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# Dietary intake of carotenoids and fiber is inversely associated with aggression score in adolescent girls

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## Abstract

**Background:** Violence and aggression are considered to be important public health issues. There is limited data on the association between dietary intake and aggression score. **Aim:** We aimed to examine the relationship between the dietary intake and aggressive behavior in Iranian adolescent girls. **Methods:** The study was carried out among 670 girls aged 12–18 years. A valid and reliable food frequency questionnaire (FFQ) containing 147 food items was used to estimate dietary intake of the study participants. Aggression score was determined using a validated Persian version of the Buss–Perry questionnaire. We analyzed our data using crude and adjusted models. **Results:** Participants in the fourth quartile of aggression score had significantly higher energy intake compared with those in the first quartile ($2808 \pm 949$ vs $2629 \pm 819$, $p$-trend $= 0.01$). Dietary intakes of soluble fiber ($0.42 \pm 0.37$ vs $0.35 \pm 0.29$, $p = 0.03$) and insoluble fiber ($2.17 \pm 1.65$ vs $1.82 \pm 1.36$, $p = 0.02$) were significantly higher in the first quartile than in the fourth quartile. In addition, the strongest negative correlations were found between aggression score and dietary soluble fiber ($p = 0.003$) and insoluble fiber intake ($p = 0.001$). Moreover, aggression score was negatively correlated with dietary $\alpha$-carotene ($p = 0.02$) and $\beta$-carotene ($p = 0.04$) intake. These associations remained significant even after adjustment for potential confounders. **Conclusions:** Our results indicated that dietary intakes of fiber, $\alpha$-carotene, and $\beta$-carotene were inversely associated with aggression score. Moreover, a significant positive association was observed between energy intake and aggression score in adolescent girls.

## Keywords

Diet, aggression, adolescents, carotenoids, dietary fiber

## Introduction

Recent studies of psychological well-being have focused on determinants of emotions and behavior (Llorca et al., 2017). Violence and aggression are considered to be important public health issues (Sadeghi et al., 2014). Aggressive behavior has many different forms and may change over the course of life (Bjorkqvist et al., 1994). Aggressive behavior is a major public health problem worldwide and many socioeconomic and biological factors are involved in the development of this behavior (Smith-Khuri et al., 2004). There are growing trends in aggressive behaviors in adolescents, especially girls. Prevalence rates of behavioral disorders and juvenile court caseloads provide an estimate of adolescent girl aggression (Cotter and Smokowski, 2017). From 1985 through 2009, the number of delinquency cases handled in US juvenile courts climbed steadily (86%) (Puzzanchera et al., 2010). Moreover, physical assault, a measure of aggressive behavior, is the

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sixth leading cause of nonfatal injury in the 15- to 19-year-old age group in the USA (Smith-Khuri et al., 2004). The prevalence of aggressive behavior and violence among Iranian adolescents and youth ranges from 30% to 65.5%, with males being affected 2.5 times more than female (Sadeghi et al., 2014). Adolescence is a period of change in behaviors and is also characterized by experimentation and risky behaviors (Perez Fuentes et al., 2016). Aggression is known to be a normal part of developmental progress in the adolescence period (Smith-Khuri et al., 2004).

Several studies have shown that adolescent aggression is affected by various factors related to lifestyle, such as television viewing, stress, socioeconomic variables, and dietary factors (Taubner et al., 2016; Wurtman and Wurtman, 1989). Growing evidence from animal experiments and clinical observations suggests that some dietary factors are linked, positively or negatively, to traits such as exploration, social interaction, depression, anxiety, and fear (Banikazemi et al., 2015; Gonoodi et al., 2018a; Haagensen et al., 2014). Studies regarding the impact of dietary factors on aggression are limited. Meyer et al. (2015) found that adult male prisoners with lower omega-3 index were more aggressive, as evidenced by higher scores on the aggression questionnaire. Another study reported that supplementation with vitamins, minerals, and essential fatty acids reduced antisocial behavior, including violence (Gesch et al., 2002). It has been shown that the intake of soft drinks containing aspartame, sodium benzoate, phosphoric or citric acid, high fructose corn syrup, and often caffeine may have an impact on behaviors among adolescents (Solnick and Hemenway, 2012). Moreover, the consumption of high energy and low nutritional content foods may increase the risk of psychiatric distress including anxiety, aggression, and violent behaviors in children and adolescents (Zahedi et al., 2014).

