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Contribution of different foods according to the Nova classification to dietary fiber intake in adolescents

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Abstract *The aims of the present study were to evaluate dietary fiber intake and associated factors in adolescents, identify food sources of the nutrient, and determine associations between indicators of dietary patterns (energy/macronutrients/micronutrients) and dietary fiber intake. A population-based cross-sectional study was conducted involving 24-hour recall data. The NOVA classification was used to determine the contribution of foods to dietary fiber intake. Reference values from the World Health Organization (≥12.5 g) and the US Institute of Medicine (14 g) per 1,000 kcal were used to assess intake. The mean intake of dietary fiber/1,000 kcal/day was 6.4 g (1.5 g of soluble fiber and 4.9 g of insoluble fiber) among the 891 adolescents. Fiber intake was low, especially among those who ate fruits, vegetables, and beans less, those who consumed soft drinks and processed meats more, and those who did not eat breakfast every day. Unprocessed/minimally processed foods provided 68.8%, 53.7%, and 72.1% of total, soluble, and insoluble fiber, respectively, whereas ultra-processed products provided 24.8%, 37.9%, and 21.0% respectively. Fiber intake was inversely associated with energy intake, fat, free sugar, and animal protein in the diet. The insufficient fiber intake underscores the need for actions that promote healthy nutrition on the individual and family levels.*

Key words *Dietary Fiber, Adolescents, Health Surveys*

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Introduction

Studies report that greater dietary fiber intake diminishes the risk of colon cancer[1], cardiovascular disease[2,3], and death due to heart disease and all-cause cancer[4]. A study analyzing data from three American prospective cohorts found an association between carbohydrate quality and the risk of type 2 diabetes, as diets with a high glycemic load and a lower quantity of cereal fibers increased the risk of the disease by around 50%[5]. A study involving European adolescents found an inverse relation between soluble dietary fiber intake and blood glucose levels[6]. The US National Health and Nutrition Examination Survey (2001-2012) identified a smaller waist circumference and lower body mass index in children and adolescents (six to 18 years of age) who ingested whole grains more[7].

Despite the health benefits, dietary fiber intake is far from the recommended values. According to the 2008-2009 Brazilian Family Budget Survey, the availability of dietary fiber in Brazilian homes was 12.3 g/day, whereas fiber intake recommended by the World Health Organization and adopted by the Brazilian Health Ministry is a minimum of 25.0 g/day[8]. In a study conducted in the United States, daily fiber intake was 17.0 g among adults (≥19 years) and adequate intake ranged from 21 to 38 g/day in this population[9]. In a study conducted in Australia, mean fiber intake was 23.8 g/day and only 28.2% of adults (≥19 years) achieved the recommended daily intake of 30 g for men and 25 g for women[10]. Among adolescents, mean fiber intakes is reported to be around 20 g for Brazilians[11], Europeans[6], and Australians[10]. Moreover, mean fiber intake is reported to be only 13 g among American children/adolescents[9].

There is no universal definition of dietary fiber. However, one of the most widely used is that proposed by *Codex Alimentarius*, which defines the nutrient as carbohydrate polymers with ten or more monomer units that are not hydrolysable by endogenous enzymes of the small intestine in humans[12,13]. *Codex* considers fiber to be carbohydrates naturally found in foods as well as isolated or extracted from the food matrix and synthesized by industrial processes that present scientifically proven health benefits[12].

Dietary fiber is subdivided based on solubility in water, viscosity, and fermentation[14-16]. Viscous, soluble fibers form a gel when in contact with water, which influences the consistency of the chyme, prolongs the digestion and absorption of nutrients, and reduces the appetite as well as the absorption of cholesterol and glucose. The fermentation (complete or partial) of fiber produces short-chain fatty acids, which furnish energy for the mucosa of the colon and play a role in the maintenance of the integrity of the intestinal barrier as well as the regulation of the immune system. Insoluble fibers exert a laxative effect and increase both fecal volume and intestinal transit time[14-16]. As the characteristics of dietary fiber coincide in foods, one's diet should contain a variety of fruit, leafy vegetables, tubers, beans, and whole grains.

The most recent edition of the Dietary Guide for the Brazilian Population recommends that foods *in natura* and minimally processed foods, such as fruit, vegetables, roots, tubers, legumes, and seeds, be predominant in the diet of individuals[17]. This recommendation is fundamental in the contemporary challenge of promoting adequate dietary fiber intake.

Considering the importance of dietary fiber, the need to evaluate fiber intake and identify source foods in the diet, as well as the scarcity of population-based studies analyzing this nutrient, the aims of the present study were to evaluate dietary fiber intake and associated factors in adolescents, identify dietary sources of this nutrient, and determine associations between indicators of dietary practices (energy, micronutrients, and macronutrients) and fiber intake.

Methods

This study involved the use of data from two population-based cross-sectional studies involving community-dwelling residents of urban areas of the city of Campinas in the state of São Paulo, Brazil. The population of the studies comprised three age domains: adolescents (10 to 19 years), adults (20 to 59 years), and older people (60 years or older).

