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Original Article

Association of fruit and vegetable consumption with markers of oxidative stress and inflammation in Cuban adolescents

Association of fruits and vegetables consumption with inflammatory and oxidative stress markers in Cuban adolescents

Association of fruit and vegetable consumption with markers of oxidative stress and inflammation in Cuban adolescents

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SUMMARY

To identify the relationship between fruit and vegetable consumption and indicators of oxidative stress and inflammation, a cross-sectional study was conducted with 39 adolescents. Oxidative stress indicators were determined in blood serum: malondialdehyde, advanced protein oxidation products,

and ferric reducing potential, and reduced glutathione in erythrocytes. Leukocyte count and differential count were determined as indicators of inflammation. Significant associations were found across quartiles of vegetable and fruit consumption with ferric reducing potential and reduced glutathione, with increases in both, as well as with malondialdehyde and advanced protein oxidation products, with decreases in both. It is concluded that higher consumption of vegetables and fruits was associated with variations in biomarkers of oxidative stress, with increases in indicators of antioxidant defenses and decreases in those of inflammatory oxidative damage.

Keywords: Food consumption frequency; Fruit and vegetable consumption; Indicators of oxidative stress; Indicators of inflammation; Adolescents.

SUMMARY

With the objective of identifying the relationship between the consumption of fruits and vegetables, the indicators of oxidative stress and inflammation, a cross-sectional study was carried out with 39 adolescents. Of the indicators of oxidative stress, malondialdehyde, advanced products of protein oxidation and ferric reducing power were determined in the blood serum, and reduced glutathione in erythrocytes and, as an indicator of inflammation, the leukocyte count and the differential count. Significant associations were found across the quartiles of vegetable and fruit consumption with ferric reducing potential and reduced glutathione with an increase in both, as well as with malondialdehyde and products of advanced protein oxidation, with a decrease in these. It is concluded that the greater consumption of vegetables and fruits was associated with variations in the biomarkers of oxidative stress, with an increase in the indicators of antioxidant defenses and a decrease in those of inflammatory oxidative damage.

Keywords: Frequency of food consumption; Fruit and vegetable consumption; Oxidative stress indicators; Inflammation indicators; Adolescents.

SUMMARY

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With the objective of identifying the relationship between the consumption of fruits and vegetables, the indicators of oxidative stress and inflammation, a cross-sectional study was carried out with 39 adolescents. Two indicators of oxidative stress, malondialdehyde, advanced protein oxidation products and ferric reducing power are determined in the blood, and reduced glutathione in erythrocytes, and leukocyte transmission and differential transmission are indicators of inflammation. Significant associations were found between the quartis of vegetable and fruit consumption with ferro-reducing potential and reduced glutathione with an increase in both, as well as with malondialdehyde and advanced protein oxidation products, with a decrease in these. It is concluded that increased consumption of vegetables and fruits is associated with variations in biomarkers of oxidative stress, with an increase in two indicators of antioxidant defenses and a decrease in oxidative inflammatory damage.

Keywords: Frequency of food consumption; Consumption of fruits and vegetables; Indicators of oxidative stress; Inflammation indicators; Teenagers.

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Introduction

The role of oxidative stress and inflammation in several chronic diseases has received considerable attention due to the identified link between these conditions and them. [1,2]

Potential factors that promote chronic low-grade inflammation are diverse. Increasing attention has been paid to dietary quality as a potential mechanism of action that can exacerbate or enhance inflammation and subsequently influence human health status. (3) It has been reported that a pro-

inflammatory diet can increase inflammatory cytokine levels by affecting redox balance and immunological mechanisms. (4)

There is growing evidence to suggest that dietary patterns or indicators represent markers of inflammatory oxidative stress. (5,6) For example, studies on dietary indicators and patterns, such as the Mediterranean Diet Score, the Italian Mediterranean Index, and the Healthy Eating Index, have shown that healthier scores are inversely associated with inflammation and oxidative stress indicators. (4,7)

Studies on the effects of adherence to the Mediterranean diet have shown that higher adherence to the diet was consistently associated with a lower risk of cardiovascular disease, diabetes, cancer and neurodegenerative diseases, as well as reduced overall mortality. (8) Such results have been attributed to the potential ability of the Mediterranean diet to decrease oxidative stress due to its high antioxidant capacity.

