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REVIEW

Dietary patterns and the risk of depression in adults: a systematic review of observational studies

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Abstract
Purpose Diet, a modifiable lifestyle factor, may influence the development of depression. We performed a systematic review of observational studies examining the relationship between dietary patterns and depression in healthy adults.
Methods A literature research was conducted searching various electronic databases up to May 2013. Study selection was based on predefined inclusion and exclusion criteria. Included studies were reviewed, and relevant data were extracted by two independent researchers. Due to a high level of heterogeneity, no meta-analysis was conducted. Therefore, main results are presented in a descriptive way.
Results In total, 16 studies met the inclusion criteria and are part of this review. Dietary patterns most commonly found were traditional/healthy patterns, Western/unhealthy patterns and Mediterranean patterns. The available literature suggests a protective effect of healthy and Mediterranean patterns, as well as a potential positive association of Western patterns and depression. However, comparison of the included studies was difficult, due to differences in relevant study characteristics and methodological limitations.
Conclusions There are indications that dietary patterns may have influence on the onset of depression, but no firm conclusion can be drawn at this point. Further research is needed to clarify the diet–depression relationship, preferably in the form of methodological strong prospective studies using more homogeneous methods.

Keywords Diet · Dietary patterns · Depression · Depressive symptoms · Systematic review · Observational studies

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Introduction

Mental health problems, in particular depression, are an increasing public health challenge. According to the World Health Organization, unipolar depressive disorders are third on the list of illnesses that contribute most to the burden of disease worldwide and are already the leading cause in the middle- and high-income countries [1]. Depression is related to emotional and cognitive dysfunction, a higher morbidity and premature mortality. It is also related to reduced social interactions, less productivity at work and early retirement [2, 3]. All these factors result in an overall decreased quality of life for affected individuals and in considerable economic costs for society. Thus, research on potential risk factors and effective prevention strategies against depression are of particular importance.

There is growing evidence that diet, a modifiable lifestyle factor, could be one component of such a prevention strategy. In different ways, diet influences physiological processes that may be involved in the development of depression, e.g., inflammation, oxidative stress or hormonal factors [4]. But in contrast to several other noncommunicable diseases, the preventive potential of diet in regard to depression is a rather new research area [5].

Prior research on the link between diet and depression focused mainly on the effects of single nutrients or foods

[6, 7]. However, in real life, people do not eat isolated nutrients or foods, but consume meals containing combinations of numerous nutrients that possibly interact with each other [8, 9]. The overall diet with its possible synergetic effects may have bigger impact on the development of health outcomes than individual nutrients, whose effects may be too small to detect [8]. Therefore, it seems more comprehensive to analyze the role of the overall diet using the more holistic approach of dietary pattern analysis [5, 8, 10].

Dietary pattern analysis is a relatively new concept in nutritional research. It aims to assess the habitual diet as one overall dietary exposure [8, 11]. In general, there are two approaches: Firstly, an a priori approach which constructs diet quality scores or indices based on predominant dietary recommendations; secondly, an a posteriori approach that uses statistical techniques to derive data-driven dietary patterns [8, 11, 12]. A third innovative approach was developed recently: hybrid methods such as reduced rank regression combine aspects of the a priori and a posteriori approaches [12].

The aim of this systematic review is to summarize available results of observational studies investigating the relationship between dietary patterns and depression in healthy adults.

Methods

This systematic review was conducted according to the 'Preferred Reporting Items for Systematic Reviews and Meta-analyses' (PRISMA) [13].

Literature search

The electronic databases PubMed, PsycINFO, PsyNDEX, PsycARTICLES, Cochrane Library, BIOSIS Previews, Web of Science and Scopus were searched for relevant articles, using combinations of the following search terms: (diet OR diets OR dietary OR 'diet quality' OR 'dietary pattern' OR 'dietary patterns') AND (depression OR depressive OR mood). Additionally, the PubMed database was searched for papers linked with the following medical subject headings (MeSH): (diet OR 'food habits') AND (depression OR 'depressive disorder'). The search was conducted in 2013 (January–May) and was restricted to English and German papers.

Included studies had to be observational studies (cohort-, case–control- or cross-sectional studies) that examined the relationship between dietary patterns as exposure and depression as the main outcome in samples of healthy free-living adult humans. For inclusion, articles had to use at least one quantitative dietary assessment and a dietary pattern analysis method. Articles that focused on the effects of single nutrients or foods were excluded. Regarding depression assessment, studies had to examine depression as the main outcome, using either clinical interviews to assess a clinical diagnosis of depression, or self-report on a previous physician-made diagnosis of depression and antidepressant medication, or validated scales for assessing depressive symptomatology. Studies examining other psychiatric diseases as the main outcome were excluded. Further exclusion criteria were the following: children or adolescents as sample subjects, patient samples (e.g., subjects with diabetes mellitus or cancer survivors), animal studies, narrative articles without primary data and articles not published in English or German.

