an informed consent form. The present study was also approved by the research ethics committee of the School of Public Health of the University of São Paulo (number 3.970.703).

For the present analysis, we excluded participants who presented previous history of cardiovascular disease (including stroke, myocardial infarction and myocardial revascularization) ($n = 477$), those with missing data from the following variables: dietary intake ($n = 22$), clinical assessment [blood pressure ($n = 1$) and blood measurement ($n = 27$)] ($n = 28$), and confounding variables ($n = 423$), totalizing a final sample of 14,155 individuals (Fig. 1).

Dietary assessment

Food consumption was assessed using a previously developed and validated semi-quantitative food frequency questionnaire (FFQ) with 114 food items [17, 18]. This FFQ consider the past 12 months and the questions are structured into three sections: (1) food products/food preparations; (2) measures of consumed products, and (3) consumption frequencies with eight response options (more than 3 times/day, 2–3 times/day, once a day, 5–6 times a week, 2–4 times a week, once a week, 1–3 times a month, and never/almost never).

The daily consumption of each FFQ item (in g/day) was obtained by multiplying the corresponding frequency by the portion size. Food measurements were then converted into nutrient intakes using the United States Department of Agriculture (USDA) Food Composition Database, except

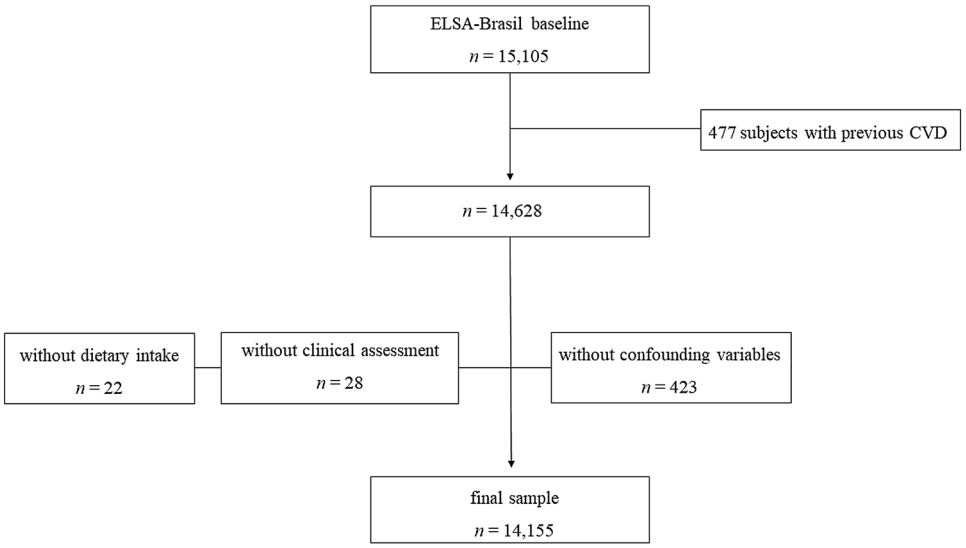

Fig. 1 Flow-chart of subjects included in the present analysis. ELSA-Brasil study 2008–2010

when its values were outside the range of 80%–120% from those described in the Brazilian Table of Food Composition, where the latter reference was used.

Planetary health diet index computation

The Planetary Health Diet Index (PHDI) is based on the recommendations of the reference diet proposed by the EAT-*Lancet* Commission [5]. This reference diet was set as a daily intake of 2500 kcal per day (kcal/day) with possible ranges of contributions from different food groups expressed as both gram per day (g/day) and kcal/day, including the exchangeability and interchangeability between some food groups (Table S1). The PHDI considers all EAT-*Lancet* food groups and the ranges and midpoints proposed for each food group were calculated as their energetic contribution to the reference diet of 2500 kcal/day.

The PHDI has a gradual scoring system, i.e., the components can be scored according to the amount of consumption. The scores are computed as a caloric intake ratio and for any given PHDI component, the caloric intake ratio was defined as the sum of calories from all foods classified in that component divided by the total calories from all PHDI foods. The total daily energy intake for the calculation of the PHDI components considered only the food groups recommended by the EAT-*Lancet* (i.e., it does not include alcohol consumption). In this case, we name it "PHDI total daily energy", to differentiate it from the total daily energy intake, which considers all foods and beverages consumed. The PHDI development, scoring criteria and cut-off points were extensively described elsewhere [11].

