Nutrition 90 (2021) 111216

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Association between diet quality index and cardiometabolic risk factors in adolescents: Study of Cardiovascular Risks in Adolescents (ERICA)

Julianna do Amaral Ritter MSc [a,*], Felipe Vogt Cureau PhD [b], Débora Barbosa Ronca MSc [c], Carina Andriatta Blume MSc [a], Gabriela Heiden Teló MD, PhD [d], Suzi Alves Camey PhD [e], Kênia Mara Baiocchi de Carvalho PhD [c], Beatriz D. Schaan MD, PhD [a,b,f]

[a] Postgraduate Program in Medical Sciences, Endocrinology, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil
[b] Postgraduate Program in Cardiology and Cardiovascular Sciences, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil
[c] Graduate Program in Human Nutrition, Universidade de Brasília, Brasília, Brazil
[d] School of Medicine and Postgraduate Program, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil
[e] Postgraduate Program in Epidemiology, Department of Statistics, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil
[f] Hospital de Clínicas de Porto Alegre, Porto Alegre, Brazil

ARTICLE INFO

Article History:
Received 13 August 2020
Received in revised form 16 February 2021
Accepted 17 February 2021

Keywords:
Diet
Diet quality index
Nutrition assessment
Biomarkers
Cardiometabolic markers
Adolescents

ABSTRACT

Objective: This study evaluated the association between diet quality, assessed by the Diet Quality Index for Adolescents adapted for Brazilians (DQIA-BR), and cardiometabolic markers in adolescents.
Methods: The DQIA-BR and cardiometabolic markers were assessed in 36 956 Brazilian adolescents (12–17 y old) enrolled in the Study of Cardiovascular Risks in Adolescents (ERICA), a national school-based cross-sectional multicenter study in Brazil. For analyses, the sample was stratified by sex and nutritional status. Multiple linear regressions were used to investigate the association between DQIA-BR and cardiometabolic markers (total cholesterol, HDL-c, LDL-c, triglycerides, fasting glucose and HOMA-IR). Adjusted models were constructed with two input levels of covariates. The first model was adjusted for sex, age, and socioeconomic status; in the second model, total energy intake, physical activity, and sedentary behavior were included.
Results: A higher DQIA-BR score was associated with a better cardiometabolic profile in girls with normal weight; however, no association was observed in those with overweight/obesity. In boys with overweight/obesity, a better quality of diet was associated with lower concentrations of total cholesterol ($\beta = -0.338$, 95% confidence interval [CI]: −0.611 to −0.066) and LDL-c ($\beta = -0.227$, 95% CI: −0.448 to −0.005), but only LDL-c remained significant in those with normal weight ($\beta = -0.115$, 95% CI: −0.224 to 0.005).
Conclusion: The effects of diet quality on cardiometabolic risk factors differ according to sex and the presence of overweight/obesity. Overall, DQIA-BR is a suitable tool to evaluate the association between diet quality and cardiometabolic markers in normal-weight adolescents, but not for adolescents, especially girls, with overweight/obesity.

Introduction

Non-communicable chronic diseases (NCDs) are the leading cause of death worldwide [1]. According to the World Health Organization (WHO), 38 million deaths were attributed to NCDs in 2012; of these, 17.5 million deaths were related to cardiovascular diseases and 1.5 million to diabetes mellitus [1]. In Brazil, NCDs were responsible for about 75% of total mortality in 2015 [2]. Although most clinical manifestations of cardiovascular disease and diabetes mellitus begin in adulthood, they should be prevented early in life, reducing related modifiable risk factors [3] such as increased sedentary behavior [4], reduced physical activity [5], unhealthy eating patterns [6], and individual genetic predisposition [2].

Adherence to unhealthy dietary patterns, including increased intake of high-calorie and poor-nutrient foods, is related to

This work was supported by the Brazilian Ministry of Health (Department of Science and Technology); the Brazilian Ministry of Science and Technology (Financiadora de Estudos e Projetos [FINEP 01090421]); and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq: 565037/2010–2, 405009/2012–7 and 457050/2013–6). This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) – Finance Code 001.

*Corresponding author: Phone/fax: +55 51 33596355.
E-mail address: juliannarit@gmail.com (J.d.A. Ritter).

https://doi.org/10.1016/j.nut.2021.111216
0899-9007/

increased risk for cardiovascular disease, diabetes mellitus, some types of cancers, and all-cause mortality in the general population [6,7]. In nutritional epidemiology, studies have associated specific foods with health outcomes, such as whole-grain food consumption as a protective factor for cardiovascular disease [8] or ultra-processed food consumption as a risk factor for cardiovascular disease [6]. Although the evaluation of a single food or nutrient may be applicable to investigate its effects on a specific health outcome [9], it is inappropriate for identifying the effects of a dietary pattern on health because it does not consider the complexity of interactions between nutrients in the diet [10].

Diet quality indices are alternative tools to recognize dietary patterns as they provide an overview of the diet in its entirety [10]. The main advantages of these indices are the possibility to assess the complexity of the human diet and summarize it into a score, taking into account dietary patterns, guidelines for a healthy diet, and food preparation methods [11]. However, most dietary indices were developed based on nutritional recommendations for adult populations and, consequently, are improper to accurately assess diet quality in adolescents.

The Diet Quality Index for Adolescents (DQI-A) was designed and validated in a sample of adolescents enrolled in the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) [9]. Recently, the DQI-A was adapted to better address the food culture of Brazilian adolescents [12]. A previous study using the Diet Quality Index for Brazilian Adolescents (DQIA-BR) indicated that the overall diet quality is inadequate in all regions of the country [12], which may negatively impact youth health.

In the adult population, higher scores of diet quality are associated with better metabolic parameters [13], such as higher values of high-density lipoprotein cholesterol (HDL-c) [14] and lower levels of low-density lipoprotein cholesterol (LDL-c) [15] and fasting glucose [14]. In adolescents, studies have shown a positive association between overall diet quality with HDL-c [16] and an inverse association with total cholesterol [17], LDL-c [16,17], triglycerides, [16,18] and insulinemia [19]; however, the association with fasting glucose remains unclear [16]. The relationship between diet quality and metabolic profile in Brazilian adolescents has not been investigated in a nationally representative sample. Therefore, the aim of this study was to investigate the association between diet quality, assessed by the DQIA-BR, and cardiometabolic markers in Brazilian adolescents aged 12 to 17 years.

