Applied nutritional investigation

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

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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 (\( \beta = -0.338, 95\% \text{ CI: } -0.611 \text{ to } -0.066 \)) and LDL-c (\( \beta = -0.227, 95\% \text{ CI: } -0.448 \text{ to } -0.005 \)), but only LDL-c remained significant in those with normal weight (\( \beta = -0.115, 95\% \text{ CI: } -0.224 \text{ to } 0.005 \)).

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.

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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

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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 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, Lider, 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) in kg/m². 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 (BMI < 85th percentile), overweight (BMI 85th – 95th percentile), or obesity (BMI ≥ 95th percentile). 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 triglycerides 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 (24hrR) 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 24hrR 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 intrindividual 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 previous paper [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 dietary 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.
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.
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 shown 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.
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 3**

<table>
<thead>
<tr>
<th>Cardiometabolic markers</th>
<th>Normal weight (n = 16 651)</th>
<th>Overweight/obesity (n = 5519)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>95% CI</td>
</tr>
<tr>
<td>Total cholesterol, mg/dL</td>
<td>-0.132</td>
<td>-0.268 to 0.004</td>
</tr>
<tr>
<td>HDL-c, mg/dL</td>
<td>0.097</td>
<td>0.039 to 0.155</td>
</tr>
<tr>
<td>LDL-c, mg/dL</td>
<td>-0.186</td>
<td>-0.283 to -0.074</td>
</tr>
<tr>
<td>Triglycerides, mg/dL</td>
<td>-0.263</td>
<td>-0.425 to -0.101</td>
</tr>
<tr>
<td>Fasting glucose, mg/dL</td>
<td>-0.069</td>
<td>-0.114 to -0.025</td>
</tr>
<tr>
<td>HbA1c, %</td>
<td>-0.0007</td>
<td>-0.003 to 0.001</td>
</tr>
<tr>
<td>HOMA-IR*</td>
<td>-0.015</td>
<td>-0.023 to -0.007</td>
</tr>
</tbody>
</table>

Model 1: adjusted for age and socioeconomic status

Model 2: adjusted for variables in model 1 plus total energy intake, physical activity and sedentary behavior

*Triglycerides and HOMA-IR were log-transformed and reported as geometric mean and 95% CI.

**Table 4**

<table>
<thead>
<tr>
<th>Cardiometabolic markers</th>
<th>Normal weight (n = 10 759)</th>
<th>Overweight/obesity (n = 4 027)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>95% CI</td>
</tr>
<tr>
<td>Total cholesterol, mg/dL</td>
<td>-0.184</td>
<td>-0.324 to -0.044</td>
</tr>
<tr>
<td>HDL-c, mg/dL</td>
<td>0.006</td>
<td>-0.107 to 0.119</td>
</tr>
<tr>
<td>LDL-c, mg/dL</td>
<td>-0.152</td>
<td>-0.271 to -0.033</td>
</tr>
<tr>
<td>Triglycerides, mg/dL</td>
<td>-0.188</td>
<td>-0.391 to -0.001</td>
</tr>
<tr>
<td>Fasting glucose, mg/dL</td>
<td>0.046</td>
<td>-0.050 to 0.142</td>
</tr>
<tr>
<td>HbA1c, %</td>
<td>0.002</td>
<td>-0.001 to 0.004</td>
</tr>
<tr>
<td>HOMA-IR*</td>
<td>0.003</td>
<td>-0.006 to 0.014</td>
</tr>
</tbody>
</table>

Model 1: adjusted for age and socioeconomic status

Model 2: adjusted for variables in model 1 plus total energy intake, physical activity and sedentary behavior

*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


