British Journal of Nutrition (2019), 121, 340–350
doi:10.1017/S0007114518003240

Association of Dietary Inflammatory Index with anthropometric indices in children and adolescents: the weight disorder survey of the Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Disease (CASPIAN)-IV study

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(Submitted 26 December 2017 – Final revision received 27 August 2018 – Accepted 16 September 2018 – First published online 3 December 2018)

Abstract

This study aimed to assess the relationship between the Dietary Inflammatory Index (DII®), a validated tool for evaluating diet-associated inflammation, and anthropometric indices in children and adolescents. This multicentre survey was conducted on 5427 school students selected via multistage cluster sampling from thirty provinces of Iran. This survey was conducted under the framework of the weight disorders survey, which is part of a national surveillance programme entitled Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Diseases-IV. For calculating the DII scores, twenty-five dietary factors were obtained from a validated 168-item FFQ. Height, weight, wrist circumference, neck circumference (NC), waist circumference (WC) and hip circumference (HC) were measured. BMI *z*-score, waist circumference:hip circumference ratio (WHR), waist circumference:height ratio (WHtR) and parental BMI were computed. Linear regression models were used to evaluate the association of DII and anthropometric indices. Significant trends were observed across quartiles of DII score for all anthropometric indices in all participants ($P < 0{\cdot}05$), except for WHR and WHtR. After adjustment for potential confounders, the multiple linear regression analysis for each anthropometric index revealed that participants in the highest DII quartile had higher BMI *z*-score, WC, HC and parental BMI compared with those in the first (or lowest) quartile. In summary, we found that a pro-inflammatory diet was associated with higher BMI *z*-score, wrist circumference, NC, WC, HC and parental BMI. The large sample size of the present study may influence the statistical significance of observed associations. Hence, the findings should be clinically interpreted with caution.

Key words: Diet: Inflammation: Obesity: BMI: Dietary Inflammatory Index

Childhood obesity is emerging as a global problem and concern[1–3]. The results of a worldwide survey demonstrated that almost one-fifth of children were above normal weight (Wt)[4]. In 2010, the prevalence of childhood obesity in Europe, Southeast Asia and the Americas was 10, 5 and 15 %, respectively[5]. Prevalence rates are reported from Iran[6] similar to

Abbreviations: CRP, C-reactive protein; DII, Dietary Inflammatory Index; HC, hip circumference; Ht, height; PA, physical activity; SES, socio-economic status; ST, screen time; WC, waist circumference; WHR, waist:hip ratio; WHtR, waist circumference:height ratio; Wt, weight.

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many other developing countries[7]. Childhood obesity represents a range of disability and is a risk factor for many chronic disorders of adulthood such as osteoarthritis, cardiovascular and gall bladder diseases, as well as diabetes[8–10].

In obesity, concentrations of biomarkers of low-grade systemic inflammation such as C-reactive protein (CRP), TNF-α, IL-6 and IL-8 are increased[11–15]. Several studies revealed positive correlation between inflammatory biomarkers and anthropometric indices of obesity[15–25]. A positive association between CRP and BMI or waist circumference (WC) is seen in several observational surveys[15,18–23]. Moreover, this association was observed between CRP and waist circumference: height ratio (WHtR)[24,25].

Components of diet can affect systemic inflammation. Results of surveys indicate that high consumption of whole grains, olive oil, fruits, vegetables and fish, and low consumption of butter and red meat and low/moderate intake of wine (Mediterranean dietary pattern) are accompanied by reduced levels of inflammation. By contrast, the Western dietary pattern (rich in refined grains, red meat and high-fat dairy products) has been associated with high levels of inflammatory biomarkers[26–28]. Numerous studies have illustrated that nutrients such as fibre[29], complex carbohydrates[30], moderate consumption of alcohol[31], n-3 PUFA[32], vitamin C[33], vitamin E[34], Mg[35] and β-carotene[36] have some anti-inflammatory effects, while SFA and sugar tend to have pro-inflammatory effects[37,38].

Several dietary indices exist for evaluating the quality of an individual's diet[39–41]. One of these indices is the Dietary Inflammatory Index (DII®), which was first described in 2009[42] and updated in 2014[43]. The DII is used to evaluate the inflammatory potential of diet based on pro- and anti-inflammatory properties of specific food items, spices, macronutrients, micronutrients and flavonoids[43]. In two observational studies, a significant association was demonstrated between DII score and anthropometric indices in adults[44,45]. Results of a cohort in the USA indicated the relationship between maternal prenatal and early childhood DII with mid-childhood WC and BMI z-score[46].