Methods

Study design and sample

The Study of Cardiovascular Risks in Adolescents (Estudo de RIscos Cardiovasculares em Adolescentes or "ERICA") is a national school-based cross-sectional multicenter survey that aimed to estimate the prevalence of cardiovascular risk factors in Brazilian adolescents (12−17 years old) enrolled in public and private schools. Data were collected between February 2013 and November 2014 in a representative sample of Brazilian municipalities with more than 100 000 inhabitants [20].

A written agreement to participate was obtained from each student, and an informed consent was signed by their parents or legal guardians. ERICA was approved by the Research Ethics Committee of the Institute of Studies on Public Health, Federal University of Rio de Janeiro, and by the Ethics Committees of the other 26 federation units in Brazil.

For this study, we used data from Brazilian students who attended schools during the morning, including students in the integral or semi-integral system, because overnight fasting was mandatory before blood sampling. A total of 36 956 adolescents who had complete data collection including questionnaires, anthropometric measurements, dietary intake assessment, and biochemical evaluation were included in this study (Fig. 1). Sample size calculation and sampling process details can be found in prior publications [20,21].

Anthropometric measurements

All the anthropometric measurements were performed by trained researchers following written standardized protocols [22]. During this evaluation, the adolescents were wearing light clothing and no shoes. Body weight was measured using a digital scale (Model P200M, Líder, São Paulo, Brazil). Height was measured using a calibrated portable stadiometer (Alturexata, Minas Gerais, Brazil). The weight and height measurements were used to calculate the body mass index (BMI), defined as weight (kg) divided by the square of height in meters (m^2). The BMI categories were determined according to the WHO reference curves [23] considering the sex- and age-specific cutoff points to classify adolescents with normal weight ($-2 <$ BMI z-score ≤ 1), overweight ($1 <$ BMI z-score ≤ 2), or obesity (BMI z-score > 2). Thereafter, overweight and obesity were combined into one category.

Assessment of cardiometabolic markers

The students were instructed to keep an overnight fast of 10 to 12 h before blood collection. A questionnaire was applied before the examination to confirm if the students had fasted. Fasting blood samples were collected for analysis of total cholesterol, HDL-c, triglycerides, glucose, glycated hemoglobin (HbA1c), and insulin. LDL-c was estimated indirectly by the Friedewald equation [24]. LDL-c concentrations were calculated only for adolescents with triglyceride concentrations lower than 400 mg/dL. The Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) was obtained using the formula: HOMA-IR = (insulin × fasting glucose)/22.5. All blood samples were analyzed by a single laboratory following a standardized protocol [25].

Dietary intake assessment

To assess dietary intake, a 24-h dietary recall (24hR) was performed in a face-to-face interview by trained interviewers using the multiple pass method to reduce underreporting of food consumption [26]. To correct the within-person variability, a second 24hR was collected on a non-consecutive day in a random subsample of approximately 10% of the total sample [27]. The National Cancer Institute method for episodically consumed foods was used to correct the intraindividual variability and to allow, with a minimal degree of uncertainty, estimation of the distribution of the usual dietary intake of food groups [27,28].

The recalls were entered directly on a netbook with software to register food consumption data, ERICA-REC24h, which was created specifically for ERICA [29]. The ERICA-REC24h software contains a list of 1626 food items using the database from the Brazilian Household Budgets Survey (POF) 2008 to 2009 [29,30]. Photographs included in the software were used to help the adolescents estimate the size of portions consumed. The preparation and quantity of food consumed were also recorded in detail. Food items that were not in the software database were entered by the researchers during the interview. Total energy intake was estimated considering the Brazilian Food Composition Table [31] and the Brazilian Portion Size Table [32]. Students who reported energy intake of <100 kcal/d were excluded from the analyses [33].

Diet Quality Index for Brazilian Adolescents

The DQIA-BR [12] was adapted from the DQI-A [9], and this was based on dietary guidelines developed specifically for adolescents [34,35]. It was also adapted to the local needs, considering Brazilian food culture and the information available on the ERICA database. All adaptations are fully described in a prior study [12].

The DQIA-BR classifies food into recommended and non-recommended food groups and evaluates daily diet through three dietary components (quality, diversity, and equilibrium). Of all food groups, eight were recommended groups: 1) bread, potatoes, and grains; 2) vegetables; 3) fruits; 4) milk products; 5) cheese; 6) meat, fish, and eggs; 7) beans; and 8) fats and oils. Two were non-recommended food groups: 9) snacks and candies and 10) sugar-sweetened beverages, fruit juices, and alcoholic beverages. For each food group, a different daily intake recommendation specifically developed for adolescents was provided. The description of these components and the technical aspects of the DQIA-BR are reported elsewhere [12].

The food groups were analyzed based on the three principal components, and the components were differently weighted; the dietary quality had twice the weight of the other groups (diversity and equilibrium). The DQIA-BR total score varies from −33% to 100% and comprises the means of the three components. A high score represents high diet quality.

Covariates

The following variables were considered as covariates: sex, age, skin color (white, black, brown, and yellow/indigenous), type of school (public or private), and geographical area (Northeast, Southeast, North, South, and Midwest). To assess economic status, an economic index, similar to the one that was implemented in the Brazilian demographic census [36], was calculated, including possession of specific goods and education of the head of household. This economic index was categorized in tertiles for the analyses.

