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Dietary antioxidants and fibre intake and depressive symptoms in Iranian adolescent girls

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Abstract

Objective: To investigate the cross-sectional association between dietary intakes of antioxidants and fibre and depressive symptoms among Iranian adolescent girls.
Design: A cross-sectional population-based study.
Setting: Primary schools in two different cities located in northeastern Iran (Mashhad and Sabzevar).
Participants: A total of 988 adolescent girls aged 12–18 years were included in the study.
Results: Subjects with no or minimal depression symptoms had significantly higher dietary intakes of α-carotene ($P = 0{\cdot}01$), β-carotene ($P = 0{\cdot}006$), lutein ($P = 0{\cdot}03$) and vitamin C ($P = 0{\cdot}04$) when compared with subjects with mild-to-severe depression symptoms. Soluble dietary fibre and insoluble dietary fibre intakes were also significantly higher in healthy adolescents compared with those with depression symptoms ($P < 0{\cdot}001$). In multivariate-adjusted model 2, the OR (95 % CI) of depressive symptoms were 0·61 (95 % CI 0·37, 1·01), 0·42 (95 % CI 0·26, 0·69), 0·50 (95 % CI 0·31, 0·79), 0·71 (95 % CI 0·44, 1·15), 0·51 (95 % CI 0·32, 0·82) and 0·42 (95 % CI 0·25, 0·68) for the highest *v.* lowest quartile of vitamin C, β-carotene, α-carotene, lutein, soluble dietary fibre and insoluble dietary fibre cereal intakes, respectively.
Conclusions: Dietary intake of some antioxidants and dietary fibre intake was inversely associated with depression symptoms among Iranian adolescent girls.

Keywords
Depressive symptoms
Dietary antioxidants
Dietary fibre
Adolescent girls

Depression is a common and very serious medical condition accompanied by a high degree of emotional distress and functional impairment[1]. The two main symptoms of depression include depressed mood and anhedonia (i.e. loss of interest in daily activities), which are often accompanied by a variety of additional symptoms[2]. The lifetime prevalence of depression varies from 11·1 % in developing countries to 14·6 % in high-income countries[3]. Moreover, depression is estimated to count for 9·6 % of years living with disability and about 4·0 % of global disability-adjusted life years[4]. The prevalence of depression substantially increases during adolescence, particularly in girls, due to physical and emotional development as well as exposure to novel stressors[5]. A systematic review and meta-analysis of twelve studies revealed that the prevalence of depression among Iranian children and adolescents was 43·5 % using the Beck Depression Inventory, with a higher prevalence among girls than boys[6]. Moreover, using the Center for Epidemiologic Studies Depression Scale, the prevalence of severe depression among Iranian female adolescents in secondary schools has been reported to be 52·6 %[7]. Since depression is probably the most important risk

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factor for teenage suicide[8], the management of adolescents with depressive disorders is of particular importance.

Inflammation and oxidative stress are linked with a number of chronic diseases including CVD, hypertension, diabetes, chronic kidney disease and cancer[9–12]. Although the aetiology of depression is not completely understood, it has been shown that depression is significantly associated with systemic inflammation up-regulation indicated by an increased production of pro-inflammatory cytokines and inflammatory mediators[13,14]. Moreover, several studies have reported that disturbed oxidative stress/antioxidant equilibrium increased the generation of reactive oxygen species and decreased antioxidant defences may be related to pathogenesis of depression[15–17]. In line with this, Rawdin *et al.* observed that the homoeostatic buffering mechanisms regulating inflammation and oxidation in healthy subjects become dysregulated in untreated depression[18]. Thus, considering the link between depressive disorders and oxidative stress, it was hypothesised that higher dietary antioxidant intake would be associated with less severe depressive symptoms.

The most important dietary antioxidants include vitamin C (ascorbic acid), vitamin E (tocopherols and tocotrienols), carotenoids (e.g. β-carotene), flavonoids and several trace minerals. Moreover, it should be noted that dietary fibre often serves as a carrier for dietary antioxidants[19]. We have previously found that dietary Zn intake was inversely associated with depressive symptoms, which was suggested to be related to its role in antioxidant enzymes[20]. Several previous studies have investigated the association between dietary antioxidants and depressive symptoms in different population groups[21–24]. Bonaccio *et al.* observed that adherence to a Mediterranean dietary pattern was associated with better mental health, which was independently explained by dietary total antioxidant and fibre content[21]. In another study, Payne *et al.* observed that vitamin C, lutein and β-cryptoxanthin intakes were significantly lower among participants with depression than in healthy individuals[22]. Moreover, Ye *et al.* observed an inverse association between intake of total carotenoids and depression score after adjustment for a range of dietary and non-dietary potential confounders[23]. Xu and colleagues conducted a study in 16 807 adults aged 20 years or older and observed an inverse association between dietary intakes of total, fruit and vegetable fibre, and depressive symptoms[24].