The aim of the 2014-15 Campinas Health Survey was to investigate demographic/socioeconomic characteristics and multiple health dimensions, such as morbidities, the use of healthcare services, preventive practices, lifestyle, and the use of medications. For such, a questionnaire organized in 12 thematic blocks was administered by trained interviewers with the aid of an electronic device (tablet).

The sample for the 2014-15 Campinas Health Survey was selected using a two-stage, probabilistic, cluster sampling process. In the first stage, 70

census sectors were randomly selected with probability proportional to size (given by the number of homes counted during the 2010 census). The sectors were ordered based on the mean income of the heads of households. Next, 14 census sectors were selected from each of the five administrative districts of the city[18].

A minimum sample size was selected for each age domain (1,000 adolescents, 1,400 adults, and 1,000 older people). The sample sizes were established considering maximum variability for the frequency of the events studied (p=0.50), a 95% confidence level (z=1,96), a sampling error of three to four percentages points for adults and four to five percentage points for adolescents and older people, and a design effect of 2[18].

The second stage consisted of the definition of the number of households necessary to reach the minimum sample size for each age domain. Thus, 3,119 households were selected for interviews with adolescents, 1,029 were selected for interviews with adults, and 3,161 were selected for interviews with older people, assuming non-response rates of 27%, 22%, and 20%, respectively. In each household, interviews were held with all residents in the age domain for which the household was selected[18].

The present study also involved an analysis of data from the 2014-15 Campinas Food Intake and Nutritional Status Survey (Campinas Nutrition Survey), which was developed with the same sample as the 2014-15 Campinas Health Survey. After participation in the health survey, the interviewers returned to the homes of the same individuals to answer a nutrition questionnaire composed of a 24-hour Recall (24hR), Food Frequency Questionnaire, and questions addressing body perception, weight loss practices, self-rated diet quality, frequency of meal consumption, etc. The data collection process was standardized through training exercises, supervision of the field team, and the creation of support material (interviewer's manual, protocol for the administration of the 24hR, and a photographic manual).

The interviews were initiated with the 24hR, for which the following statement was made: "Please, tell me what you ate and drank yesterday from the moment you woke up until the time you went to sleep"[19]. The Multiple Pass Method was used to stimulate the respondent's memory and obtain more precise estimates of food intake[20]. This method consists of an interview structured in five steps: *Quick List* (spontaneous report of all foods and beverages ingested the previous day), *Forgotten Foods* (checking for frequently forgotten foods), *Time and Eating Occasion* (records of the time, name, and place of the consumption of meals), *Detail Cycle* (detailing of each item, such as preparation method, composition of meals, type, and respective quantities), and *Final Probe* (general review)[20].

The foods and culinary preparations were recorded in household units or measures. Trained nutritionists reviewed the 24hRs to identify and correct possible errors and subsequently quantified the household measures of the foods into units of weight and volume using household measure tables[21,22], food labels, and consumer services. The food intake data were entered into the Nutrition Data System for Research (NDS-R, version 2015, Nutrition Coordinating Center, University of Minnesota) by the team of nutritionists. Typical culinary preparations not found in the database of the program were evaluated based on standard recipes[21-23]. These preparations were stored in the *User Recipe* module and were available for use when needed.

The fieldwork was conducted on different days of the week, including Saturdays and Sundays, and the interviews lasted an average of 30 minutes (CI95%: 28.6 to 31.3). The questionnaire of the Campinas Nutrition Survey was entered into a mask developed with the use of the EpiData program, version 3.1 (EpiData Assoc., Odense, Denmark). After entering the dietary data of the NDS-R and the data from the questionnaire in the EpiData program, a consistency analysis was performed to correct any typographical errors.

Variables used in the study

The variable of interest was *total, soluble, and insoluble dietary fiber intake* (g/day) obtained from the 24hR. The quantities of total dietary fiber and the fractions (soluble and insoluble) were expressed as energy density (g/1000 kcal/day). Reference values from the WHO (≥12.5 g/1,000 kcal) and the US Institute of Medicine (IOM) (14 g/1,000 kcal) were used to evaluate dietary fiber intake.

The following were the independent variables:

Demographic and socioeconomic characteristics: sex (male and female), age group (10 to 14 and 15 to 19 years), self-reported race/skin color (white and non-white), schooling of head of household (0 to 4, 5 to 8, 9 to 11 and ≥12 years of study), and family income *per capita* using the Brazilian monthly minimum wage (BMMW) as reference (< 0.5, ≥0.5 to <1.0, ≥1.0 to <1.5 and ≥1.5 times the BMMW).

Food intake, checking of food labels, self-rated diet quality, and body mass index (BMI): frequency of weekly consumption of fruit, raw and cooked vegetables, beans, and milk (≥five and <five times)[24], soft drinks and processed meats (≤two and >two times)[24], weekly frequency of having breakfast (seven and <seven times)[24,25], and practice of checking food labels (no and yes/sometimes)[26]. Self-rated diet quality was obtained based on the answer to the following question "What do you consider the quality of your diet to be?" (categorized as very good/good, fair, and poor/very poor). The BMI [weight (kg)/height² (m)] was calculated using reported weight and measured height, as reported height has lower validity than reported weight in adolescents[27]. Nutritional status was classified according to BMI for age as underweight/ideal (≤85th percentile) and overweight/obesity (>85th percentile)[28].