Given that there is no study focusing on the association between the DII and anthropometric indices in children and adolescents in Middle Eastern countries, the present study was conducted to evaluate this relationship using data derived from the fourth survey of an Iranian national surveillance programme entitled the Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Diseases (CASPIAN-IV). The hypothesis of the present study is that high inflammatory potential of diet, indicated by higher DII score, is related to higher levels of anthropometric indices.

Methods

Ethical statement

The study protocol was approved by the Ethics Committee of Isfahan and Alborz Universities of Medical Sciences (code: 194049). The objectives of the study were explained to the students and their parents, and the informed consent form and oral assent were obtained from eligible parents and students who wished to participate. The study was conducted according to the guidelines of the Declaration of Helsinki (Seoul, 2008).

Study design and population

The present study is based on data obtained from the CASPIAN-IV study. This nationwide cross-sectional survey was performed among students aged 6–18 years, from urban and rural areas of thirty provinces of Iran in 2011–2012. Students were selected by multistage, cluster sampling. Stratification was done in each province according to the number of students (proportional to size) in each residential area (urban/rural) and education grade (elementary/intermediate/high school) with equal numbers of boys and girls. Cluster sampling with equal clusters (eighty-three clusters) was used in each province to reach the necessary sample size. Clusters were defined at the level of schools and ten students were selected in each cluster. The sampling frame was defined based on the information bank of Ministry of Education. In each province, schools were categorised by type and name of school and the number of students was added cumulatively in each province. A total of ten students were randomly selected from clusters when the clusters were defined in each province. Finally, eighty-three clusters were selected and a total of 25 000 students were selected. In each province approximately a quarter of clusters, a total of 6505 students, were selected randomly for dietary assessment. Among 6505 invited students for dietary assessment, students following special diets (104 students); those having a history of chronic diseases, for example, type 1 diabetes, the metabolic syndrome (MetS), CVD (212 students); those using medications such as glucose-, lipid- and blood pressure-lowering medications (eighty-eight students); and those with incomplete dietary data (674 subjects) were excluded from our analysis. A total of 5427 students were included in the present study. None of these students consumed fortified foods. The methodology of the present study was published previously[47].

Demographic information

Demographic variables were collected using a validated questionnaire provided based on the WHO Global School-based Student Health Survey[48,49]. The data were obtained from all participants through conducting an interview with one of their parents in the sampled classes of the selected schools. The variables related to the family consisted of family history of chronic diseases (diabetes, hypertension, obesity and dyslipidaemia), level of parental education (the total years of schooling), having a family private car, type of home (rented/owned), dietary behaviours, physical activity (PA) and sedentary lifestyle behaviours.

Dietary assessment

Assessment of usual dietary intakes for students was conducted using a validated 168-item semi-quantitative FFQ[50,51], which included a description of standard serving sizes. This questionnaire was validated for children and adolescents

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before (Cronbach's α coefficient = 0·96)[52]. The FFQ for children <10 years old was completed by the student's parent; students ≥10 years old completed the form by themselves. Reports consisted of the standard portion size and frequency of consumption of each food item during the previous year on a daily, weekly, monthly or yearly basis, as appropriate. Frequencies of consumption of foods for each person were converted to daily frequencies and then the gram amount consumed daily for each food item was computed using household scale guide. For nutrient analyses, Nutritionist 4 software (First Databank; Hearst), including the United States Department of Agriculture (USDA) food composition data, was used. Other food items, which were not included in this database, were analysed by means of Iranian food composition table[53].

Anthropometric measurements

Expertly trained staff conducted all anthropometric measurements in the selected schools. Body Wt was evaluated to the nearest 0·1 kg without shoes and wearing only light clothing. Height (Ht) was assessed to the nearest 0·1 cm with each participant standing without shoes and the shoulders positioned against a stadiometer. Wt and Ht were used to calculate the BMI (BMI = Wt (kg)/Ht (m)^2)[54,55]. Parental Wt and Ht also were measured. BMI *z*-scores of the students for age and sex were computed based on WHO growth reference standards for children aged between 5 and 19 years.