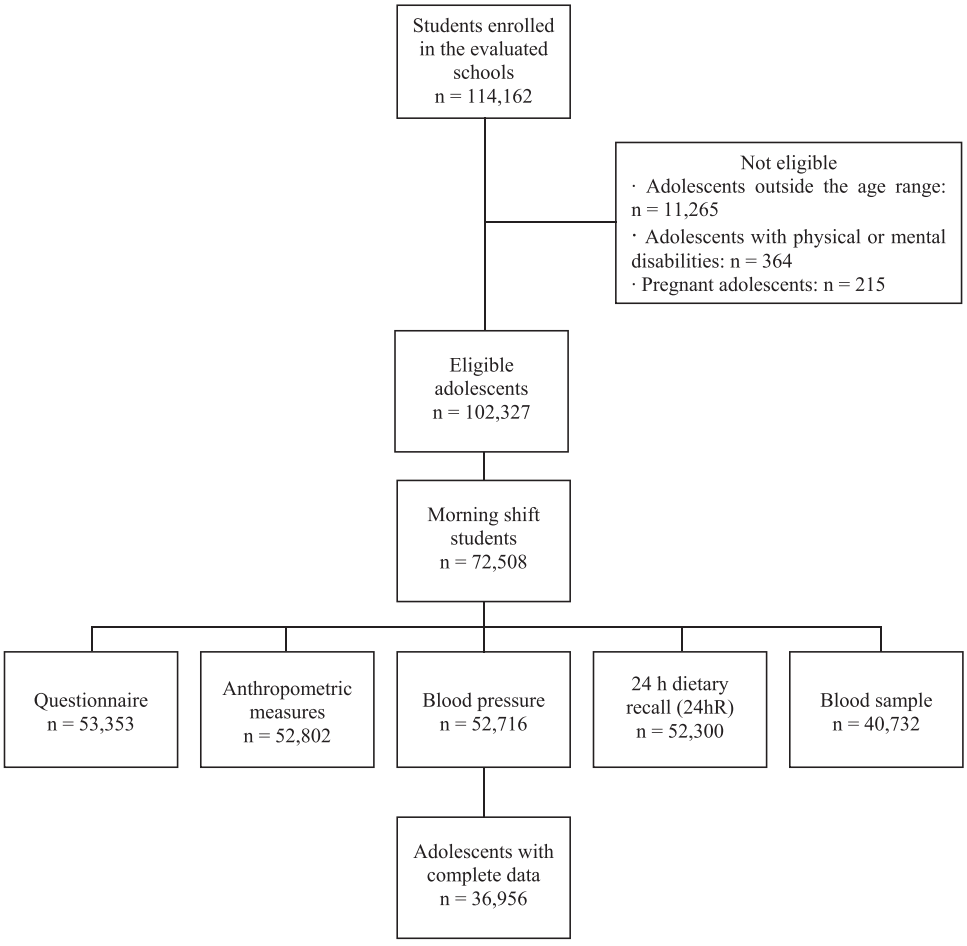

Fig. 1. Flowchart of eligible adolescents. Study of Cardiovascular Risks in Adolescents (ERICA), 2013–2014.

Statistical analysis

Descriptive analyses were reported as means and confidence intervals (CI) (95%) for continuous variables and percentages for categorical variables. Fasting triglycerides and HOMA-IR were logarithmically transformed owing to their skewed distributions and presented as geometric means and 95% CI. To obtain population-representative findings, ERICA sample weights and complex sample design were considered in all analyses [21].

All estimates were stratified by sex and nutritional status, considering that the diet differed in adolescents with overweight/obesity and that this group also had higher values for all cardiometabolic parameters evaluated. Multiple linear regressions were used to analyze the association between the DQIA-BR and the cardiometabolic markers. The dependent variables were the cardiometabolic markers and the independent variable was the DQIA-BR. Adjusted models were constructed with two input levels of covariates. The first model was adjusted for age and socioeconomic status; in the second model, previous variables were kept in the model and total energy intake, physical activity, and sedentary behavior were included. All adjustment variables were chosen according to the literature [19], and only the variables that obtained $P < 0.1$ in the crude analysis were included. There was no collinearity between the adjustment variables of both models.

All data analyses were conducted in Stata software (version 14.0, Stata Corporation, College Station, TX, USA). All tests were bi-caudal and a P value of <0.05 was regarded as statistically significant.

Results

The study sample consisted of 36 956 adolescents (60% girls), and the mean age was 14.7 years. The baseline characteristics of the sample are shown in Table 1. Overall, the prevalence of adolescents with overweight and obesity was 17.6% (95% CI: 17.2; 18.0) and 8.2% (95% CI: 7.9; 8.5), respectively. The mean total energy intake was 2312 kcal/d (95% CI: 2300; 2323), while the DQIA-BR score ranged from 0.9% to 45.8% and was higher in boys.

Table 2 describes the values of cardiometabolic markers and DQIA-BR scores according to sex and weight status. Overall, adolescents with overweight/obesity had higher total cholesterol, LDL-c, fasting glucose, and HOMA-IR than normal-weight adolescents. This subsample also had lower values for HDL-c and diet quality than normal-weight subjects.

While assessing the association between the DQIA-BR score and the cardiometabolic markers by weight status, DQIA-BR was positively associated with HDL-c and negatively associated with LDL-c, triglycerides, fasting glucose, and HOMA-IR in normal-weight girls in the finally adjusted model (Table 3). In girls with overweight/obesity, DQIA-BR was positively associated with fasting glucose and HbA1c. However, in the finally adjusted model in, only HbA1c maintained a significant association.

Table 4 shows the association of DQIA-BR score with the cardiometabolic markers in boys by weight status. In normal-weight boys, DQIA-BR was negatively associated with total cholesterol and LDL-c in the sociodemographically adjusted model. After behavior adjustment, only LDL-c was significantly associated. In boys with overweight/obesity, DQIA-BR was negatively associated with total cholesterol and LDL-c, even in the finally adjusted model.

Table 1
Characteristics of study participants. ERICA, 2013–2014.