Despite these observations, to our knowledge, no studies to date have investigated the association between dietary antioxidants and fibre intake and depressive symptoms in Iranian adolescent girls, a population known to have a high prevalence of depression. Therefore, the primary objective of the present study was to investigate (1) the association between dietary intake of antioxidants and severity of depression symptoms and (2) the association between dietary intake of fibre and severity of depression symptoms among Iranian adolescent girls.

Methods

Study population

A total of 1026 adolescent girls aged 12–18 years were randomly recruited from several schools in two cities located in northeastern Iran (Mashhad and Sabzevar), using a random cluster sampling method. The participation rate was 96 %, and a total of 988 adolescent girls were studied. Subjects with a history of autoimmune diseases, cancer, metabolic bone disease, hepatic or renal failure, cardiovascular disorders, malabsorption or thyroid, parathyroid or adrenal diseases were not included in our study. All the subjects and their parents were asked to complete written informed consent before participating in the study. This study was approved by the ethic committee of Mashhad University of Medical Sciences (MUMS), Mashhad, Iran (ID: 931188).

Demographic, anthropometric and biochemical measurements

Demographic information of the study participants including age, supplement use, chronic diseases, smoking status, menstruation status, psychological treatment and medical history were collected by trained interviewers. Anthropometric variables including weight, height and waist circumference were obtained using standard protocols. Body weight was measured in an overnight fasting status without shoes in a minimal clothing state by the use of a digital scale to the nearest 0·1 kg. Height (without shoes) was assessed to the nearest 0·1 cm using a stadiometer. Thereafter, BMI was calculated by dividing weight (kg) by the square of height (m^2). Waist circumference was measured at the midpoint between the lowest rib margin and the iliac crest during minimal respiration[25,26]. Systolic blood pressure and diastolic blood pressure were measured by sphygmomanometer twice in exactly the same manner. It was measured on the left arm when the individuals remained seated at rest for 15 min. The third measurement was taken if the first two readings differ by more than 15 mmHg in diastolic blood pressure or more than 25 mmHg in systolic blood pressure. Physical activity information was gathered using a validated questionnaire allowing conversion into metabolic equivalent hours[27]. Blood samples were collected after 12–14 h overnight fast, and serum was separated after centrifugation and stored at −20 °C until analysed. Biochemical parameters including TAG, total cholesterol, LDL-cholesterol, HDL-cholesterol and fasting blood glucose were measured for all participants, as described previously[28]. Friedewald formula was used to calculate LDL-cholesterol if serum TAG concentration was lower than 400 mg/dl[29]. Serum high-sensitivity C-reactive protein concentration was estimated using an immunoturbidimetric method, with a detection limit of 0·06 mg/l (Pars Azmun, Karaj, Iran).

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Assessment of dietary intake

A validated FFQ was used to measure dietary intakes[30,31]. To estimate energy and nutrient intakes, the reported portion size in FFQ and dietary records was converted to grams using household measures and then entered to the Nutritionist IV software (version 7.0; N-Squared Computing) which was modified for Iranian food items.

Assessment of depression

In this study, the twenty-one-item Beck Depression Inventory was used for assessing the symptoms of depression[32]. Each item represents a single symptom associated with depression including feelings of guilt, feelings of hopelessness, sadness, crying, sleep disturbance, fear and loss of appetite over the past 2 weeks[33]. Scores are classified as the following: 0–13 minimal or no depression, 14–19 mild depression, 20–28 moderate depression and 29–63 severe depression[33]. Ghassemzadeh *et al.* (2005) have validated this questionnaire in its Persian (Farsi) translation, with an acceptable internal consistency (Cronbach's alpha = 0·87) and test–retest reliability ($r = 0{\cdot}74$)[34].

