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Dietary patterns and depression risk: A meta-analysis

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A R T I C L E I N F O

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Dietary patterns
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Meta-analysis

A B S T R A C T

Although some studies have reported potential associations of dietary patterns with depression risk, a consistent perspective hasn't been estimated to date. Therefore, we conducted this meta-analysis to evaluate the relation between dietary patterns and the risk of depression. A literature research was conducted searching MEDLINE and EMBASE databases up to September 2016. In total, 21 studies from ten countries met the inclusion criteria and were included in the present meta-analysis. A dietary pattern characterized by a high intakes of fruit, vegetables, whole grain, fish, olive oil, low-fat dairy and antioxidants and low intakes of animal foods was apparently associated with a decreased risk of depression. A dietary pattern characterized by a high consumption of red and/or processed meat, refined grains, sweets, high-fat dairy products, butter, potatoes and high-fat gravy, and low intakes of fruits and vegetables is associated with an increased risk of depression. The results of this meta-analysis suggest that healthy pattern may decrease the risk of depression, whereas western-style may increase the risk of depression. However, more randomized controlled trails and cohort studies are urgently required to confirm this findings.

1. Introduction

Depressive disorder is a leading cause of disability worldwide, affecting approximately 350 million people (Vermeulen et al., 2016). According to the statistics from the World Health Organization in 2012, depression is the fourth most common global burden of disease, and will be the second leading cause of disease burden, after cardiovascular disease, by the year 2020 (Lin et al., 2010). In Europe and North America, the lifetime prevalence of depression is estimated between 10–20%, and two times higher in women than in men (Le Port et al., 2012). In China, the incidence of depression in elderly people ranged from 4% to 26.5%, and it has become a substantial burden (Gao et al., 2009). It is well-known that diet is related to inflammation, oxidative stress and brain plasticity and function; all of these physiological factors are potentially involved in depression (Jacka et al., 2011).

In the past several decades, many epidemiological studies have pointed out that diet plays an important role in mental health and investigated the relation between the intake of individual foods or nutrients and the risk of depression (Murakami et al., 2010; Appleton et al., 2007; Lucas et al., 2011). However, in real life, people do not take isolated nutrients or foods, but consume meals containing combinations of many nutrients and foods that possibly interact with each other (Zhang et al., 2015). In this context, dietary pattern analysis has been recommended to become a more recognizable approach because it considered the complexity of overall diet and can potentially facilitate nutritional recommendations (Ruusunen et al., 2014).

To date, several previous studies have been performed to elucidate the associations between dietary patterns and depression risk. however, the results have been inconsistent (Chocano-Bedoya et al., 2013; Akbaraly et al., 2009; Kim et al., 2015; Gougeon et al., 2015). The healthy/prudent dietary patterns have tended to show inverse associations with depression risk (Chocano-Bedoya et al., 2013; Kim et al., 2015), whereas western dietary pattern has either shown a positive association (Chocano-Bedoya et al., 2013; Akbaraly et al., 2009), or no significant association (Gougeon et al., 2015; Okubo et al., 2011). Besides, the scientific report of the 2015 Dietary Guidelines Advisory Committee has concluded that current evidence on the association of dietary patterns with depression is limited (Dietary Guidelines Advisory Committee, 2015). Meanwhile, a previous systematic review examining the association between dietary patterns and depression was published by Rahe et al. (2014). The authors didn't find a protective effect of healthy dietary pattern on the risk of depression. Recently, another

Abbreviations: OR, Odds ratio; CI, Confidence interval

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systematic review has also reported the associations between dietary patterns and risk of depression in community-dwelling adults, but no firm conclusions have been made on the association between the Western diet and risk of depression (Lai et al., 2014). In a word, the evidence about the relation between dietary patterns and depression is limited and inconsistent. In view of this, we carried out this meta-analysis of studies published up to September 2016, to further clarify the potential association between dietary patterns and the risk of depression.

2. Methods

2.1. Literature search strategy

An electronic literature search was performed on MEDLINE and EMBASE databases to identify relevant studies written in the English and Chinese languages published up to September 2016, with the following keywords or phrases: "diet" OR "dietary pattern" OR "dietary patterns" OR "eating pattern" OR "eating patterns" OR "food pattern" OR "food patterns" AND "depression" OR "psychological stress" OR "depressive disorder" OR "depressive symptoms". Besides, no restrictions on the age of the study participants were imposed. Furthermore, we manually searched all references cited in original studies and reviews identified.

2.2. Studies included criteria

Two independent reviewers (Y. L. and M.-R.L) read the titles and abstracts of all articles retrieved in the initial search to identify studies that reported the association of overall dietary patterns with the risk of depression. Differences between the two independent reviewers were resolved by consensus or by a third independent reviewer (B. L) if necessary. When all agreed (Y. L., M.-R.L. and B. L), the full-text versions of articles were reviewed against inclusion and exclusion criteria for this meta-analysis. To be eligible, the studies had to fulfill the following criteria: (1) The study was an original report investigating the association of dietary patterns with the risk of depression; (2) Dietary patterns were identified using e.g. factor analysis, cluster analysis, reduced rank regression and principal component analysis in this study; (3) Odds ratios, hazards ratio or relative risks and percentage of depression (or sufficient information to calculate them) had been listed;(4) If the data in original publication lacked sufficient detail, the corresponding author of this study was contacted for additional information by email; (5)Depression was diagnosed based on clinical interviews, or self-report on a previous physician-made diagnosis of depression and antidepressant medication, or validated scales for assessing depressive symptomatology.

Moreover, to minimize error, the independent reviewers ensured that the selected dietary patterns were similar with regard to factor loadings of foods, which are consumed within those dietary patterns. For example, the healthy pattern is characterized to have high factor for foods, such as fruit, vegetables, whole grain, fish, olive oil, low-fat dairy and antioxidants (e.g. vitamin C, vitamin E, flavonoids, and carotenoids). The articles under consideration labelled it as "healthy"(Le Port et al., 2012; Okubo et al., 2011; Rashidkhani et al., 2013; Chatzi et al., 2011; Khosravi et al., 2015; Sugawara et al., 2012), "prudent" (Chocano-Bedoya et al., 2013; Jacka et al., 2014), "whole food"(Akbaraly et al., 2009), "green vegetables"(Kim et al., 2015), "traditional diet"(Gougeon et al., 2015; Weng et al., 2012), "vegetables-fruits"(Chan et al., 2014; Xia et al., 2016; Mihrshahi et al., 2015), "Mediterranean"(Sánchez-Villegas et al., 2015), "AHEI score"(Akbaraly et al., 2013), "whole plant foods"(Liu et al., 2016), "healthy Japanese" (Nanri et al., 2010), "dietary pattern 1″(Miki et al., 2015) and "Balanced Japanese"(Suzuki et al., 2013).The "Western-style" dietary pattern is mainly characterized by high factor loadings for foods, such as refined grains, red and/or processed meat, sweets, desserts, fast food, butter, high-fat dairy products, carbonated drink and low intakes of fruits and vegetables. The papers labelled it as "Western" (Le Port et al., 2012; Chocano-Bedoya et al., 2013; Okubo et al., 2011; Jacka et al., 2014; Chatzi et al., 2011; Sugawara et al., 2012), "processed food"(Akbaraly et al., 2009), "meats" (Kim et al., 2015), "convenience diet"(Gougeon et al., 2015), "meat-fish"(Chan et al., 2014), "animal foods"(Liu et al., 2016; Nanri et al., 2010; Xia et al., 2016; Weng et al., 2012), "unhealthy"(Rashidkhani et al., 2013; Khosravi et al., 2015) and "westernized"(Suzuki et al., 2013). Finally, twenty-one studies relevant to the role of dietary patterns and/or food and depression risk were included in the current meta-analysis.