Food processing category: the 500 food items reported on the 24hRs were coded using the NOVA classification, which considers the extent and purpose of the industrial processing of foods[29]. The food items were then united into four groups: 1) *in natura or minimally processed*, legumes, fruit, leafy vegetables, tubers, milk, meat, eggs, grains (rice, oats, wheat, corn, cassava [whole and flours]), seeds, etc.; 2) *processed*, French roll, cheese, fruit in syrup, pickled vegetables/legumes; 3) *ultra-processed*, sweetened beverages, cookies/crackers, sandwich bread, margarine, processed meats, chocolate milk, instant pasta, candies, snacks, chips; 4) *culinary ingredients*, butter, salt, sugar, and vegetable oil[29]. The contribution of the groups and respective foods to total fiber was expressed as energy density and percentage.

Indicators of eating practices: energy, carbohydrates, total protein, proteins of a vegetable and animal origin, total fat, saturated fat, trans fat, added sugar, cholesterol, sodium, and potassium. The indicators were derived from the 24hRs and were selected based on the WHO nutrient intake guidelines[30,31].

Data analysis

Mean and standard deviation (SD) values were calculated for the density of total, soluble, and insoluble fiber (g/1,000 kcal/day) according to the categories of the independent variables. Generalized linear regression models adjusted by sex were also created to estimate mean dietary fiber intake (total and soluble/insoluble fractions). Variables with a p-value <0.20 in the bivariate analysis were incorporated into each model and those with a p-value <0.05 after the adjustments remained in the models. Graphic techniques and the Akaike Information Criterion (AIC) revealed that gamma distribution best fit the fiber intake data. The contribution of the food groups and respective foods was then calculated in relation to total and fractional fiber content. Linear regression analysis was employed to determine the association between indicators of eating practices and fiber intake (categories in quartiles) and the general significance of the model was determined using the F test. The level of significance on the statistical tests was set to 5%. All analyses were performed with the aid of the svy module of the Stata program (version 15.0), which considers weights and sampling design.

Ethical considerations

The Campinas Health Survey and Campinas Nutrition Survey received approval from the Human Research Ethics Committee of *Universidade Estadual de Campinas* (UNICAMP) as well as the National Research Ethics Committee (CEP/CONEP system). The present study also received approval from the UNICAMP Human Research Ethics Committee.

Results

Among the 1,023 adolescents interviewed during the Campinas Health Survey, 109 did not participate in the Campinas Nutrition Survey (10.7% refusal/loss rate). Among the 914 interviews, 866 (94.7%) were held with the adolescents themselves and 48 (5.3%) were held with parents or guardians (mothers constituted the majority of such cases [67.7%]).

Regarding the 24hR, 11 individuals declined to answer (adolescents or parents/guardians) and another twelve 24hRs were excluded for an implausible total energy value (<600 kcal [n=10] or >6000 kcal). Therefore, the present study involved information from 891 adolescents. Mean age was 14.6 years (CI95%: 14.4 to 14.8).

The sample had slightly higher proportions of boys (52.0%), adolescents 15 to 19 years of age (52.7%), and self-declared white individuals (55.5%). A total of 19.7% of the heads of households had up to four years of schooling and 26.1% of the families received less than half the BMMW *per capita*. A low frequency of fruit consumption (<five times/week) was reported

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by 61.9% of the adolescents. A low frequency of the consumption of beans (<five times/week) was reported by 28.3% and a high frequency of soft drink consumption (>two times/week) was reported by 50.7%. A total of 63.7% of the sample had breakfast every day and 31.4% had the practice of reading food labels (Tables 1 and 2).

Mean total fiber intake was 12.6 g (CI95%: 12.2 to 13.2), mean soluble fiber intake was 3.0 g (CI95%: 2.8 to 3.2), and mean insoluble fiber intake was 9.6 g (CI95%: 9.2 to 10.0). Regarding sex, mean daily total, soluble, and insoluble fiber intake was respectively 11.7 g (CI95%: 11.2 to 12.3), 2.9 g (CI95%: 2.7 to 3.0), and 8.8 g (CI95%: 8.4 to 9.3) among the girls and 13.5 g (CI95%: 12.9 to 14.2), 3.1 g (CI95%: 2.9 to 3.3), and 10.4 g (CI95%: 9.8 to 10.9) among the boys (data not presented in tables).

Daily dietary fiber intake was estimated at 6.4 g/1,000 kcal in the overall sample, corresponding to 1.5 g/1,000 kcal of the soluble fraction and 4.9 g/1,000 kcal of the insoluble fraction. Girls had a higher total dietary fiber intake than boys. Soluble dietary fiber intake was higher among girls and adolescents in the higher strata with regards to schooling of the head of the household (≥12 years in comparison to ≤four years of study) and family income *per capita* (≥1.5 times the BMMW compared to <0.5 times the BMMW) (Table 1).