Briefly, the PHDI has 16 components divided into four categories: (i) adequacy components (nuts and peanuts, fruits, legumes, vegetables and whole grain cereals), (ii) optimum components (eggs, dairy products, fish and seafood, tubers and potatoes and vegetable oils), (iii) ratio components (dark green vegetables/total vegetables and red–orange vegetables/total vegetables) and (vi) moderation components (red meat, chickens and substitutes, animal fats and added sugars). The adequacy, optimum, and moderation components can score proportionally from 0 to 10 points, while the ratio components can score proportionally from 0 to 5 points.

The PHDI scores were calculated through the procedure previously describe [11]. All mixed dishes identified through the FFQ were decomposed into individual ingredients based on household standard recipes according to the national literature [19, 20]. For highly processed food products based on a major ingredient (e.g., products based primarily on maize starch or wheat flour), we compute the fraction of the total energy of these ingredients based on the content of total fat and added sugars, as described in the nutrient database [21], except for processed meats, which were classified according to their predominant ingredient origin or most commonly marketed formulation into the respective red meat (e.g., sausage, ham, and salami) or chicken and substitutes (e.g., pate, nuggets, etc.) groups[11]. Table S2 describes the food and ingredients included in each of the 16 components.

Clinical assessment

Blood pressure was measured with the participant seated, in a quiet room with controlled temperature, after five minutes of rest, using an oscillometer equipment (Omron HEM 705CPINT) [15].

All blood samples were collected after a 12-h overnight fasting and aliquots were stored in freezers at -80ºC until the date of transportation to the Central Laboratory for

analysis by an ADVIA 1200 Siemens system (Deerfield, United States). Fasting glucose was determined by the hexokinase method (enzymatic colorimetric) and insulin was determined by immunoenzymatic assay. Total cholesterol (TC) was determined by cholesterol oxidase method (enzymatic colorimetric), triglycerides (TG) by glycerol-phosphate peroxidase (enzymatic colorimetric); HDL-c by homogeneous colorimetric without precipitation. The LDL-c was estimated by the Friedewald equation when TG were < 400 mg/dL, and by a homogeneous colorimetric without precipitation when TG were > 400 mg/dL. HOMA-IR was calculated from fasting glucose and insulin as [fasting glucose (mg/dL) × 0.0555 × fasting serum insulin (mUI/L)/22.5].

Covariates

Each participant was interviewed at his or her workplace and visited the research center for clinical examinations, according to standard protocols. These interviews focused on sociodemographic characteristics, which were obtained using a general questionnaire [16]. Some sociodemographic characteristics were used: sex, age, self-reported race and income per capita. Participants were classified according to sex (male and female) and according to age as adults (34–59 years) and elderly (≥ 60 years). Self-reported race was classified in white, brown, black or Asian and Indigenous, according to previous ELSA-Brasil studies [13, 14]. Per capita family income, also based on self-report, was calculated as the total family monthly income divided by the number of family members and then divided in tertiles. Smoking was stratified as non-smokers, ex-smokers and current smokers. Alcohol consumption was obtained according to the amount ingested per week (male ≥ 210 g; female ≥ 140 g) and then dichotomized in high alcohol consumption (yes or no) [14, 22]. Level of physical activity during leisure time was classified as low (no or less than moderate category), moderate (> 150 min/week of moderate activity) or vigorous (≥ 75 min/week of vigorous activity) according to the International Physical Activity Questionnaire [23].

The anthropometric measures of weight and height were obtained using international criteria and standard techniques [13]. The body weight was measured with the subject barefoot, fasted, and wearing a standard uniform over their underwear. An electronic scale (Toledo®, model 2096PP) was used, with a capacity of 200 kg and a precision of 50 g. The height was measured with a wall stadiometer (Seca®, Hamburg, BRD) with a precision of 1 mm, attached to the wall, with the individual in a supine position, barefoot, leaning their head, buttocks, and heels against the wall and staring in the horizontal plane. The BMI was calculated as weight (kg) divided by squared height (m^2) [13].

