

Association of dietary fiber intake with general and abdominal obesity in children and adolescents: The Weight disorder survey of the CASPIAN-IV Study

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Abstract.

BACKGROUND: Dietary fiber intake might have a protective role against obesity. The aim of this study is to explore the association of dietary fiber intake with general and abdominal obesity in Iranian children and adolescents.

MATERIAL AND METHODS: This cross-sectional nationwide study was conducted on 5187 students aged 6–18 years, living in 30 provinces of Iran. They were selected randomly through cluster sampling method. Data on demographic and anthropometric indices including weight, height and waist circumference (WC) were collected by trained interviewers. A valid and reliable 168-item semi-quantitative food frequency questionnaire (FFQ) was used to assess student's usual dietary intake including total dietary fiber. All dietary reports were converted to daily consumption (g/day) using household measures for different portion sizes. Food items were then converted to their nutrient content. Energy-adjusted dietary fiber intake (g/1000 kcal/day) was also calculated using the energy density method. Multivariate regression models were applied to explore the association between dietary fiber intake and anthropometric indices.

RESULTS: The mean and standard deviation (SD) for age of participants were 11.40 (3.20) years. Of 5187 students, 52.6% were boys and 72.5% were from urban areas (participation rate: 79.7%). White bread (32.5%), white rice (17.1%) and potato (11.7%) were the most common sources of dietary fiber intake. Each 1 g/1000 Kcal increase in dietary fiber intake was significantly associated with lower weight and waist circumference ($P=0.006$ and $P=0.008$, respectively).

CONCLUSION: Higher fiber intake was associated with lower anthropometric indices including weight and WC. Increased fiber intake should be encouraged for children and adolescents.

Keywords: Dietary fiber, body mass index, overweight and obesity, waist circumference, children and adolescents

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1. Introduction

Childhood overweight and/or obesity are known as an important predictor of obesity during adult life. Overweight and obesity in childhood are in alarming stage, worldwide [1]. Furthermore, health-related consequences of overweight, including type two diabetes, metabolic syndrome, cardiovascular disease (CVD), and some types of cancer are associated with poor quality of life, and higher prevalence of mortality [2, 3].

Dietary fiber, categorized as water-soluble and water-insoluble fiber, has been documented as an important cause of prevention and management of overweight and/or obesity and its co morbidities during the past four decades [4]. Dietary fiber is known as a residue of plant food that is resistant to digest and hydrolysis by human alimentary enzymes, and a heterogenic mixed of poly-saccharides and lignin, with potential health advantages for human body [5]. Previous studies have demonstrated a significant decrease in dietary fiber intake and thus a dramatic rise in overweight and/or obesity prevalence [6]. According to World Health Organization (WHO) recommendations, an average intake of 20 g/day of non-starch poly-saccharides and a minimum of 25 g/day of total dietary fiber might protect overweight and obesity health-related conditions [5]. Results of previous research show lower dietary fiber intake among European adolescents compared to the WHO recommendations [7–9].

An intervention study revealed better improvement in risk factors including fasting blood sugar, blood lipids and serum insulin levels of overweight and obese adults with higher fiber consumption [10]. A recent longitudinal study found that higher dietary fiber intake had favorable effects on body composition of children [11] and C-reactive protein (CRP) [12]. Evidence suggests that fiber intake might play an important role in prevention and management of child overweight and/or obesity [11, 13]. This effect is mediated through a balanced energy intake, and thus results in weight maintenance and regulation of blood lipids [14, 15].

The prevalence of child overweight or obesity is increasing worldwide [16], as well as Iran [17]. In recent years, change in lifestyle and dietary behaviors, including higher intake of energy-dense foods, have resulted in increasing prevalence of overweight and obesity both in developed [18] and developing countries such as Iran [19]. These rapid changes can be explained partly by nutrition transition in developing countries with getting away from healthy traditional foods and higher desire to convenient and Western food patterns [20]. The nutrition transition has began in the 1980s in Iran and its health-related outcomes have emerged since the 1990s [21, 22]. However, due to the lack of comprehensive information on dietary fiber intake of children and adolescents, the aim of the present study was to examine the association of fiber intake with general and abdominal obesity among a relatively large representative sample of Iranian children and adolescents.