The Mediterranean diet is characterized by a high consumption of fruits, vegetables, cereals, legumes, nuts, and seeds; a low to moderate intake of dairy products, fish, poultry, and wine; and a low consumption of red meat and eggs; with olive oil as the main source of fat. Adherence to this diet has been reported to result in decreased levels of oxidized LDL and malondialdehyde (MDA), as well as positive associations with the activities of the enzymes superoxide dismutase (SOD), glutathione peroxidase, and the plasma ratio of reduced to oxidized glutathione (GSH/GSSG ratio). (7)

Children and adolescents have unique nutritional needs and an immature immune system, therefore susceptible to infections.(4) The consumption of fruits and vegetables is an important source of nutrients for healthy growth and development, as well as a protective factor against chronic non-communicable diseases associated with inflammatory oxidative stress.(9) For this reason, it is important to identify the relationship between the consumption of fruits and vegetables and indicators of oxidative stress and inflammation in Cuban adolescents.

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Methods

A cross-sectional analytical observational study was conducted with 39 first-year medical students from the Faculty of Medical Sciences of Bayamo in late adolescence (between 17 and 19 years old).Each patient gave written consent, and the study was approved by the institution's Ethics Committee. Adolescents who had an acute illness or reported any diagnosed chronic illness at the time of the study were excluded.

Each individual's nutritional status was determined using the anthropometric indicators Body Mass Index (BMI) and Waist Circumference (WC).Patients were classified as obese when the BMI was ≥ 30 kg/m2; overweight between 25 and 29.9 kg/m2; normal weight between 18.5 and 24.9 kg/m2 and underweight < 18.5 kg/m2. Abdominal obesity (OA) was admitted when the ICC was ≥ 102 cm in men and 88 cm in women. (10)

The dietary assessment was conducted through a semi-quantitative food frequency survey conducted during the 30 days prior to the survey, using the self-interview technique. The survey is validated by the authorized institution for nutrition in Cuba. To ensure the highest accuracy of the results, it was conducted by qualified personnel using standardized home measurements. The daily intake of each nutrient was supplemented by the intake of vitamin supplements. The data were subsequently transformed into energy and nutrient values using the values from the Cuban Food Composition Table for Practical Use, using the CERES computer program. The food frequency data were expressed in terms of daily consumption. Another survey similar to the one indicated was administered, which included only fruit and vegetable consumption, and which allowed for the accuracy of the results to be verified by comparing it with the previous survey. This survey was conducted by qualified and experienced personnel, different from those who conducted the first survey. Fruit and vegetable consumption was expressed in g/day.

A blood sample was taken from each participant after fasting for approximately 10 hours. In whole blood, hematocrit (Htc) was determined, along with a global leukocyte count and a differential count. In blood serum, the concentration of malondialdehyde plus 4-hydroxyalkenals (MDA + 4HDA) was

determined by the spectrophotometric method of Esterbauer and Cheeseman, and the concentration of advanced protein oxidation products (APOP) according to the spectrophotometric technique described by Witko-Sarsat et. al. Meanwhile, as indicators of antioxidant defenses, the ferric reducing potential (FRP) was determined by the Bahr and Basulto colorimetric assay, and in erythrocytes, the concentration of reduced glutathione (GGE) was determined by the Beutler colorimetric method.

Categorical variables are presented as absolute frequencies (n) and relative frequencies (%). Normally distributed continuous variables are described as means ± standard deviation, while those that did not follow a normal distribution and required statistical treatment were transformed and are described similarly. The Shapiro-Wilk test was used to check for data normality.

The association between BMI, treated as an ordinal variable, and sex was tested using the Mann-Whitney test, while WC, as a categorical variable, and sex were tested using the Chi-square test. The Student t test was used to compare the means of energy, fruit, vegetable, and fruit and vegetable consumption by sex group. A multivariate linear regression model was used to examine the association between measures of oxidative stress and inflammation indicators and fruit and vegetable consumption by quartile. The values for ferric reducing potential and erythrocyte reduced glutathione were log-transformed, and those for malondialdehyde and 4-hydroxyalkenals were log-transformed. In all cases, the significance level was set at 95%.Statistical analysis was performed using the Statistical Package (SPSS), version 23.0

Results

Table 1 shows the results of the analysis of the relationship between anthropometric variables and dietary indicators of the study participants by sex. Nutritional status according to BMI was not associated with sex. Normal-weight adolescents predominated, followed by underweight adolescents, and overweight and obese adolescents with a low percentage. However, an association between nutritional status and waist circumference was observed in favor of women. No statistically significant

differences were found in energy consumption, as well as in vegetable and fruit consumption, and in total vegetable and fruit consumption by sex.

Table 1. Anthropometric characteristics and dietary data of adolescents by sex.