2.3. Data extraction

We extracted the following data from all eligible studies: the authors, year of publication, geographic, study design, sample size, percentage of depression, the method of assessment of diet, identification of dietary patterns and the factors that were adjusted for in our analyses.

2.4. Assessment of heterogeneity

Heterogeneity across studies was measured by Cochran's Q statistic and I^2 statistic. I^2 values of 25%, 50%, and 75% were used as evidence of low, moderate, and high heterogeneity, respectively. If the P value of the Q-test was < 0.10 or an I^2 *value* ≥ *50%,* ORs were pooled according to the DerSimonnian and Laird method in the random-effect model. In contrast, the fixed-effects model (Mantel-Haenszel) was used to indicate the summary OR (Higgins et al., 2003).

2.5. Quality assessment

The Newcastle-Ottawa Quality Assessment scale was used for quality assessment (Stang et al., 2010). Eight questions were assessed and each satisfactory answer received one point (may receive two points in comparability categories), resulting in a maximum score of nine. Only those studies in which most of the questions were deemed satisfactory (i.e. with a score of six or higher) were considered to be of high methodological quality (Zheng et al., 2016).

2.6. Statistical analysis

Statistical analyses were performed by using Review Manager, version 5.0 (Nordic Cochrane Centre Copenhagen, Denmark) and STATA, version 12 (Stata Corp, College Station, TX, USA). The original studies reported the results of dietary patterns in terms of tertiles, quartiles, and quintiles of dietary factor scores and the risk of depression. We used meta-analysis to evaluate the risk of depression in the highest versus the lowest categories of healthy and western-style dietary patterns. Random-effect models were used to calculate the pooled odd ratio (OR) for dietary patterns in highest categories compared with lowest categories. If studies reported RR instead of OR, it was treated the same as OR when the reported incident depression was less than 20%. Multivariable adjusted Odds ratios, hazards ratios and relative risks with 95% CIs from individual studies were combined to produce an overall OR. Publication bias was assessed by inspection of the funnel plot and by formal testing for "funnel plot" asymmetry using Begg's test and Egger's test (Begg et al., 1994). Sensitivity analysis was conducted to determine whether differences in study design, sample size, age and races affected study conclusions. All statistical tests were two-sided and P values less than 0.05 were considered significant.

3. Results

3.1. Overview of included studies for the systematic review

An electronic literature search in the database of MEDLINE(n = 304) and EMBASE(n = 148) identified 452 studies, 412 of which were excluded based on the flowing reasons(in Fig. 1): duplicate records

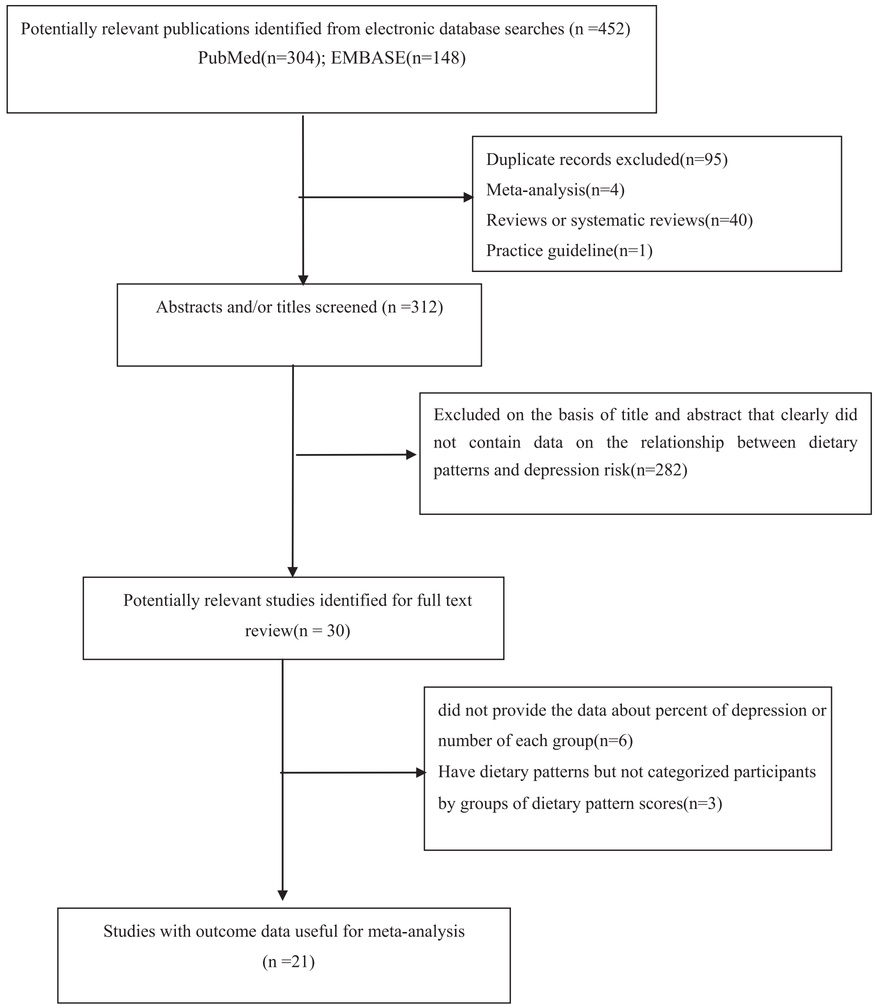

Fig. 1. Flow chart of article screening and selection process.