Variables	All (n = 36 956)	Girls (n = 22 170)	Boys (n = 14 786)
	Frequency or mean (95% CI)		
Age, years	14.7 (14.6–14.7)	14.7 (14.7–14.7)	14.6 (14.6–14.6)
Skin color, %			
Brown	47.9 (46.2–49.7)	49.5 (47.5–51.5)	46.3 (44.0–48.6)
White	39.8 (37.9–41.7)	40.0 (37.7–42.3)	39.6 (37.4–41.8)
Black	7.7 (6.9–8.5)	6.8 (5.9–7.9)	8.5 (7.4–9.7)
Other	4.7 (4.1–5.3)	3.7 (3.2–4.3)	5.6 (4.8–6.6)
Type of school, %			
Public	77.7 (72.3–82.3)	78.0 (72.5–82.7)	77.4 (72.0–82.0)
Private	22.3 (17.7–27.7)	22.0 (17.3–24.5)	22.7 (18.1–28.0)
Geographical area, %			
Northeast	31.0 (30.5–31.4)	31.1 (30.5–31.7)	30.7 (30.0–31.5)
Southeast	22.8 (22.4–23.2)	23.2 (22.6–23.7)	22.3 (21.6–23.0)
North	19.1 (18.7–19.5)	18.8 (18.3–19.3)	19.5 (18.9–20.1)
Midwest	14.6 (14.3–15.0)	15.0 (11.6–12.5)	14.1 (13.6–14.7)
South	12.6 (12.2–12.9)	12.0 (14.5–15.4)	13.4 (12.8–14.0)
Socioeconomic status (tertile), %			
First (lowest)	38.5 (36.6–40.4)	42.8 (42.2–43.5)	35.5 (34.8–36.3)
Second	33.4 (32.1–34.7)	31.2 (30.6–31.8)	32.6 (31.9–33.4)
Third	28.1 (26.6–29.7)	26.0 (25.5–26.6)	31.9 (31.1–32.6)
Cardiometabolic markers			
Total cholesterol, mg/dL	148.2 (147.2–149.2)	152.6 (151.3–153.9)	143.8 (142.6–145.0)
HDL-c, mg/dL	47.3 (46.7–47.9)	49.6 (48.9–50.3)	45.0 (44.4–45.5)
LDL-c, mg/dL	86.3 (84.5–86.1)	87.2 (86.3–88.1)	83.5 (82.3–84.6)
Triglycerides*, mg/dL	71.4 (70.1–72.6)	72.8 (71.5–74.1)	70.0 (68.4–71.5)
Fasting glucose, mg/dL	86.3 (85.9–86.7)	85.1 (84.6–85.6)	87.6 (87.1–88.0)
HbA1c, %	5.4 (5.4–5.4)	5.4 (5.3–5.4)	5.4 (5.4–5.4)
HOMA-IR*	1.7 (1.6–1.7)	1.8 (1.8–1.9)	1.5 (1.5–1.6)
Body mass index, kg/m^2	21.4 (21.3–21.6)	21.6 (21.4–21.8)	21.2 (21.0–21.4)
Physical activity, %	42.7 (42.2–43.2)	29.6 (28.1–31.1)	60.8 (58.9–62.7)
Energy intake (kcal/day)	2,312 (2,300–2,323)	2,156 (2,142–2,171)	2,545 (2,526–2,563)
DQIA-BR	16.8 (16.6–17.1)	14.9 (14.7–15.1)	18.7 (18.4–19.1)

CI, confidence interval; DQIA-BR, Diet Quality Index for Adolescents adapted for Brazilians; ERICA, Study of Cardiovascular Risks in Adolescents; HbA1c, glycated hemoglobin; HDL-c, high-density lipoprotein cholesterol; HOMA-IR, Homeostatic Model Assessment for Insulin Resistance; LDL-c, low-density lipoprotein cholesterol.
*Triglycerides and HOMA-IR were log-transformed and reported as geometric mean and 95% CI.

Discussion

The present study investigated the association between DQIA-BR and cardiometabolic markers in a nationally representative sample of Brazilian adolescents. In normal-weight girls, higher DQIA-BR scores were associated with better cardiometabolic profiles; however, no association was observed in those with overweight/obesity. In boys, a better quality of diet was associated with lower concentrations of LDL-c, independent of the weight status, and with total cholesterol only in those with overweight/obesity.

The observations from this study are important if we consider that prospective studies suggest that cardiometabolic risk factors present in childhood and adolescence may persist into adulthood, increasing the risk for premature development of cardiovascular disease and type 2 diabetes [37]. Additionally, recent studies have showed that a high quality of diet is a protective factor for cardiometabolic alterations and cardiovascular disease in children and adolescents [38], reinforcing the idea that a low-quality diet is an important modifiable risk factor for cardiometabolic abnormalities in youth.

Table 2
Cardiometabolic markers and Diet Quality Index for Adolescents adapted for Brazilians (DQIA-BR) scores of study participants according to gender and the presence of overweight/obesity, ERICA 2013–2014 (n = 36,956)

Variables	Girls (n = 22,170)		Boys (n = 14,786)	
	Normal weight (n = 16 651)	Overweight/obesity (n = 5519)	Normal weight (n = 10 759)	Overweight/obesity (n = 4027)
	Mean (95% CI)			
Cardiometabolic markers				
Total cholesterol, mg/dL	151.8 (150.5–153.2)	154.7 (152.2–157.2)	141.5 (140.0–143.0)	149.8 (147.9–151.8)
HDL-c, mg/dL	50.8 (50.0–51.6)	46.3 (45.7–46.9)	46.0 (45.4–46.7)	42.1 (41.5–42.7)
LDL-c, mg/dL	85.8 (84.9–86.6)	91.0 (88.9–93.2)	81.3 (80.0–82.6)	89.2 (87.4–90.9)
Triglycerides*, mg/dL	70.8 (69.6-72.1)	79.2 (76.9-81.5)	65.5 (64.2-66.7)	83.4 (80.4-86.5)
Fasting glucose, mg/dL	84.6 (84.1–85.1)	86.4 (85.6–87.3)	87.2 (86.7–87.8)	88.4 (88.0–88.9)
HbA1c, %	5.3 (5.3–5.4)	5.4 (5.3–5.4)	5.4 (5.4–5.4)	5.4 (5.4–5.4)
HOMA-IR*	1.6 (1.5-1.7)	2.5 (2.4-2.6)	1.3 (1.2-1.4)	2.2 (2.1-2.3)
DQIA-BR	14.9 (14.7–15.2)	14.7 (14.2–15.1)	19.0 (18.6–19.5)	17.9 (17.5–18.3)

CI, confidence interval; DQIA-BR, Diet Quality Index for Adolescents adapted for Brazilians; HDL-c, high-density lipoprotein cholesterol; HbA1c, glycated hemoglobin cholesterol; HOMA-IR, Homeostatic Model Assessment for Insulin Resistance; LDL-c, low-density lipoprotein cholesterol.
*Triglycerides and HOMA-IR were log-transformed and reported as geometric mean and 95% CI.