Variables		Total N (%)/ M (SD)	Male N (%)/ M (SD)	Female N (%)/ M (SD)	p
BMI (Kg/m2)	Underweight	8 (20.5)	1 (2.6)	7 (17.9)	0.48
	Normal weight	25 (64.1)	6 (15.4)	19 (48.7)	
	Overweight	4 (10.3)	2 (5.1)	2 (5.1)	
	Obese	2 (5.1)	0 (0)	2 (5.1)	
DC (cm)	Without abdominal obesity	38 (97.4)	9 (23.1)	29 (74.4)	0.00
	Abdominal obesity	1 (2.6)	0 (0)	1 (2.6)	
Energy (Kcal)		1475.34 (576.95)	1776.2 (878.98)	1385.08 (431.89)	0.27
Vegetables (g)		54.18 (48.87)	69.8 (45.9)	49.5 (49.49)	0.19
Fruits (g)		76.64 (70.36)	72.98 (55.18)	77.74 (75.11)	0.97
Vegetables and fruits (g)		130.82 (99.9)	142.78 (81.28)	127.24 (105.82)	0.52

Table 2 shows the behavior of oxidative stress and inflammation indicators across quartiles of combined vegetable and fruit consumption. No differences were observed in the mean values of the leukocyte count and differential count across quartiles. Regarding oxidative stress indicators, an upward trend was observed in the mean values of PRF and erythrocyte concentrations of reduced glutathione, while the mean concentrations of malondialdehyde and 4-hydroxyalkenals decreased, as did those of advanced protein oxidation products.

Table 2. Indicators of oxidative stress and inflammation in adolescents across quartiles of fruit and vegetable consumption.

Characteristics	Consumption of vegetables and fruits			
	R1 (x ≤ 50.4)	R2 (50.4 < x	R3 (111.3 < x	R4 (x > 151.3)

		≤111.3)	≤151.3)	
	Mean (± SD)			
Total leukocytes	6.58 (1.21)	6.8 (0.92)	6.02 (0.69)	6.4 (1.42)
Neutrophils	0.59 (0.06)	0.6 (0.04)	0.57 (0.03)	0.58 (0.05)
Eosinophils	0.03 (0.03)	0.03 (0.03)	0.04 (0.03)	0.05 (0.05)
Monocytes	0.01 (0.01)	0.02 (0.02)	0.01 (0.01)	0.02 (0.02)
Lymphocytes	0.37 (0.07)	0.35 (0.04)	0.37 (0.06)	0.36 (0.07)
PRF (µmol Fe^{2+}/L)	124.91 (27.14)	121.92 (21.74)	136.43 (33.82)	151.37 (56.48)
GSHe (mmol/L erythr.)	4.6 (0.55)	4.76 (0.63)	5.16 (0.82)	5.55 (0.7)
MDA+4HDA (µmol/L)	3.84 (1.08)	3.32 (1.36)	2.99 (1.21)	2.42 (0.76)
PAOP (µmol/L)	16.38 (2.49)	15.13 (2.81)	13.97 (2.34)	12.33 (1.56)

The results of the estimation of the association between oxidative stress and inflammation indicators with the quartiles of the values of combined fruit and vegetable consumption are shown in Table 3. No significant associations were found with the white blood cell count or the differential white blood cell count, as indicators of low-grade chronic inflammation. Regarding oxidative stress indicators, positive and significant associations were found with PRF ($p < 0.05$) and erythrocyte reduced glutathione ($p < 0.01$), while negative and significant associations were observed with malondialdehyde plus 4-hydroxyalkenals and PAOPs ($p < 0.01$).

Table 3.β values of vegetable and fruit consumption in the multivariate linear regression model.

Indicators	β values	IC (95%)	P
FRP (µmol Fe2+ /L)	0.034	0.006 / 0.062	0.017
GSHe (mmol/L erythrocytes)	0.027	0.011 / 0.043	0.002
MDA + 4HDA (µmol/L)	-4,456	-7,503 / -1,408	0.005
PAOP (µmol/L)	-1,326	-2.002 / -0.650	0.000
Total leukocytes	-0.028	-0.089 / 0.034	0.370
Neutrophils	-0.008	-0.021 / 0.006	0.278
Lymphocytes	-0.001	-0.019 / 0.016	0.882
Eosinophils	0.021	-0.015 / 0.056	0.243
Monocytes	0.004	-0.020 / 0.029	0.717

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Discussion

Systemic inflammation is associated with adverse health outcomes. Diet is a critical associated factor (11), as diet quality is closely related to body weight. This is especially important for adolescents, who are becoming more self-sufficient in their diet.

