Diet quality and depression risk: A systematic review and dose-response meta-analysis of prospective studies

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Abstract

Background: It has been claimed that the quality of a diet is associated with the incidence of depressive disorders. We sought to investigate the evidence for this claim.

Methods: Systematic searches were performed up to March 6th 2017 in order to identify prospective cohort studies that reported on exposure to dietary patterns or food groups and the incidence of depression/depressive symptoms. Data from 24 independent cohorts (totalling 1,959,217 person-years) were pooled in random-effects meta-analyses.

Results: Adherence to a high-quality diet, regardless of type (*i.e.,* healthy/prudent or Mediterranean), was associated with a lower risk of depressive symptoms over time (odds ratios ranged 0.64 to 0.78 in a linear dose-response fashion [$P < .01$]). A relatively low dietary inflammatory index was also associated with a somewhat lower incidence of depressive symptom (odds ratio = 0.81), although not in a dose-response fashion. Similar associations were found for the consumption of fish and vegetables (odds ratios 0.86 and 0.82 respectively) but not for other high quality food groups (*e.g.,* fruit). Studies that controlled for depression severity at baseline or that used a formal diagnosis as outcome did not yield statistically significant findings. Adherence to low quality diets and food groups was not associated with higher depression incidence.

Limitations: Our ability to detect confounders was only limited.

Conclusion: There is evidence that a higher quality of a diet is associated with a lower risk for the onset of depressive symptoms, but not all available results are consistent with the hypothesis that diet influences depression risk. Prospective studies that control for relevant confounders such as obesity incidence and randomized controlled prevention trials are needed to increase the validity of findings in this field.

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Introduction

Adherence to a healthy or high-quality, or healthy, diet has been shown to co-vary with better mental health, with the latter almost always conceptualized as the absence of unipolar depressive symptoms. Conversely, adherence to low-quality diets has been associated with the presence of depressive symptoms (for reviews and meta-analyses see Li, Liu, & Zhang, 2015; Li *et al.,* 2017; O'Neil *et al.,* 2014; Quirk *et al.,* 2013).

A difficulty in establishing the diet-depression link however is that not all findings have been consistently replicated (Jacka, Cherbuin, Anstey, & Butterworth 2014; Lai *et al.,* 2016). Complicating the issue further is that the larger part of the evidence comes from cross-sectional studies (Khalid, Williams, & Reynolds 2017; O'Neil *et al.,* 2014). Depression and factors that predispose to its onset (Rucker 1906; Darmon & Drenowski, 2015) are associated with altered eating patterns (Stunkard, Faith, & Allison 2003) in many, but not all cases (Jacka *et al.,* 2015). Hence, cross-sectional data cannot differentiate to what extent diet or dietary behaviour is a risk factor, a consequence, or a concomitant phenomenon of depression (Kendler 2012; Stunkard, Faith, & Allison 2003). A final complicating factor is that the mechanistic understanding of the potential association between diet and depression is limited, although hypotheses exist (Jacka, 2017; Sarris *et al.,* 2015b).

In the absence of primary prevention trials on the effects of diet on depression incidence, the best available evidence on this association comes from prospective cohort studies. Here we pool the accumulated prospective evidence on the putative (dose-response) relation between diet quality and the incidence of depression/depressive symptoms and investigate whether the proposed association is influenced by methodological decisions made in individual studies (*e.g.,* statistical control for baseline depressive symptoms).

The experts gathered in the International Society for Nutritional Psychiatry Research [the ISNPR]), stated that "diet and nutrition are central determinants of mental health" and that "nutrition is a crucial factor in the high incidence and prevalence of mental disorders" (Sarris *et al.,* 2015a page 271). Hence, we expect consistent associations between dietary exposure and depression incidence.

Methods

We followed the guidelines stated in the PRISMA statement (Moher, Liberati, Tetzlaff, & Altman 2009). A protocol for this study was drafted and registered at PROSPERO (ID CRD42016041800).