2. Material and methods

This cross-sectional nation-wide study was performed in 2011-2012 as the fourth phase of the Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable disease (CASPIAN-IV), named as the weight disorders survey [23]. More details on the study objects and protocol have been described elsewhere [24]. Briefly, in this study, 23183 Iranian school-aged children and adolescents, 6–18 years old, of 30 provinces of the country were randomly selected via cluster sampling method. A 168-food item semi-quantitative food frequency questionnaire (FFQ) was used to assess student's usual dietary intake. This FFQ contained a list of foods with standard serving size commonly consumed in Iran. Parents were asked to report the child frequency consumption of each food group/item during the previous year according to the regular consumption such as daily (e.g., bread), weekly (e.g., rice, cheese) or monthly (e.g., fish). All dietary reports were converted to daily consumption (g/day) using household measures for different portion sizes. Food items were then converted to their nutrient content based on the protocol using Nutritionist IV, which was modified for Iranian foods [25]. Reliability and relative validity of the FFQ was examined before the study initiation [23]. Energy-adjusted dietary fiber intake (g/1000 kcal/day) was also calculated using the energy density method. Students with energy intake less than 800 Kcal and higher than 4200 Kcal were excluded from analysis

[26, 27]. Dietary guidelines for Americans was used to compare dietary fiber intake according to dietary fiber recommendations [28].

The ethics committees and all related organizations at national and provincial levels have approved the study protocol. After clarifying the study aims and protocols, written informed consent and oral assent were obtained from both parents and students, respectively.

Data on demographic and anthropometric measures were collected. Anthropometric indices including weight, height, waist circumference (WC), and hip circumference (HC) were examined by trained health care professionals under standard protocol using calibrated instruments. Weight was measured to the nearest 0.1 Kg in barefoot and lightly dressed condition. Standing height was recorded using a non-elastic tape, without shoes and to the nearest 0.1 Cm. Body mass index (BMI) was then calculated as weight in Kg divided by height in squared meters (m^2). Waist circumference (WC) was measured by a non-elastic tape to the nearest 0.2 cm at the end of expiration at the midpoint between the top of iliac crest and the lowest rib in standing position [23]. Waist-to-height ratio (WHtR) was calculated via division of waist to height and showing abdominal obesity if it was more than 0.5 [29].

We examined physical and screen time activities via the Physical Activity Questionnaire-Children (PAQ-C) [30]. Family socio-economic status (SES) was based on variables such as parental education and occupation, having own computer, type of student school (public vs. private), and family own car.

The World Health Organization (WHO) standard curves were used to identify underweight, overweight, and obesity in children and adolescents. Underweight was defined based on BMI less than 5th percentile for age and gender. Overweight individuals were classified as BMI between 85th and 95th percentiles, and obesity was defined as BMI more than the 95th centile for age and gender. We used the WHO Child Growth Standards, because they can be used to assess children everywhere, regardless of ethnicity, socioeconomic status and type of feeding [31].

2.1. Statistical analysis

To analyze the data, SPSS (version 20.0, SPSS, Chicago, IL) was used. One-way ANOVA, Independent sample *t*-test and Chi-square tests were used for quantitative and qualitative variables, respectively. Mean, standard deviation (SD) and frequency (percentages) were calculated for quantitative and qualitative variables, respectively. Multivariate analysis was applied to explore the association between dietary fiber intake and anthropometric indices. All analysis were adjusted for confounders including age, gender, physical activity, SES, and energy intake. *P*-value less than 0.05 was considered as the significant level.

3. Results

The mean and standard deviation (SD) for age of participants were 11.40 (3.20) years. Data of FFQ and analysis of dietary nutrients was available for 5187 students. Of 5187 students participated in the present study, 52.6% were boys and 72.5% were from urban areas (participation rate: 79.7%). Demographic and anthropometric characteristics of students are presented in Table 1. Mean of BMI, WC, HC and WHtR was significantly different between both genders. Total dietary fiber intake was significantly different between three age categories, 6–9.9, 10–13.9 and 14–18 years, of boys ($P=0.05$) and girls ($P=0.004$). Girls aged 6–9.9 years had lower intake of total dietary fiber compared to girls aged 10–13.9 (P -value of *Post-Hoc* test = 0.03) and 14–18 years (P -value of *Post-Hoc* test = 0.02).