Statistical analysis

Data analysis was carried out using SPSS-18 software (SPSS Inc.). The normality of data was evaluated using Kolmogorov–Smirnov test. Descriptive statistics including mean, frequency and SD were determined for all variables and expressed as mean ± SD for normally distributed variables. χ^2 tests were used to compare the qualitative variables. For normally distributed variables, independent sample *t* test was performed. All the analyses were two-sided, and *P*-value < 0·05 was considered as significant. Moreover, crude and adjusted logistic regression analyses were conducted to investigate the relationship between depression symptoms and quartiles of nutrient intakes. Age and energy intake were controlled in the first model. Further adjustments were made for menstruation, family members, parental death, parental divorce, physical activity and BMI in the second model.

Results

Over 25 % (*n* 255) of the subjects were diagnosed with mild-to-severe depression symptoms, and about 74 % had no or minimal depression symptoms. Demographic and biochemical characteristics of study participants in no or minimal and mild-to-severe groups are presented in Table 1. There were no significant differences in age, weight, BMI, waist circumference, physical activity, menstruation, high-sensitivity C-reactive protein, fasting blood glucose, HDL-cholesterol, LDL-cholesterol, total cholesterol and TAG between subjects with no or minimal or mild-to-severe depression symptoms. Patients with mild-to-severe depression symptoms had significantly lower diastolic blood pressure compared with healthy subjects ($P = 0{\cdot}03$), but there was no significant difference in the case of systolic blood pressure ($P = 0{\cdot}1$). The percentage of passive smokers was significantly higher in mild to severe group as compared with no or minimal group ($P = 0{\cdot}006$).

Dietary fibre and antioxidant intakes of participants in no or minimal and mild-to-severe groups are reported in Table 2. No significant difference was observed between two groups regarding the amount of energy intake ($P = 0{\cdot}9$). There were no significant differences in dietary intakes of vitamin A ($P = 0{\cdot}7$), vitamin E ($P = 0{\cdot}7$) and lycopene ($P = 0{\cdot}8$) between groups. Subjects with no or minimal depression symptoms had significantly higher dietary intakes of α-carotene ($P = 0{\cdot}01$), β-carotene ($P = 0{\cdot}006$), lutein ($P = 0{\cdot}03$) and vitamin C ($P = 0{\cdot}04$) when compared with subjects with mild-to-severe depression symptoms. Soluble dietary fibre and insoluble dietary fibre intakes were also significantly higher in healthy adolescents compared with those with depression symptoms ($P < 0{\cdot}001$, Table 2).

Crude and adjusted OR for depression symptoms across quartiles of nutrients intakes are presented in Table 3. In all our multivariate analyses, the group who was in the first quartile of dietary fibre and antioxidant intake served as a reference group (Q2, Q3, Q4 *v.* Q1). Although we observed no significant association between depression severity and vitamin C intake in crude model ($P_{trend} = 0{\cdot}18$), significant associations were found after adjusting for age and energy intake ($P_{trend} = 0{\cdot}04$) and also after further adjusting for menstruation, family members, parental death, parental divorce, physical activity and BMI ($P_{trend} = 0{\cdot}04$). The multivariable-adjusted (model II) OR (95 % CI) for the lowest through the highest quartiles of β-carotene intake were 1·00 (reference), 0·91 (95 % CI 0·58, 1·42), 0·77 (95 % CI 0·50, 1·20) and 0·42 (95 % CI 0·26, 0·69) ($P_{trend} = 0{\cdot}003$). The multivariable-adjusted (model II) OR (95 % CI) for the lowest through the highest quartiles of α-carotene intake were 1·00 (reference), 0·69 (95 % CI 0·45, 1·07), 0·63 (95 % CI 0·41, 0·98) and 0·50 (95 % CI 0·31, 0·79) ($P_{trend} = 0{\cdot}004$). In multivariate-adjusted model 2, the OR (95 % CI) of depressive symptoms were 0·71 (95 % CI 0·44, 1·15), 0·51 (95 % CI 0·32, 0·82) and 0·42 (95 % CI 0·25, 0·68) for the highest *v.* lowest quartile of lutein, soluble dietary fibre and insoluble dietary fibre cereal intakes, respectively (Table 3).

Discussion

Our results suggest that higher dietary intakes of vitamin C, but not vitamin E, were associated with lower depression symptoms among Iranian adolescent girls. Moreover, dietary intakes of some carotenoids (β-carotene, α-carotene and lutein) and dietary fibre intake (both soluble and insoluble) were inversely associated with the severity of depression symptoms. Overall, subjects with mild-to-severe depression symptoms had significantly lower intake of dietary antioxidants.