Search strategy

We performed comprehensive literature searches in Embase, PUBMED, and Web of Science to identify relevant articles (up to March 6th 2017). The set of search terms that was used can be found in the online supplement. Additionally, we checked the references that were made to the two seminal papers on the subject (Hakkarainen *et al.,* 2004; Timonen *et al.,* 2004). Earlier meta-analyses (Lai *et al.,* 2014; Li, Liu, & Zhang, 2015; Li, Yan, Liu, & Zhang, 2016; Li *et al.,* 2017; Psaltopoulou *et al.,* 2013) and reviews (Khalid, Williams, & Reynolds, 2017; O'Neil *et al.,* 2014; Quirk *et al.,* 2013; Rahe, Unrath, & Berger, 2014; Sanhueza, Ryan, & Foxcroft, 2013) that partly addressed the topic of the current study also were inspected. Our efforts stand out from earlier meta-analyses in that we pool (dose-response) prospective data only on all age-groups and all dietary patterns and food groups.

Inclusion and exclusion criteria

We retained studies that reported on the association between dietary patterns or the consumption of food groups and the incidence of depression (DSM-IV APA, 2000; DSM-5 APA 2013; ICD 10 WHO, 2016) *and/or* changes in depressive symptoms. We considered a dietary pattern or food group to be of high-quality when the *a priori* definition or the factor loadings derived through factor- or principal component analysis aligned with the food groups mentioned by the experts (Sarris *et al.,* 2015a; b) as being healthy or when they were defined as such by the authors of the paper. In a similar manner, we defined unhealthy dietary patterns and food groups. **Tables S1** and **S2** in the online supplement specify the categorization and operationalization of the exposure- and outcome variables. We also defined a neutral exposure category; food groups on which no predictions have been made with regard to depression risk (*e.g.,* eggs). Jacka *et al.* (2015) only reported results that were in line with the study hypothesis, which was evident in 1 of 3 age cohorts. For analyses, we estimated the OR for the entire sample (*i.e.,* we bootstrapped between OR's = 0.85 and 1.14 for high- and low-quality diets respectively [the observed effects in 1 cohort] and OR = 1 (the estimated effects in the other two age cohorts).

Papers that reported on the association between the dietary inflammatory index and incidence of depression or depressive symptoms were also subjected to a meta-analysis. This analysis was not *a priori* registered but performed at request of one of the reviewers, recognizing that inflammatory processes may play a part in the pathophysiology of depressive disorder (*e.g.,* Miller & Raison, 2016).

Studies had to be written in English, Dutch, French, German, or Spanish in order to be retained. In case multiple articles reported on data that were derived from the same cohort, using the same

exposure variable, we excluded the article with the shortest follow-up. This occurred in one instance in which Sánchez-Villegas *et al.* (2015) was chosen over Sánchez-Villegas *et al.* (2009).

Data extraction and quality assessment

We extracted data on demographic, clinical, and methodological characteristics and effect-sizes and corresponding 95% Confidence Intervals (CI) on the association of interest. We extracted effect-size estimates from the model with the largest degree of statistical control for potential confounders (see **Table S3**). The methodological quality of the retained articles was assessed using the method proposed by Lievense *et al.* (2002) and is presented in **Tables S4** and **S5**.

Statistical analysis

Statistical analyses were performed in STATA (StataCorp 2013) with statistical significance set at $P < .05$. As effect-size measure we used the odds ratio (OR).

We pooled the data on depression/depressive symptom incidence as a function of highest compared to lowest category of adherence to (a) high-quality dietary patterns and food groups and (b) low-quality dietary patterns and food groups. In case a study provided input on > 1 exposure variable for one of the meta-analyses (*e.g.,* on the association between vegetable- and fruit intake and depression risk) and hence could be included twice in the healthy food group analysis, we averaged the effect-sizes over exposure variables and initially ran meta-analysis using this within-study pooled effect size (see the online supplement). Next, we stratified effect-size estimates by the components that made up the primary exposure variables (*e.g.,* a meta-analysis on the effect of fruit rather than pooling effect-size estimates over types of healthy food groups). We presented results from random-effects models (Borenstein, Hedges, & Higgins 2009). Outcomes were weighted using inverse variance methods.

After evaluating the pooled effects of highest compared to lowest exposure (*e.g.,* fifth *versus* first quintile), we calculated the risk of depression in the intermediate exposure categories compared to the lowest category (*e.g.,* fifth *versus* second quintile). Dose-response associations were estimated by pooling the reported *P*-values for trends over exposure categories using Edgington's additive method (Edgington 1972). To illustrate the clinical relevance of our findings we calculated the number of persons (and 95% CI) that would need to change their diets in order to prevent one case of depression (Number Needed to Benefit; NNB).