Table 2 presents the common sources of different food groups to total dietary fiber intakes of students; white bread (32.5%), white rice (17.1%) and potato (11.7%) were the most common sources of dietary fiber intake.

Table 3 shows the estimated mean total energy intake, total fiber and energy-adjusted fiber intake of students according to gender and three age-categories. Mean energy-adjusted fiber intake was significantly different

Table 1
Demographic and anthropometric characteristics of students participated in the Weight disorders survey of the CASPIAN-IV study

	Boys (2728)	Girls (2459)	Total (5187)	P-value
Age ¹ (Year)	11.26 [11.12 11.40]	11.55 [11.42 11.68]	11.40 [11.31 11.49]	0.003*
Weight ¹ (Kg)	42.16 [18.4318.84]	42.28 [19.1219.59]	42.22 [41.70 42.75]	0.815
BMI ¹ (Kg/m ²)	18.63 [41.38 42.92]	19.35 [41.38 42.92]	18.97 [18.8119.11]	<0.001*
WC ¹ (Cm)	67.24 [66.7767.77]	65.80 [65.2866.29]	66.56 [66.1866.89]	<0.001*
HC ¹ (Cm)	79.44 [78.9279.98]	82.17 [81.5882.78]	80.73 [80.29 81.15]	<0.001*
WHR ¹	0.46 [0.4540.460]	0.45 [0.4490.455]	0.45 [0.4530.457]	0.017*
Abdominal obesity (%)	16.6%	15.4%	16.0%	0.30
Overweight (%)	14.9%	16.6%	15.7%	0.13
Obesity (%)	10.8%	8.7%	9.7%	0.02*
Father education (%)				
Illiterate/under diploma	64.2%	59.8%	62.1%	0.012*
Diploma	23.8%	26.1%	24.9%	
Bachelor and upper	12%	14.1%	13%	
Mother education (%)				
Illiterate/under diploma	68.4%	66.5%	67.5%	0.38
Diploma	22.5%	23.6%	23%	
Bachelor and upper	9.1%	10%	9.5%	
Family size (%)				
Equal or less than 4 person	51.4%	52.1%	51.7%	0.66
More than 4 person	48.6%	47.9%	48.3%	
SES (%)				
Low	33.1%	33.0%	33.0%	0.82
Moderate	33.2%	34.1%	33.6%	
High	32.7%	32.9%	33.3%	
Physical activity (%)				
Mild	21.4%	44%	31.9%	<0.001*
Moderate	35.3%	35.2%	35.3%	
Vigorous	43.2%	20.8%	32.8%	
WatchingTV(%)				
>2 h/day	53.4%	58.8%	58.6%	0.810
≤2 h/day	41.6%	41.2%	41.4%	
Using computer and internet (%)				
>2 h/day	18.6%	10.3%	14.6%	<0.001*
≤2 h/day	81.4%	89.7%	85.4%	
Screen time activity (%)				
>4 h/day	32.7%	26.1%	29.6%	<0.001*
≤4 h/day	67.3%	73.9%	70.4%	

¹ Values are shown as mean and confidence intervals (95% CI). Abdominal obesity: waist-to-height >0.5. BMI; body mass index, WC; waist circumference, HC; hip circumference, WHtR; waist-to-height ratio, SES; socio-economic status.

among 6–9.9, 10–13.9 and 14–18 years old students ($P=0.006$). Students aged 6–9.9 year had significantly lower intake of energy-adjusted dietary fiber than students of 10–13.9) P -value of *Post-Hoc* test = 0.005) and 14–18 year (P -value of *Post-Hoc* test = 0.05).