The purpose of the current study was to investigate the association between dietary intake of macro and micronutrients and aggression in adolescent girls. Therefore, we hypothesized that some components of diet may be associated with aggressive behavior in adolescent girls.

## Methods

### Study population

The current study was performed within a sample of Iranian adolescent girls who were recruited from Mashhad and Sabzevar cities in 2015. The participants were selected using a stratified-cluster random sampling method. The total population included 670 girls aged between 12 and 18 years. Patients diagnosed with any chronic diseases were not included in our study. In addition, individuals on antidepressant, antidiabetic, or anti-obesity drugs, taking anti-inflammatory, vitamin D, or calcium supplements, or undergoing hormone therapy were not included. All study participants completed written informed consent forms prior to study enrollment. The study protocol was reviewed and approved by the Ethics Committee of Mashhad University of Medical Sciences.

### Assessment of demographic status

General demographic data including age, smoking status, menstruation status, psychological treatment, chronic diseases, medical history, and supplement use was collected by expert interviewers. Physical activity information was obtained by using the validated Modifiable Activity Questionnaire (MAQ) (Delshad et al., 2015). Physical activity level was calculated based on metabolic equivalent task (MET) minutes per week.

### Anthropometric and biochemical assessment

Anthropometric variables including weight, height, and waist circumference (WC) were obtained using a standard protocol. Weight was measured in participants wearing minimum clothes and without shoes using a Seca digital scale. Height was measured by a measuring tape for participants without shoes in the standing position. Body mass index (BMI) was calculated as weight (kg) divided by square of height (m). WCs were measured using a flexible tape measure from the narrowest point between the lowest rib and the iliac crest. Blood pressure was measured two times using a standardized protocol. The mean of two recorded measurements was reported as the participant's blood pressure. Fasting blood samples were obtained early in the morning at baseline and after the 9 weeks intervention while performing an overnight fast. Blood samples were immediately centrifuged at 3500 r/min at room temperature for 10 min to separate serum. Then, the samples were stored at $-80°C$ at the reference laboratory in Mashhad University of Medical Science. Biochemical parameters including triglycerides (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), fasting blood glucose (FBG), creatinine, blood urea nitrogen (BUN), calcium, phosphorus, and high sensitivity C-reactive protein (hs-CRP) were obtained via enzymatic methods (Pars Azmun, Karaj, Iran) and by an auto-analyzer (BT3000). LDL-C was calculated by using the Friedewald formula if serum TG concentrations were lower than 400 mg/dL (Gonoodi et al., 2018b).

### Dietary assessment

A valid and reliable food frequency questionnaire (FFQ) containing 147 food items was administered by trained interviewers to estimate dietary intakes of the study participants (Hosseini Esfahani et al., 2010). This FFQ has nine multiple-choice frequency response categories that varies from "never or $<1$/mo" to "$\geq 12$/d." To calculate daily nutrient intakes for each participant, we used the US Department of Agriculture's national nutrient databank (Pehrsson et al., 2000).