Students' WC was measured to the nearest 0·1 cm in the midpoint between of the lowest rib and the iliac crest, with the students standing and breathing out (i.e. expiring). Hip circumference (HC) was assessed to the nearest 0·1 cm at maximum level of the ileac crest without any pressure to body surface. Neck circumference (NC) was evaluated underneath the Adam's apple at a comfortable position to the nearest 0·1 cm. Wrist circumference was assessed on the dominant arm to the nearest 0·1 cm. The participants were asked to hold their arm on a flat surface such as a table. The superior border of the tape measure was placed just distal to the prominences of radial and ulnar bones. All assessments were carried out using a non-elastic tape. Waist:hip ratio (WHR) and WHtR were calculated by dividing WC to HC and WC to Ht, respectively[47].

Socio-economic status

Principal components analyses were used to provide a summary measure of socio-economic status (SES) of students. Relevant questions entered in this analysis included type of home, parental education, parent's job, possessing private car, school type (public/private) and having personal computer. These variables were incorporated as a unit index[56], and finally this index was categorised into three grades (low, moderate and high). Questions about SES were asked to the student's parent for children <10 years, while students ≥10 years old completed the questionnaire independently.

Physical activity and screen time

The Physical Activity Questionnaire for Adolescents (PAQ-A) was used to evaluate the levels of PA in children and adolescents. In this questionnaire, the students' 7-d recalls of sports or activities were assessed by a self-administrated questionnaire. The validity and reliability of the questionnaire has been tested in the Iranian paediatric population[52]. The questions included sports or activities that caused the participants to sweat or feel tired in their legs or exercises that made them breathe with difficultly, for example, running, climbing and playing on rope. The questionnaire also collected information regarding PA during the physical education period, leisure time, lunch time and after school, in the evenings and during weekends[57,58]. The total score of PAQ-A questionnaire was 1–5, and PA was categorised as low (students with scores between 1 and 1·9) and high (students with scores between 2 and 5) levels[58,59].

In the present study, the average number of hours per day in which the students spent watching personal computer, television and electronic games was used to estimate the screen time (ST) behaviour during the entire week. According to the international ST recommendations, this variable was categorised into two: low (<2 h/d) and high (2 h/d or more) grades[60,61]. Parents of children <10 years of age completed questions about PA and ST behaviour of students, while students ≥10 years old completed their questionnaire independently.

Dietary Inflammatory Index

The DII® was developed to determine the inflammatory potential of the diet. Development of this index has been described completely elsewhere[43]. Briefly, 1943 papers published from 1950 to 2010 that assessed the effect of whole foods, spices and nutrients (forty-five dietary factors) on specific inflammatory markers (IL-1β, IL-4, IL-6, IL-10, TNF-α and CRP) were reviewed and scored. Each dietary factor that was accompanied by a significant higher values of IL-1β, IL-6, TNF-α or CRP or lower values of IL-4 or IL-10 was considered a pro-inflammatory component (+1 score), and each dietary factor that was associated with significant lower amounts of IL-1β, IL-6, TNF or CRP or higher amounts of IL-4 or IL-10 was considered as an anti-inflammatory component (–1 score); 0 was obtained for items that had no significant effect on six inflammatory biomarkers.

First, global mean intake of each dietary factor was subtracted from dietary intake of it, and then this value was divided by world standard deviation intake of that factor as derived from the data sets of eleven countries (i.e. to obtain the *z*-score). To minimise the effect of 'right skewing', dietary factor-specific *z*-scores were converted to a proportion (i.e. with values from 0 to 1). Next, these values were multiplied by 2 and then 1 was subtracted to achieve a symmetrical distribution with a range of –1 to +1 and centred on 0. To obtain the factor-specific DII score of each food, the amount for each dietary factor was multiplied by the overall dietary factor-specific inflammatory effect score. Finally, all dietary factor-specific DII scores were summed to calculate the overall DII score for each student.

https://doi.org/10.1017/S0007114518003240 Published online by Cambridge University Press

Data on twenty-five items of forty-five possible dietary factors that could be used to calculate the DII score were available in this study. Energy, carbohydrate, protein, total fat, cholesterol, SFA, vitamin B_{12} and Fe were the pro-inflammatory components, and MUFA, PUFA, fibre, folic acid, niacin, riboflavin, thiamin, vitamin A, vitamin C, vitamin D, vitamin E, vitamin B_6, Zn, Se, Mg, β-carotene and caffeine were the anti-inflammatory items. The remaining components of DII were not collected as part of the FFQ.