Table 2
Common sources of different food groups to total dietary fiber intakes of students participated the Weight disorders survey of the CASPIAN-IV study

Food groups ¹	Total dietary fiber		
	All	Boys (2728)	Girls (2459)
Beverages	1	1	1.1
Bread and breakfast:			
White bread	32.5	35.2	30.9
Whole-grain bread	12.7	12.5	13.4
Potatoes and grains:			
Starch roots and wheat flour	2.09	2.1	2.2
Potatoes	11.7	12	11.9
Pasta and noodles	8.05	8.2	8.2
rice and other cereals	17.1	17.7	17.2
Total vegetables:			
Fresh vegetables, vegetable salad, cooked vegetables, excluding potatoes	26.01	25.5	27.6
Legume, soy products:			
Pulses (excluding fresh peas, sweet corn and broad bean)	7	7	7.2
Total fruits:			
Fresh fruits	16.8	16.7	17.7
Canned fruits	0.38	0.4	0.4
Dried fruits	1.5	1.4	1.7
Olives	0.98	0.9	1.1
Milk, milk products, cheese	1.9	1.9	1.9
Meat, poultry, fish, eggs, nut and seeds:			
Nuts	5.9	6.2	5.8
Rest group ² (snacks and desserts):	1.6	1.7	1.7
Cakes, pies, biscuits	1.2	1.3	1.3
Chocolate	1.9	1.9	2
pickles	1.2	1.1	1.3

¹Top 10 food groups and subgroups contributed to most total fiber intake: (1) beverages (including juices, excluding the rest group) including subgroups of (a) water, (b) soups (c) coffee and tea, (d) fruit and vegetable juices, (e) carbonated/soft drinks; (2) bread and breakfast cereals including subgroups of (a) White bread, (b) Whole-grain bread; (3) potatoes and grains including subgroups of (a) starch roots and wheat flour, (b) potatoes, (c) pasta and noodles, (d) rice and other cereals; (4) total vegetables including subgroups of fresh vegetables, vegetable salad, cooked vegetables, excluding potatoes, (5) legume, soy products including subgroups of pulses (excluding fresh peas, sweet corn and broad bean), (6) total fruits including subgroups of (a) fresh fruits, Canned fruits, dried fruits, (b) olives; (7) milk, milk products, cheese including subgroups of (a) white-milk and buttermilk, (b) yogurt, (c) milk and yogurt beverages, (d) cheese, (e) desserts and puddings milk based (including ice cream), (f) other milk products; (8) fat, oil, cream cheese including subgroups of (a) butter and animal fats, (b) margarine and lipids of mixed origins; (9) meat, poultry, fish, eggs, nut and seeds including subgroups of (a) meat, poultry and processed meat, (b) fish products, (c) eggs, (d) nuts and seeds (including nut- and seed-spreads), (10) rest group including subgroups of (a) cakes, pies, biscuits, (b) chocolate, (c) creams (including non-dairy and coffee creams), (d) sugar, honey, jam and syrup, (e) confectionery non chocolate, (f) other sugar products, (g) sauces (excluding dessert sauces), (h) products for special nutritional use. ²Rest group (snacks and desserts) was defined as energy-dense, low-nutritious foods. Data represented as percent.

As presented in Table 4, anthropometric parameters of both genders were compared according to dietary fiber recommendations (by age and gender). Students with equal or higher dietary fiber intake according to recommendations had significantly lower weight ($P=0.001$ for boys, $P<0.001$ for girls), body mass index

Table 3

Estimated mean total energy intake, and total, energy-adjusted, water-soluble and water-insoluble dietary fiber intakes of students participated in the Weight disorders survey of the CASPIAN-IV study according to gender and age categories

	Total (5187)	Boys (2728)	Girls (2459)	<i>P</i> -value	6–9.9 years (1387)	10–13.9 years (1659)	14–18 years (1279)	<i>P</i> -value
	Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)	
Energy (Kcal/day)	2553.44 (781.5)	2519.2 (795.6)	2524.5 (770.2)	0.83	2479.2 (775.4)	2545.5 (790.8)	2554.3 (778.2)	0.024*
Total fiber (g/day)	27.41 (10.76)	27.02 (11.13)	26.70 (10.40)	0.33	25.97 (10.44)	27.35 (10.92)	27.41 (10.95)	0.001*
Energy-adjusted fiber (g/1000 Kcal/day)	11.04 (3.45)	11.01 (3.67)	10.88 (3.38)	0.22	10.71 (3.34)	11.12 (3.70)	11.01 (3.53)	0.006*

SD: standard deviation.