In addition to the electronic database search, database services such as *related article search* and *cited reference search* were used to identify further articles. In a next step, the references of relevant articles were reviewed by hand search. To reduce the possibility of publication bias, the authors also tried to identify unpublished results, for instance, in the form of meeting abstracts or conference papers.

Data extraction and quality assessment

Two independent researchers reviewed the included articles individually and extracted and tabulated relevant information on the following study characteristics: authors, year of publication, country, study design, sample characteristics (e.g., sample size, sex, age, ethnic group), diet assessment, depression assessment, main results and additional relevant details (e.g., validation of assessment methods, adjustment for potential confounders, sensitivity analyses).

The quality of a systematic review is depending on the quality of the included original studies [14, 15]. Since there is still no consensus about how to assess the overall quality of primary studies [15, 16], a list of predefined criteria was used to determine the methodological quality of each included study, checking the following criteria: verbalization of aims and hypotheses, study design, appropriate exposure and outcome assessment, statistical considerations (e.g., proper adjustment for confounders, sample size, follow-up duration, response rate) and a clear presentation of methodology and main results. Each study received a summed score with respect to the above-mentioned items and was rated as either of low or intermediate or high quality.

Grouping of dietary patterns

Most of the included studies identified a multitude of different dietary patterns simultaneously. However, although

the patterns were never exactly the same, some comparable dietary patterns were found in several studies. These specific dietary patterns were based on very similar underlying dietary characteristics, but were labeled slightly differently across the published studies. To increase clarity of the present review, the identified dietary patterns were compared with regard to their dietary composition and were grouped into the most common patterns that were found in at least three studies. These most common dietary patterns are presented in detail below.

Statistical analyses

Values of Q and I^2 were calculated as measures of heterogeneity across the studies, considering I^2 values of <25 % as low heterogeneity [17]. Due to major methodological differences and the results of the heterogeneity tests, it was not advisable to conduct meta-analyses and to calculate pooled effect estimates. For this reason, the results of the present review are limited to a descriptive presentation. For better visualization and comparison, modified forest plots are presented that contain the individual results of the included studies, but no pooled effect estimates. In these forest plots, all studies that reported proper risk estimates [such as odds ratios (OR), relative risks (RR) or hazard ratios (HR) plus correspondent confidence intervals (CI)] were integrated. Studies that presented their results in other forms (such as β-coefficients or p values) could not be integrated in the forest plots, but are included in the text additionally.

All statistical analyses were conducted using the *meta command* in STATA (version 11.0; StataCorp, Texas, USA). All reported p values were considered to be statistically significant at $p < 0.05$, except for Rienks et al. [25] who set their level of significance at 0.1 % ($p < 0.001$).

Results

Included studies

Detailed information about the literature search process is shown in Fig. 1. Overall, a total of 16 studies met the eligibility criteria and were included in the present systematic review. Table 1 (cohort studies) and Table 2 (cross-sectional studies) provide a detailed overview of all included studies, their relevant study characteristics and main results.

Dietary pattern analysis is a relatively new approach in nutritional research. For this reason, most of the identified studies were published in recent years: Ten of the 16 included studies were published in the last 3 years (2011–2013) [9, 18–26], actually four of these in 2013 [9, 24–26]. The first identified study was published in 2008 [27]. The studies were conducted in eight countries: France [22, 27], Greece [18], Spain [28], Norway [20], United Kingdom [9, 29], United States of America [26, 30], Australia [4, 21, 24, 25] and Japan [19, 23, 31]. Eleven studies examined both genders [9, 20, 22–24, 26–31], whereof four studies conducted gender-stratified analyses with separate results for men and women [9, 20, 22, 27]. Further five studies conducted their analyses with female samples only [4, 18, 19, 21, 25]. Regarding dietary patterns analysis, four studies used diet scores or indices [9, 26, 28, 30], eight studies used statistical dietary pattern analyses [18, 19, 22, 23, 25, 27, 29, 31] and four studies used both approaches simultaneously [4, 20, 21, 24]. Regarding depression assessment, only two studies used clinical interviews: One study examined the effects of diet in regard to major depression/dysthymia [4], the other one focused on bipolar disorder [21]. The vast majority of the identified studies examined depressive symptoms as a general indicator of depression assessed by depression scales (most studies used the Center for Epidemiologic Studies–Depression Scale (CES-D)). Two studies investigated the relationship between diet during pregnancy and postpartum depression using the Edinburgh Postpartum Depression Scale (EDPS) [18, 19]. In terms of study design, nine studies showed a prospective [9, 18, 19, 22, 24–26, 28, 29] and seven a cross-sectional design [4, 20, 21, 23, 27, 30, 31]. The quality assessment showed that the cohort studies were of relatively high quality, whereas the cross-sectional studies ranged from intermediate to high quality. No study was grouped into the low-quality category. Therefore, all identified studies were included in the further analysis.