Statistical analyses

Data analyses were performed using STATA® software (version 11). Means and standard deviations and percentages were used to illustrate quantitative and qualitative variables, respectively. DII score and intake of energy and macronutrients were presented as medians and interquartile ranges in both sexes of students. The independent-samples *t* test was performed for comparison of the means between two groups. One-way ANOVA was used to compare the trend of mean values of the anthropometric indices across DII quartiles. The Mann–Whitney *U* test was applied for comparing medians of energy, macronutrients and DII score in two groups of students. The percentages of categorical variables were compared using Pearson's χ^2 test. For evaluating the association between anthropometric indices (dependent variables) and DII score (categorised and continuous independent variables), linear regression models were used. There was no adjustment for covariates in one of the models (model I), while age, sex, place of residence, ST and PA and SES were adjusted in the other model (model II). The first quartile of DII score was considered the referent. A cluster sampling procedure was applied in all analyses. All *P* values were corrected using the Benjamini–Hochberg correction method to control the false discovery rate due to the multiple comparison problem[62]. The adjusted *P* value <0·05 was considered as statistically significant after the multiple comparison correction.

Results

In this national survey, 5427 students (53·2 % boys) with a mean age of 12·61 (SD 3·23) years were included. The anthropometric indices and other characteristics of participants were presented by sex (Table 1). Among anthropometric indices Ht, wrist circumference, NC, WC and WHR were significantly higher in boys than in girls (P for all <0·001). Girls had significantly higher BMI *z*-score and HC compared with boys (P for all <0·001). The BMI of girls' parents was slightly higher than boys' parents (27·40 (SD 5·32) *v.* 27·06 (SD 5·05) kg/m^2) ($P=0·01$).

Most participants lived in urban areas (71·4 %). In general, no significant association was found between sex and SES ($P=0·08$). However, more boys had high PA levels than that observed in girls (62·5 *v.* 35·8 %) ($P<0·001$) (Table 1). Also, ST was significantly higher in boys than in girls (81·7 *v.* 77·1 %) ($P<0·001$).

Table 2 shows sex-specific means of DII, intake of energy and macronutrients. All differences among both sexes were not statistically significant.

Table 3 presents means and standard deviations of anthropometric indices according to the DII quartiles. The lower and upper limits of the DII for each quartile are provided. Overall, higher means of BMI *z*-score, NC, wrist circumference, HC and WC were associated with higher DII score (P_{trend} <0·001 in all comparisons). Anthropometric indices in boys had a significant escalating trend across DII quartiles for all parameters except for WHR and WHtR (P_{trend} in all comparisons was significant). In girls higher DII score was associated with higher BMI *z*-score, HC and WC (P_{trend} for all comparisons <0·05).

Table 4 presents results from the linear regression models fit to describe the association between anthropometric indices and quartiles of DII score as categorical and continuous variable. In the categorical form of DII quartile, in the multivariate model (after adjustment for potential confounders), students in the highest quartile of DII had higher BMI *z*-scores compared with those in the first quartile as reference ($P<0·05$). With respect to WC, individuals in the highest quartile of the DII had higher level of WC compared with those in the lowest quartile ($P<0·05$). Moreover, students in the highest quartile of DII had higher level of HC compared with the individuals in the first quartile ($P<0·05$). Students' parents in the second, third and highest quartiles of the DII had higher BMI compared with those in the lowest quartile ($P<0·05$). When we considered DII quartile as a continuous variable, a significant association was observed between the DII quartile and WC, HC and parental BMI ($P<0·05$). In the crude and multivariate model, the association of WHR and WHtR with DII quartiles was not statistically significant.

Discussion

In this nationwide study performed on Iranian students, the association between overall inflammatory potential of diet, estimated by DII score, and anthropometric indices was assessed. Higher DII scores were associated with higher BMI *z*-scores, wrist circumference, NC, WC and HC in all students and BMI of their parents. These associations were observed among boys, whereas higher DII score was associated with higher BMI *z*-score, WC and HC in girls. Results that included positive relationship between DII and BMI *z*-score of students, HC, WC and parental BMI persisted after adjusting for potential confounders, including age, sex, place of area, ST, PA and SES.