To assess potential sources of heterogeneity, we ran meta-analyses as a function of method of exposure assessment (*i.e.,* FFQ *vs* other), outcome assessment (*i.e.,* diagnosis *vs* self-report), whether the study controlled for depressive symptoms at baseline (yes *vs* no), geographic region

where the study was performed (in line with Li *et al.,* 2017 defined as: European an American *vs* Asian and others and additionally as Mediterranean *vs* non-Mediterranean) and whether analyses were controlled for time-varying covariates (*e.g.,* diabetes onset; yes *vs* no). Additionally, we related mean age and sex distribution of the sample, depression incidence, months of follow-up, and the methodological quality of a study to individual study outcome. Analyses on geographic region were requested by a reviewer and were not *a priori* registered.

Publication bias was assessed by means of visual inspection of funnel plots and Egger's tests (Egger, Smith, Schneider, & Minder, 1997).

Results

Study selection

Our initial search yielded 39,153 records (*k*). Of these, 32,433 were unique records. A total of 32,268 records were excluded after reading title and/or abstract, leaving 167 articles for consideration. Applying the inclusion and exclusion criteria led to a further exclusion of 138 articles. Twenty-nine records (see **Table 1**) were retained and included in quantitative synthesis. Study selection is presented in **Figure 1**.

--- FIGURE 1 ABOUT HERE ---

The selected 29 articles reported on 24 prospective cohorts (see **Table 1**). Information on overlap among samples is provided in the online supplement. The pooled data spanned 1,959,217 person-years of observations. **Table 1** and **S6** provide additional information on the input studies.

--- TABLE 1 ABOUT HERE ---

Meta-analysis

High-quality diet and food groups and depression incidence

The highest category of adherence to a high-quality diet, whether it was conceptualized as healthy/prudent-, Mediterranean-, pro-vegetarian or Tuscan, was associated with lower depression incidence when compared to the lowest category (OR's range 0.77, 0.75, 0.78 and 0.64 respectively, see **Table 2** panel 1 and **Figure 2** for a forest plot). The shape of the dose-response association between adherence to a dietary pattern and depression risk was linear with decreased depression incidence over increasing categories of adherence to a healthy diet ($P < .01$, see **Table S7**).

A similar association, although not dose-response, was observed for the intake of fish and vegetable but not for fruit, legumes/pulses, nuts/seeds/soy, and whole grain (pooled OR's ranged from 0.82 to 0.92, see **Table 2** panel 2 and **Figure S1** for a forest plot).

Five studies reported on 7 independent associations (*N* = 72,985) between the dietary inflammatory index and the incidence of depression or depressive symptoms. A meta-analysis on these associations showed that the lowest category of the dietary inflammation index was associated with a lower depression incidence when compared to the highest category (OR = 0.81, 95% *CI* = 0.71 to 0.92, *P* < .01). There was not much between-study heterogeneity (I^2 = 18.12, χ^2= 7.32, *P* = 0.29).

--- FIGURE 2 ABOUT HERE ---

Between-group heterogeneity was evident in all analyses (see **Table 2**) and this could not be explained for by continuous moderators such as number of months of follow-up or methodological quality (see **Table S8a**) nor by the geographic region in which the data was gathered (see **Table S8b**). There were no differences in effect size estimates as a function of exposure assessment or statistical control for time-varying covariates (see **Table 3**). Some heterogeneity could be explained by the definition of outcome assessment and statistical control for sub-clinical depression at baseline. Adherence to healthy dietary patterns or healthy food groups was not associated with depression incidence in studies in which a formal diagnosis was used as outcome and in studies that controlled for depression severity at baseline (see **Table 3**).

We estimated that 47 individuals (95% *CI* = 34 to 80) would need to change their dietary patterns from the lowest to the highest quality category in order to prevent 1 case of depression (or case change on a severity scale). This number would be larger when the dietary change was smaller, for instance from the second lowest to the highest quality category (number needed to benefit [NNB] = 65; 95% *CI* = 43 to 175). For the intake of combined healthy food groups, we estimated a NNB of 95 (95% *CI* = 61 to 211) in order to prevent a single *case of depression*.

Evidence for publication bias was not detected (see **Table 2**) in the analyses presented above and results were not unduly driven by a single study.