Table 4

Meandifference between two group of dietary fiber intake in the Weight disorders survey of the CASPIAN-IV study according to gender and age categories

Dependent Variable	Group	Boys (2728) (I= 1085 J= 1530)				Girls (2459) (I= 1315 J= 1067)			
		Mean	SD	Mean Difference (I-J) (SD)	<i>P</i> -value	Mean	SD	Mean Difference (I-J) (SD)	<i>P</i> -value
Weight (Kg)	J: dietary fiber intake < recommended*	45.87	0.505	-8.92 (0.81)	0.001*	43.5	0.555	-4.58 (0.72)	<0.001*
BMI (Z-score)	I: dietary fiber intake ≥ recommended	36.95	0.617			38.92	0.488		
WC (Cm)	J: dietary fiber intake < recommended	19.01	0.130	-0.951 (0.21)	0.001*	19.25	0.170	-0.521 (0.22)	0.019*
WHtR	I: dietary fiber intake ≥ recommended	18.06	0.159			18.73	0.149		
	J: dietary fiber intake < recommended	69.12	0.356	-4.27 (0.57)	<0.001*	66.02	0.398	-1.74 (0.52)	0.01*
	I: dietary fiber intake ≥ recommended	64.85	0.435			64.28	0.350		
	J: dietary fiber intake < recommended	0.453	0.002	-0.011 (0.003)	<0.001*	0.445	0.002	-0.009 (0.003)	0.002*
	I: dietary fiber intake ≥ recommended	0.464	0.002			0.454	0.002		

*:Daily recommendation intakes of fiber by age and gender. Girls aged 4–8:5 g/day, girls aged 9–13:26 g/day, girls aged 14–18:29 g/day. Boys aged 4–8:25 g/day, boys aged 9–13:31 g/day, boys aged 14–18:38 g/day. *Adapted from 2005 dietary guideline advisory committee. Nutrition and your health: dietary guidelines for Americans. J: dietary fiber intake < recommended. I: dietary fiber intake ≥ recommended. SD; standard deviation, BMI; body mass index, WC; waist circumference, WHtR; waist-to-height ratio. Adjusted model for physical activity, total fat intake, age.

z-score ($P=0.001$ for boys, $P=0.019$ for girls), WC ($P<0.001$ for boys, $P=0.01$ for girls) and waist-to-height ratio (WHtR) ($P<0.001$ for boys, $P=0.002$ for girls) compared to those with lower intakes.

Association of dietary fiber intake with obesity indicators are shown in Table 5. Each 1 g/1000 Kcal increase in dietary fiber intake was significantly associated with reduction of weight and WC ($P=0.006$ and $P=0.008$, respectively).

Table 5
Association between dietary fiber intake and indicators of obesity of students participated in the Weight disorders survey of the CASPIAN-IV study

Dependent variables	Energy-adjusted total dietary fiber			P-value
	β	SE	95% CI	
Weight (Kg)	-0.381	0.138	[-0.651 -0.111]	0.006*
BMI (Z-score) (Kg/m ²)	0.021	0.012	[-0.002 0.044]	0.077
WC (Cm)	-0.325	0.122	[-0.565-0.086]	0.008*
WHtR	0.001	0.001	[-0.001 0.002]	0.497

SE; standard error of coefficient, BMI; body mass index, WC; waist circumference, WHtR; waist-to-height ratio. Adjusted model for age, gender, physical activity, total fat intake, total carbohydrate intake and two way interaction between age and energy-adjusted total dietary fiber.

4. Discussion

The present study is the first large Iranian nation-wide survey to provide useful information on total dietary fiber, energy-adjusted dietary fiber, common food sources and its association with anthropometric indices.

The result showed that intake of higher fiber was associated with lower anthropometric indices including weight and WC. We found that on average, students with equal or higher dietary fiber intake according to recommendations had significantly lower weight, BMI z-score, WC and WHtR compared to those with lower intakes. In addition, white bread, white rice, refined cereals and potato were the common sources of dietary fiber intake.