Lakshmi, E. (12) found no association between BMI and food intake in adolescents. Their results showed that the percentage of food intake adequacy showed a deficit in the consumption of green leafy vegetables, fruits, milk and dairy products, which showed that a high percentage of adolescents were underweight. The results of this research are somewhat consistent with those of the aforementioned study regarding the lack of association, despite the fact that it included only female adolescents and in this study there was a predominance of females. Regarding the adequacy of intake, in this study we did not calculate the adequacy of consumption.

In another study with adolescents in which the association between food consumption and its relationship with overweight and obesity was evaluated, it was reported that the strongest associations between the consumption of a healthy diet were observed with the high consumption of fruits and vegetables, while a low frequency of sweets and snacks intake was associated with overweight/obesity, in turn, an appropriate choice of butter/margarine consumption, but with the frequent intake of vegetables was negatively associated with overweight/obesity. (13) Although it is considered that the consumption of vegetables and fruits in the participants of the present study was not high, normal weight and low weight predominated, which we attribute to the fact that the average energy consumption is slightly below the daily recommendations for the Cuban population. (14)

The results of other studies on the relationship between levels of inflammatory biomarkers associated with general and central adiposity and the consumption of fiber from cereals, grains, fruits and vegetables, confirm the positive influence of the consumption of fiber from cereals and grains in the decrease of these biomarkers, with the influence of sex and the most direct measurement of adipose

tissue mass. (15) The significant association between nutritional status according to abdominal perimeter and sex in the present study is attributed to the difference between the number of males and females and the distribution observed in adolescents without abdominal obesity and with abdominal obesity.

Regarding fruit and vegetable consumption by adolescents, several studies show that it is low, but young girls consumed more fruits and vegetables than young boys. (9, 16) Low fruit and vegetable consumption has also been reported in another study, but no gender differences were found. (17) The results of the present study are consistent with those reported, in that the diet of our adolescents was poor in fruits and vegetables, but with no significant differences between sexes.

The differences found in some studies regarding fruit and vegetable consumption in favor of women have been attributed to the greater concern of women for weight loss than men and for skin protection, therefore, they may prefer diets that are more deficient in energy and high in fiber such as fruits and vegetables. Alternatively, men generally engage in tasks that demand more energy than women, so they may be more prone to consume high energy density foods. (9) In our case, we attribute it more to the low availability during the study period and the high cost of these foods, since energy consumption did not show differences between sexes.

The significant decrease in the means of the indicators of oxidative damage to lipids and proteins across the quartiles of vegetable and fruit consumption and the increase in the indicators of antioxidant defenses found in our research are consistent with those reported in other studies, in which different indicators have been used. (18, 19) Thus, when evaluating the effect of consuming a diet rich in fruits and vegetables in obese patients, it was found that a higher consumption of fruits and vegetables was associated with a significant decrease in inflammatory markers, such as high-sensitivity CRP and Tumor Necrosis Factor α and in the concentrations of thiobarbituric acid reactive substances (TBARS), a marker of oxidative damage to lipids, as well as with an increase in the activity of antioxidant enzymes (catalase, glutathione peroxidase) compared to a low consumption, which was independent of changes in body weight and waist circumference.(20)

More than the studies that evaluate the consumption of fruits and vegetables, those that study the influence of dietary patterns on oxidative stress and inflammation abound. The Mediterranean diet, a dietary pattern that includes fruits and vegetables and in general foods with phytochemicals and nutrients with antioxidant properties, has been shown to decrease MDA levels and increase GSH concentrations, results consistent with those of our study. It has also been reported that the Dietary Pattern to Reduce Blood Pressure (DASH), characterized by the consumption of a large amount of fruits and vegetables, low sodium intake, and low-fat milk and dairy products, has been shown to reduce lipid peroxidation biomarkers such as MDA and TBARS, and increase blood serum GSH and PRF concentrations. (7)

Regarding PAOPs, it has been suggested that they are a mediator of inflammation and that they increase with increasing risk factors for cardiovascular disease. Therefore, it is not unreasonable to think that their concentration, like other biomarkers of oxidative damage, can be reduced with a diet rich in antioxidants.

Conclusions

The results of this study allow us to conclude that increased consumption of vegetables and fruits was associated with variations in oxidative stress biomarkers, particularly with increased indicators of antioxidant defenses and decreased indicators of inflammatory oxidative damage, despite no changes in inflammatory biomarkers such as total leukocyte levels and their types.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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