--- TABLE 2 ABOUT HERE ---

Low quality diet and food groups and depression incidence

The highest *vs* lowest category of adherence to a low-quality diet or food groups was not associated with depression incidence (OR's range 1.03 to 1.11, all *P*-values > .20; see **Table 2** panel 3 and 4 and **Figures 2** and **S2** for forest plots). Dose-response associations were not observed (see **Table S7**). Publication bias was not detected except for some small-scale analyses that applied low-quality food groups as exposure variable (see **Table 2**). Analyses in which we removed each individual study at a time did not change these results (data not shown).

Between-study heterogeneity in outcomes was large for all meta-analyses (see **Table 2**) and this could not be explained for by the categorical moderators defining assessment and differences in statistical control between studies (see **Table 3**) nor by other potential moderators including, for instance, mean age of the sample or the percentage of persons in a study who became depressed (see **Table S8**). NNB's were not calculated because of the absence of a statistical significant main effects.

--- FIGURE 3 ABOUT HERE ---

--- TABLE 3 ABOUT HERE ---

Adherence to supposedly neutral food groups (*e.g.,* eggs) was not associated with depression risk (see the online supplement).

Discussion

We sought to empirically test the expert claims that "diet and nutrition are central determinants of mental health" and that "nutrition is a crucial factor in the high incidence and prevalence of mental disorders" (Sarris *et al.,* 2015a page 271). These claims are supported by our finding that adherence to high-quality, healthy diets – regardless whether it was a healthy/prudent, Mediterranean, pro-vegetarian, or Tuscan diet - was associated with a lower incidence of depressive symptoms in a linear dose-response fashion. The consumption of more fish and vegetables was similarly associated with lower depression risk, although not in a linear dose-response pattern. Also consistent is the finding that adherence to a diet with a low inflammatory index was associated with a somewhat lower incidence of depression. Other findings, however,attenuate the conclusion that diet is crucially or causally involved. Dietary exposure was not associated with depression incidence in studies that controlled for baseline depression severity and those that used a diagnosis of depression as outcome. Furthermore, unhealthy dietary patterns and food groups and most of the healthy food groups were not associated with depression incidence.

Our findings generally are in line with earlier meta-analyses and reviews on this topic (see *e.g.,* Khalid, Williams, & Reynolds 2017). Yet they stand out from earlier efforts in that we only pool prospective dose-response data and did this in all age-groups and for all dietary patterns and food groups. Besides, we performed dose-response meta-analyses on these topics.

If quality of diet is a central determinant of depression , we would expect consistent statistical associations between these two concepts. Such consistent associations were not evident in our data. What also is needed is knowledge of the potential underlying mechanisms. Many interesting hypotheses exist. Some suggest an effect of nutrients on the brain's immune-, antioxidant defense-, and neurotrophic systems, which in turn could modulate depression risk (Sarris *et al.,* 2015a). Others have conceptualized the association in terms of metabolic health (Jørgensen *et al.,* 2016; Molero *et al.,* 2017). According to this view, that is not touched upon by the recently published reviews [Jacka, 2017; Sarris *et al.,* 2015a; b], certain dietary habits may predispose to metabolic illness, which in turn poses risk for depression. Conclusive data to explain the mechanism(s) that underlie the putative associations are not available, however. Future studies should present their results stratified for changes in metabolic health (*e.g.,* obesity incidence, diabetes incidence) in order to investigate how much of the association between diet and depression is moderated by such changes.

Dietary behaviour is the product of the interplay among a large number of factors that are not random (Darmon & Drewnowski 2015; Vandenbroucke 2008). Hence, many potential confounders should be traced and controlled for. If not, errors in inference may result. Two of our findings illustrate these concerns and they lead to doubts regarding the internal validity of the studies in the field.

Firstly, the association between dietary exposures and depression risk ceased to exist when analyses were controlled for baseline subclinical depressive symptoms. Subclinical depressive symptoms predict (more) severe depressive symptoms over time (Zuidersma *et al.,* 2013) and are related to less healthy dietary habits (Jacka *et al.,* 2010). A relative low quality diet thus may be a concomitant phenomenon of the early stage of depression without being genuinely associated to depression risk. If indeed so, this would indicate reversed causation. On the other hand, correcting for baseline depressive symptoms could be overcorrection. Dietary habits are often lifelong habits (Van 't Riet, Sijtsema, Dagevos, & de Bruijn 2011), so correcting for symptoms at the time a cohort starts, may result in cancelling out the effects that the diet had in the years before the study started.