Dietary fiber intake was lower among adolescents who consumed fruits, raw and cooked vegetables, and beans less than five times per week and consumed soft drinks and processed meats more than twice per week. Individuals who did not eat breakfast every day and those who did not have the practice of checking food labels had lower mean dietary fiber intake. Total and insoluble dietary fiber intakes were lower among adolescents who rated the quality of their diet as poor/very poor compared to those who rated their diet quality as very good/good (Table 2).

Table 3 displays the results of the generalized linear regression models for total, soluble, and insoluble dietary fiber intake. Adolescents who consumed fruits, raw vegetables, and beans at a lower weekly frequency, those who consumed soft drinks and processed meats with a greater weekly frequency, and those who did not eat breakfast every day had lower mean total dietary fiber intake. Mean soluble fiber intake was higher

Table 1. Mean density of total. soluble. and insoluble dietary fiber according to sociodemographic variables among adolescents 10 to 19 years of age. 2014-2015 Campinas Nutrition Survey.

Variables	n (%)	Total fiber g/1000 kcal	SD	Soluble g/1000 kcal	SD	Insoluble g/1000 kcal	SD
Sex							
Male	463 (52.1)	6.2[a]	±2.4	1.4[a]	±0.9	4.8	±2.1
Female	428 (47.9)	6.6[b]	±3.9	1.6[b]	±1.4	5.0	±3.1
Total	891	6.4	±2.7	1.5	±0.9	4.9	±2.4
Age group (in years)							
10 to 14	422 (47.4)	6.4	±2.5	1.5	±0.8	4.8	±2.0
15 to 19	469 (52.6)	6.5	±3.5	1.5	±1.1	4.8	±2.8
Race/skin color							
White	487 (55.5)	6.4	±2.9	1.6	±1.1	4.8	±2.4
Non-white	400 (44.5)	6.4	±3.4	1.5	±1.4	4.9	±2.6
Schooling of head of family (in years)							
0 to 4	177 (19.6)	6.2	±2.5	1.4[a]	±1.1	4.8	±2.0
5 to 8	292 (33.6)	6.5	±4.1	1.6[a.b]	±1.5	5.0	±3.0
9 to 11	257 (28.9)	6.1	±3.5	1.5[a.b]	±1.6	4.7	±2.7
12 or more	150 (17.8)	6.7	±4.9	1.8[b]	±1.6	4.9	±3.8
Family income per capita (minimum wage)*							
<0.5	234 (26.1)	6.4	±2.6	1.4[a]	±1.1	5.0	±2.4
≥0.5 to <1.0	302 (33.0)	6.5	±4.2	1.5[a.b]	±1.4	5.0	±3.6
≥1.0 to <1.5	190 (21.3)	6.1	±3.3	1.5[a.b]	±1.4	4.6	±2.7
≥1.5	165 (19.6)	6.6	±4.6	1.7[b]	±1.5	4.9	±3.7

n: number of adolescents in unweighted sample; %: Percentage in weighted sample; SD: standard deviation; *BMMW: Brazilian monthly minimum wage; a.b: different letters indicate statistically significant differences.

Source: Food Consumption and Nutritional Status Survey of the city of Campinas. Brazil (2014-2015 Campinas Nutrition Survey).

Table 2. Mean density of total, soluble, and insoluble dietary fiber according to food consumption, checking food labels, self-rated diet quality, and body mass index among adolescents 10 to 19 years of age. 2014-2015 Campinas Nutrition Survey.