Several studies have investigated the association between dietary antioxidant intakes and depressive symptoms in different population groups[22,35,36]. In agreement

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Table 1 Demographic and biochemical characteristics of study population with no or minimal and mild-to-severe depression symptoms

	Depression severity				
	No or minimal (*n* 733)		Mild to severe (*n* 255)		
Variables	Mean	SD	Mean	SD	*P*-value
Age (years)	14·5	1·52*	14·5	1·54	0·880
Weight (kg)	52·9	11·6	52·5	12·6	0·627
BMI (kg/m^2)	21·2	4·16	21·0	4·52	0·458
WC (cm)	70·3	8·9	70·3	9·5	0·914
Physical activity (MET)	45·4	3·4	45·4	3·8	0·952
SBP (mmHg)	96·9	13·9	95·5	14·6	0·110
DBP (mmHg)	63·08	13·3	61·05	13·6	0·033
Passive smoker, yes (%)	32·4		43·1		0·006
Menstruation, yes (%)	85·9		86·3		0·972
hs-CRP (mg/l)	1·52	1·73	1·53	1·9	0·911
FBG (mg/dl)	86·4	11·8	85·4	11·4	0·207
HDL-cholesterol (mg/dl)	46·9	8·7	47·3	9·5	0·546
LDL-cholesterol (mg/dl)	99·0	24·4	99·0	26·9	0·932
TC (mg/dl)	161·1	28·5	161·2	29·4	0·944
TAG (mg/dl)	83·2	36·4	86·9	44·1	0·203

WC, waist circumference; MET, metabolic equivalent; SBP, systolic blood pressure; DBP, diastolic blood pressure; hs-CRP, high-sensitivity C-reactive protein; FBG, fasting blood glucose; TC, total cholesterol.
*Values are expressed as mean ± SD. Independent sample *t* test and χ^2 test were used to analyse differences in demographic and biochemical characteristics.

Table 2 Dietary fibre and antioxidant intakes of participants with no or minimal and mild-to-severe depression symptoms

	Depression severity				
	No or minimal (*n* 733)		Mild to severe (*n* 255)		
Variables	Mean	SD	Mean	SD	*P* value
Energy (kcal)	2711	824*	2718	849	0·901
Vitamin C (mg/d)	99·1	65·9	90	53·7	0·041
Vitamin A (mcg/d)	600·7	364·2	584·6	790·9	0·723
Vitamin E (mg/d)	13·7	6·68	13·5	7·49	0·716
β-Carotene (mcg/d)	3558	2876	3024	2321	0·006
α-Carotene (mcg/d)	588·9	633	479·1	507·7	0·014
Lutein (mcg/d)	2031	1837	1763	1507	0·034
Lycopene (mcg/d)	3807	2910	3759	2849	0·804
Soluble dietary fibre (g/d)	0·42	0·36	0·34	0·25	< 0·001
Insoluble dietary fibre (g/d)	2·17	1·62	1·79	1·19	< 0·001

*Values are expressed as mean ± SD. Independent sample *t* test was used to analyse differences in dietary fibre and antioxidant intakes.

with our findings, Prohan *et al.* found that young male university students with major depressive disorder consumed less dietary antioxidants such as vitamin C, β-carotene, lutein and zeaxanthin than healthy controls[35]. In another study on 278 elderly participants, Payne *et al.* observed that vitamin C, lutein and β-cryptoxanthin intakes were significantly lower among individuals with depression than in healthy participants. Additionally, fruit and vegetable consumption was lower in individuals with depression[22]. Amr *et al.* conducted a 6-month, double-blind, placebo-controlled pilot trial and found vitamin C as an effective adjuvant agent in the treatment of paediatric major depressive disorder[37]. Moreover, adherence to a Mediterranean dietary pattern was found to be associated with better mental health, which was independently explained by dietary total antioxidant and fibre content[21]. Furthermore, Tsai and colleagues conducted a prospective cohort study among a sample of free-living elderly and found that more frequent consumption of vegetables was protective against depressive symptoms, which was suggested to be due to high antioxidant content[36].