Ideal cardiovascular health

Ideal Cardiovascular Health (ICH) is a seven-metric score for evaluating the cardiovascular health proposed by the AHA [4]. The 7 ideal ICH metrics are: (1) diet: 4 adequate components from (a) ≥ 4 servings of fruit and vegetables per day; (b) ≥ 7 oz of fish per week; (c) ≥ 2 servings of fiber-rich whole grains per day; (d) ≤ 450 kcal of sugar-sweetened beverages per week; and (e) sodium consumption ≤ 1500 mg/d; (2) physical activity: ≥ 75 min/week of vigorous physical activity, or ≥ 150 min/week of moderate physical activity or ≥ 150 min/week of moderate + vigorous physical activity; (3) smoking: never smoked or former smoker with age at quitting at least 2 years less than the age at baseline; (4) body mass index: < 25 kg/m^2; (5) SBP < 120 mm/Hg and DBP < 80 mm/Hg, without antihypertensive medication; (6) fasting plasma glucose: < 100 mg/dL, without hypoglycemic medication; and (7) total cholesterol: < 200 mg/dL, without lipid-lowering medication. The total ICH score can range from 0 to 7 points and according to AHA the ICH score can be classified as having poor (0–2), intermediate (3–4), and optimal (5–7) cardiovascular health [4].

In the present study, as we aimed to evaluate the association between the PHDI with ICH, we removed the diet metric from the total ICH, to avoid a spurious association. For the associations, we used the ICH continuous and dichotomized. In the present study, the total ICH range from 0 to 6 points. We also adapted the ICH categorization in non-ideal ICH (0–4 points) and ideal ICH (5–6 points).

Statistical analyses

The normality of the variables was evaluated through their distribution and histogram. HDL-c, TG and HOMA-IR were log-transformed to meet the normality assumptions. We used the PHDI scores categorized in quintiles and continuous (increase of 10 points in the total PHDI score) as explanatory variables in all models.

We calculated means and standard deviations (SD ±) or percentages for each variable across the PHDI quintiles as descriptive analyses in the baseline characteristics. ANOVA or Pearson's chi-square tests were used to assess the statistical significance of differences between means or proportions, respectively.

Crude and adjusted linear regression models were built to assess the relation between PHDI and the outcome variables. All models were presented as age-adjusted and fully adjusted models with additional adjustments for sex, self-reported race, per capita income, smoking, alcohol consumption, physical activity level, and total daily energy intake.

Considering that BMI is associated with cardiometabolic risk profile and with non-communicable diseases, additional analyses were performed including BMI in the models.

Quasi-Poisson regression models were built to evaluate the association between the PHDI scores with the ICH continuously. The quasi-Poisson model are similar with the classic Poisson model, without assuming that the variance and the mean estimate are equals. More details can be found in previous ELSA-Brasil studies that used the quasi-Poisson for the ICH metric as well [24, 25]. Based on the quasi-Poisson model estimates, we calculated relative predicted score differences (rPSD). rPSDs correspond to the expected change in the ICH score associated with PHDI quintiles. Positive rPSD values indicate higher ICH scores.

Logistic regression models were also built to evaluated the associations between PHDI and ICH categorized. First, we built models using the ICH ideal as ≥ 5 points as a reference. The quasi-Poisson and logistic regression models were adjusted for sex, age, self-reported race, per capita income and total energy intake, as ICH metric considering the physical activity level, smoking and alcohol consumption habits.

Interaction between PHDI score and sex was tested, due to the differences in dietary intake in men and women. However, no statistical significance was found ($p > 0.05$), thus, we chose to evaluate the associations in the entire population.

All statistical analyses were performed using STATA® (Statistical Software for Professionals, College Station, Texas, USA) version 14.2, except the quasi-Poisson analysis, which was performed using the R package version 4.1.1. The p value ≤ 0.05 was considered statistically significant.

Results

Table 1 presents the baseline characteristics of the participants according to the PHDI quintiles. Those with higher adherence to the EAT-*Lancet* diet (PHDI, 5th quintile) were more likely to be elderly, female, who self-reported white, had high per capita income, non-smokers, those with lower sporadic alcohol consumption and with moderate to vigorous physical activity level.

In the fully adjusted linear regression models, those individuals with higher adherence to the PHDI score (5th quintile) had − 0.81 mmHg in SBP (95% CI − 1.54: − 0.07), − 0.66 mmHg in DBP (95% CI − 1.19:− 0.12), − 3.22 mg/dL in total cholesterol (95% CI − 5.33: − 1.12), − 4.12 mg/dL in LDL-c (95% CI − 5.95: − 2.29), and − 2.69 mg/dL in the non-HDL-c (95% CI − 4.70: − 0.68). No association was found for HDL-c mg/dL, TG mg/dL and HOMA-IR (Table 2).