Variables	n (%)	Total fiber g/1.000 kcal	SD	Soluble g/1.000 kcal	SD	Insoluble g/1.000 kcal	SD
Consumption of fruit							
≥5 times per week	330 (38.0)	7.1[a]	±3.2	1.7[a]	±1.1	5.4[a]	±2.5
<5 times per week	561 (62.0)	6.0[b]	±4.7	1.4[b]	±1.6	4.5[b]	±3.5
Consumption of raw vegetables							
≥5 times per week	246 (28.3)	7.1[a]	±3.1	1.7[a]	±1.1	5.4[a]	±2.6
<5 times per week	645 (71.7)	6.1[b]	±5.3	1.5[b]	±2.0	4.7[b]	±4.3
Consumption of cooked vegetables							
≥5 times per week	99 (11.2)	7.4[a]	±4.1	1.8[a]	±1.6	5.5[a]	±3.0
<5 times per week	792 (88.8)	6.2[b]	±11.8	1.4[b]	±4.5	4.7[b]	±8.4
Consumption of milk							
≥5 times per week	469 (52.9)	6.5	±2.6	1.5	±1.1	4.9	±2.2
<5 times per week	422 (47.1)	6.3	±3.3	1.5	±1.4	4.7	±2.5
Consumption of beans							
≥5 times per week	641 (71.7)	6.6[a]	±2.3	1.5[a]	±1.0	5.1[a]	±2.3
<5 times per week	250 (28.3)	6.0[b]	±3.6	1.7[b]	±1.4	4.2[b]	±2.7
Consumption of soft drinks							
≤2 times per week	441 (49.4)	6.7[a]	±2.7	1.6[a]	±1.0	5.1[a]	±2.3
>2 times per week	450 (50.6)	6.0[b]	±3.4	1.4[b]	±1.3	4.6[b]	±2.7
Consumption of processed meats							
≤2 times per week	495 (55.4)	6.6[a]	±3.1	1.6	±1.1	5.0[a]	±2.4
>2 times per week	396 (44.6)	6.2[b]	±3.6	1.5	±1.4	4.7[b]	±2.8
Breakfast (frequency)							
7 times per week	569 (63.8)	6.7[a]	±2.6	1.6[a]	±0.9	5.0[a]	±2.1
<7 times per week	322 (36.2)	5.9[b]	±3.4	1.4[b]	±1.1	4.5[b]	±2.7
Checking of food labels							
No	613 (68.7)	6.2[a]	±2.5	1.5[a]	±1.0	4.7[a]	±2.2
Yes/sometimes	278 (31.3)	6.8[b]	±3.7	1.7[b]	±1.3	5.1[b]	±2.8
Self-rated diet quality							
Very good/good	509 (57.3)	6.5[a]	±2.7	1.5	±1.1	5.0[a]	±2.3
Fair	311 (34.6)	6.4[a,b]	±2.6	1.5	±1.0	4.9[a,b]	±2.1
Poor/very poor	71 (8.1)	5.6[b]	±3.2	1.6	±1.5	4.0[b]	±2.1
Body mass index (kg/m²)							
Underweight/ideal	543 (66.5)	6.4	±2.7	1.6	±0.9	4.8	±2.1
Overweight/obesity	275 (33.5)	6.5	±2.8	1.6	±1.2	4.9	±2.3

n: number of adolescents in unweighted sample; %: percentage in weighted sample; SD: standard deviation; a,b: different letters indicate statistically significant differences.

Source: Food Consumption and Nutritional Status Survey of the city of Campinas, Brazil (2014-2015 Campinas Nutrition Survey).

among girls and adolescents whose heads of the household had more schooling and was lower among those who consumed fruits, raw vegetables, and beans at a lower weekly frequency, those who consumed soft drinks at a greater weekly frequency, and those who did not eat breakfast every day. Lower insoluble dietary fiber intake was associated with the consumption of fruits, raw vegetables, and beans less than five times per week, processed meats more than twice per week, and breakfast less than seven days per week.

Foods *in natura* and minimally processed foods provided 68.0% of total dietary fiber, processed foods provided 7.2%, and ultra-processed

Table 3. Generalized linear regression models of variables associated with total, soluble, and insoluble dietary fiber density (g/1000 kcal). 2014-2015 Campinas Nutrition Survey.

Variables	Model 1 - Total dietary fiber*	
	Estimate	p-value
Intercepto	7.9	
Sex (female)/(male)	0.36	0.064
Fruit (<5 days/week)/(≥5)	-0.78	<0.001
Raw vegetables (<5 days/week)/(≥5)	-0.60	0.001
Beans (<5 days/week)/(≥5)	-0.55	0.007
Soft drinks (>2 days/week)/(≤2)	-0.32	0.037
Processed meats (>2 days/week)/(≤2)	-0.40	0.014
Breakfast (<7 days/week)/(7)	-0.60	0.001
Variables	**Model 2 - Soluble dietary fiber****	
	Estimate	**p-value**
Intercept	1.7	
Sex (female)/(male)	0.14	0.035
Fruit (<5 days/week)/(≥5)	0.26	0.036
Raw vegetables (<5 days/week)/(≥5)	-0.14	0.024
Beans (<5 days/week)/(≥5)	-0.17	0.010
Soft drinks (>2 days/week)/(≤2)	0.27	0.002
Processed meats (>2 days/week)/(≤2)	-0.16	0.013
Breakfast (<7 days/week)/(7)	-0.23	<0.001
Variables	**Model 3 - Insoluble dietary fiber*****	
	Estimate	**p-value**
Intercept	6.1	
Sex (female)/(male)	0.22	0.143
Fruit (<5 days/week)/(≥5)	-0.66	<0.001
Raw vegetables (<5 days/week)/(≥5)	-0.47	0.004
Beans (<5 days/week)/(≥5)	-0.82	<0.001
Soft drinks (>2 days/week)/(≤2)	-0.36	0.008
Processed meats (>2 days/week)/(≤2)	-0.44	0.004

*Variables incorporated into model 1: sex, weekly consumption of fruit, beans, raw and cooked vegetables, soft drinks, and processed meats, self-rated diet quality, practice of checking food labels, and weekly consumption of breakfast; **Variables incorporated into model 2: sex, race/skin color, schooling of head of household, family income, weekly consumption of fruit, beans, raw and cooked vegetables, and soft drinks, practice of checking food labels, and weekly consumption of breakfast; ***Variables incorporated into model 3: sex, weekly consumption of fruit, beans, raw and cooked vegetables, milk, soft drinks, and processed meats, self-rated diet quality, practice of checking food labels, and weekly consumption of breakfast.