Dietary patterns were not associated with depression incidence in studies that used a formal diagnosis as outcome. Dietary exposure is linked to metabolic disease onset (Fontana & Partridge

2015) and this group of diseases shares symptoms with depression (*e.g.,* fatigue) also when comorbidity between the two is not present (De Jonge *et al.,* 2006). The inverse association between high-quality dietary exposures and a lower depression incidence was only evident in studies that used symptom severity scales of depression as outcome. These measures assess the presence of symptoms of depression, regardless of whether the formal diagnostic criteria of depression are fulfilled. Fatigue and weight gain, for instance, may be signs of depression but also of metabolic disease (Glader, Stegmayr, Asplund 2002). If not many of the other diagnostic criteria are present (in particular, the core symptoms depressed mood and anhedonia), these symptoms will not lead to 'caseness' but will lead to a somewhat higher score on a depression questionnaire. Hence, symptom severity scales may overestimate a diet-depression link. On the other hand, a dimensional scale (symptom severity) may be more sensitive than a categorical scale (diagnosis). .

In line with a recent narrative review (Khalid, Williams, & Reynolds 2017), it needs to be mentioned that potential confounders, such as baseline social economic status, are not always taken into account. Confounder selection matters crucially at the outcome level, as was demonstrated by Jacka *et al.* (2015) and Sánchez-Villegas *et al.* (2016).

From a public health perspective, it is important to know whether depressive symptoms can be prevented by changing diet. Based on our data we can state that this may be the case. However, the number of persons who would need to change their diet, from the lowest- to the highest-quality category in order to prevent one case of depression is approximately 47. This number would be larger for less drastic dietary changes. However, dietary change is not easy to establish nor to retain (Appel *et al.,* 2006; Goode, Reeves, & Eakin 2012). It is possible that the NNB is overestimated and the other effect sizes are underestimated due to measurement error and/or unreliability of exposure and outcome assessment.

Still, an NNB of around 50 compares favourably to the NNB for widely prescribed medications such as statins in the primary prevention of cardiac disease (Ray *et al.,* 2010). Furthermore, medications have side-effects while high-quality food has none. Adherence to a high-quality diet is very attractive in this sense; it comes at no risk, only gain (Fontana and Partridge 2015) and everybody is exposed to a diet. However, the claim that a low-quality diet is a central determinant of depression risk is, given the current data, questionable.

A number of limitations regarding our findings and their implications needs to be mentioned. There was considerable between-study heterogeneity in outcome that could not be explained when following our preregistered plan of analyses. Furthermore, it is difficult to detect potential confounding variables using a study-level meta-analysis. The nature of our input studies also set

limits. Most studies measured dietary habits in a single assessment while multiple assessments are more accurate, account for change, and assess *habits*. Secondly, studies applied different outcome definitions (*e.g.,* a structured interview *versus* antidepressant use). All these reflect the construct of depression (Turvey, Wallace, & Herzog 1999) but have different levels of specificity and sensitivity, and this does matter (see the results obtained for symptom severity scales *vs.* diagnosis). Future studies should apply multiple exposure and outcome measurements at multiple moments in order to validly capture depression incidence (and course) as a function of dietary exposure. At the outcome level distinctions should be made regarding type of depression in order to decrease noise in the data. For instance, it may be more difficult to demonstrate an effect of dietary habits on the onset of seasonal affective disorder, as a strong determinant for this subtype is already known. Assessment of time-varying changes in variables related to depression outcome such as incident metabolic illness/obesity and exposure to stress (Kendler, 2012; Stunkard, Faith, & Allison 2003) could shed light on mechanisms and should be made into routine practice. Finally, many challenges or problems concerning confounders can be circumvented by means of randomized controlled prevention trials (Vandenbroucke, 2008). To date, no such a trial has been performed. Trials that test the related question of whether dietary recommendations can be used as an (adjunctive) treatment for depression do exist. These trials, reviewed by Opie, O'Neil, Itsiopoulos and Jacka (2015) show mixed results. Two intervention trials that were not part of the review by Opie *et al.* (2015) deserve further mention. The first of these showed a non-significant inverse effect of adherence to a Mediterranean dietary pattern on depression incidence (Sánchez-Villegas *et al.,* 2013). However, this trial focused on cardiac outcomes; depression was not a pre-determined primary or secondary outcome and was assessed from medical records. The second study showed a very large positive effect of dietary recommendations on the primary outcome depressive symptoms (Jacka *et al.,* 2017), however this trial was underpowered.