**Table 1.** Demographic, anthropometric, and biochemical features across quarters of aggression score.

| | Aggression score quartile | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | *p*-trend[b] | *p*-value[a] |
| Age (y) * | 14.4 ± 1.56 | 14.7 ± 1.5 | 14.5 ± 1.59 | 14.5 ± 1.46 | 0.23 | 0.92 |
| Weight (kg) | 52.7 ± 11.6 | 52.5 ± 11.9 | 52.4 ± 10.9 | 53.7 ± 13.6 | 0.63 | 0.44 |
| BMI (kg/m$^2$) | 21.2 ± 4.21 | 21.05 ± 4.47 | 21.04 ± 3.81 | 21.4 ± 4.76 | 0.68 | 0.64 |
| Waist circumference (cm) | 70.3 ± 9.12 | 70.1 ± 9.1 | 70.06 ± 8.68 | 71.1 ± 9.88 | 0.61 | 0.48 |
| Physical activity (MET) | 45.3 ± 3.56 | 45.6 ± 3.79 | 45.1 ± 2.94 | 45.5 ± 3.99 | 0.51 | 0.99 |
| Systolic blood pressure (mmHg) | 96.3 ± 14.6 | 97.4 ± 14.7 | 95.4 ± 14.5 | 96.6 ± 12.6 | 0.5 | 0.75 |
| Diastolic blood pressure (mmHg) | 62.06 ± 14.6 | 64.7 ± 12.9 | 60.4 ± 12.6 | 62.08 ± 13.1 | 0.006 | 0.28 |
| hs-CRP (mg/L) | 1.53 ± 1.85 | 1.52 ± 1.89 | 1.36 ± 1.42 | 1.71 ± 1.99 | 0.29 | 0.54 |
| Fasting blood glucose (mg/dL) | 86.2 ± 12.01 | 85.03 ± 11.3 | 85.1 ± 12.03 | 85.06 ± 11.2 | 0.13 | 0.11 |
| HDL-c (mg/dL) | 46.9 ± 9.62 | 48.1 ± 8.35 | 47 ± 7.97 | 46.2 ± 10.13 | 0.19 | 0.26 |
| LDL-c (mg/dL) | 98.2 ± 24.6 | 102.1 ± 24.5 | 97.8 ± 27.3 | 98.2 ± 25.1 | 0.3 | 0.62 |
| Total cholesterol (mg/dL) | 161.7 ± 27.8 | 164.1 ± 29.8 | 158.1 ± 29.04 | 161 ± 28.7 | 0.2 | 0.35 |
| Triglyceride (mg/dL) | 83.8 ± 38.9 | 88.02 ± 45.03 | 80.8 ± 33.7 | 86.1 ± 38.7 | 0.25 | 0.96 |
| Creatinine (mg/dL) | 0.68 ± 0.12 | 0.68 ± 0.11 | 0.69 ± 0.12 | 0.66 ± 0.1 | 0.11 | 0.21 |
| Blood urea nitrogen (mg/dL) | 12.6 ± 3.56 | 12.9 ± 4.98 | 13.05 ± 3.45 | 12.9 ± 3.02 | 0.71 | 0.42 |
| Calcium (mg/dL) | 9.33 ± 0.68 | 9.52 ± 0.54 | 9.47 ± 0.61 | 9.44 ± 0.67 | 0.01 | 0.11 |
| Phosphorus (mg/dL) | 3.97 ± 0.46 | 3.93 ± 0.45 | 4.03 ± 0.45 | 3.94 ± 0.48 | 0.11 | 0.81 |

*All values are mean ± SD.
[a]*p*-values from analysis of the variance (ANOVA) for groups comparison.
[b]*p*-values for linear trend across quarters of aggression score.

### *Assessment of aggression*

Aggression score was obtained using a validated Persian version of the Buss–Perry questionnaire (Rahman et al., 2012). This questionnaire includes 29 questions in a multiple-choice format.

### *Statistical methods*

We categorized individuals by quartiles of aggression score. We used one-way analysis of variance (ANOVA) to examine significant differences in continuous variables across quartiles of aggression score. Dietary intakes of participants were examined by one-way ANOVA across quartiles of aggression score. Linear regression was used to investigate the relationship between dietary intakes and quartiles of aggression score. In the adjusted model, we controlled for age and energy intake, physical activity, and BMI. We examined overall trends for the odds ratios by increasing quartiles of aggression score by using of linear regression. A $p$-value < 0.05 was defined as statistically significant. SPSS software version 15.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

## Results

A total of 670 adolescent girls between 12 and 18 years of age were included in this study. We categorized individuals by quartiles of aggression score. Demographic, anthropometric characteristics, and clinical feature measurements of the participants across quarters of aggression score are shown in Table 1. Significant differences were observed in diastolic blood pressure ($p = 0.006$) and serum calcium concentrations ($p = 0.01$) for the participants in different quartiles. There were no significant differences in demographic characteristics and other anthropometric and biochemical parameters across quarters of aggression score.