Source: Food Consumption and Nutritional Status Survey of the city of Campinas, Brazil (2014-2015 Campinas Nutrition Survey).

foods provided 24.8%. In the *in natura* group, beans, grains, fruit, roots, and tubers were the main sources of dietary fiber and beans contributed the most insoluble fiber. Among processed foods, French rolls contributed the most fiber. Among ultra-processed foods, cookies/crackers, sandwich bread, and chocolate milk contributed the most fiber. Approximately 38.0% of soluble fiber came from ultra-processed foods (Table 4).

An increase in dietary fiber intake was associated with a reduction in energy content, animal protein, total fat, saturated fat, cholesterol, and added sugar. The increase in dietary fiber intake was also associated with an increase in carbohydrates, vegetable protein, and potassium (Table 5).

Discussion

In the present study, mean dietary fiber intake adjusted for energy was 6.4 g/1,000 kcal/day. The total was 12.7 g (13.5 g among boys and 11.7 g among girls). These values are below the intake

Table 4. Density and contribution of food groups/items in relation to total, soluble, and insoluble dietary fiber (in grams). 2014-2015 Campinas Nutrition Survey.

Food groups	Density (g/1000 kcal/day)			Contribution (%)		
	TDF	SDF	IDF	TDF	SDF	IDF
In natura/minimally processed	4.2	0.8	3.4	68.0	53.7	72.1
Beans	1.7	0.1	1.6	28.2	4.7	35.1
Grains	0.7	0.2	0.5	10.8	15.5	9.5
Fruit	0.6	0.2	0.4	9.1	15.1	7.4
Roots and tubers	0.4	0.2	0.2	7.1	13.6	5.2
Rice	0.4	0.0	0.4	6.3	0.2	8.1
Vegetables	0.4	0.1	0.3	5.9	4.6	6.3
Processed	0.4	0.1	0.3	7.2	8.4	6.9
French roll	0.4	0.1	0.3	6.5	7.6	6.2
Ultra-processed	1.5	0.5	1.0	24.8	37.9	21.0
Cookies/crackers	0.3	0.1	0.2	5.2	8.8	4.2
Sandwich bread	0.3	0.1	0.2	4.5	8.1	3.5
Chocolate milk	0.2	0.0	0.2	3.5	3.3	3.6
Processed sauces	0.2	0.1	0.1	2.9	3.7	2.8
Sweets	0.2	0.1	0.1	2.8	4.2	2.3
Salty snacks	0.1	0.0	0.1	2.2	2.5	2.1
Instant pasta	0.1	0.0	0.1	1.4	1.8	1.3

TDF: total dietary fiber; SDF: soluble dietary fiber; IDF: insoluble dietary fiber.

Source: Food Consumption and Nutritional Status Survey of the city of Campinas, Brazil (2014-2015 Campinas Nutrition Survey).

Table 5. Mean energy and nutrient intake according to density of dietary fiber in quartiles among adolescents 10 to 19 years of age. 2014-2015 Campinas Nutrition Survey.

Variables	Total mean	Density of dietary fiber (g/1000 kcal) in quartiles				p-value*
		1	2	3	4	
Energy (kcal/day)	2034.0	2164.8	2142.2	1978.8	1849.5	<0.001
% of energy from:						
Carbohydrates	50.6	46.5	49.6	51.8	54.8	<0.001
Total protein	15.8	16.6	15.7	15.5	15.4	0.083
Plant protein	5.4	4.0	5.2	5.9	6.6	<0.001
Animal protein	10.4	12.6	10.6	9.6	8.8	<0.001
Total fat	33.6	36.6	34.6	32.7	30.4	<0.001
Saturated fat	10.8	12.4	11.4	10.3	9.2	<0.001
Trans fat	1.2	1.4	1.2	1.2	1.1	0.064
Free sugar	11.8	15.0	12.3	10.2	9.4	<0.001
Cholesterol (mg)	239.2	311.2	244.8	212.4	187.7	<0.001
Sodium (g)	3.5	3.5	3.7	3.4	3.3	0.072
Potassium (mg)	1968.8	1724.0	1953.5	1996.5	2203.1	<0.001

Dietary fiber ranges (g/1000 kcal) in each quartile: 1 (0.46 to ≤4.78); 2 (>4.78 to ≤6.20); 3 (>6.20 to ≤7.64); 4 (>7.64 to 22.58); *F test: used to determine significance of linear regression model.

Source: Food Consumption and Nutritional Status Survey of the city of Campinas, Brazil (2014-2015 Campinas Nutrition Survey).

recommended by the WHO (≥25 g/day or 12,5 g/1,000 kcal)[30] and the IOM (38 g/day for boys and 26 g for girls or 14 g/1,000 kcal/day)[32].