We conclude that dietary quality seems to be associated with the incidence of depressive symptoms but also that the evidence is less than unequivocal (*e.g.,* Jacka 2017; Sarris et al., 2015a, b). This research area would benefit from: (I) data on how dietary exposure is mechanistically connected to depression, (II) prospective cohort studies that control for the most relevant confounders (*a.o.,* metabolic illness/obesity incidence or baseline stress exposure) and (III) randomized controlled prevention trials.

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Figure legends

Figure 1 Flowchart on identification, screening and inclusion of eligible publications.

Figure 2 Forest-plot showing that adherence to a high-quality diet is associated with decreased odds on incident depression (pooled diagnosis and symptoms).

The exact type of dietary exposure is given as an abbreviation (between brackets) after the study name (HD = Healthy Diet, MedD = Mediterranean Diet, MIX = mixture of healthy diets; the plotted effect is the effect size pooled through meta-analysis on effect-sizes within cohort, TD = Tuscan Diet).

[M] = Male and [F] = female in case an individual study presented results stratified by sex.

Figure 3 Forest-plot showing that adherence to an low-quality diet is not associated with the odds on incident depression (pooled diagnosis and symptoms).

The exact type of dietary exposure is given as an abbreviation (between brackets) after the study name (Pr = processed diet, JF = Junk Food diet, We = Western diet, FS = Fat and Sugar diet).

[M] = Male and [F] = female in case an individual study presented results stratified by sex.

Tables

Table 1 Basic characteristics of the included studies (in chronological and alphabetical order).

Author	Analysis [a]	Exposure	Outcome	*N*	Months of follow-up	% Female	Mean age	Country
Hakkarainen *et al.* (2004)	III	FFQ	Diagnosis	27,111	108	0	60	Finland
Timonen *et al.* (2004)	III	FFQ	Diagnosis	5,689	372	52	31	Finland
Astorg *et al.* (2008)	III	Dietary recall	ADs	1864	96	57	49	France

Akbaraly *et al.* (2009)	I, II	FFQ	CES-D	3,486	60	27	55	UK
Colangelo *et al.* (2009)	III	FFQ	CES-D	3,317	120	55	32	USA
Sánchez-Villegas *et al.* (2009)	III, IV, V	FFQ	Diagnosis/ADs	10,094	51	58	37	Spain
Wiles *et al.* (2009)	II	FFQ	SDQ	4,000	30	NK	7	UK
Chatzi *et al.* (2011)	I, II, III, IV, V	FFQ	EPDS	529	6.5	100	29	Greece
Li *et al.* (2011)	III	Single question	CES-D/ADs	5,068	128	59	25-74 [b]	USA
Okubo *et al.* (2011)	I, II	FFQ	EPDS	865	9	100	30	Japan
Le Port *et al.* (2012)	I, II	FFQ	CES-D	12,358	120	25	53	France
McMartin *et al.* (2012)	I, III	YAQ	Diagnosis	3,757	48	52	10	Canada
Sánchez-Villegas *et al.* (2012)	IV	FFQ	Diagnosis	8,964	74	58	39	Spain
Tsai *et al.* (2012)	III, IV, V	Dietary recall	CES-D	1,609	48	42	75	Taiwan
Akbaraly *et al.* (2013)	I, III	FFQ	CES-D/ADs	4,215	120	25	60	UK
Chocana-Bedoya *et al.* (2013)	I, II	FFQ	Diagnosis/ADs	50,605	144	100	62	USA
Hodge *et al.* (2013)	I	FFQ	K-10	8,660	144	64	71	Australia
Rienks *et al.* (2013)	III, IV, V	FFQ	CES-D	7,588	36	100	56	Australia
Skarupski *et al.* (2013)	I	FFQ	CES-D	3,502	86	59	74	USA
Smith *et al.* (2014)	III	Dietary recall	Diagnosis	1,386	60	62	32	Australia
Gangwisch *et al.* (2015)	III, IV, V	FFQ	Burnam scale	69,954	36	100	64	USA
Gougeon *et al.* (2015)	II	Dietary recall	GDS	1,358	36	50	74	Canada
Jacka *et al.* (2015)	I, II	FFQ	GDS	3,663	~120	56	20-64 [b]	Australia
Mihrshahi *et al.* (2015)	III	Single question	CES-D	6,271	72	100	61	Australia
Pasco *et al.* (2015)	V	Dietary recall	Diagnosis	722	112	100	36 and 63 [c]	Australia
Sánchez-Villegas *et al.* (2015)	I	FFQ	Diagnosis/ADs	15,093	120	58	38	Spain
Lai *et al.* (2016)	I	DQES	CES-D	11,046	144	100	56	Australia
Vermeulen *et al.* (2016)	I	FFQ	CES-D	1,362	108	55	68	Italy
Adjibade *et al.* (2017)	I	Dietary recall	CES-D	3,523	151	58	50	France