We found an inverse association between dietary intakes of β-carotene, α-carotene and lutein, but not lycopene, and depression symptoms. In this regard, several previous studies have investigated the relationship between dietary intake and plasma status of carotenoids and depressive symptomatology[23,38,39]. In line with our observations, Ye *et al.* observed an inverse association between intake of total carotenoids and depression score after adjustment for age, sex, education, smoking, BMI, energy intake, plasma cholesterol, vitamin B_6, vitamin C and homocysteine. Interestingly, similar association was

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Table 3 Crude and adjusted OR (with 95 % CI) of dietary intake of antioxidants (expressed as quartiles, Q2, Q3, Q4 *v.* Q1) and elevated depressive symptoms among Iranian adolescent girls

	Quartiles of nutrients intake*						
	Reference group (Q1) and Q2		Reference group (Q1) and Q3		Reference group (Q1) and Q4		
	OR	95 % CI	OR	95 % CI	OR	95 % CI	P_{trend}
Vitamin C							
Crude	0·87	0·57, 1·33	0·80	0·52, 1·22	0·76	0·49, 1·16	0·182
Model I	0·80	0·52, 1·24	0·68	0·43, 1·09	0·61	0·37, 1·00	0·043
Model II	0·81	0·52, 1·26	0·68	0·42, 1·09	0·61	0·37, 1·01	0·047
β-Carotene							
Crude	1·06	0·7, 1·61	0·87	0·57, 1·33	0·52	0·33, 0·80	0·010
Model I	0·96	0·62, 1·50	0·80	0·52, 1·24	0·43	0·27, 0·71	0·004
Model II	0·91	0·58, 1·42	0·77	0·50, 1·20	0·42	0·26, 0·69	0·003
α-Carotene							
Crude	0·75	0·49, 1·14	0·73	0·48, 1·11	0·58	0·37, 0·88	0·013
Model I	0·72	0·46, 1·10	0·67	0·43, 1·04	0·51	0·32, 0·81	0·005
Model II	0·69	0·45, 1·07	0·63	0·41, 0·98	0·50	0·31, 0·79	0·004
Lutein							
Crude	1·21	0·80, 1·84	0·71	0·46, 1·09	0·79	0·52, 1·21	0·072
Model I	1·16	0·75, 1·78	0·68	0·43, 1·07	0·71	0·44, 1·14	0·042
Model II	1·18	0·76, 1·82	0·66	0·42, 1·05	0·71	0·44, 1·15	0·031
Soluble dietary fibre							
Crude	0·94	0·62, 1·42	0·78	0·51, 1·18	0·61	0·39, 0·93	0·011
Model I	0·84	0·54, 1·29	0·69	0·44, 1·08	0·52	0·33, 0·84	0·005
Model II	0·81	0·52, 1·25	0·66	0·42, 1·04	0·51	0·32, 0·82	0·004
Insoluble dietary fibre							
Crude	0·89	0·59, 1·35	0·70	0·46, 1·07	0·52	0·34, 0·80	0·002
Model I	0·83	0·54, 1·28	0·61	0·39, 0·95	0·43	0·26, 0·70	< 0·001
Model II	0·80	0·52, 1·23	0·58	0·36, 0·91	0·42	0·25, 0·68	< 0·001

*OR with 95 % CI obtained from multinomial logistic regression analysis both crude and adjusted for potential confounders. Model I: Adjusted for age and energy intake. Model II: Additionally, adjusted for menstruation, family members, parental death, parental divorce, physical activity and BMI.

observed for plasma carotenoids[23]. Milaneschi *et al.* also found that low plasma concentrations of carotenoids were associated with depressive symptoms among a sample of women and men aged 65 years and older[38]. Similarly, total carotenoids (mainly *β*-carotene and lutein + zeaxanthins) in serum were found to be associated with less severe depression symptoms among community-dwelling US adults[39]. Furthermore, Li and colleagues showed that, in a group of 6680 adults aged 17–39 years, a history of attempted suicide was associated with low levels of carotenoids and antioxidant vitamins[40].

Similar to our findings, several studies have found an inverse association between dietary intake of fibre and severity of depressive symptoms[24,41,42]. In a study on 1977 Japanese workers between ages 19 and 69 years, Miki *et al.* found a significant inverse association between dietary fibre intake from vegetables and fruits and depressive symptoms. However, no association was found between depressive symptoms and dietary intake of total, soluble, insoluble and cereal fibre[41]. The authors suggested that the stronger association for fibre from vegetable and fruit could be attributable to its more readily fermentable properties compared with fibre from cereal. However, since the participants were Japanese manufacturing workers, care must be taken before generalising the findings[41]. In another study on 16 807 adults aged 20 years or older, it was revealed that dietary intakes of total fibre, fruit fibre and vegetable fibre were inversely associated with depressive symptoms[24]. Moreover, a Chinese study, which was conducted in 3394 community-dwelling older adults showed that total fibre intake was inversely associated with depression score[42]. The exact mechanism linking dietary intake of fibre to depression is unclear, but several possibilities are proposed. First, this can be partly explained by the potential involvement of dietary fibre in the transportation of dietary antioxidants through the gastrointestinal tract[19]. Second, SCFA, which are the products of colonic bacterial fermentation of dietary fibre, may improve inflammation[43], an underlying mechanism of depression[44]. Further, another possible mechanism may be related to the effects of fibre on gut microbiota and its subsequent impact on gut–brain axis for which there is emerging evidence of the importance in depression pathogenesis[45,46].