The association remains when considering a 10-point increase in the PHDI score with SBP (β − 0.22; 95% CI − 0.44: − 0.01) mmHg, DBP (β − 0.19; 95% CI − 0.33: − 0.04) mmHg, total cholesterol (β − 1.01; 95% CI − 1.59: − 0.43) mg/dL, LDL-c (β − 1.28; 95% CI − 1.78: − 0.77) mg/dL, and non-HDL-c (β − 0.81; 95% CI − 1.36: − 0.25) mg/dL No associations were found between a 10-point increase in the PHDI score and HDL-c, TG, and HOMA-IR (Table 2).

The additional analysis including BMI in the fully adjusted models demonstrated a little effect on the associations, with no impact in the direction's associations (Table S3).

In the quasi-Poisson models, those in the 5th PHDI quintile group had an ICH 8.05% (rPSD 8.05%; 95% CI 5.54%: 10.62%) higher than those in the 1st PHDI quintile group, after adjustment for age, sex, self-reported race, per capita income and total energy intake. In the fully adjusted logistic regression models, we observed that those in the 5th PHDI quintile group had 49% lower odds for having ICH < 5 (OR 0.61, 95% CI 0.50:0.74), compared to the 1st PHDI quintile group. Similar directions were found in analyses using the PHDI as 10-point increasing in the total score (Table 3).

Discussion

In the present study, higher adherence to the EAT-*Lancet* diet—evaluated through the PHDI—was significantly associated with lower values for blood pressure (SBP and DBP), total cholesterol, LDL-c, and non-HDL-c. Higher adherence to the EAT-*Lancet* diet was also associated with better cardiovascular health assessed by the ICH score, after adjustment for multiple confounding factors.

We observed that the population evaluated showed poor adherence to the EAT-*Lancet* diet, since the PHDI total average was 60.4 points, from a total score that can range from 0 to 150 points. This result is similar to other study in a national population-based study in Brazil, which also showed poor adherence to the EAT-*Lancet* diet evaluated through the PHDI [26]. However, even with the population reaching only half of the possible points, those individuals showing a higher adherence to the EAT-*Lancet* diet had lower values in cardiometabolic risk factors, indicating that following these model diet can be beneficial to human health, in addition to planetary one.

Few studies assessed the relationship between adherence to the EAT-*Lancet* diet with health-related outcomes. In a previous study with the same population, the authors found that higher adherence to the EAT-*Lancet* diet, also evaluated by using the PHDI score, was associated with lower values in the BMI and in the waist circumference (WC), besides lower odds for overweight and obesity, after controlling for potential cofounding factors [27]. Our results are reinforced by these aforementioned results, since overweight

Table 1 Baseline characteristics of the participants according to Planetary Health Diet Index quintiles. Brazilian Longitudinal Study of Adult Health (ELSA-Brasil) 2008–2010. ELSA-Brasil, 2008–2010