Dietary fiber intake in the present study was lower than that described for adolescents in Europe (20.3 g and 8.4 g/1,000 kcal/day)[6], the Unit-

ed States (13.2 g/day)[9], and Australia (19.8 g/day for children/adolescents nine to 13 years of age and 18.8 g/day for adolescents 14 to 18 years of age)[10]. It was also lower than that estimated for Brazilian adolescents in a previous study (20.4 and 18.8 g for boys and girls 10 to 13 years of age, respectively; 23.4 and 18.5 g for body and girls 14 to 18 years of age, respectively)[11].

Dietary patterns in the Brazilian population have undergone intense transformations in recent decades, with a reduction in the consumption of traditional foods, such as rice, beans, and cassava, and an increase in the consumption of highly processed foods, such as cookies/crackers, ice creams, and fast food[33,34]. Besides the scarcity of fiber and other nutrients, these products have characteristics that stimulate excessive consumption, such as high palatability, broad advertising, and accessibility to all social strata[17]. Data from the 2008-2009 Brazilian Family Budget Survey showed that 69.5% and 21.5% of total energy intake came from food *in natura* and ultra-processed products[35]. These figures were respectively 28.6% and 50.7% in the United Kingdom in 2008[36].

During food processing, dietary fiber is added to food products due to its technological role, such as water and fat retention capacity, thickening, texture modification, flavor modification, gel formation, the control of the crystallization of sugar, etc[37]. For instance, inulin is a soluble fiber used to replace fat in baked goods, dairy products, sauces, and creamy spreads[37]. In the United States, a diversity of synthetic non-digestible carbohydrates (polydextrose, short-chain fructooligosaccharides, and galactooligosaccharides) and isolates (alginate and fiber from the cell wall of plants) are used in commercial products and have been defined as dietary fiber by the US Food and Drug Administration[38]. However, one should bear in mind that, regardless of the presence of these types of fiber, ultra-processed products are not healthy.

Girls had greater total and soluble dietary fiber intake than boys in the bivariate analysis and had greater soluble fiber intake in the final model. Among the participants of the cross-sectional Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA-CCS) study, dietary fiber intake was higher among girls than boys (8.9 g/1,000 kcal *versus* 7.8 g/1,000 kcal; p<0,001) and compliance with the IOM recommended intake was also higher among girls than boys (11.4% *versus* 2.1%)[6]. In Australia, no significant differences between the sexes were found regarding the proportion of adolescents who achieved the reference values established for the population of the country[10]. In a study involving Brazilian adolescents, the prevalence of inadequate dietary fiber intake (≤12.5 g/1,000 kcal) was higher among girls, reaching as high as 86.0% in the group aged 14 to 18 years[11]. The results of national surveys reveal that unhealthy eating patterns are more common among female adolescents than males[24,39]. Maia et al.[24] found that an unhealthy eating pattern characterized by the consumption of sweets, fried foods, instant pasta, chips, crackers, and processed meats was associated with inadequate behaviors, such as the habit of not eating breakfast, not having meals with one's parents, and eating at fast food restaurants. Therefore, the finding in the present study may be due to the greater consumption of unhealthy foods among girls.

The consumption of soluble fiber was higher in homes in which the head of the household had a higher level of schooling compared to those with up to only four years of schooling. A study conducted in Australia found that dietary fiber intake was higher in the segment with a higher income, as 51.1% of the richest individuals achieved the recommended intake of this nutrient compared to 33.3% of the poorest individuals[10]. In a previous study, a higher consumption of fruit and vegetables was found among Brazilian adolescents whose mothers had a complete university/college education compared to those whose mothers had an incomplete primary school education[40]. The fast growth in the participation of ready-to-eat or nearly ready-to-eat food products and the reduction in the consumption of foods *in natura* is a phenomenon that touches all social segments of the population[34]. Data from the 2008-2009 Brazilian Family Budget Survey revealed a 7.5% reduction in the caloric contribution of foods *in natura* and an 19.3% increase in the participation of ready-to-eat products in the population classified in the first and last income quintiles[34].

Lower dietary fiber intake was found among adolescents who consumed fruit, raw vegetables, and beans less and consumed soft drinks and processed meat more during the week. Plant-based foods have different quantities of dietary fiber. The main sources are grains (preferably whole), tubers, legumes, vegetables, and fruit[14-16]. Pectin is a fermentable, viscous, soluble fiber found in fruit, legumes, oats, potato, and the white portion of orange peel. Cellulose is a non-fermentable soluble fiber found in grains, vegetables, fruit peels, nuts, and seeds[14-16]. Data

from the 2008-2009 Brazilian Family Budget Survey demonstrate that the consumption of ultra-processed products negatively affects dietary quality, as the fiber contents is three times lower in the portion of the diet composed of ultra-processed produced compared to foods *in natura*[35].

Lower total, soluble, and insoluble dietary fiber intake was also found among individuals who did not eat breakfast every day. The results of the 2013-2014 *Estudo de Riscos Cardiovasculares em Adolescentes de 12-17 anos* (ERICA [Study of Cardiovascular Risk in Adolescents 12 to 17 years of age]) indicate that 21.9% of the participants never ate breakfast (25.8% of the girls and 18.2% of the boys)[41]. In a study conducted in the city of São Paulo, 38.0% did not eat breakfast, whereas the contribution of this meal to total dietary fiber among adolescents was nearly 20.0% (4.0 g for boys and 3.4 g for girls)[42]. In the United Kingdom, children and adolescents (four to 18 years of age) who ate breakfast every day had a greater intake of dietary fiber, calcium, iron, and folate.[42] Breakfast is one of the three main meals of the day[17] and makes an important contribution to dietary fiber intake through the consumption of fruit, bread, and whole grains.