Table 3
Association between Diet Quality Index for Adolescents adapted for Brazilians (DQIA-BR) and cardiometabolic markers among girls according to the presence of overweight/obesity, ERICA 2013–2014 (n = 22 170)

Cardiometabolic markers	Normal weight (n = 16 651)			Overweight/obesity (n = 5519)		
	β	95% CI	*P*	β	95%CI	*P*
Total cholesterol, mg/dL	−0.132	−0.268 to 0.004	0.058	−0.068	−0.362 to 0.226	0.651
HDL-c, mg/dL	0.097	0.039 to 0.155	0.001	−0.078	−0.177 to 0.020	0.118
LDL-c, mg/dL	−0.178	−0.283 to −0.074	0.001	0.028	−0.215 to 0.272	0.819
Triglycerides*, mg/dL	−0.263	−0.425 to −0.101	0.003	−0.064	−0.338 to 0.210	0.919
Fasting glucose, mg/dL	−0.069	−0.114 to −0.025	0.002	0.188	0.020 to 0.356	0.029
HbA1c, %	−0.0007	−0.003 to 0.001	0.493	0.005	0.001 to0.009	0.021
HOMA-IR*	−0.015	−0.023 to −0.007	0.007	−0.015	−0.049 to 0.019	0.714
Model 1: adjusted for age and socioeconomic status						
Total cholesterol, mg/dL	−0.139	−0.280 to 0.002	0.054	−0.059	−0.355 to 0.236	0.696
HDL-c, mg/dL	0.088	0.027 to 0.150	0.005	−0.075	−0.169 to 0.020	0.123
LDL-c, mg/dL	−0.179	−0.285 to −0.073	0.001	0.035	−0.210 to 0.280	0.778
Triglycerides*, mg/dL	−0.245	−0.408 to −0.081	0.007	−0.077	−0.353 to 0.199	0.868
Fasting glucose, mg/dL	−0.056	−0.101 to −0.017	0.017	0.183	0.014 to 0.353	0.034
HbA1c, %	−0.0004	−0.002 to 0.002	0.726	0.005	0.001 to 0.009	0.024
HOMA-IR*	−0.014	−0.022 to −0.006	0.025	−0.015	−0.049 to 0.019	0.675
Model 2: adjusted for variables in model 1 plus total energy intake, physical activity and sedentary behavior						
Total cholesterol, mg/dL	−0.149	−0.299 to 0.001	0.052	−0.032	−0.369 to 0.310	0.854
HDL-c, mg/dL	0.092	0.031 to 0.153	0.003	−0.054	−0.150 to 0.042	0.273
LDL-c, mg/dL	−0.189	−0.303 to −0.077	0.001	0.026	−0.255 to 0.307	0.857
Triglycerides*, mg/dL	−0.280	−0.447 to −0.114	0.003	0.055	−0.239 to 0.350	0.869
Fasting glucose, mg/dL	−0.061	−0.106 to −0.015	0.010	0.167	−0.012 to 0.345	0.067
HbA1c, %	−0.0001	−0.002 to 0.002	0.925	0.005	0.001 to 0.009	0.024
HOMA-IR*	−0.013	−0.022 to −0.004	0.021	−0.019	−0.056 to 0.017	0.701

CI, confidence interval; DQIA-BR, Diet Quality Index for Adolescents adapted for Brazilians; HbA1c, glycated hemoglobin; HDL-c, high-density lipoprotein cholesterol; HOMA-IR, Homeostatic Model Assessment for Insulin Resistance; LDL-c, low-density lipoprotein cholesterol.
*Triglycerides and HOMA-IR were log-transformed and reported as geometric mean and 95% CI.

In our study, we also observed that normal-weight girls had a better lipid profile as dietary quality scores increased. In boys, this was observed even independently of weight status. This finding is consistent with other studies in young subjects that reported positive associations between diet quality and HDL-c and negative associations with other cardiometabolic risk factors, such as LDL-c, total cholesterol, and triglycerides [17,18]. However, no association was observed in girls with overweight/obesity. We speculate that null results can be partially explained by hormonal effects during puberty [39], differences in lipid accumulation between sexes [40], and even possible unknown lifestyle-related confounding factors [6].

In relation to glucose metabolism markers, our findings in normal-weight girls are consistent with previous studies, indicating that a higher quality of diet is associated with lower values of

Table 4
Association between Diet Quality Index for Adolescents adapted for Brazilians (DQIA-BR) and cardiometabolic markers among boys according to the presence of overweight/obesity, ERICA 2013–2014 (n = 14 786).