Our results revealed that adolescents with mild-to-severe depressive symptoms had significantly lower diastolic blood pressure compared with those with no or minimal depressive symptoms. A cross-sectional population-based study conducted in 60 799 men and women aged 20–89 years also showed that there is an association between low blood pressure and depression across all age and sex groups[47]. Further, in the 22-year follow-up of the Nord-Trøndelag Health Study in Norway, Hildrum *et al.* found that symptoms of depression and anxiety are associated with decrease in blood pressure[48]. Our results also showed that adolescents with mild-to-severe depressive symptoms were more likely to be passive smokers. Similarly, using data from the

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2005–2006 National Health and Nutrition Examination Survey, it was found that second-hand smoke exposure was positively associated with depressive symptoms in never-smokers aged ≥ 20 years[49]. Using cross-sectional data from a series of ten population surveys, Patten *et al.* reported that the pooled annual prevalence of major depressive disorder was 6·1 % in non-smokers with second-hand smoke exposure compared with 4·0 % in non-smokers without second-hand smoke exposure[50]. These results provide support for public health measures aiming to reduce second-hand smoke exposure to protect the health of non-smokers.

The strengths of our study include a relatively large sample of adolescent girls, a group with a high prevalence of depressive disorders, and using a standardised tool for assessment of depression symptoms. We acknowledge the limitations in our study including: (a) inclusion of only female sex, (b) the use of self-administered tool instead of more accurate face-to-face interviews and (c) the fact that we have assessed both depression symptoms and dietary intakes at baseline and no longitudinal assessment was performed. Therefore, we cannot say whether having depressive symptoms leads to lower consumption of foods rich in antioxidants or low dietary intakes of antioxidants and fibre contributes to the emergence of depressive symptoms.

In conclusion, this study showed a significant inverse association between dietary intake of some antioxidants and depression symptoms among Iranian adolescent girls. Moreover, higher dietary intakes of both soluble and insoluble fibre were associated with less severe depression symptoms.