Dietary intakes of participants across quarters of aggression score are presented in Table 2. The findings showed that participants in the fourth quartile of aggression score had significantly higher energy intake compared with those in the first quartile ($2808 \pm 949$ vs $2629 \pm 819$, $p$-trend $= 0.01$). This resulted in a strong positive correlation between energy intake and aggression score. The individuals in the fourth quartile consumed significantly more amounts of fat compared with those in the first quartile ($108.6 \pm 46.2$ vs $98.7 \pm 39.7$, $p = 0.04$). However, there was no significant correlation between aggression and dietary fat intake. In contrast, dietary intake of soluble fiber ($0.42 \pm 0.37$ vs $0.35 \pm 0.29$, $p = 0.03$) and insoluble fiber ($2.17 \pm 1.65$ vs $1.82 \pm 1.36$, $p = 0.02$) were significantly higher in the first quartile than in the fourth quartile. In addition, the strongest negative correlations were found between aggression score and dietary soluble fiber ($p = 0.003$) and insoluble fiber intake ($p = 0.001$). Moreover, aggression score was negatively correlated with dietary α-carotene ($p = 0.02$) and β-carotene ($p = 0.04$) intake (Table 2).

## Discussion

In the present study, we examined the association between dietary intake and aggression score using a large sample of adolescent girls between 12 and 18 years of age. To the best