Cardiometabolic markers	Normal weight (n = 10 759)			Overweight/obesity (n = 4 027)		
	β	95% CI	*P*	β	95% CI	*P*
Total cholesterol, mg/dL	−0.184	−0.324 to −0.044	0.010	−0.402	−0.697 to −0.107	0.008
HDL-c, mg/dL	0.006	−0.107 to 0.119	0.914	−0.044	−0.141 to 0.054	0.380
LDL-c, mg/dL	−0.152	−0.271 to −0.033	0.012	−0.276	−0.503 to −0.049	0.017
Triglycerides*, mg/dL	−0.188	−0.391 to −0.001	0.048	−0.375	−0.776 to 0.026	0.175
Fasting glucose, mg/dL	0.046	−0.050 to 0.142	0.346	−0.052	−0.125 to 0.022	0.169
HbA1c, %	0.002	−0.001 to 0.004	0.194	−0.001	−0.003 to 0.002	0.557
HOMA-IR*	0.003	−0.006 to 0.014	0.531	−0.006	−0.020 to 0.007	0.346
Model 1: adjusted for age and socioeconomic status						
Total cholesterol, mg/dL	−0.158	−0.301 to 0.015	0.030	−0.364	−0.645 to −0.082	0.011
HDL-c, mg/dL	0.020	−0.093 to 0.134	0.727	−0.024	−0.121 to 0.073	0.625
LDL-c, mg/dL	−0.138	−0.253 to −0.022	0.020	−0.257	−0.474 to −0.039	0.021
Triglycerides*, mg/dL	−0.201	−0.401 to −0.001	0.033	−0.398	−0.797 to 0.001	0.177
Fasting glucose, mg/dL	0.054	−0.047 to 0.155	0.296	−0.045	−0.118 to 0.027	0.220
HbA1c, %	0.002	−0.001 to 0.004	0.141	−0.00002	−0.003 to 0.002	0.987
HOMA-IR*	0.004	−0.006 to 0.014	0.506	−0.006	−0.020 to 0.007	0.478
Model 2: adjusted for variables in model 1 plus total energy intake, physical activity and sedentary behavior						
Total cholesterol, mg/dL	−0.110	−0.255 to 0.034	0.134	−0.338	−0.611 to −0.066	0.015
HDL-c, mg/dL	0.035	−0.075 to 0.146	0.529	−0.037	−0.138 to 0.063	0.466
LDL-c, mg/dL	−0.115	−0.224 to 0.005	0.040	−0.227	−0.448 to −0.005	0.045
Triglycerides*, mg/dL	−0.150	−0.358 to 0.057	0.089	−0.390	−0.839 to 0.058	0.287
Fasting glucose, mg/dL	0.058	−0.039 to 0.154	0.242	−0.064	−0.131 to 0.003	0.060
HbA1c, %	0.002	−0.001 to 0.004	0.199	0.0004	−0.002 to 0.003	0.762
HOMA-IR*	0.005	−0.005 to 0.016	0.334	−0.006	−0.021 to 0.008	0.468

CI, confidence interval; DQIA-BR, Diet Quality Index for Adolescents adapted for Brazilians; HbA1c, glycated hemoglobin; HDL-c, high-density lipoprotein cholesterol; HOMA-IR, Homeostatic Model Assessment for Insulin Resistance; LDL-c, low-density lipoprotein cholesterol.
*Triglycerides and HOMA-IR were log-transformed and reported as geometric mean and 95% CI.

fasting glucose, HbA1c, and HOMA-IR in adolescents. In Chinese children, healthy diets are associated with lower levels of fasting glucose [16,17]. When assessing Australian adolescents, Ambrosini, et al. [19] concluded that diet quality is negatively associated with fasting glucose and HOMA-IR, regardless of sex. Although the literature constantly shows similar results in large adolescent populations, in our study this pattern was observed only in a specific portion of our sample, composed of girls with normal weight.

Diet quality has been negatively associated with HOMA-IR [19], indicating that better eating patterns may reflect lower chances of developing insulin resistance, independent of potential confounders including sex, weight status, total energy intake, and physical activity. In our study, the results indicate that higher-quality diets are associated with better insulin sensitivity in girls with normal weight; however, in girls with overweight/obesity, this effect was not observed. Studies have reported that hypercaloric diets, higher adiposity, and sedentary behavior are significantly associated with insulin resistance in adolescents, especially in girls with overweight/obesity [41]. In agreement with these studies, others suggest that low-calorie diets may be more beneficial than higher-quality diets to improve the metabolic profile of this specific population [41].

The prevalence of insulin resistance and diabetes in children and adolescents is constantly increasing, and individuals with overweight and obesity are more insulin resistant than those with normal weight [42]. Only a few studies have investigated blood glucose variation in adolescent populations, but a possible explanation for our findings may be pre- and postpubertal hormonal changes. During puberty, metabolic changes such as hormonal regulation [39], variations in the proportion and distribution of body fat [43], and increased insulin resistance [44] occur rapidly and dynamically, especially in girls [45]. On the other hand, common difficulties in assessing eating habits, such as underreporting and dietary modifications, should be considered, especially in this subsample.

The differences in results between girls and boys can be in part explained by lifestyle behaviors. For example, boys were more physically active than girls [46], and physical activity is a well-known behavior associated with better cardiometabolic risk factors [47]. In addition, physically active adolescents more frequently adopt a healthier diet. However, girls seem to receive less social support and have fewer opportunities to engage in physical activity; in addition, girls often report concerns about weight and body image, which can lead to the adoption of restrictive diets with low nutrition quality [48]. Factors related to somatic development, typical of this age group, can also impact boys and girls differently according to their maturation stage and weight status [49]. These issues should be addressed in longitudinal studies.

We believe that our study adds to previous findings, showing that the effects of diet quality on adolescent metabolism differ according to sex and weight status. Improvements in diet quality may contribute to decreasing the risk of abnormal cardiometabolic risk factors in normal-weight girls. In relation to girls with overweight/obesity, our null results should be interpreted with caution. The quality of diet may need to be combined with other dietary strategies for weight reduction to improve the cardiometabolic profile in this population. In boys, diet quality seems to have a major influence on LDL-c concentration but was not associated with other cardiometabolic markers. These findings differ from those reported by other studies [16,19], reinforcing the need for more studies on this issue in adolescents from different settings.

Limitations

Potential limitations of this study must be addressed. A cross-sectional study includes temporal bias. Some of the covariables analyzed were self-reported, which may introduce reporting bias. Furthermore, a limitation of the food consumption assessment is that information was obtained for only two days, and it may not reflect the individual's real habitual dietary intake. In addition, the accuracy of data collected using the 24hR may be influenced by reporting bias as it depends on the individual's ability to remember everything that has been consumed in the last 24 hours. Also, the total DQIA-BR score was low, which did not allow us to evaluate the effects of a very high-quality diet on participants' metabolic profile. Finally, the association of this diet quality index with sensitive markers, such as inflammation and oxidative stress, was not investigated.

Strengths

The present study has several strengths. It includes a large and representative sample of adolescents from a developing country in which diet patterns change a lot across the country. Analyses were adjusted for several potential confounders and split for sex and weight status. Moreover, DQIA-BR is a specific tool that assesses the global dietary pattern of Brazilian adolescents, taking into account the complexity of the human diet and the adherence to specific nutritional recommendations. In addition, all blood samples were analyzed by standardized procedures in one central laboratory.