	Planetary health diet index (PHDI)					*p* value[1]
	1st	2nd	3rd	4th	5th	
N	2838	2842	2839	2799	2837	
Age group, *n (%)*						< 0.001
Adults (34–59 years)	2301 (20.5)	2310 (20.6)	2276 (20.3)	2233 (19.9)	2096 (18.7)	
Elderly (≥ 60 years)	537 (18.3)	532 (18.1)	563 (19.2)	566 (19.3)	741 (25.2)	
Sex, *n (%)*						0.208
Men	1,306 (20.4)	1,303 (20.3)	1,279 (20.0)	1,290 (20.1)	1,231 (19.2)	
Women	1,532 (19.8)	1,539 (19.9)	1,560 (20.1)	1,509 (19.5)	1,606 (20.7)	
Self-reported race, *n (%)*						< 0.001
White	1398 (18.9)	1416 (19.2)	1525 (20.6)	1504 (20.3)	1550 (21.0)	
Brown	878 (22.0)	840 (21,1)	788 (19.8)	757 (19.0)	727 (18.2)	
Black	467 (20.5)	488 (21.5)	435 (19.1)	439 (19.3)	446 (19.6)	
Indigenous and Asians	95 (19.1)	98 (19.7)	91 (18.3)	99 (19.9)	114 (22.9)	
Per capita family income[2], *n (%)*						< 0.001
Low	1099 (21.1)	1101 (21.1)	1090 (20.9)	1030 (19.8)	894 (17.2)	
Medium	948 (19.5)	994 (20.5)	935 (19.3)	971 (20.0)	1009 (20.8)	
High	791 (19.4)	747 (18.3)	814 (19.9)	798 (19.5)	934 (22.9)	
Smoking, *n (%)*						< 0.001
Never	2393 (19.4)	2469 (20.1)	2465 (20.0)	2474 (20.1)	2516 (20.4)	
Current smoker	445 (24.2)	373 (20.3)	374 (20.4)	325 (17.7)	321 (17.5)	
High alcohol consumption, *n (%)*						0.006
No	2443 (19.9)	2436 (19.9)	2461 (20.1)	2402 (19.6)	2515 (20.5)	
Yes	395 (20.8)	406 (21.4)	378 (19.9)	397 (20.9)	322 (17.0)	
Physical activity, *n (%)*						< 0.001
Low	2308 (21.2)	2,242 (20.6)	2,191 (20.1)	2,135 (19.6)	2,015 (18.5)	
Moderate-to-Vigorous	530 (16.2)	600 (18.4)	648 (19.9)	664 (20.3)	822 (25.2)	
PHDI total score, *mean (SD)*	44.7 (4.4)	53.8 (1.9)	60.0 (1.7)	66.2 (2.0)	76.8 (6.1)	< 0.001
SBP mmHg, *mean (SD)*	122.0 (17.8)	121.6 (17.5)	121.0 (17.4)	121.4 (16.5)	121.7 (17.2)	0.303
DBP mmHg, *mean (SD)*	77.0 (10.9)	76.8 (10.8)	76.3 (10.8)	76.6 (10.6)	76.1 (10.5)	0.005
Total cholesterol mg/dL, *mean (SD)*	202.8 (40.9)	200.9 (40.5)	201.7 (39.5)	199.9 (39.9)	200.4 (42.1)	0.061
LDL-c mg/dL, *mean (SD)*	122.1 (37.1)	120.0 (34.5)	119.6 (33.6)	118.4 (34.7)	118.2 (35.1)	< 0.001
HDL-c mg/dL, *mean (SD)*	53.5 (13.0)	53.4 (13.1)	54.2 (13.4)	53.3 (13.1)	53.9 (13.6)	0.065
TG mg/dL, *mean (SD)*	127.9 (83.2)	126.7 (94.7)	129.6 (92.0)	131.2 (95.6)	132.0 (110.9)	0.1830
Non-HDL-c mg/dL, *mean (SD)*	149.3 (39.0)	147.5 (38.8)	147.6 (37.7)	146.7 (38.3)	146.5 (40.4)	0.055
HOMA-IR, *mean (SD)*	2.3 (2.1)	2.4 (3.4)	2.2 (2.6)	2.5 (2.8)	2.5 (3.6)	< 0.001
BMI (kg/m^2), *mean (SD)*	27.1 (4.7)	27.0 (4.8)	26.9 (4.7)	27.2 (4.8)	26.8 (4.7)	0.002
ICH continuous, *mean (SD)*	2.6 (1.3)	2.7 (1.3)	2.8 (1.3)	2.7 (1.3)	2.8 (1.3)	< 0.001
Energy intake kcal/day, *mean (SD)*	1,953.4 (756.1)	1,975.0 (716.9)	1,947.2 (702.6)	1,937.2 (666.8)	1,860.6 (604.1)	< 0.001

SBP systolic blood pressure, *DBP* diastolic blood pressure, *TG* triglycerides, *ICH* ideal cardiovascular health

[1]ANOVA or Pearson's Chi-square tests

[2]Per capita income: low (1st tertile), medium (2nd tertile), and high (3rd tertile)

and obesity are known to be associated with cardiovascular diseases risk [1–3].

Similar to our study, Knuppel et al. found significantly lower blood pressure, total cholesterol, non-HDL-c and higher HDL-c values in those participants with higher scores in the EAT-*Lancet* diet score, a binary score index that can range from 0 to 14 points developed and applied in the EPIC-Oxford study [9]. Knuppel et al. also found an association between higher scores in the EAT-*Lancet* diet score with lower risk of ischemic heart disease and type 2 diabetes, but not with stroke [9]. On the other hand, Ibsen et al. also used the EAT-*Lancet* diet score in Danish adults and

Table 2 Linear associations between Planetary Health Diet Index and cardiovascular risk markers in the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil) 2008–2010