Abbreviations: ADs, Antidepressants; CES–D, the Center for Epidemiologic Studies Depression scale; DQES, Dietary Questionnaire for Epidemiological Studies; EPDS, Edinburgh Postpartum Depression Scale; GDS, Goldberg Depression Scale; FFQ, Food Frequency Questionnaire; K10, Kessler psychological distress scale; PedsQL, the Pediatric Quality of Life Inventory; SDQ, the strengths and difficulties questionnaire; YAQ, Youth and adolescent food frequency questionnaire

[a] This column indicates in which analysis the study in the corresponding row is included

Dietary patterns → depression risk: [**I**] healthy diet; [**II**] unhealthy diet

Food groups → depression risk: [**III**] healthy food groups (fish, fruit, legumes, nuts, pulses, seafood, seeds, soy, vegetables); [**IV**] unhealthy food groups (junk/fast food; meat; refined grain); [**V**] neutral food groups (cereals, dairy, eggs, potatoes, starch, rice)

[b] Only a range was available

[c] Results in this study were reported separately for 2 different samples that differed with regard to age

Table 2 Highest versus lowest category of dietary- and food group exposure (by type) and the odds on depression incidence.

	k [a]	*N* [a]	Odds ratio (95% CI)	Heterogeneity		Publication bias
				I^2	X^2	*P*-value Egger's *t*
1 - *healthy dietary patterns - overall*	17	127,973	**0.77** (0.69 to 0.84)***	88.3	136.7***	0.20
Healthy / prudent	12	105,494	**0.77** (0.67 to 0.89)***	87.7	89.8**	0.23
Mediterranean	5	38,366	**0.75** (0.67 to 0.84)***	66.0	11.8*	0.16
Pro-vegetarian	1	15,093	**0.78** (0.64 to 0.93)***	*N.A.* [b]	*N.A.* [b]	*N.A.* [b]

Tuscan	1	1,165	**0.64** (0.51 to 0.77)*	*N.A.*[b]	*N.A.*[b]	*N.A.*[b]
2 - *healthy food groups - overall*	18	147,011	**0.89** (0.83 to 0.95)***	71.3	59.2***	0.39
Fish	16	69,469	**0.86** (0.78 to 0.95)**	68.4	47.4***	0.11
Fruit	6	89,708	**0.89** (0.78 to 1.03)	81.8	27.5***	0.54
Legumes/pulses	4	82,186	**0.93** (0.79 to 1.10)	43.1	5.3	0.93
Nuts/seeds/soy	2	70,483	**0.92** (0.84 to 1.02)	0.1	0.3	*N.A.*[b]
Vegetables	7	99,802	**0.82** (0.70 to 0.97)*	82.0	33.3***	0.30
Whole grain	1	69,954	**0.92** (0.83 to 1.02)	*N.A.*[b]	*N.A.*[b]	*N.A.*[b]
3 - *unhealthy dietary patterns - overall*	10	84,870	**1.05** (0.99 to 1.12)	45.2	16.4	0.67
Western	7	69,424	**1.06** (0.94 to 1.19)	18.8	2.5	0.76
Other [Junk – fast food]	3	15.446	**1.03** (0.97 to 1.09)	54.9	13.3*	0.23
4 - *unhealthy food groups - overall*	7	97,632	**1.09** (1.00 to 1.19)	26.2	8.13	0.04
Fast/junk food	2	16,552	**1.11** (0.87 to 1.43)	39.8	1.7	*N.A.*[b]
Meat	4	19,820	**1.04** (0.97 to 1.12)	0.2	2.7	0.08
Refined grains	1	69,954	**1.12** (1.01 to 1.24)	*N.A.*[b]	*N.A.*[b]	*N.A.*[b]
5 - *neutral food groups - overall*	7	98,084	**0.91** (0.84 to 1.00)	42.8	10.5	0.89

Abbreviations: N.A., Not Applicable

[a] Numbers do not add up to the total *k* or *N* because of overlapping studies in the subcategories of diet and food group exposure

[b] This could not be calculated because only 1 or 2 estimates were available

* Statistical significant at $P < .05$; ** Statistical significant at $P < .01$; *** Statistical significant at $P < .001$.