Conclusion

In conclusion, the available evidence suggests that the DQIA-BR is a suitable tool to evaluate the association between diet quality and cardiometabolic markers in adolescents. However, further investigation is necessary to explore the unexpected associations and to evaluate if increases in DQIA-BR scores may reflect a better metabolic profile in this population, especially in the presence of overweight/obesity. In this context, specific regional variations of diet and dietary behaviors can be considered, in combination with quality of diet, to better explain the role of diet quality in adolescent metabolic health.

Conflict of interest

The authors declare have no conflict of interest.

References

[1] World Health Organization. Global status report on noncommunicable diseases 2014. Available at: https://www.who.int/nmh/publications/ncd-status-report-2014/en/. Accessed March 2nd, 2020.
[2] Malta DC, França E, Abreu DMX, Perillo RD, Salmen MC, Teixeira RA, et al. Mortality due to noncommunicable diseases in Brazil, 1990 to 2015, according to estimates from the Global Burden of Disease study. Sao Paulo Med J 2017;135:213–21.
[3] Juonala M, Juhola J, Magnussen CG, Würtz P, Viikari JSA, Thomson R, et al. Childhood environmental and genetic predictors of adulthood obesity: the cardiovascular risk in young Finns study. J Clin Endocrinol Metab 2011;96:E1542–9.
[4] Jalayondeja C, Jalayondeja W, Mekhora K, Bhuanantanondh P, Dusadi-Isariyavong A, Upiriyasakul R. Break in sedentary behavior reduces the risk of noncommunicable diseases and cardiometabolic risk factors among workers in a petroleum company. Int J Environ Res Public Health 2017;14:501.
[5] Oliveira JS, Barufaldi LA, Abreu GA, Leal VS, Brunken GS, Vasconcelos SML, et al. ERICA: use of screens and consumption of meals and snacks by Brazilian adolescents. Rev Saude Publica 2016;50:7s.
[6] Appannah G, Pot G, Huang RC, Oddy WH, Beilin LJ, Mori TA, et al. Identification of a dietary pattern associated with greater cardiometabolic risk in adolescence. Nutr Metab Cardiovasc Dis 2015;25:643–50.
[7] Sotos-Prieto M, Bhupathiraju SN, Mattei J, Fung TT, Li Y, Pan A, et al. Association of changes in diet quality with total and cause-specific mortality. N Engl J Med 2017;377:143–53.