	Planetary health diet index						
	1st	2nd	3rd	4th	5th	*p* for trend[1]	Continuous (10 points)[2]
SBP mmHg							
Age-adjusted, *Coef. (95% CI)*	Ref	− 0.36 (− 1.21:0.50)	**−1.13 (− 1.98:− 0.27)**	**− 0.93 (− 1.79: − 0.07)**	**− 1.45 (− 2.31:− 00.59)**	< 0.001	**− 0.47 (− 0.70: − 0.23)**
Fully adjusted, *Coef. (95% CI)*	Ref	− 0.43 (− 1.23:0.37)	**− 0.86 (− 1.65: − 0.04)**	− 0.76 (− 1.57:0.05)	**− 0.81 (− 1.54: − 0.07)**	0.040	**− 0.22 (− 0.44: − 0.01)**
DBP mmHg							
Age-adjusted, *Coef. (95% CI)*	Ref	− 0.19 (− 0.74:0.37)	**− 0.76 (− 1.32:− 0.21)**	− 0.52 (− 1.08: 0.03)	**− 1.14 (− 1.70:− 0.59)**	< 0.001	**− 0.35 (− 0.50:− 0.19)**
Fully adjusted, *Coef. (95% CI)*	Ref	− 0.21 (− 0.74:0.32)	**− 0.58 (− 1.11:− 0.05)**	− 0.41 (− 0.94:0.12)	**− 0.66 (− 1.19:− 0.12)**	0.012	**− 0.19 (− 0.33:− 0.04)**
Total cholesterol mg/dL							
Age-adjusted, *Coef. (95% CI)*	Ref	− 1.93 (− 4.02:0.17)	− 1.28 (− 3.38:0.82)	**− 3.24 (− 5.35:− 1.14)**	**− 3.57 (− 5.68:− 1.47)**	< 0.001	**− 1.11 (− 1.69:− 0.53)**
Fully adjusted, *Coef. (95% CI)*	Ref	− 1.76 (− 3.85:0.32)	− 1.04 (− 3.13:1.05)	**− 2.99 (− 5.10:− 0.89)**	**− 3.22 (− 5.33:− 1.12)**	< 0.001	**− 1.01 (− 1.59:− 0.43)**
LDL-c mg/dL							
Age-adjusted, *Coef. (95% CI)*	Ref	**− 2.12 (− 3.94:− 0.30)**	**− 2.58 (− 4.39:− 0.76)**	**− 3.92 (− 5.75:− 2.10)**	**− 4.46 (-6 .28:− 2.63)**	< 0.001	**− 1.38 (− 1.88:− 0.88)**
Fully adjusted, *Coef. (95% CI)*	Ref	**− 1.96 (− 3.77:− 0.14)**	**− 2.35 (− 4.17:− 0.53)**	**− 3.66 (− 5.49:− 1.84)**	**− 4.12 (− 5.95:− 2.29)**	< 0.001	**− 1.28 (− 1.78:− 0.77)**
HDL-c mg/dL							
Age-adjusted, *Coef. (95% CI)*	Ref	− 0.002 (− 0.014:0.010)	0.011 (− 0.002:0.023)	− 0.007 (− 0.019:0.006)	0.001 (− 0.012:0.013)	0.824	− 0.001 (− 0.004: 0.003)
Fully adjusted, *Coef. (95% CI)*	Ref	− 0.004 (− 0.015:0.007)	0.007 (− 0.004:0.018)	− 0.010 (− 0.021:0.001)	− 0.011 (− 0.022:0.000)	0.060	− 0.004 (− 0.007:0.001)
Non-HDL-c mg/dL							
Age-adjusted, *Coef. (95% CI)*	Ref	− 1.81 (− 3.82:0.20)	− 1.88 (− 3.89:0.13)	**− 2.89 (− 4.91:− 0.87)**	**− 3.67 (− 5.69:− 1.65)**	< 0.001	**− 1.10 (− 1.66:− 0.54)**
Fully adjusted, *Coef. (95% CI)*	Ref	− 1.57 (− 3.57:0.43)	− 1.47 (− 3.47:0.53)	**− 2.48 (− 4.49:− 0.47)**	**− 2.69 (− 4.70:− 0.68)**	0.006	**− 0.81 (− 1.36:− 0.25)**
TG mg/dL							
Age-adjusted, *Coef. (95% CI)*	Ref	− 0.010 (− 0.037:0.017)	0.003 (− 0.024:0.030)	0.017 (− 0.010:0.044)	0.002 (− 0.025:0.029)	0.316	0.003 (− 0.005: 0.010)
Fully adjusted, *Coef. (95% CI)*	Ref	− 0.006 (− 0.032:0.019)	0.011 (− 0.014:0.037)	0.024 (− 0.002:0.049)	0.028 (− 0.002:0.054)	0.066	0.011 (− 0.004: 0.018)
HOMA-IR							
Age-adjusted, *Coef. (95% CI)*	Ref	− 0.001 (− 0.050:0.048)	− 0.076 (− 0.125:0.027)	0.025 (− 0.024:0.074)	− 0.014 (− 0.063:0.035)	0.958	− 0.005 (− 0.019: 0.009)
Fully adjusted, *Coef. (95% CI)*	Ref	0.001 (− 0.048:0.049)	− 0.068 (− 0.117:0.020)	0.030 (− 0.018:0.079)	0.012 (− 0.037:0.061)	0.346	0.003 (− 0.011: 0.016)