Higher DII score was associated with general obesity (assessed by BMI *z*-score) in the students. This finding might be associated with the consumption of more pro-inflammatory diets (e.g. fast foods, cookies and crackers), which tend to be energy dense[63,64]. This result is line with the study of Ramallal *et al.*[65] that showed consumption of an anti-inflammatory diet (lower DII) was associated with lower BMI; with the corollary that participants with pro-inflammatory diet (higher DII) tended to be overweight or obese. The findings of the present study in children and adolescents are consistent with the results of a Spanish study conducted in 7236 adult participants[45]. An observational study on 430 young Americans, aged 21–35 years, indicated no significant association between DII and BMI[66]. This discrepancy may have resulted from the small sample size

https://doi.org/10.1017/S0007114518003240 Published online by Cambridge University Press

Table 1. Characteristics of the study population according to sex in the weight disorders survey of the Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Disease-IV study
(Mean values and standard deviations)

	Total (*n* 5427)	Boys (*n* 2886)	Girls (*n* 2541)	*P**
Age (years)				0·04
Mean	12·6	12·5	12·7	
SD	3·2	3·3	3·1	
Weight (kg)				0·36
Mean	70·6	71·0	70·2	
SD	13·5	13·6	13·4	
Height (cm)				<0·001
Mean	161·2	162·0	160·3	
SD	8·8	9·4	8·11	
BMI *z*-score				<0·001
Mean	0·0	0·0	0·0	
SD	0·0	0·8	0·9	
Wrist circumference (cm)				<0·001
Mean	14·8	15·0	14·7	
SD	2·2	2·0	2·3	
NC (cm)				<0·001
Mean	30·4	30·8	30·0	
SD	4·9	5·0	4·8	
WC (cm)				<0·001
Mean	67·0	67·8	66·1	
SD	11·9	12·4	11·2	
HC (cm)				<0·001
Mean	81·2	80·0	82·5	
SD	13·6	13·1	14·0	
WHR				<0·001
Mean	0·8	0·8	0·8	
SD	0·1	0·1	0·1	
WHtR				0·84
Mean	0·4	0·4	0·4	
SD	0·2	0·1	0·2	
Parental BMI (kg/m^2)				0·01
Mean	27·2	27·0	27·4	
SD	5·1	5·0	5·32	
ST (h/d)				<0·001
Mean	3·3	3·5	3·1	
SD	2·1	2·2	2·1	
Place of residence (%)				<0·001
Urban	71·4	68·7	74·4	
Rural	28·6	31·3	25·6	
SES (%)				0·08
Low	33·2	34·6	31·6	
Moderate	33·5	32·9	34·3	
High	33·3	32·5	34·1	
PA (%)				<0·001
Low	50·0	37·5	64·2	
High	50·5	62·5	35·8	
ST (%)				<0·001
Low	20·4	18·3	22·9	
High	79·6	81·7	77·1	

NC, neck circumference; WC, waist circumference; HC, hip circumference; WHR, waist:hip ratio; WHtR, waist:height ratio; ST, screen time; SES, socio-economic status; PA, physical activity.
* *P* values for the comparisons between quantitative variables were derived using the independent-samples *t* test, while for the comparisons of categorical variables the χ^2 test was used.

of that study. In line with the present study, a meta-analysis was performed on three cross-sectional studies, indicating higher protein (a pro-inflammatory dietary factor) consumption in obese *v.* non-obese subjects[67]. A cross-sectional study conducted in 2013–2014 found that high fat (a pro-inflammatory dietary factor) intake is associated with higher BMI, and individuals with normal BMI consumed higher amounts of fibre compared with the obese persons[68].

The present finding on the association between DII and WC is consistent with a previous research conducted on older adults[45]. Similarly, a case–control study performed on Cuban-American population with and without type 2 diabetes and aged >30 years indicated a direct association between WC and CRP[23]. Likewise, another observational study observed this positive relationship in participants with abdominal obesity[69]. It was hypothesised that visceral fat is the main anatomic site for secretion of IL-6[70], and this inflammatory biomarker could stimulate CRP production by liver[71]. A cross-sectional study on 722 adolescents aged 10–19 years, indicated that participants in the highest quartile of healthy eating index-2010 had lower risk

Table 2. Dietary Inflammatory Index (DII) and intake of energy and macronutrients according to sex in the weight disorders survey of the Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Disease-IV study
(Medians and interquartile ranges (IQR))

	Total (*n* 5427)	Boys (*n* 2886)	Girls (*n* 2541)	*P* (for sex difference)*
DII				0·76
Median	0·0	0·0	0·0	
IQR	–1·6, 1·5	–1·6, 1·5	–1·5, 1·4	
Energy intake (kJ/d)				0·76
Median	11459·4	11482·5	11418·5	
IQR	8627·1, 15403·7	8548·9, 15655·7	8723·2, 15159·6	
Carbohydrate intake (g/d)				0·15
Median	374·5	383·4	367·0	
IQR	281·4, 511·6	281·5, 520·2	281·3, 497·8	
Protein intake (g/d)				0·90
Median	90·2	90·5	89·8	
IQR	65·9, 120·4	65·6, 120·8	66·3, 119·9	
Total fat intake (g/d)				0·17
Median	102·3	100·6	104·0	
IQR	71·6, 142·1	70·9, 141·4	72·4, 143·2	