(n = 95); practice guideline(n = 1); meta-analysis(n = 4); systematic review (n = 40); title and abstract did not contain the data on the relation between dietary patterns and depression(n = 282); did not provide the data about percent of depression or number of each group(n = 6); had dietary patterns but not categorized participants by groups of dietary pattern scores(n = 3). A total of twenty-one articles (Le Port et al., 2012; Chocano-Bedoya et al., 2013; Akbaraly et al., 2009, 2013; Kim et al., 2015; Gougeon et al., 2015; Okubo et al., 2011; Chan et al., 2014; Sánchez-Villegas et al., 2015; Liu et al., 2016; Rashidkhani et al., 2013; Jacka et al., 2014; Nanri et al., 2010; Xia et al., 2016; Miki et al., 2015; Chatzi et al., 2011; Mihrshahi et al., 2015; Khosravi et al., 2015; Weng et al., 2012; Suzuki et al., 2013; Sugawara et al., 2012) met the eligibility criteria and were included in the present meta-analysis, including11 cohort studies (Le Port et al., 2012; Gao et al., 2009; Akbaraly et al., 2009, 2013; Gougeon et al., 2015; Okubo et al., 2011; Chan et al., 2014; Sánchez-Villegas et al., 2015; Jacka et al., 2014; Chatzi et al., 2011; Mihrshahi et al., 2015;), 6 cross-sectional studies (Liu et al., 2016; Nanri et al., 2010; Miki et al., 2015; Weng et al., 2012; Suzuki et al., 2013; Sugawara et al., 2012) and 4 case-control studies (Kim et al., 2015; Rashidkhani et al., 2013; Xia et al., 2016; Khosravi et al., 2015;). Study characteristics were presented in Table 1.

3.2. Healthy dietary pattern

In general, the healthy dietary pattern is characterized by high intakes of vegetables, fruits, whole grains, olive oil, fish, soy, poultry and low fat dairy. Fig. 2 shows an obvious evidence of a decreased risk of depression in the highest compared with the lowest category of healthy dietary pattern (OR = 0.64; CI: 0.57, 0.72; $P < 0.00001$). A random-effects model is used to assess the including data. The heterogeneity was apparent in all the studies ($P < 0.00001$; $I^2 = 79\%$).

3.3. Western-style/unhealthy dietary pattern

The western-style dietary pattern is mainly characterized by a high consumption of red and/or processed meat, refined grains, sweets, high-fat dairy products, butter, potatoes and high-fat gravy, and low intakes of fruits and vegetables. Fig. 3 shows the forest plot for the risk of depression in the highest compared with the lowest category of western-style dietary pattern. There was significant heterogeneity ($I^2 = 71\%$, $P < 0.00001$) and hence the effect was assessed using the the random-effects model. The results demonstrated that western-type dietary pattern was associated with an increased risk of depression (OR = 1.18; CI: 1.05, 1.34; $P = 0.006$).

3.4. Publication bias

Inspection of funnel plots did not reveal evidence of asymmetry (in Appendix A). Egger's tests for publication bias was not statistically significant (highest compared with lowest category: “healthy” dietary pattern $P = 0.321$, and “Western-style” dietary pattern $P = 0.101$).

3.5. Quality assessment

The quality of each study in terms of population and sampling

Table 1
Characteristics of 21 studies included in the meta-analysis (2009–2016).

Author Publication Year	Location	Study design	Total number of subjects	Age	Diet-assessment method	Factors adjusted for in analyses (Multivariable)	Dietary patterns identified
Le Port et al. (2012) [3]	France	Cohort	9272 men 3132 women	45–60y	FFQ	age in 1989, employment position at 35, professional activity, BMI, marital status, physical activity, tobacco smoking status and alcohol intake at baseline.	Men: low-fat, healthy, western, fat-sweet, and snacking; Women: low-fat, healthy, traditional, snacking, animal protein, dessert
Chocano-Bedoya et al. (2013) [11]	United states	Cohort	50,605	50–77y	FFQ	age (mo) and total caloric intake (continuous), BMI (continuous), smoking, physical activity (quintiles), menopause status, use of hormonal replacement therapy, marital status, caffeine (quintiles), multivitamin use (yes or no), retired (yes or no), participation in a community group or volunteering (yes or no), and reported diagnosis of cancer, high blood pressure, hypercholesterolemia, heart disease (myocardial infarction or angina), or diabetes, and the 5-item Mental Health Inventory at baseline (continuous).	Prudent and western
Akbaraly et al. (2009)[12]	England	Cohort	3846	35–55y	FFQ	marital status, employment grade, level of education, physical activity, smoking habits, marital status, employment grade, level of education, physical activity and smoking habits,hypertension, diabetes, cardiovascular disease, self-reported stroke, use of antidepressive drugs and cognitive functioning	Whole food, processed food
Kim et al. (2015) [13]	Korean	Case-control	849	12–18y	FFQ	Menstrual regularity and energy intake	Green vegetables; meats
Gougeon et al. (2015) [14]	Canada	Cohort	1358	Mean:75y	FFQ	Age, sex.total energy intake, marital status, smoking status, education, physical activity. body mass index, hypertension, physical functioning, cognitive functioning, social activities and stressful life events	Varied diet, traditional diet, convenience diet
Okubo et al. (2011) [15]	Japan	Cohort	865	Mean: 29.9y	FFQ	age (years, continuous), gestation (weeks, continuous), parity, cigarette smoking (never, former and current), change in diet in the preceding 1 month (none or seldom, slight and substantial), family structure (nuclear and expanded), occupation (outside work and housewife), family income, education, season in which data at baseline survey were collected (spring, summer, autumn and winter), BMI (kg/m2, continuous), time of delivery before the second survey (,4 and $4 months), medical problems in pregnancy (yes and no), baby's sex (male and female) and baby's birth weight (g, continuous).	Healthy, Western, Japanese
Chan et al. (2014) [23]	China	Cohort	2211	≥65y	FFQ	age, sex and daily energy intake , BMI, PASE, number of IADLs, smoking status, alcohol use, education and marital status,self-reported history of diabetes mellitus, hypertension, heart disease and stroke, and CSI-D score	vegetables-fruits,snacks-drinks-milk products, and meat-fish.
Sánchez-Villegas et al. (2015) [24]	Spain	Cohort	15,093	< 50y	FFQ	age, sex, body mass index, smoking, physical activity during leisure time, use of vitamin supplement, z scores for Mediterranean Diet Score, total energy intake and presence of several diseases at baseline (cardiovascular disease, type 2 diabetes, hypertension and dyslipidaemia)	Mediterranean diet, pro-vegetarian,Alternative healthy eating index − 2010
Akbaraly et al. (2013)[25]	Italy	Cohort	4215	Mean > 60y	FFQ	age, sex, ethnicity, and total energy intake at phase 7,SES, retirement, living alone, smoking, physical activity, coronary artery disease, type 2 diabetes, hypertension, HDL cholesterol, use of lipid-lowering drugs, central obesity, and cognitive impairment assessed at phase 7	AHEI score
Liu et al. (2016) [26]	China	Cross-sectional	906	48–65y	FFQ	the study (study 1 for Soy protein study and study 2 for whole soy study), age and menopausal years; education, marital status, per capita living space and income; and BMI, hypertension, diabetes, coffee, alcohol, supplements usage, total energy, and total physical activity.	Processed foods, whole plant foods, and animal foods
Rashidkhani et al. (2013) [27]	Iran	Case-control	Case:45 Control:90	25–45y	FFQ	smoking,family support, family history of depression, sleep duration and the number of stressful life events	Healthy; unhealthy
Jacka et al. (2014) [28]	Australia	Cohort	3663	20–64y	FFQ	Age, and sex.	Prudent; western
Nanri et al. (2010) [29]	Japan	Cross-sectional	521	21–67y	FFQ	age (year, continuous), sex, workplace (A or B), marital status (married or unmarried), body mass index (kg/m2, continuous), job position (low, middle or high), occupational physical activity (sedentary or active work), current smoking (yes or no), non-job physical activity, history of	Healthy Japanese; Animal food, westernized breakfast