All the fully adjusted models were adjusted for age, sex, self-reported race, per capita income, smoking, alcohol consumption, physical activity level, and total energy intake. Bold values mean statistical significance

SBP systolic blood pressure, *DBP* diastolic blood pressure, *TG* triglycerides, *Coef.* linear regression beta coefficient, *95% CI* 95% confidence interval

[1]P-trend modeling quintiles as an independent ordinal variable

[2]Each 10-point increase in the PHDI total score

found an association between higher scores with lower risk of stroke, especially with subarachnoid hemorrhage [28]. In the same direction, Xu et al., in a prospective cohort study with participants from UK Biobank, found an inverse association between higher scores in the EAT-*Lancet* diet score

Table 3 Associations between the planetary health diet index and ideal cardiovascular health in the Brazilian longitudinal study of adult health (ELSA-Brasil) 2008–2010

	Planetary Health Diet Index						Continuous (10 points)[2]
	1st	2nd	3rd	4th	5th	*p* for trend[1]	
Models							
ICH continuous[3]							
Age-adjusted, *rPSD % (95% CI)*	Ref	3.66 (1.25:6.12)	5.57 (3.13:8.07)	5.33 (2.86:7.85)	9.53 (6.95:12.17)	< 0.001	2.73 (2.06:3.40)
Fully adjusted, *rPSD % (95% CI)*	Ref	3.68 (1.32:6.10)	4.98 (2.60:7.43)	4.69 (2.28:7.16)	8.05 (5.54:10.62)	< 0.001	2.23 (1.57:2.89)
ICH ≥ 5[4]							
Age-adjusted, *OR (95% CI)*	Ref	0.83 (0.68:1.02)	0.77 (0.63:0.94)	0.72 (0.59:0.88)	0.64 (0.52:0.78)	< 0.001	0.87 (0.82:0.92)
Fully adjusted, *OR (95% CI)*	Ref	0.80 (0.065:0.99)	0.77 (0.62:0.95)	0.72 (0.58:0.88)	0.65 (0.53:0.80)	< 0.001	0.88 (0.83:0.93)

[1]P-trend modeling quintiles as an independent ordinal variable

[2]Each 10-point increase in the PHDI total score

[3]Quasi-Poisson regression models. [4]Logistic regression models. rPSD: relative predicted score differences. OR: odds ratio. 95% CI: 95% confidence interval. ICH: ideal cardiovascular health. All the fully adjusted models were adjusted for age, sex, self-reported race, per capita income, and total energy intake

with lower risk of type 2 diabetes [29]. However, in opposite to these findings, one study found no association between the EAT-*Lancet* diet score with obesity and cardiovascular risk in a representative sample of Canadian adults [30].

Although these interesting findings, the EAT-*Lancet* diet score may not be the best tool to evaluate the adherence to the EAT-*Lancet* diet [10, 30]. Some criticisms are due to the fact that this diet score has a binary score system, i.e., individuals receive 0 points if they meet the recommendations and 1 point if they do not. This type of scoring system does not take into account the inter-individual variability and does not allow for a greater distribution of the population adherence to the EAT-*Lancet* recommendations. In addition, one study did not find satisfactory results regarding the validity and reliability parameters of the EAT-*Lancet* diet score [30]. Some reviews about diet quality indices/scores suggest that these tools should consider a gradual scoring system over a binary or discrete one, since the gradual scoring system allows for a better discrimination of population adherence [31–33]. The PHDI has a gradual scoring system (i.e., the components can score from 0 to 10 points, with the exception of the ratio components, which score from 0 to 5 points) and the total score can vary from 0 to 150 points [12]. In this way, the PHDI allows a more adequate distinction between the individuals' degrees of adherence, favoring an interpersonal distribution and closer to a normal distribution. The greater variance in the PHDI score more accurately reflects eating behaviors and can be used to further examine the food groups that are driving the PHDI scores, i.e., adherence to the EAT-*Lancet* diet.