* The Mann–Whitney *U* test was used.

of central obesity than those in the lowest quartile[72]. The results of a cohort study conducted with the aim of examining the association of Dietary Approaches to Stop Hypertension (DASH) and the MetS on 425 Iranian children and adolescents demonstrated higher adherence to DASH diet was associated with lower abdominal obesity[73].

WHtR is one of the anthropometric indices associated with body fat[74]. In a large cross-sectional study conducted with the aim of determination of the association between DII and anthropometric indices in Spain, the findings demonstrated a positive relationship between the inflammatory potential of diet and WHtR[45], which is not in agreement with the outcome of the present study. In this study, the DII score was calculated from only twenty-five dietary factors; whereas in the previous report data for thirty-three food components were available for calculating the DII score. Therefore, this discrepancy may be the reason for the difference in the results. However, we have shown previously that there is no drop off in predictability in going from 44 to 27 parameters used for DII calculation[75]. On the contrary to our study, in a cross-sectional survey conducted on British children and adolescents, the dietary glycaemic load in adolescents was independently associated with higher WHtR[76]. This dietary index was positively associated with carbohydrate (a pro-inflammatory dietary factor)[77]. This disagreement may be associated with missing data on twenty dietary factors in the DII calculation. However, it should be noted that the range of DII score (from –4·42 to 4·26) is typical of what we see in many of our studies[44–46,66]. An observational study on 347 Italian children and preadolescents indicated high consumption of protein was associated with greater WHtR[78]. It must be kept in mind that the nutritional requirements of children are different than those of adults, owing largely to the metabolic requirements for growth[79,80]. In particular, we believe that it is important to point out that protein intake may be particularly important, especially for children during growth spurts and those who are involved in extreme athletic activities (e.g. weightlifting, marathon running)[81,82]. So even though protein is pro-inflammatory, the need for growth and development may outweigh its effect on inflammation. This is a matter separate and distinct from energy balance, which may be the main driving force in this population of children[83,84].

No association was observed between DII and WHR. This lack of association may be due to the relatively small number of participants with abdominal obesity. Similarly, a survey on Finnish elderly aged ≥90 years indicated no association between WHR and levels of TNF-α, CRP and IL-6 in both sexes[85]. On the contrary, in a study conducted on 377 adolescents and young adults in India, high WHR was associated with high levels of CRP[86]. A cross-sectional study that assessed the relationship between inflammatory biomarkers and obesity on young adults aged 18–30 years showed that WHR was positively associated with the levels of IL-6 and CRP[87]. In another observational study conducted on 1248 Taiwanese participants aged 65 years or older, a positive significant association was found between WHR and the levels of CRP[88]. The results confirmed that inflammatory biomarkers can be produced in visceral fat[70,89,90].

The results of the present study indicted the DII was positively associated with parental BMI. In an extensive study carried out among Korean households, the significant correlations were observed between the pattern of vitamin intake (B_1, B_2, B_3, C and A), Fe, Ca and P in parents and their offsprings[91]. In another study conducted on 294 families, the findings demonstrated the significant positive association between consumption of total carbohydrate, SFA, PUFA, energy and cholesterol in children and adolescents and their parents[92]. Vauthier *et al.*[93] show that there is association between consumption of energy and macronutrients in parents and their children and adolescents in French families. Recently, a cross-sectional study carried out among 401 child/parent pairs in New Zealand represented an inverse association between parental diet quality and snack consumption pattern in their preadolescents[94]. These findings reinforced the correlation between parent's and children's diet in one family.