(continued on next page)

Table 1 *(continued)*

Author Publication Year	Location	Study design	Total number of subjects	Age	Diet-assessment method	Factors adjusted for in analyses (Multivariable)	Dietary patterns identified
						hypertension (yes or no), history of diabetes mellitus (yes or no) and total energy intake (kcal/day)	
Xia et al. (2016) [30]	China	Case-control	1351 cases 1351controls	< 50 y	FFQ	other two dietary patterns scores	Vegetables and fruits, sweets, and animal foods
Miki et al. (2015) [31]	Japan	Cohort	2006	19–69 y	FFQ	age (year,continuous),sex,site (survey in April 2012 or in May 2013),marital status (married or other), job grade (low,middle,or high),night or Rotating shift work (yes or no),overtime work physical activity at work and housework or in commuting to work, leisure-time physical activity, smoking),and total energy intake (kcal/day,continuous).	Dietary pattern 1
Chatzi et al. (2011) [32]	Greece	Cohort	529	< 50y	FFQ	maternal age, maternal education, parity, house tenure, depression in previous pregnancies and total energy intake during pregnancy.	Western, healthy
Mihrshahi et al. (2015) [33]	Australia	Cohort	6271	45–50y	FFQ	education, marital status, BMI, physical activity, alcohol intake, fish and energy intake and comorbidities.	Fruit and vegetable
Khosravi et al. (2015) [34]	Iran	Case-control	330cases 660 controls	< 50y	FFQ	Non-depression drug use, job, BMI, children number, and marital status.	Healthy and unhealthy dietary patterns
Weng et al. (2012) [35]	China	Cross-sectional	5003	11–16y	FFQ	age, gender, maternal education, paternal education, family income BMI,and physical activity.	Snack, animal food, traditional
Suzuki et al. (2013) [36]	Japan	Cross-sectional	2266	21–65y	FFQ	age (year,continuous),gender,workplace (urban or rural), living state (alone or not), occupational physical activity (sedentary or active work),body mass index (kg/m2, continuous), total energy intake (kcal/day),job position (low, middle or high), education level (low, middle or high) and equivalent income, Strain (demand/control) support (support from superiors + co-workers).	Balanced Japanese, fish consumption, Westernized
Sugawara et al. (2012) [37]	Japan	Cross-sectional	791	22–86 y	FFQ	age, gender and exercise-habit, and the fully adjusted model was further adjusted for body mass index, amount of education, marital status, current smoking, history of hypertension and diabetes mellitus	Healthy, western, bread and confectionery, alcohol and accompanying

FFQ: Food frequency questionnaire; AHEI: Alternative Healthy Eating Index;SES, socioeconomic status;EPDS, Edinburg Postpartum Depression Scale.

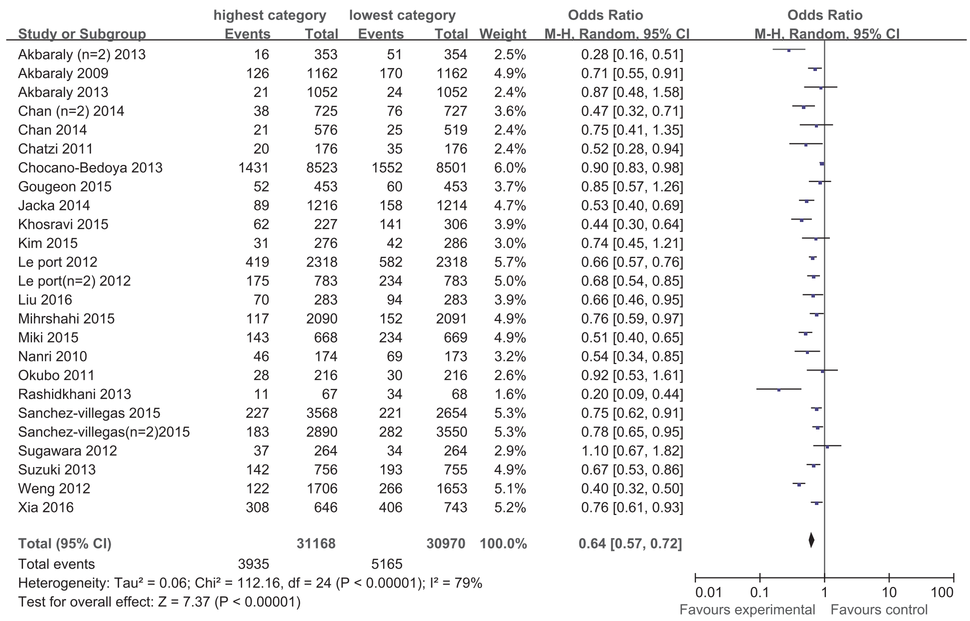

Fig. 2. Forest plot for ORs of the highest compared with the lowest category of intake of the healthy dietary pattern and depression.

methods, description of exposure and outcomes, and statistical adjustment of data, is summarized in Appendix B. All studies received a score of 6 or higher on the Newcastle-Ottawa Quality assessment scale and were considered to be of high methodological quality (Le Port et al., 2012; Chocano-Bedoya et al., 2013; Akbaraly et al., 2009, 2013; Gougeon et al., 2015; Okubo et al., 2011; Chan et al., 2014; Sánchez-Villegas et al., 2015; Liu et al., 2016; Rashidkhani et al., 2013; Jacka et al., 2014; Xia et al., 2016; Miki et al., 2015; Chatzi et al., 2011; Mihrshahi et al., 2015; Weng et al., 2012; Suzuki et al., 2013; Sugawara et al., 2012).

3.6. Sensitivity analysis

The sensitivity analysis revealed that differences in age, sample size, region and study design had an impact on the associations between dietary patterns and risk of depression. When the highest category was compared with the lowest category of healthy dietary pattern, the healthy dietary pattern/depression association was obvious when subjects were Asian and other. When the results were analyzed by removing European and American, subjects more than 50 years old age and case-control or cross-sectional design, the positive association between western-style dietary pattern and the risk of depression was more obvious. As these variables have a strong effect on association between dietary patterns and depression risk, their differences may partially explain the heterogeneity between studies (Table 2).

4. Discussion

Data on the association between dietary patterns and depression are scare in Chinese populations. To the best of authors' knowledge, this is the latest meta-analysis of depression risk and dietary patterns. In the present study, we have an update on the previous systematic review (Rahe et al., 2014 and Lai et al., 2014), and further identify the positive association between Western dietary pattern and the risk of depression. Results indicated that the healthy dietary pattern is associated with a decreased risk of depression, whereas the Western-style/unhealthy dietary pattern is associated with an increased risk of depression. Data from 21 studies involving 117,229 participants were included in the this meta-analysis. Our findings have further confirmed the significant association between dietary patterns and depression risk, and provided information that may be translated into preventive strategies to reduce its serious population impact and costs.