[8] Mellendick K, Shanahan L, Wideman L, Calkins S, Keane S, Lovelady C. Diets rich in fruits and vegetables are associated with lower cardiovascular disease risk in adolescents. Nutrients 2018;10:136.
[9] Vyncke K, Fernandez EC, Fajó-Pascual M, Cuenca-García M, De Keyzer W, Gonzalez-Gross M, et al. Validation of the Diet Quality Index for Adolescents by comparison with biomarkers, nutrient and food intakes: the HELENA study. Br J Nutr 2013;109:2067–78.
[10] Marshall S, Burrows T, Collins CE. Systematic review of diet quality indices and their associations with health-related outcomes in children and adolescents. J Hum Nutr Diet 2014;27:577–98.
[11] Toffano RBD, Hillesheim E, Mathias MG, Coelho-Landell CA, Salomão RG, Almada MORV, et al. Validation of the Brazilian Healthy Eating Index-Revised using biomarkers in children and adolescents. Nutrients 2018;10:154.
[12] Ronca DB, Blume CA, Cureau FV, Camey SA, Leotti VB, Drehmer M, et al. Diet quality index for Brazilian adolescents: the ERICA study. Eur J Nutr 2019;59:539–56.
[13] Nicklas TA, O'Neil CE, Fulgoni VL 3rd. Diet quality is inversely related to cardiovascular risk factors in adults. J Nutr 2012;142:2112–8.
[14] Livingstone KM, McNaughton SA. Association between diet quality, dietary patterns and cardiometabolic health in Australian adults: a cross-sectional study. Nutr J 2018;17:19.
[15] Wang Z, Siega-Riz AM, Gordon-Larsen P, Cai J, Adair LS, Zhang B, et al. Diet quality and its association with type 2 diabetes and major cardiometabolic risk factors among adults in China. Nutr Metab Cardiovasc Dis 2018;28:987–1001.
[16] Shang X, Li Y, Liu A, Zhang Q, Hu X, Du S, et al. Dietary pattern and its association with the prevalence of obesity and related cardiometabolic risk factors among Chinese children. PLoS One 2012;7:e43183.
[17] Mikkilä V, Räsänen L, Raitakari OT, Marniemi J, Pietinen P, Rönnemaa T, Viikari J. Major dietary patterns and cardiovascular risk factors from childhood to adulthood. The Cardiovascular Risk in Young Finns Study. Br J Nutr 2007;98:218–25.
[18] Mohensi-Takalloo S, Mirmiran P, Mehrabi Y, Hosseini-Esfahani F, Ataii M, Azizi F. Diet quality and its relationship with metabolic syndrome in adolescents: Tehran Lipid and Glucose Study. Iranian J Endocrinol Metab 2013;15:3–13.
[19] Ambrosini GL, Huang RC, Mori TA, Hands BP, O'Sullivan TA, de Klerk NH, et al. Dietary patterns and markers for the metabolic syndrome in Australian adolescents. Nutr Metab Cardiovas Dis 2010;20:274–83.
[20] Bloch KV, Szklo M, Kuschnir MCC, Abreu GA, Barufaldi LA, Klein CH, et al. The study of cardiovascular risk in adolescents—ERICA: rationale, design and sample characteristics of a national survey examining cardiovascular risk factor profile in Brazilian adolescents. BMC Public Health 2015;15:94.
[21] Vasconcellos MTL, Silva PLN, Szklo M, Kuschnir MCC, Klein CH, Abreu GA, et al. Sampling design for the study of cardiovascular risks in adolescents. Cad Saude Publica 2015;31:921–30.
[22] Lohmann TG, Roche AF, Martorell R. Anthropometric standardization reference manual. Michigan: Human Kinetics Books; 1988.
[23] World Health Organization. Growth reference data for 5—19 years. Available at: www.who.int/growthref/who2007_bmi_for_age/en/index.html. Accessed March 2nd, 2020.
[24] Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 1972;18:499–502.
[25] Cureau FV, Bloch KV, Henz A, Schaan CW, Klein CH, de Oliveira CL, et al. Challenges for conducting blood collection and biochemical analysis in a large multicenter school-based study with adolescents: lessons from ERICA in Brazil. Cad Saude Publica 2017;33:e00122816.
[26] Conway JM, Ingwersen LA, Vinyard BT, Moshfegh AJ. Effectiveness of the US Department of Agriculture 5-step multiple-pass method in assessing food intake in obese and nonobese women. Am J Clin Nutr 2003;77:1171–8.
[27] Freedman LS, Guenther PM, Dodd KW, Krebs-Smith SM, Midthune D. The population distribution of ratios of usual intakes of dietary components that are consumed every day can be estimated from repeated 24-hour recalls. J Nutr 2009;140:111–6.
[28] Kipnis V, Midthune D, Buckman DW, Dodd KW, Guenther PM, Krebs-Smith SM, et al. Modeling data with excess zeros and measurement error: application to evaluating relationships between episodically consumed foods and health outcomes. Biometrics 2009;65:1003–10.
[29] Barufaldi LA, Abreu GA, Veiga GV, Sichieri R, Kuschnir MCC, Cunha DB, et al. Software to record 24-hour food recall: application in the Study of Cardiovascular Risks in Adolescents. Rev Bras Epidemiol 2016;19:464–8.
[30] Souza AM, Pereira RA, Yokoo EM, Levy RB, Sichieri R. Most consumed foods in Brazil: National Dietary Survey 2008—2009. Rev Saude Publica 2013;47:190s–9.
[31] Instituto Brasileiro de Geografia e Estatística. Pesquisa de Orçamentos Familiares, 2008—2009: tabela de composição nutricional dos alimentos consumidos no Brasil. 2011. Available at: https://biblioteca.ibge.gov.br/visualizacao/livros/liv50002.pdf. Acessed March 2nd, 2020.
[32] Instituto Brasileiro de Geografia e Estatística. Pesquisa de Orçamentos Familiares, 2008—2009: tabela de medidas referidas para os alimentos consumidos no Brasil. 2011. Available at: https://biblioteca.ibge.gov.br/visualizacao/livros/liv50000.pdf. Acessed March 2nd, 2020.
[33] Silva TLN, Klein CH, Souza AM, Barufaldi LA, Abreu GA, Kuschnir MCC, et al. Response rate in the study of cardiovascular risks in adolescents—ERICA. Rev Saude Publica 2016;50:3s.
[34] Schildknechtstraat G, Vanhauwaert E. De actieve voedingsdriehoek: een praktische voedings-en beweeggids. Available at: https://www.ikhebeenvraag.be/mediastorage/FSDocument/233/actieve_voedingsdriehoek_maart_2012.pdf. Accessed March 2nd, 2020.
[35] Clay W. Preparation and use of food-based dietary guidelines. Food Nutr Agric 1997;19:42–7.
[36] Associação Brasileira de Empresas de Pesquisa. Critério de classificação econômica Brasil, Available at: http://www.abep.org/criterio-brasil. Accessed March 2nd, 2020.
[37] Pires A, Sena C, Seiça R. Dyslipidemia and cardiovascular changes in children. Curr Opin Cardiol 2016;31:95–100.
[38] Satija A, Bhupathiraju SN, Rimm EB, Spiegelman D, Chiuve SE, Borgi L, et al. Plant-based dietary patterns and incidence of type 2 diabetes in US men and women: results from three prospective cohort studies. PLoS Med 2016;13:e1002039.
[39] Bau AM, Ernert A, Krude H, Wiegand S. Hormonal regulatory mechanisms in obese children and adolescents after previous weight reduction with a lifestyle intervention: maintain - paediatric part - a RCT from 2009—15. BMC Obes 2016;3:29.
[40] Eissa MA, Mihalopoulos NL, Holubkov R, Dai S, Labarthe DR. Changes in fasting lipids during puberty. J Pediatr 2016;170:199–205. https://doi.org/10.1016/j.jpeds.2015.11.018.
[41] Armeno ML, Krochik AG, Mazza CS. Evaluation of two dietary treatments in obese hyperinsulinemic adolescents. J Pediatr Endocrinol Metab 2011;24:715–22.
[42] Levy-Marchal C, Arslanian S, Cutfield W, Sinaiko A, Druet C, Marcovecchio ML, Chiarelli F. Insulin resistance in children: consensus, perspective, and future directions. J Clin Endocrinol Metab 2010;95:5189–98.
[43] Taylor RW, Grant AM, Williams SM, Goulding A. Sex differences in regional body fat distribution from pre-to postpuberty. Obesity 2010;18:1410–6.
[44] Kelsey MM, Zeitler PS. Insulin resistance of puberty. Curr Diab Rep 2016;16:64.
[45] Rocha NP, Milagres LC, Longo GZ, Ribeiro AQ, de Novaes AF. Association between dietary pattern and cardiometabolic risk in children and adolescents: a systematic review. J Pediatr (Rio J) 2017;93:214–22.
[46] Cureau FV, Silva TLN, Bloch KV, Fujimori E, Belfort DR, de Carvalho KMB, et al. ERICA: leisure-time physical inactivity in Brazilian adolescents. Rev Saude Publica 2016;50:4s.
[47] Poitras VJ, Gray CE, Borghese MM, Carson V, Chaput JP, Janssen I, et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. Appl Physiol Nutr Metab 2016;41:S197–239.
[48] Madalosso MM, Schaan B, Cureau FV. Association between body weight perception and quality of diet in Brazilian adolescents. Rev Paul Pediatr 2020;38:e2020057.
[49] Kelsey MM, Pyle L, Hilkin A, Severn CD, Utzschneider K, Van Pelt RE, et al. The impact of obesity on insulin sensitivity and secretion during pubertal progression: a longitudinal study. J Clin Endocrinol Metab 2020;105:e2061–8.