Strengths

This national report covered a large group of Iranian children and adolescents as well as their parents. Using a validated

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Table 3. Anthropometric measures according to quartiles (*Q*) of the Dietary Inflammatory Index (DII) in the weight disorders survey of the Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Disease-IV study
(Mean values and standard deviations)

		DII quartiles								
		Q_1* (*n* 1357)		Q_2 (*n* 1357)		Q_3 (*n* 1357)		Q_4 (*n* 1356)		
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	P_{trend}†
Boy students	BMI *z*-score	–0·1	0·8	0·0	0·8	0·0	0·8	0·0	0·8	<0·001
	Wrist circumference (cm)	14·8	1·9	14·8	1·9	15·1	2·1	15·3	2·0	<0·001
	NC (cm)	30·4	4·8	30·6	5·4	30·9	4·9	31·3	4·7	<0·001
	WC (cm)	66·3	12·4	66·9	12·0	68·1	12·5	69·7	12·3	<0·001
	HC (cm)	78·4	13·5	78·9	12·6	80·6	13·5	82·1	12·6	<0·001
	WHR (cm)	0·8	0·1	0·8	0·1	0·8	0·1	0·8	0·0	0·27
	WHtR (cm)	0·4	0·1	0·4	0·07	0·4	0·2	0·4	0·2	0·27
Parental	BMI (kg/m^2)	26·5	4·8	26·8	5·1	27·2	5·0	27·5	5·0	<0·001
Girl students	BMI *z*-score	0	0·8	0·0	0·9	0·0	0·8	0·1	0·9	0·004
	Wrist circumference	14·7	3·2	14·5	1·8	14·7	2·2	14·8	1·9	0·34
	NC	30·0	4·9	29·6	5·0	30·0	4·5	30·3	4·8	0·19
	WC	64·8	11·1	65·8	11·8	66·4	10·9	67·6	10·9	<0·001
	HC	80·7	13·7	81·7	14·6	83·0	13·7	84·7	13·5	<0·001
	WHR	0·8	0·0	0·8	0·1	0·8	0·0	0·8	0·0	0·61
	WHtR	0·4	0·2	0·4	0·2	0·4	0·3	0·4	0·0	0·61
Parental	BMI	26·6	5·2	27·5	5·2	27·5	5·1	27·9	5·5	<0·001
Total students	BMI *z*-score	–0·1	0·8	0	0·9	0·0	0·8	0·0	0·8	<0·001
	Wrist circumference	14·7	2·6	14·7	1·8	14·9	2·2	15·1	2·0	<0·001
	NC	30·2	4·8	30·1	5·2	30·5	4·7	30·9	4·8	<0·001
	WC	65·6	11·9	66·3	11·9	67·3	11·8	68·7	11·7	<0·001
	HC	79·5	13·6	80·3	13·7	81·7	13·6	83·3	13·1	<0·001
	WHR	0·8	0·1	0·8	0·1	0·8	0·1	0·8	0·0	0·28
	WHtR	0·4	0·2	0·4	0·1	0·4	0·3	0·4	0·1	0·28
Parental	BMI	26·5	5·0	27·1	5·2	27·3	5·1	27·7	5·2	<0·001

NC, neck circumference; WC, waist circumference; HC, hip circumference; WHR, waist:hip ratio; WHtR, waist:height ratio.
* Range of quartiles for total participants: Q_1 = (–4·42, –1·63), Q_2 = (–1·62, –0·05), Q_3 = (–0·04, 1·51) and Q_4 = (1·50, 4·26).
† One-way ANOVA was used.

https://doi.org/10.1017/S0007114518003240 Published online by Cambridge University Press

Table 4. Associations between the Dietary Inflammatory Index (DII) and anthropometric measures in the weight disorders survey of the Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Disease-IV study
(*β* Estimates and 95 % confidence intervals)