In our analyses, the healthy dietary pattern was associated with

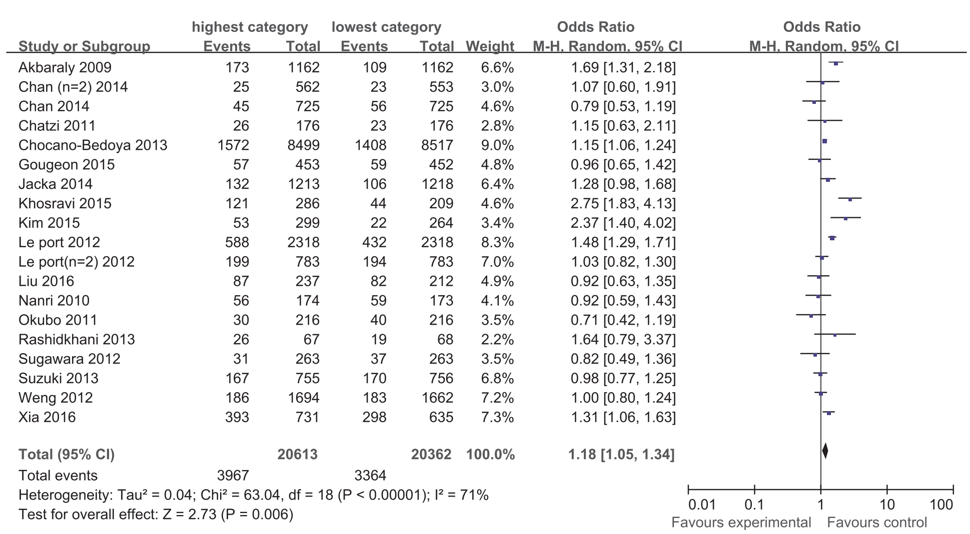

Fig. 3. Forest plot for ORs of the highest compared with the lowest category of intake of the western-style dietary pattern and depression.

Table 2
Dietary patterns and depression: sensitivity analysis.

Study characteristic	Category	Healthy dietary pattern (95% CI)	Western-style/unhealthy dietary pattern (95% CI)
Age	> 50	0.70(0.58, 0.84)	1.08(0.93, 1.26)
	< 50	0.61(0.53,0.70)	1.31(1.06, 1.61)
Sample size	Large (> 5000)	0.69(0.57, 0.84)	1.17(0.99, 1.38)
	Small (< 5000)	0.61(0.53, 0.71)	1.19(0.99,1.43)
Region	European and American	0.82(0.80, 1.07)	1.14(0.92, 1.41)
	Asian and Other	0.59(0.49, 0.71)	1.25(1.08, 1.45)
Study design	Case-control/cross-sectional	0.58(0.46, 0.74)	1.25(0.98, 1.59)
	Cohort	0.68(0.59, 0.77)	1.16(1.01, 1.34)

lower risk of depression. This finding is in line with some previous studies about the inverse association between the healthy/prudent dietary patterns and depression risk (Ruusunen et al., 2014; Xia et al., 2016). Most recently, a systematic review of observational studies conducted by Rahe et al.(Rahe et al., 2014) indicated that the healthy dietary pattern characterized by a high intake of fruit and vegetables, fish, and whole grain products, was associated with a decreased risk of depression. There are several possible explanations for this favorable effect of the healthy dietary pattern on the prevention of depression. Firstly, the high content of antioxidants (e.g. vitamin C, vitamin E, and other carotenoids compounds) in fruits and vegetables may have beneficial protective effects against depression. Some previous studies have indicated that higher antioxidant levels are associated with a reduced level of oxidative stress, inducing neuronal damage, particularly neurons in the hippocampus, which is thought to contribute to depression (Akbaraly et al., 2009; Sarandol et al., 2007). Secondly, the potential protective effect of the healthy dietary pattern could also come from folate rich in vegetables and fruits. Studies have shown that folate deficiencies may result in increased homocysteine concentrations and reduced availability of S-adenosylmethionine, which in turn are suggested to play a critical role in the pathophysiology of depression (Beydoun et al., 2010; Tolmunen et al., 2004). Thirdly, high consumption of fish has been shown to be associated with reduced likelihood of depression (Hibbeln et al., 1998). The protective effect of fish consumption may be attributed to its high content of long-chain omega-3 polyunsaturated fatty acids, which have anti-inflammatory properties and may contribute to brain functioning and serotonin neurotransmission (e.g. providing fluidity to neurons cell membrane)(Kiecolt-Glaser et al., 2010). Besides, recent evidence also suggests that adding omega-3 fatty acids to antidepressants may improve mood in major depression (Gertsik et al., 2012; Freeman et al., 2006). Furthermore, some foods with anti- inflammatory properties in the healthy dietary pattern were shown to influence concentrations of monoamines, which are thought to play an important role in the regulation of emotions and cognition (Kiecolt-Glaser et al., 2010).

The Western-style/unhealthy dietary pattern characterized by high intakes of red and/or processed meat, refined grains, sweets, and high-fat dairy product, was associated with an increased risk of depression in this meta-analysis. Our results were inconsistent with recent a systematic review (Sugawara et al., 2012), which indicated no statistically significant association between the Western diet and depression. Besides, in a study of Japanese population, the Western dietary pattern (high loadings for beef/pork, processed meat, mayonnaise/dressing and ice cream) was not associated with the risk of depression (Weng et al., 2012). In the present study, our findings are in agreement with some previous reports, which have shown a positive relationship between this pattern and risk of depression (Kim et al., 2015; Jacka et al., 2014). To our knowledge, there are several plausible mechanisms underlying this association. Firstly, high consumption of processed food may be related to inflammation and cardiovascular diseases, which are involved in the pathogenesis of depression (Lopez-Garcia et al., 2004; Tiemeier et al., 2003). Secondly, a previous study demonstrated the Western-type diet with a high intake of refined grains, processed meat, foods with high-sugar and high-fat was associated with higher levels of low-grade inflammation (C-reactive protein) and subsequent brain atrophy, which are positively associated with depression (Liu et al., 2002). Thirdly, the deleterious effect of the Western-style dietary pattern could also come from sugar rich in sweets and soft drinks. An observational study from eight countries reported that high sugar intake was associated with an increased risk of depression because it altered endorphin levels and oxidative stress (Westover et al., 2002). Besides, a previous study has also confirmed that soft drink consumption is associated with high depressive symptoms in Chinese (Yu et al., 2015). Finally, coffee contains high concentrations of caffeine, which may be associated with an increased risk of depressive symptoms (Fulkerson et al., 2004).