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References

1. Ayuso-Mateos JL, Vazquez-Barquero JL, Dowrick C *et al.* (2001) Depressive disorders in Europe: prevalence figures from the ODIN study. *Br J Psychiatry* **179**, 308–316.
2. Uher R, Payne JL, Pavlova B *et al.* (2014) Major depressive disorder in DSM-5: implications for clinical practice and research of changes from DSM-IV. *Depress Anxiety* **31**, 459–471.
3. Bromet E, Andrade LH, Hwang I *et al.* (2011) Cross-national epidemiology of DSM-IV major depressive episode. *BMC Med* **9**, 90.
4. Ferrari AJ, Charlson FJ, Norman RE *et al.* (2013) Burden of depressive disorders by country, sex, age, and year: findings from the global burden of disease study 2010. *PLoS Med* **10**, e1001547.
5. Hankin BL, Abramson LY, Moffitt TE *et al.* (1998) Development of depression from preadolescence to young adulthood: emerging gender differences in a 10-year longitudinal study. *J Abnorm Psychol* **107**, 128–140.
6. Sajjadi H, Kamal SHM, Rafiey H *et al.* (2013) A systematic review of the prevalence and risk factors of depression among Iranian adolescents. *Glob J Health Sci* **5**, 16.
7. Moeini B, Bashirian S, Soltanian AR *et al.* (2019) Prevalence of depression and its associated sociodemographic factors among Iranian female adolescents in secondary schools. *BMC Psychol* **7**, 25.
8. Windfuhr K, While D, Hunt I *et al.* (2008) Suicide in juveniles and adolescents in the United Kingdom. *J Child Psychol Psychiatr* **49**, 1155–1165.
9. Ridker PM (1998) C-reactive protein and risks of future myocardial infarction and thrombotic stroke. *Eur Heart J* **19**, 1.
10. Biswas SK, Peixoto EB, Souza DS *et al.* (2008) Hypertension increases pro-oxidant generation and decreases antioxidant defense in the kidney in early diabetes. *Am J Nephrol* **28**, 133–142.
11. Cachofeiro V, Goicochea M, De Vinuesa SG *et al.* (2008) Oxidative stress and inflammation, a link between chronic kidney disease and cardiovascular disease: new strategies to prevent cardiovascular risk in chronic kidney disease. *Kidney Int* **74**, S4–S9.
12. Madeddu C, Gramignano G, Floris C *et al.* (2014) Role of inflammation and oxidative stress in post-menopausal oestrogen-dependent breast cancer. *J Cell Mol Med* **18**, 2519–2529.
13. Shafiee M, Tayefi M, Hassanian SM *et al.* (2017) Depression and anxiety symptoms are associated with white blood cell count and red cell distribution width: a sex-stratified analysis in a population-based study. *Psychoneuroendocrinology* **84**, 101–108.
14. Tayefi M, Shafiee M, Kazemi-Bajestani SMR *et al.* (2017) Depression and anxiety both associate with serum level of hs-CRP: A gender-stratified analysis in a population-based study. *Psychoneuroendocrinology* **81**, 63–69.
15. Shafiee M, Ahmadnezhad M, Tayefi M *et al.* (2018) Depression and anxiety symptoms are associated with prooxidant-antioxidant balance: A population-based study. *J Affect Disord* **238**, 491–498.
16. Yanik M, Erel O & Kati M (2004) The relationship between potency of oxidative stress and severity of depression. *Acta Neuropsychiatr* **16**, 200–203.
17. Sarandol A, Sarandol E, Eker SS *et al.* (2007) Major depressive disorder is accompanied with oxidative stress: short-term antidepressant treatment does not alter oxidative–antioxidative systems. *Hum Psychopharmacol-Clin Exp* **22**, 67–73.
18. Rawdin BJ, Mellon SH, Dhabhar FS *et al.* (2013) Dysregulated relationship of inflammation and oxidative stress in major depression. *Brain, Behav, Immun* **31**, 143–152.
19. Saura-Calixto F (2011) Dietary fiber as a carrier of dietary antioxidants: an essential physiological function. *J Agric Food Chem* **59**, 43–49.