			Students														Parental	
			BMI *z*-score		Wrist circumference (cm)		NC (cm)		WC (cm)		HC (cm)		WHR		WHtR		BMI (kg/m^2)	
			β	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI
Model I†‡	DII quartiles	Q_1 (−4·42, −1·63) *n* 1357		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.
		Q_2 (−1·63, −0·05) *n* 1357	0·08*	0·01, 0·15	−0·07	−0·23, 0·09	−0·10	−0·47, 0·27	0·74	−0·15, 1·63	0·81	−0·21, 1·83	0·003	−0·005, 0·01	0·00	−0·01, 0·01	0·62*	0·23, 1·01
		Q_3 (−0·05, 1·51) *n* 1357	0·08*	0·02, 0·15	0·21*	0·04, 0·37	0·30	−0·07, 0·67	1·72*	0·83, 2·62	2·25*	1·23, 3·28	−0·001	−0·009, 0·007	0·01	0·00, 0·03	0·83*	0·43, 1·22
		Q_4 (1·51, 4·26) *n* 1356	0·18*	0·11, 0·25	0·35*	0·18, 0·51	0·64*	0·27, 1·02	3·11*	2·21, 4·01	3·82*	2·80, 4·84	−0·001	−0·009, 0·007	0·00	−0·01, 0·02	1·18*	0·79, 1·57
	DII (quartile)§		0·05*	0·03, 0·07	0·13*	0·08, 0·18	0·23*	0·11, 0·35	1·03*	0·75, 1·31	1·29*	0·97, 1·61	−0·001	−0·003, 0·002	0·00	−0·01, 0·01	0·37*	0·25, 0·49
Model II†‖	DII quartiles	Q_1		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.
		Q_2	0·05	−0·01, 0·12	−0·12	−0·28, 0·02	−0·26	−0·61, 0·07	0·16	−0·63, 0·96	0·11	−0·70, 0·92	0·004	−0·005, 0·01	−0·001	−0·02, 0·01	0·43*	0·002, 0·86
		Q_3	0·01	−0·04, 0·08	0·06	−0·09, 0·21	−0·02	−0·36, 0·32	0·21	−0·59, 1·01	0·63	−0·18, 1·45	−0·002	−0·01, 0·008	0·01	−0·008, 0·03	0·73*	0·29, 1·16
		Q_4	0·07*	0·01, 0·14	0·06	−0·09, 0·21	−0·08	−0·43, 0·26	0·89*	0·07, 1·70	1·13*	0·29, 1·96	0·00	−0·01, 0·01	0·004	−0·01, 0·02	1·05*	0·61, 1·49
	DII (quartile)§		0·01	−0·002, 0·04	0·03	−0·01, 0·08	0·00	−0·11, 0·11	0·27*	0·01, 0·53	0·39*	0·13, 0·65	−0·001	−0·004, 0·002	0·002	−0·004, 0·009	0·34*	0·20, 0·48

Ref., referent values; NC, neck circumference; WC, waist circumference; HC, hip circumference; WHR, waist to hip ratio; WHtR, waist to height ratio; ST, screen time; PA, physical activity; SES, socio-economic status.
* Statistically significant.
† Linear regression was used.
‡ Crude association.
§ DII quartile considered as continuous variable.
‖ Adjusted for age, sex, place of residence, ST, PA and SES.

dietary assessment instrument and PA questionnaire, applying an updated and validated tool for evaluating the inflammatory effect of diet and estimating the relationship between DII and anthropometric indices after adjustment for potentially confounding factors are the other strengths of the present study.

Limitations and other considerations

The present study was carried out on school students and their parents; hence, the results cannot be generalised to all Iranians or to children in other countries or those of different SES. Moreover, information bias could result from using the FFQ for dietary assessment. Therefore, misclassification is a potential problem common in epidemiologic reports. The questionnaires of children under 10 years of age were completed by one of their parents; this may bias the results. Another limitation is non-availability of data on twenty dietary factors, which may affect the results, primarily by underestimating the DII (as most missing dietary factors are anti-inflammatory though most are probably consumed only infrequently). So, these dietary factors may have no great effect on the DII scoring. Another consideration for the present study is its sample size. Although large sample size is one of the main strengths of this study, having such a large sample size may lead to observing statistically significant association between the DII score and a variety of outcomes. Therefore, we should consider this point when considering the clinical significance of results.

Conclusion

The present investigation observed a positive association between pro-inflammatory diet and greater indices of generalised and abdominal obesity in young children and adolescents. Prospective studies are warranted to confirm our findings.

Acknowledgements

This large observational study was performed with the cooperation of the Ministry of Health and Medical Education, Ministry of Education and Training, Child Growth and Development Research Center, Isfahan University of Medical Sciences and Alborz University of Medical Sciences. This study was supported by Isfahan University of Medical Sciences and Alborz University of Medical Sciences.

N. S. and J. R. H. supported the study by grant number R44DK103377 from the United States National Institute of Diabetes and Digestive and Kidney Diseases.

J. R. H. owns controlling interest in Connecting Health Innovations LLC (CHI), a company planning to license the right to his invention of the DII from the University of South Carolina to develop computer and smart phone applications for patient counseling and dietary intervention in clinical settings. N. S. is an employee of CHI.

M. Q., R. K. and M. E. M. formulated the research questions and designed the study. H. A. and A. M.-G. carried it out the interviews. M. Q. analysed the data and Z. A., J. R. H. and N. S. computed the DII score and contributed to writing the article.

The authors declare that there are no conflicts of interest.

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