To further explore the possible reasons for heterogeneity, we performed the subgroup analysis and identified some factors. Dietary habits may be related to region and their local culture. The difference in region could potentially influence the relationship between dietary patterns and the risk of depression. The results indicated that the associations between healthy dietary pattern or Western-style dietary pattern and depression were obvious when subjects were Asian and other. Besides, the differences in age and study design have an impact on the associations between dietary patterns and risk of depression. The results from subgroup analysis showed that the association was obvious when subjects less than 50 years old age and cohort studies. Furthermore, to minimize error, we ensured that the selected dietary patterns were similar with regard to factor loadings of foods, which are consumed within those dietary patterns. However, the actual foods within the same dietary pattern were never identical between studies. Finally, the inconsistent adjustment for potential confounders in the included studies could also have contributed to heterogeneity. In our analyses, some studies included in the present meta-analysis provided crude estimates of association. In a word, these covariates might partially explain the observed heterogeneity between included studies.

4.1. Strengths and limitations

The present meta-analysis holds its own strengths and limitations. Firstly, this is the latest meta-analysis reporting the associations between dietary patterns and the risk of depression. We not only have an update on the earlier systematic review (Rahe et al., 2014; Lai et al., 2014), but also further clarify the positive association of western-style dietary pattern with the risk of depression. Secondly, the cases of depression have been diagnosed through clinical interviews, physician-made diagnosis of depression,antidepressant medication, and validated scales, avoiding misdiagnosis. Thirdly, no signs of publication bias were evident in the funnel plot, and the statistical test for publication bias was non-significant. However, some limitations should be considered when interpreting the results in this meta-analysis. Firstly, the principal limitation of this study was the use of potentially biased evidence. On the one hand, our diet data were derived from the FFQ, allowing for possible measure error. On the other hand, there is the problem of residual confounding. Most of the included studies adjusted for relevant confounders, but residual confounding can still be present, due to unmeasured, improper measured, or entirely unknown confounding factors. As a result, the data included in our analyses might suffer from differing degrees of completeness and accuracy. Secondly, 9 of 21 studies used a case-control or cross-sectional design, which is more susceptible to recall and selection bias, especially dietary recall bias, than a cohort design. Thirdly, even though some covariates have been taken into consideration, we cannot rule out the possibility that unmeasured factors might contribute to the association observed. Finally, the geographical regions covered in the present paper mainly included Asia (e.g. China, Korean, Japan, and Iran). Thus, our results have limited generalization to the all populations.

5. Conclusion

In conclusion, the present meta-analysis suggested that the healthy dietary pattern was associated with a decreased risk of depression, whereas Western-style/unhealthy dietary pattern was associated with an increased risk of depression. Our findings add to the evidence of the role of dietary patterns in the the prevention and management of depression. Therefore, it makes sense to elucidate the potential association between dietary patterns and depression risk and provide a scientific rational for formulating dietary guidelines. Further studies are urgently required to confirm the causal relationship between dietary patterns and the risk of depression.

Ethics

Ethical approval and participant consent were not required for this meta-analysis, since the study involved review and analysis of previously published data.

Competing interests

None.

Authors' contributions

Y.L., M.-R. L.and B.L. Designed and wrote the manuscript; Y.-J. W. Reviewed and edited the manuscript; L.S. designed the study and edited the manuscript; J.-X. Z. and H.-G. Z conducted the statistical analyses. All authors read and approved the final manuscript.

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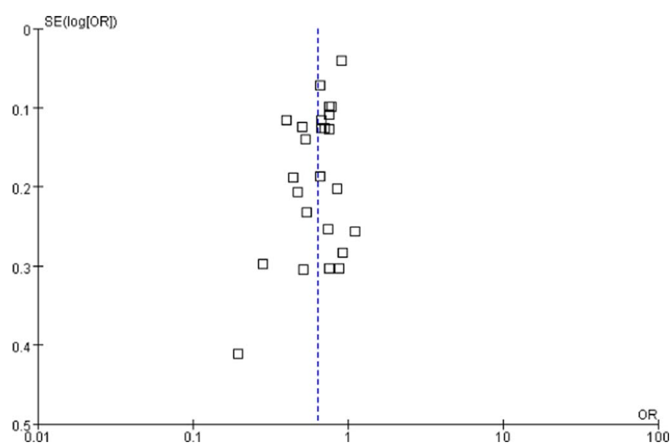
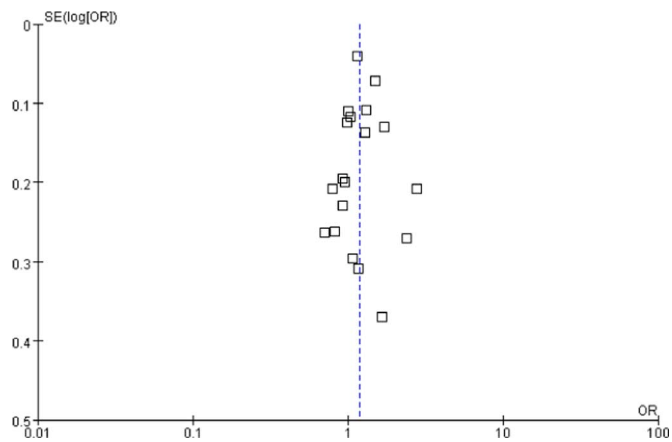
Appendix A.



Funnel plots for depression in the highest compared with the lowest category of intake of the healthy dietary pattern in all studies.



Funnel plots for depression in the highest compared with the lowest category of intake of the western-style dietary pattern in all studies.

Appendix B. Dietary patterns and depression: Assessment of Study Quality

Studies	Selection				Comparability		Outcome			
	1	2	3	4	5A	5B	6	7	8	Score
Le Port et al. (2012)	*	*	*		*		*	*		******
Chocano-Bedoya et al. (2013)	*	*	*	*	*		*	*	*	********
Akbaraly et al. (2009)	*		*	*	*		*	*		******
Kim et al. (2015)	*			*	*		*	*		*****
Gougeon et al. 2005	*	*	*	*	*		*	*		*******
Okubo et al. (2011)	*	*	*	*	*		*	*		*******
Chan et al. (2014)	*	*	*	*	*	*	*	*	*	*********
Sánchez-Villegas et al. (2015)	*	*	*	*	*		*	*	*	********
Akbaraly et al. (2013)	*	*	*	*	*		*	*	*	*********
Liu et al. (2016)	*		*	*	*		*	*		******
Rashidkhani et al. (2013)	*	*	*	*	*		*	*	*	********
Jacka et al. (2014)	*		*	*	*		*	*		*******
Nanri et al. (2010)	*		*		*		*	*		*****
Xia et al. (2016)	*	*	*	*	*		*	*		*******
Miki et al. (2015)	*	*	*	*	*		*	*	*	********
Chatzi et al. 2011	*		*	*	*		*	*		******
Mihrshahi et al. (2015)	*	*	*	*	*		*	*	*	********
Khosravi et al. (2015)	*			*	*		*	*		*****
Weng et al. (2012)	*	*	*		*		*	*	*	*******
Suzuki et al. (2013)	*	*	*	*	*		*	*		*******
Sugawara et al. (2012)	*		*	*	*		*	*		******

Appendix C. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.psychres.2017.04.020.

References

Akbaraly, T.N., Brunner, E.J., Ferrie, J.E., Marmot, M.G., Kivimaki, M., Singh-Manoux, A., 2009. Dietary pattern and depressive symptoms in middle age. Br., J. Psychiatry 195, 408–413.