Table 3 Dietary patterns and food group adherence and the odds (in bold) on depression incidence by, exposure- and outcome assessment and levels of statistical control.

		k	*N*	Odds ratio (95% CI)	Heterogeneity		Publication bias
					I^2	X^2	*P*-value Egger's *t*
1. *healthy dietary patterns*							
Assessment							
Exposure:	FFQ	14	119,335	**0.74** (0.66 to 0.83)***	89.6	125.1***	0.11
	other	3	8,638	**0.76** (0.68 to 0.84)*	1.2	0.1	0.50
Outcome:	diagnosis	3	69,455	**0.91** (0.68 to 1.23)	94.1	33.7***	0.83

	self-reported	14	58.518	**0.72** (0.65 to 0.81)***	85.3	88.1***	0.11
Statistical control							
Depressive symptoms at baseline[1]: yes		3	65,314	**0.96** (0.87 to 1.06)[b]	60.9	5.1	0.24
	no	14	62,856	**0.72** (0.65 to 0.79)***[b]	80.9	68.2***	0.94
Time varying illness covariates:	yes	5	73,888	**0.74** (0.58 to 0.93)*	94.8	38.6***	0.50
	no	12	54,085	**0.76** (0.68 to 0.86)***	82.9	64.3***	0.28
2. *healthy food groups*							
Assessment							
Exposure:	FFQ	10	127,056	**0.95** (0.87 to 1.03)	51.3	16.4*	0.61
	other	8	19,955	**0.88** (0.83 to 0.91)**	80.2	40.3***	0.10
Outcome:	diagnosis	9	52,675	**0.92** (0.84 to 1.01)	52.1	16.7*	0.38
	self-reported	9	94,336	**0.89** (0.83 to 0.95)*	78.6	37.3***	0.49
Statistical control							
Depressive symptoms at baseline[1]: yes		1	27,111	**0.97** (0.71 to 1.33)	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]
	no	17	119,900	**0.88** (0.83 to 0.95)***	71.3	59.2***	0.35
Time varying illness covariates:	yes	0	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]
	no	18	147,011	**0.89** (0.83 to 0.95)***	71.3	59.2***	0.39
3. *unhealthy dietary patterns*							
Assessment							
Exposure:	FFQ	9	85,512	**1.06** (0.99 to 1·13)	49.7	15.9*	0.50
	other	1	1,358	**0.89** (0.61 to 1.30)	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]
Outcome:	diagnosis	1	50,605	**1.09** (0.98 to 1.22)	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]
	self-reported	9	34,265	**1.05** (0.97 to 1.13)	49.2	15.7*	0·71
Statistical control							
Depressive symptoms at baseline[1]: yes		1	34.265	**1.05** (0.97 to 1.12)	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]
	no	9	50.605	**1.09** (0.98 to 1.22)	49.3	15.8*	0.70
Time varying illness covariates:	yes	2	53.922	**1.18** (0.88 to 1.59)	38.5	1.6	*N.A.*[a]
	no	8	30.948	**1.04** (0.96 to 1.12)	48.2	13.5	0.95
4. *unhealthy food groups*							
Assessment							
Exposure:	FFQ	6	96,023	**1.07** (0.99 to 1.15)	40.5	8.4	0.03
	other	1	1,609	**1.18** (0.78 to 1.79)	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]
Outcome:	diagnosis	1	10,094	**1.36** (1.08 to 1.64)	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]
	self-reported	6	87,538	**1.04** (0.99 to 1.09)	0.3	5.3	0.05
Statistical control							
Depressive symptoms at baseline[1]: yes		0	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]
	no	7	97,632	**1.58** (0.90 to 2.77)	26.2	8.1	0.04
Time varying illness covariates:	yes	1	3,317	**1.09** (1.00 to 1.19)	*N.A.*[a]	*N.A.*[a]	*N.A.*[a]
	no	6	94,315	**1.07** (0.99 to 1.18)	26.3	6.2	0.11

Abbreviations: N.A., Not Applicable

1. Depressive symptoms at baseline refer to sub-clinical depressive symptoms

[a] This could not be calculated because zero or only 1 or 2 estimates were available

[b] Statistically significant different at $P < .01$ as compared to the other condition