Rate of overweight and obesity is increasing worldwide among both children and adults [32–34]. Dietary fiber intake has beneficial effects on prevention and/or treatment of obesity in children and adults [35], however, previous research on fiber intake and body composition has mostly focused on adult population and data of children and adolescents are not consistent [36–38]. According to our results, dietary fiber intake was associated with significantly decrease in body weight and WC, but not in BMI z-score. Previous studies demonstrated an inverse association of dietary fiber intake and obesity among healthy female adolescents [39] and central adiposity in overweight adolescents [11, 40].

Another study on a sample of British children found that lack of dietary fiber intake was related to higher adiposity [37] and 15 g additional fiber in accordance to a low-calorie diet resulted in 2 Kg more weight reduction [41]. However, several other studies found no association between high intakes of dietary fiber and favorable changes in body weight and body composition [42, 43].

Previous findings indicated that dietary fiber intake might not have an effect on body fat percentages (BF%) or BMI during puberty. Similar to our findings, non-significant changes were documented in BMI and BF% of adolescents with high consumption of whole grains, as a fiber source [43] and no relation was observed between dietary fiber intake and adiposity among overweight Latino youth [38]. Results of a review study stated that dietary fiber derived from fruit and vegetable intake might not directly result in reduced risk of overweight and obesity, while water insoluble fiber is directly responsible for overweight or obesity management [44].

One possible explanation for the favorable effect of dietary fiber intake on body weight might be the increase of satiety feeling [36]. Higher viscosity of soluble fiber intake could result in postprandial glucose levels and higher insulin sensitivity, followed by delayed gastric emptying and increasing satiety [36]. However, inconsistent findings might be due to different time periods, diverse populations, the amount and type of fiber evaluated in these studies [36].

It is noteworthy that physical activity (PA) was an important confounder, as the association of dietary fiber consumption with obesity parameters was modified after adjustment for PA levels. Other potential confounding factors such as Tanner stage, region and unknown underlying factors might explain the conflicting effects of

dietary fiber intake on obesity indicators. Although, statistical analysis of the current study were adjusted for age, gender, PA, and total calorie intake, it is possible that the observed non-significant association of BMI z-score and dietary fiber consumption might be due to misreporting. Puberty, in particular, might affect the association between dietary fiber intake and obesity-related indices [39, 42, 43].

The Weight disorder survey of the CASPIAN-IV Study is the first large scale nation-wide survey evaluating nutrition related aspects of Iranian children and adolescents through standard procedures. In the current study, we assessed consumption of total and energy-adjusted dietary fiber in relation to obesity related indices including BMI, WC, and WHtR in a large representative sample of Iranian children and adolescents. Standardized methods were conducted to estimate student's dietary intake by using a valid FFQ [23].

However, some limitations of the current study need to be addressed. First, the nature of this study precludes any cause and effect relations. Second, since definition of dietary fiber differ between different food composition tables and due to a large number of missing data for fiber content of food items in these tables, we used a same food composition table to estimate nutrient intake. Third, food processing was not accounted in the current study, which might have an effect on accurate estimation of total dietary fiber. Forth, only dietary fiber but not functional fiber could be estimated in this data set. Moreover, only data on total dietary fiber, but not soluble and insoluble dietary fiber was available and therefore the particular effects of these two types of dietary fiber were not evaluated. Fifth, the accuracy of self-reported dietary intake data is often a limiting factor. Although we used a valid and reliable FFQ, accuracy of collected dietary data might not reflect true intake due to recall bias and under, over-reporting, thus misclassification of students according to dietary fiber intake might occur.

These findings show a favorable association of dietary fiber intake and anthropometric indices of general and abdominal obesity. Most of the students in this study consumed dietary fiber less than the recommendations (data not shown). Therefore, children and adolescents should be encouraged to eat more fiber-rich foods such as fruits, vegetables and whole grains. Increasing amount of intake of fiber could have a protective effect against the risk of obesity and obesity-related complications among youth, including metabolic syndrome, type two diabetes, and cardio-vascular disease.

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