Akbaraly, T.N., Sabia, S., Shipley, M.J., Batty, G.D., Kivimaki, M., 2013. Adherence to healthy dietary guidelines and future depressive symptoms: evidence for sex differentials in the Whitehall II study. Am. J. Clin. Nutr. 97, 419–427.

Appleton, K.M., Woodside, J.V., Yarnell, J.W., Arveiler, D., Haas, B., Amouyel, P., Montaye, M., Ferrières, J., Ruidavets, J.B., 2007. Depressed mood and dietary fish intake: direct relationship or indirect relationship as a result of diet and lifestyle? J. Affect. Disord. 104, 217–223.

Begg, C.B., Mazumdar, M., 1994. Operating characteristics of a rank correlation test for publication bias. Biometrics 50, 1088–1101.

Beydoun, M.A., Shroff, M.R., Beydoun, H.A., Zonderman, A.B., 2010. Serum folate, vitamin B-12, and homocysteine and their association depressive symptoms among U.S. adults. Psychosom. Med. 72, 862–873.

Chan, R., Chan, D., Woo, J., 2014. A prospective cohort study to examine the association between dietary patterns and depressive symptoms in older Chinese people in Hong Kong. PLoS. One 9, e105760.

Chatzi, L., Melaki, V., Sarri, K., Apostolaki, I., Roumeliotaki, T., Georgiou, V., Vassilaki, M., Koutis, A., Bitsios, P., Kogevinas, M., 2011. Dietary patterns during pregnancy and the risk of postpartum depression: the mother-child 'Rhea' cohort in Crete, Greece. Public. Health Nutr. 14, 1663–1670.

Chocano-Bedoya, P.O., O'Reilly, E.J., Lucas, M., Mirzaei, F., Okereke, O.I., Fung, T.T., Hu, F.B., Ascherio, A., 2013. Prospective study on long-term dietary patterns and incident depression in middle-aged and older women. Am. J. Clin. Nutr. 98, 813.

Dietary Guidelines Advisory Committee, 2015. Scientific Report of the 2015. Washington, DC: Dietary Guidelines Advisory Committee.

Freeman, M.P., Hibbeln, J.R., Wisner, K.L., Davis, J.M., Mischoulon, D., Peet, M., Keck Jr., P.E., Marangell, L.B., Richardson, A.J., 2006. Omega-3 fatty acids: evidence basis for treatment and future research in psychiatry. J. Clin. Psychiatry 67, 1954–1967.

Fulkerson, J.A., Sherwood, N.E., Perry, C.L., Neumark-Sztainer, D., Story, M., 2004. Depressive symptoms and adolescent eating and health behaviors: a multifaceted view in a population-based sample. Prev. Med. 38, 865.

Gao, S., Jin, Y., Unverzagt, F.W., Liang, C., Hall, K.S., Ma, F., Murrell, J.R., Cheng, Y., Matesan, J., Li, P., Bian, J., Hendrie, H.C., 2009. Correlates of depressive symptoms in rural elderly Chinese. Int. J. Geriatr. Psychiatry 24, 1358–1366.

Gertsik, L., Poland, R.E., Bresee, C., Rapaport, M.H., 2012. Omega-3 fatty acid augmentation of citalopram treatment for patients with major depressive disorder. J. Clin. Psychopharmacol. 32, 61–64.

Gougeon, L., Payette, H., Morais, J., Gaudreau, P., Shatenstein, B., Gray-Donald, K., 2015. Dietary patterns and incidence of depression in a cohort of community-dwelling older Canadians. J. Nutr. Health Aging 19, 431–436.

Hibbeln, J.R., 1998. Fish consumption and major depression. Lancet 351, 1213.

Higgins, J.P., Thompson, S.G., Deeks, J.J., Altman, D.G., 2003. Measuring inconsistency in meta-analyses. BMJ 327, 557–560.

Jacka, F.N., Mykletun, A., Berk, M., Bjelland, I., Tell, G.S., 2011. The association between habitual diet quality and the common mental disorders in community-dwelling adults: the Hordaland Health study. Psychosom. Med. 73, 483–490.

Jacka, F.N., Cherbuin, N., Anstey, K.J., Butterworth, P., 2014. Dietary patterns and depressive symptoms over time: examining the relationships with socioeconomic position, health behaviours and cardiovascular risk. PLoS. One 9, e87657.

Khosravi, M., Sotoudeh, G., Majdzadeh, R., Nejati, S., Darabi, S., Raisi, F., Esmaillzadeh, A., Sorayani, M., 2015. Healthy and Unhealthy Dietary Patterns Are Related to Depression: a Case-Control Study. Psychiatry Investig. 12, 434–442.

Kiecolt-Glaser, J.K., 2010. Stress, food, and inflammation: psychoneuroimmunology and nutrition at the cutting edge. Psychosom. Med. 72, 365–369.

Kim, T.H., Choi, J.Y., Lee, H.H., Park, Y., 2015. Associations between Dietary Pattern and Depression in Korean Adolescent Girls. J. Pediatr. Adolesc. Gynecol. 28, 533–537.

Lai, J.S., Hiles, S., Bisquera, A., Hure, A.J., McEvoy, M., Attia, J., 2014. A systematic review and meta-analysis of dietary patterns and depression in community-dwelling adults. Am. J. Clin. Nutr. 99, 181–197.

Le Port, A., Gueguen, A., Kesse-Guyot, E., Melchior, M., Lemogne, C., Nabi, H., Goldberg, M., Zins, M., Czernichow, S., 2012. Association between dietary patterns and depressive symptoms over time: a 10-year follow-up study of the GAZEL cohort. PLoS. One 7, e51593.

Lin, P.Y., Huang, S.Y., Su, K.P., 2010. A meta-analytic review of polyunsaturated fatty acid compositions in patients with depression. Biol. Psychiatry 68, 140–147.

Liu, S., Manson, J.E., Buring, J.E., Stampfer, M.J., Willett, W.C., Ridker, P.M., 2002. Relation between a diet with a high glycemic load and plasma concentrations of high-sensitivity C-reactive protein in middle-aged women. Am. J. Clin. Nutr. 75, 492–498.