20. Gonoodi K, Moslem A, Ahmadnezhad M *et al.* (2018) Relationship of dietary and serum zinc with depression score in Iranian adolescent girls. *Biol Trace Elem Res* **186**, 91–97.
21. Bonaccio M, Di Castelnuovo A, Bonanni A *et al.* (2013) Adherence to a Mediterranean diet is associated with a better health-related quality of life: a possible role of high dietary antioxidant content. *BMJ Open* **3**, e003003.
22. Payne ME, Steck SE, George RR *et al.* (2012) Fruit, vegetable, and antioxidant intakes are lower in older adults with depression. *J Acad Nutr Diet* **112**, 2022–2027.
23. Ye X, Scott T, Falcon LM *et al.* (2010) Dietary intake and plasma status of total carotenoids are inversely associated with depressive symptomatology in the Boston Puerto Rican Health Study. *FASEB J* **24**, 92.6.
24. Xu H, Li S, Song X *et al.* (2018) Exploration of the association between dietary fiber intake and depressive symptoms in adults. *Nutrition* **54**, 48–53.
25. Bahrami A, Mazloum SR, Maghsoudi S *et al.* (2018) High dose vitamin D supplementation is associated with a reduction in depression score among adolescent girls: a nine-week follow-up study. *J Diet Supplements* **15**, 173–182.
26. World Health Organization (1995) *Physical Status: The Use of and Interpretation of Anthropometry, Report of a WHO Expert Committee*. Geneva: World Health Organization.
27. Delshad M, Ghanbarian A, Ghaleh NR *et al.* (2015) Reliability and validity of the modifiable activity questionnaire for an Iranian urban adolescent population. *Int J Prev Med* **6**, 3.
28. Khayyatzadeh SS, Bagherniya M, Fazeli M *et al.* (2018) A Western dietary pattern is associated with elevated level of high sensitive C-reactive protein among adolescent girls. *Eur J Clin Invest* **48**, e12897.
29. Castelli WP, Garrison RJ, Wilson PW *et al.* (1986) Incidence of coronary heart disease and lipoprotein cholesterol levels: the Framingham Study. *JAMA* **256**, 2835–2838.
30. Asghari G, Rezazadeh A, Hosseini-Esfahani F *et al.* (2012) Reliability, comparative validity and stability of dietary patterns derived from an FFQ in the Tehran Lipid and Glucose Study. *Br J Nutr* **108**, 1109–1117.
31. Hosseini Esfahani F, Asghari G, Mirmiran P *et al.* (2010) Reproducibility and relative validity of food group intake in a food frequency questionnaire developed for the Tehran Lipid and Glucose Study. *J Epidemiol* **20**, 150–158.
32. Dozois DJ, Dobson KS & Ahnberg JL (1998) A psychometric evaluation of the Beck Depression Inventory–II. *Psychol Assess* **10**, 83.
33. Scogin F, Beutler L, Corbishley A *et al.* (1988) Reliability and validity of the short form Beck Depression Inventory with older adults. *J Clin Psychol* **44**, 853–857.
34. Ghassemzadeh H, Mojtabai R, Karamghadiri N *et al.* (2005) Psychometric properties of a Persian-language version of the Beck Depression Inventory-Second edition: BDI-II-PERSIAN. *Depression Anxiety* **21**, 185–192.
35. Prohan M, Amani R, Nematpour S *et al.* (2014) Total antioxidant capacity of diet and serum, dietary antioxidant vitamins intake, and serum hs-CRP levels in relation to depression scales in university male students. *Redox Rep* **19**, 133–139.
36. Tsai AC, Chang TL & Chi SH (2012) Frequent consumption of vegetables predicts lower risk of depression in older Taiwanese-results of a prospective population-based study. *Public Health Nutr* **15**, 1087–1092.
37. Amr M, El-Mogy A, Shams T *et al.* (2013) Efficacy of vitamin C as an adjunct to fluoxetine therapy in pediatric major depressive disorder: a randomized, double-blind, placebo-controlled pilot study. *Nutr J* **12**, 31.
38. Milaneschi Y, Bandinelli S, Penninx BW *et al.* (2012) The relationship between plasma carotenoids and depressive symptoms in older persons. *World J Biol Psychiatr* **13**, 588–598.
39. Beydoun MA, Beydoun HA, Boueiz A *et al.* (2013) Antioxidant status and its association with elevated depressive symptoms among US adults: national Health and Nutrition Examination Surveys 2005–6. *Br J Nutr* **109**, 1714–1729.
40. Li Y & Zhang J (2007) Serum concentrations of antioxidant vitamins and carotenoids are low in individuals with a history of attempted suicide. *Nutr Neurosci* **10**, 51–58.
41. Miki T, Eguchi M, Kurotani K *et al.* (2016) Dietary fiber intake and depressive symptoms in Japanese employees: the Furukawa Nutrition and Health Study. *Nutrition* **32**, 584–589.
42. Woo J, Lynn H, Lau WY *et al.* (2006) Nutrient intake and psychological health in an elderly Chinese population. *Int J Geriatr Psychiatr* **21**, 1036–1043.
43. Vinolo MA, Rodrigues HG, Nachbar RT *et al.* (2011) Regulation of inflammation by short chain fatty acids. *Nutrients* **3**, 858–876.
44. Berk M, Williams LJ, Jacka FN *et al.* (2013) So depression is an inflammatory disease, but where does the inflammation come from? *BMC Med* **11**, 1–16.
45. Foster JA & McVey Neufeld KA (2013) Gut-brain axis: how the microbiome influences anxiety and depression. *Trends Neurosci* **36**, 305–312.
46. Dinan TG & Cryan JF (2013) Melancholic microbes: a link between gut microbiota and depression? *Neurogastroenterol Motil* **25**, 713–719.
47. Hildrum B, Mykletun A, Stordal E *et al.* (2007) Association of low blood pressure with anxiety and depression: the Nord-Trøndelag Health Study. *J Epidemiol Commun Health* **61**, 53–58.
48. Hildrum B, Romild U & Holmen J (2011) Anxiety and depression lowers blood pressure: 22-year follow-up of the population based HUNT study, Norway. *BMC Public Health* **11**, 601.
49. Bandiera FC, Arheart KL, Caban-Martinez AJ *et al.* (2010) Secondhand smoke exposure and depressive symptoms. *Psychosomatic Med* **72**, 68.
50. Patten SB, Williams JV, Lavorato DH *et al.* (2018) Major depression and secondhand smoke exposure. *J Affective Disorders* **225**, 260–264.

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