**Table 2.** Dietary intakes of study participants across quarters of aggression score.

| | Aggression score quarters | | | | | | Correlation coefficient |
|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | p-trend[b] | p-value[a] | (p-adjusted)[c] |
| Macronutrients | | | | | | | |
| Energy (kcal)* | 2629 ± 819 | 2657 ± 793 | 2769 ± 780 | 2808 ± 949 | 0.12 | 0.01 | 0.08 (0.01) |
| Carbohydrate (g/d) | 360.9 ± 119.7 | 366.6 ± 119.7 | 376.2 ± 116.5 | 380.8 ± 136.7 | 0.4 | 0.08 | −0.07 (0.39) |
| Protein (g/d) | 89.7 ± 30.2 | 90.7 ± 29.8 | 94.3 ± 30.1 | 93.3 ± 34.5 | 0.43 | 0.15 | −0.07 (0.32) |
| Total fat (g/d) | 98.7 ± 39.7 | 98.6 ± 40.5 | 106.2 ± 39.6 | 108.6 ± 46.2 | 0.04 | 0.007 | 0.07 (0.25) |
| Soluble dietary fiber (g/d) | 0.42 ± 0.37 | 0.4 ± 0.31 | 0.38 ± 0.32 | 0.35 ± 0.29 | 0.18 | 0.03 | −0.11 (0.003) |
| Insoluble dietary fiber (g/d) | 2.17 ± 1.65 | 2.11 ± 1.46 | 2 ± 1.43 | 1.82 ± 1.36 | 0.13 | 0.02 | −0.12 (0.001) |
| Antioxidants | | | | | | | |
| Beta-carotene (mcg/d) | 3463 ± 2716 | 3288 ± 2494 | 3681 ± 3183 | 2948 ± 2169 | 0.06 | 0.25 | −0.08 (0.04) |
| Alpha-carotene (mcg/d) | 597.6 ± 699.8 | 550.9 ± 528.6 | 568.1 ± 564.6 | 467 ± 550.9 | 0.19 | 0.06 | −0.08 (0.02) |
| Lutein (mcg/d) | 1928 ± 1559 | 1966 ± 1844 | 2110 ± 2066 | 1687 ± 1241 | 0.13 | 0.39 | −0.07 (0.07) |
| Vitamin E (mg/d) | 13.4 ± 6.64 | 12.8 ± 6.5 | 14.2 ± 6.36 | 14.2 ± 8.3 | 0.13 | 0.09 | 0.01 (0.73) |
| Vitamin C (mg/d) | 91.9 ± 56.4 | 92.2 ± 53.8 | 102.7 ± 73.3 | 95.8 ± 60.8 | 0.26 | 0.24 | 0.007 (0.86) |
| Lycopene (mcg/d) | 2885 ± 2293 | 2701 ± 2193 | 3105 ± 2933 | 2909 ± 3386 | 0.74 | 0.66 | 0.003 (0.92) |
| Minerals | | | | | | | |
| Sodium (mg/d) | 4024 ± 1611 | 4157 ± 1773 | 4141 ± 1754 | 4462 ± 1946 | 0.12 | 0.03 | 0.04 (0.4) |
| Calcium (mg/d) | 1116 ± 499 | 1142 ± 481 | 1164 ± 448 | 1151 ± 558 | 0.81 | 0.42 | −0.03 (0.43) |
| Phosphorus (mg/d) | 1709 ± 587 | 1708 ± 605 | 1793 ± 600 | 1768 ± 710 | 0.44 | 0.19 | −0.06 (0.34) |
| Magnesium (mg/d) | 486.2 ± 183.4 | 490.8 ± 211.8 | 517.6 ± 193.4 | 507.1 ± 211.6 | 0.38 | 0.16 | −0.04 (0.46) |
| Iron (mg/d) | 19.5 ± 7.222 | 19.6 ± 7.37 | 20.4 ± 7.06 | 20.2 ± 7.8 | 0.55 | 0.2 | −0.06 (0.34) |
| Zinc (mg/d) | 13.4 ± 4.93 | 13.9 ± 6.18 | 14.5 ± 5.47 | 14.2 ± 5.58 | 0.32 | 0.12 | −0.02 (0.66) |
| Selenium (mcg/d) | 146.4 ± 67.4 | 144.2 ± 71.8 | 149.4 ± 67.4 | 149.1 ± 70.9 | 0.87 | 0.56 | −0.05 (0.24) |

*All values are mean ± SD.
[a]p-value from analysis of the variance (ANOVA) for groups comparison.
[b]p-values for linear trend across quarters of aggression score.
[c]p-values adjusted for energy intakes, age, BMI and physical activity.

of our knowledge, this is the first study looking directly at the association between dietary intake and aggression score in adolescent girls. Our study showed that even after adjustment for several confounding factors (i.e. energy intake, age, BMI, and physical activity), there was a significant association between aggression score and some dietary factors, including energy intake, insoluble and soluble dietary fiber intake, and α- and β-carotene intake.

Among adolescents, aggression is a common behavioral problem and growing trends have been observed in adolescent female aggression (Cotter and Smokowski, 2017). Diet is a potential factor that may play an important role in the control of aggression (Han and Dingemanse, 2017). In this study, we found a significant positive association between energy intake and aggression score. One study has previously shown that dietary intake of trans fatty acids are significantly associated with behavioral problems such as aggression (Golomb et al., 2012). Haagensen et al. (2014) analyzed the relationship between a high-fat low-carbohydrate diet and aggression in male Gottingen minipigs. The authors showed that adherence to a high-fat/cholesterol, low-carbohydrate diet was associated with less aggressive behavior (Haagensen et al., 2014). Hilakivi-Clarke et al. (1996) reported that dietary fat increased aggression behavior in male mice and rats, which was suggested to be due to elevating circulating estradiol levels. Another study showed that a high polyunsaturated fatty acid diet during pregnancy increased aggression behavior in mice. It was suggested that this was partly explained by the observed increase in protein kinase C activity in the hypothalamus (Raygada et al., 1998). Moreover, Greenwood and Young (2001) reported that the lipid composition of developing human brain is largely dependent on dietary lipid intake. In this regard, it was shown that the brains of formula-fed infants had lower levels of total omega-3 fatty acids and higher levels of omega-6 fatty acids than breast-fed infants (Makrides et al., 1994). Furthermore, in a study by Zahedi et al. (2004), junk food consumption (high-energy and low nutritional content foods) increased the risk of violent behaviors and psychiatric distress in Iranian children and adolescents. The authors suggested that normal functioning of the brain depends on a continuous supply of nutrients, including vitamins, and essential fatty acids that are needed for proper functioning of central nervous system and may have an effect on behavior via the synthesis of neurotransmitters (Zahedi et al., 2014).