In the bivariate analysis, an association was found between self-rated diet quality as poor/very poor and low fiber intake and an association was found between the practice of checking food labels and greater fiber intake. These findings reveal the importance of eating habits and healthy behaviors to promoting the consumption of foods that are sources of fiber. A previous study found a poor overall diet quality, lower consumption of whole grains and fruit, and a higher consumption of solid fats and added sugar among adolescents who considered the quality of their diet to be poor/very poor[44].

In the city of Campinas, 31.2% (CI95%: 26.8 to 35.9) of the adolescents had the practice of checking food labels and mainly looked at the expiration date (82.1%), calories (19.7%), and fat content (10.7%), whereas only 1.0% checked the dietary fiber content. Therefore, the association between fiber intake and label reading does not reflect a concern on the part of these adolescents regarding the content of this nutrient, but rather a concern for other characteristics of food.

In the present study, foods *in natura* and minimally processed foods provided 68.0% of total dietary fiber, 53.7% of the soluble fraction, and 72.1% of the insoluble fraction. Among Brazilians aged ten years or older, the foods that most contributed dietary fiber were beans (36.9%), rice (9.8%), bread (9.3%), vegetables (7.8%), fruit (7.7%), and cassava flour (5.5%)[8]. Among European adolescents, the foods that most provided fiber were bread (20.8%, 24.4%, and 18.4% of total, soluble, and insoluble fiber, respectively), grains, roots, and tubers (17.5%, 20.1%, and 17.9%), sweets/salty snack foods (16.7%, 11.5%, and 19.1%), fruit (13.9%, 13.1%, and 14.0%), and vegetables (9.8%, 9.3%, and 10.0%)[6]. Ultra-processed products provided nearly 25.0% of the total fiber in the diet of the adolescents of Campinas. This results merits reflection, as the contribution of these products to fiber intake equals that of its energy contribution, meaning that an increase in the consumption of ultra-processed products would tend to lead to a reduction in dietary fiber intake[35]. Ultra-processed foods are nutritionally unbalanced and, according to the recommendations of the Food Guide for the Brazilian Population, should be avoided[17].

The increase in fiber intake was inversely associated with energy content, animal protein, total fat, saturated fat, cholesterol, and free sugar in the diet. Dietary fiber is naturally found in plant-based foods, which are good sources of nutrients and generally have a lower energy density in comparison to foods of an animal origin. Indeed, the current national recommendation is for predominantly plant-based foods *in natura* to be the basis of one's diet[17]. A study conducted with American adults (≥19 years) found that an increase in fiber intake contributed significantly to the increase in the diet quality score[45], showing that this nutrient is an important marker of the quality of one's diet, as found in the present investigation.

Among the limitations of this study, the use of a single 24hR does not represent the habitual food intake of adolescents due to the variability in the diet[19]. However, the 24hR is considered adequate for estimating the average intake of foods and nutrients when administered in a population-based study on different days of the week and months of the year.

Another limitation regards the use of self-rated diet quality, which is a construct that has been explored little in the literature. In 2017, Rodrigues et al.[46] investigated the applicability of the question "In your opinion, what is the quality of your diet?" to evaluate diet quality in adolescents and found 28% sensitivity and 79% specificity in detecting diets of good and poor nutritional quality, respectively. The authors pointed out the limitation in the use of this question for adolescents, as products such as cookies/crackers,

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sweets, sweetened beverages, and fast food were not perceived as being part of a diet of poor quality[46]. In the present study, lower fiber intake was found among the adolescents who rated their diet as being poor, which is in line with a result found in a study that reports an inverse relation between the consumption of ultra-processed foods and dietary fiber intake[35].

This study offers information on total dietary fiber intake as well as the soluble and insoluble fractions and describes food sources of this nutrient according to the NOVA classification in a representative sample of adolescents from the city of Campinas, Brazil. The results reveal insufficient fiber intake in all subgroups analyzed. Foods *in natura*/minimally processed foods provided nearly 70% of the total fiber content of the diet. Moreover, the consumption of energy, fat, free sugar, and animal protein diminished with the increase in fiber intake.

These findings underscore the importance of the recommendation for foods *in natura* and minimally processed foods[17] to constitute the basis of one's diet. The findings can also contribute to the planning of actions that promote healthy eating on both the individual and family levels.

Collaborations

RCF Meira participated in the proposal of the article, literature review, and writing of the manuscript. CD Capitani, AA Barros Filho, and MBA Barros performed a critical review of the intellectual content and statistical analyses. D Assumpção guided the proposal of the article, performed the data analysis, and contributed to the writing of the manuscript. All authors approved the final version of the manuscript.

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