In addition to the PHDI, another diet index with a gradual score system was proposed by Stubbendorff et al., who assessed the adherence to the EAT-*Lancet* diet in the Swedish population using a diet index that comprises 14 components with a total score that can range from 0 to 42 points [34]. These authors found an inverse association between higher adherence to the EAT-*Lancet* diet and risk of cardiovascular mortality in this Swedish population [34]. Wang et al. suggested that a global adherence to the EAT-*Lancet* diet could prevent 25% of total deaths and that the largest number of preventable deaths was due to coronary heart disease, based on a modeling analysis of a global adherence to the EAT-*Lancet* diet [8].

Besides the aforementioned studies which evaluated the relationship between CVD or cardiometabolic risk profile and EAT-*Lancet*-based indices, there have been numerous studies that have investigated the associations between other diet quality scores that reflecting recommendations towards plant-based and sustainable diets (e.g., the Mediterranean diet and the DASH diet) with CVD and cardiometabolic profile. The findings suggest that higher adherence to plant-based diets could reduce CVD incidence and mortality [35, 36], while other studies found protective effects of higher adherence to the Mediterranean and DASH diet with lower CVD incidence [37, 38] and lower cardiometabolic risk, including lower values for blood pressure, lipid profile and insulin resistance [39–42]. On the other hand, a population-based study which assessed the relationship between the adherence to a sustainable diet index and CVD risk, found no association over a 4-year follow-up in French adults participating in the NutriNet-Santé study [43].

Our study featured some strengths. One of these strengths was that we assessed the adherence to the EAT-*Lancet* diet through a validated index that consider all EAT-*Lancet* diet food groups, has the cut-off points considering the intermediate values proposed in the report, using a proportionally scoring system and a caloric intake ratio value for all components, allowing the adherence assessment regardless of the calories consumed [11, 12], besides was related to lower GHGE values [11] and lower odds for overweight and obesity [27]. Another strength of our study was also using a validated semi-quantitative FFQ to estimate the usual intake of the population [17]. Notably, the disaggregation of dishes into underlying ingredients provided a more precise estimate of the individual dietary consumption and allows a better distribution in the PHDI components and better degree in evaluate the adherence to the EAT-*Lancet* diet. We used data from a study that followed strict data collection and processing protocols, the ELSA-Brasil study. It was designed to assess risk factors and associations for cardiovascular diseases and diabetes with a multicenter cohort design that follows individuals from six different Brazilian cities across three major Brazilian regions, allowing the inclusion of a population with ethnic and social diversity similar to that of heterogeneous populations mainly of middle income who live in large Brazilian cities [13, 14].

Despite these strengths, some limitations should be noted. For instance, these results must be considered within the context of the study design, since this was a cross-sectional analysis, which cannot evaluate causality. Besides that, the baseline data were collected between 2008 and 2010—more than 10 years ago. In addition, food consumption was assessed using an FFQ, an instrument that despite being one of the most commonly used methods in nutritional epidemiological studies, still features some limitations, such as the finitude of its foods list and dietary misreporting bias. Another limitation may be regarding the use of the PHDI, when compared to the use of other scores based on the EAT-*Lancet* diet that consider absolute values in grams, due to the need for a nutritional composition table linked to the food consumption database, needed to generate the calorie values and subsequently calculate the cut-off points for the PHDI components. However, this limitation may be relative, since the vast majority of epidemiological studies have data on the energy of the foods consumed. From an environmental perspective, we believe that there is no limitation in the use of PHDI, as it considers caloric values and these are derived from absolute values in grams. In the case of the EAT-*Lancet*, the recommendations are both in grams per day and in calories per day. According to the EAT-*Lancet* report, the recommended values are proposed as acceptable values in terms of human and planetary health. Nonetheless, comparing results using the PHDI and other EAT-*Lancet*-based diet indices that use grams per day could be a next step in future research to address this point.

Conclusion

Our findings show that higher adherence to the EAT-*Lancet* diet was associated with better cardiovascular health and with lower values for blood pressure, total cholesterol and some its fractions, such as LDL-c and non-HDL-c. These results support that a healthy and sustainable diet proposed by the EAT-*Lancet* may play a positive role in the cardiovascular health and in some cardiometabolic risk factors, contributing to the findings regarding the benefits of the adoption of a healthy and sustainable diet.

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Declarations

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