We observed a significant negative association between soluble and insoluble dietary fiber intake and aggression score in adolescent girls. In an animal study, Sapkota et al. (2016) showed that dietary fiber and resistance starch reduced aggressive behavior in gestating sows. The mechanism linking aggression to dietary fiber is unclear, but several possibilities have been suggested. It has been reported that dietary fiber reduces the glycemic index and provides a moderate but lasting effect on brain chemistry, mood, and memory (Guligowska et al., 2016). Current evidence suggests that dietary fiber intake also affect the composition of the gut microbiota, which have beneficial effects on mental health (Moloney et al., 2014; O'Mahony et al., 2015; Selhub et al., 2014). In this regard, Logan and Katzman (2005) suggested that probiotics may serve as adjuvant therapy for patients with major depressive disorder. Moreover, a high dietary fiber intake is also strongly correlated with intake of phytochemicals, which are supposed to exert positive effects on human health (Bahramsoltani et al., 2015). Furthermore, vegetables and fruit are rich in micronutrients and vitamins. B vitamins, such as B9 are associated with depression, in which low levels of B vitamins can cause high homocysteine levels which in turn can impair methylation processes involved in the metabolism and synthesis of neurotransmitters that may affect behavior (Nguyen et al., 2017).

In this study, we found a significant inverse association between dietary α- and β-carotene and aggression score. One study has shown that supplementation with carotenoids reduced psychological stress in young adults (Stringham et al., 2018). Another study showed that carotenoids and F2-isoprostanes are associated with depressive symptoms (Black et al., 2016). The brain is especially susceptible to oxidative stress and antioxidants defend against the negative effects of oxidative stress in brain (Payne et al., 2012). Another underlying mechanism that may be responsible for this effect is that antioxidants have beneficial effects upon oxidative and inflammatory markers, which are often elevated during depression (Shafiee et al., 2017, 2018; Tayefi et al., 2017). A cohort study examined the relationship between high fruit and vegetable consumption and psychological behavior. Fruit and vegetables are rich in vitamins and antioxidants such as vitamins C, E, and polyphenols that may help to reduce oxidative stress (Nguyen et al., 2017). A potential mechanism for the relationship between aggression and carotenoids intake is unclear and no previous study on this topic was found.

The strengths of our study include a relatively large sample of adolescent girls, a group with a relatively high rate of aggression, and using a standardized tool for assessment of aggression behavior. Moreover, we collected extensive data on potential confounders, including personal characteristics (age), anthropometric factors (BMI), and lifestyle habits (physical activity and energy intake). We also acknowledge some limitations in our study including: (a) the use of a self-administered tool instead of more accurate face-to-face interviews; (b) the limited generalizability of the results; and (c) the fact that we have assessed both aggression score and dietary intake at baseline and no longitudinal assessment was performed.

In summary, our results indicated that dietary intakes of fiber, α-carotene and β-carotene were inversely associated with aggression score. Moreover, we found a significant positive association between energy intake and aggression score in adolescent girls. However, due to the cross-sectional design of the present study, longitudinal or interventional studies are required to confirm these findings before clinical recommendations can be provided.


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## Ethical approval

The Ethics Committee of Mashhad University of Medical Sciences approved the study (IR.MUMS.fm.REC.1395.12).

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