Liu, Z.M., Ho, S.C., Xie, Y.J., Chen, Y.J., Chen, Y.M., Chen, B., Wong, S.Y., Chan, D., Wong, C.K., He, Q., Tse, L.A., Woo, J., 2016. Associations between dietary patterns and psychological factors: a cross-sectional study among Chinese postmenopausal

women. Menopause 23, 1294–1302.
Lopez-Garcia, E., Schulze, M.B., Fung, T.T., Meigs, J.B., Rifai, N., Manson, J.E., Hu, F.B., 2004. Major dietary patterns are related to plasma concentrations of markers of inflammation and endothelial dysfunction. Am. J. Clin. Nutr. 80, 1029–1035.
Lucas, M., Mirzaei, F., O'Reilly, E.J., Pan, A., Willett, W.C., Kawachi, I., Koenen, K., Ascherio, A., 2011. Dietary intake of n-3 and n-6 fatty acids and the risk of clinical depression in women: a 10-y prospective follow-up study. Am. J. Clin. Nutr. 93, 1337–1343.
Mihrshahi, S., Dobson, A.J., Mishra, G.D., 2015. Fruit and vegetable consumption and prevalence and incidence of depressive symptoms in mid-age women: results from the Australian longitudinal study on women's health. Eur. J. Clin. Nutr. 69, 585–591.
Miki, T., Kochi, T., Kuwahara, K., Eguchi, M., Kurotani, K., Tsuruoka, H., Ito, R., Kabe, I., Kawakami, N., Mizoue, T., Nanri, A., 2015. Dietary patterns derived by reduced rank regression (RRR) and depressive symptoms in Japanese employees: the Furukawa nutrition and health study. Psychiatry Res. 229, 214–219.
Murakami, K., Sasaki, S., 2010. Dietary intake and depressive symptoms: a systematic review of observational studies. Mol. Nutr. Food Res. 54, 471–488.
Nanri, A., Kimura, Y., Matsushita, Y., Ohta, M., Sato, M., Mishima, N., Sasaki, S., Mizoue, T., 2010. Dietary patterns and depressive symptoms among Japanese men and women. Eur. J. Clin. Nutr. 64, 832–839.
Okubo, H., Miyake, Y., Sasaki, S., Tanaka, K., Murakami, K., Hirota, Y., 2011. Dietary patterns during pregnancy and the risk of postpartum depression in Japan: the Osaka Maternal and Child Health Study. Br. J. Nutr. 105, 1251–1257.
Rahe, C., Unrath, M., Berger, K., 2014. Dietary patterns and the risk of depression in adults: a systematic review of observational studies. Eur. J. Nutr. 53, 997–1013.
Rashidkhani, B., Pourghassem Gargari, B., Ranjbar, F., Zareiy, S., Kargarnovin, Z., 2013. Dietary patterns and anthropometric indices among Iranian women with major depressive disorder. Psychiatry Res. 210, 115–120.
Ruusunen, A., Lehto, S.M., Mursu, J., Tolmunen, T., Tuomainen, T.P., Kauhanen, J., Voutilainen, S., 2014. Dietary patterns are associated with the prevalence of elevated depressive symptoms and the risk of getting a hospital discharge diagnosis of depression in middle-aged or older Finnish men. J. Affect. Disord. 159, 1–6.
Sánchez-Villegas, A., Henríquez-Sánchez, P., Ruiz-Canela, M., Lahortiga, F., Molero, P., Toledo, E., Martínez- González, M.A., 2015. A longitudinal analysis of diet quality scores and the risk of incident depression in the SUN Project. BMC Med. 13, 197.
Sarandol, A., Sarandol, E., Eker, S.S., Erdinc, S., Vatansever, E., Kirli, S., 2007. Major depressive disorder is accompanied with oxidative stress: short-term antidepressant treatment does not alter oxidative-antioxidative systems. Hum. Psychopharmacol. 22, 67–73.
Stang, A., 2010. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur. J. Epidemiol. 25, 603–605.
Sugawara, N., Yasui-Furukori, N., Tsuchimine, S., Kaneda, A., Tsuruga, K., Iwane, K., Okubo, N., Takahashi, I., Kaneko, S., 2012. No association between dietary patterns and depressive symptoms among a community-dwelling population in Japan. Ann. Gen. Psychiatry 11, 24.
Suzuki, T., Miyaki, K., Tsutsumi, A., Hashimoto, H., Kawakami, N., Takahashi, M., Shimazu, A., Inoue, A., Kurioka, S., Kakehashi, M., Sasaki, Y., Shimbo, T., 2013. Japanese dietary pattern consistently relates to low depressive symptoms and it is modified by job strain and worksite supports. J. Affect. Disord. 150, 490–498.
Tiemeier, H., Hofman, A., van Tuijl, H.R., Kiliaan, A.J., Meijer, J., Breteler, M.M., 2003. Inflammatory proteins and depression in the elderly. Epidemiology 14 (1), 103–107.
Tolmunen, T., Hintikka, J., Ruusunen, A., Voutilainen, S., Tanskanen, A., Valkonen, V.P., Viinamäki, H., Kaplan, G.A., Salonen, J.T., 2004. Dietary folate and the risk of depression in Finnish middle-aged men. A prospective follow-up study. Psychother. Psychosom. 73, 334–339.
Vermeulen, E., Stronks, K., Visser, M., Brouwer, I.A., Schene, A.H., Mocking, R.J., Colpo, M., Bandinelli, S., Ferrucci, L., Nicolaou, M., 2016. The association between dietary patterns derived by reduced rank regression and depressive symptoms over time: the Invecchiare in Chianti (InCHIANTI) study. Br. J. Nutr. 115, 2145–2153.
Weng, T.T., Hao, J.H., Qian, Q.W., Cao, H., Fu, J.L., Sun, Y., Huang, L., Tao, F.B., 2012. Is there any relationship between dietary patterns and depression and anxiety in Chinese adolescents? Public. Health Nutr. 15, 673–682.
Westover, A.N., Marangell, L.B., 2002. A cross-national relationship between sugar consumption and major depression? Depress Anxiety 16, 118.
Xia, Y., Wang, N., Yu, B., Zhang, Q., Liu, L., Meng, G., Wu, H., Du, H., Shi, H., Guo, X., Liu, X., Li, C., Han, P., Dong, R., Wang, X., Bao, X., Su, Q., Gu, Y., Fang, L., Yu, F., Yang, H., Kang, L., Ma, Y., Sun, S., Wang, X., Zhou, M., Jia, Q., Guo, Q., Wu, Y., Song, K., Niu, K., 2016. Dietary patterns are associated with depressive symptoms among Chinese adults: a case-control study with propensity score matching. Eur. J. Nutr. http://dx.doi.org/10.1007/ s00394-016-1293-y.
Yu, B., He, H., Zhang, Q., Wu, H., Du, H., Liu, L., Wang, C., Shi, H., Xia, Y., Guo, X., Liu, X., Li, C., Bao, X., Su, Q., Meng, G., Chu, J., Mei, Y., Sun, S., Wang, X., Zhou, M., Jia, Q., Zhao, H., Song, K., Niu, K., 2015. Soft drink consumption is associated with depressive symptoms among adults in China. J. Affect. Disord. 172, 422–427.
Zhang, X.Y., Shu, L., Si, C.J., Yu, X.L., Liao, D., Gao, W., Zhang, L., Zheng, P.F., 2015. Dietary patterns, alcohol consumption and risk of coronary heart disease in adults: a meta-analysis. Nutrients 7, 6582–6605.
Zheng, P.F., Shu, L., Si, C.J., Zhang, X.Y., Yu, X.L., Gao, W., 2016. Dietary Patterns and Chronic Obstructive Pulmonary Disease: A Meta-analysis. COPD. 13, pp. 515–22.