Three main diets became apparent in the included studies: (1) traditional/healthy dietary patterns, (2) Western/unhealthy dietary patterns and (3) Mediterranean dietary patterns. Many other patterns were found that could not be grouped into one of these three major groups because of their different underlying dietary compositions. In the following, the results for the main dietary patterns and their relationship with depression will be presented separately.

Traditional/healthy dietary patterns and depression

In general, healthy dietary patterns are mainly characterized by a high intake of fruit and vegetables, fish and seafood, and whole grain products [12]. Identified dietary patterns with such diet compositions were named slightly different, for instance, ‘healthy,’ ‘health conscious,’ ‘whole food’ or ‘traditional’ pattern. Dietary patterns labeled ‘traditional’ laid special emphasis on the adherence to traditional meal patterns (e.g., with regular mealtimes at

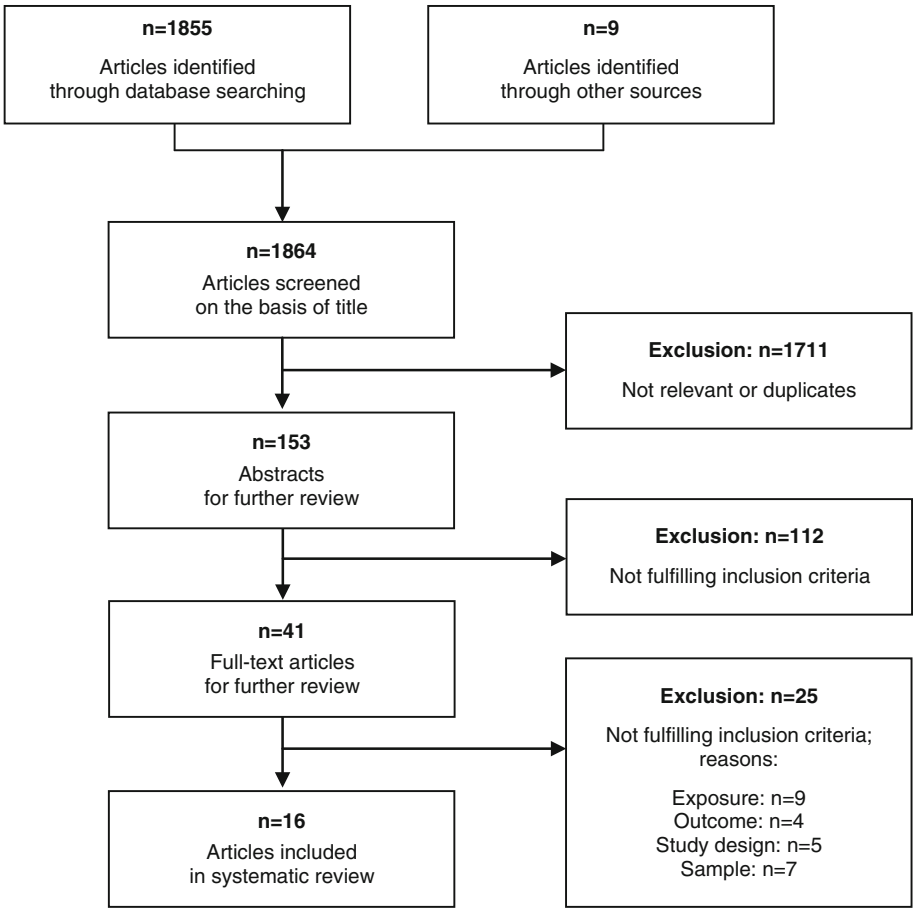

Fig. 1 Flow diagram of the literature search process

breakfast, lunch and dinner) and on a low consumption of processed foods. Diet scores were grouped to healthy patterns, if the score criteria were based on the above-listed foods and represented the adherence to a high-quality diet. In total, the association between traditional or healthy dietary patterns and the risk of depression was examined in eleven studies. The results of the studies reporting proper risk estimates as well as the results of the heterogeneity tests are presented in Fig. 2.

Prospective studies

Only one prospective study used a diet score for its analysis: Akbaraly et al. [9] examined the association between the Alternative Healthy Eating Index (AHEI) and the risk of recurrent depression. The researchers conducted gender-stratified analyses and found a significant inverse association in women, but not in men. In 2009, Akbaraly et al. [29] conducted another analysis, this time using statistical dietary pattern analysis techniques. A 'whole food' pattern was identified and showed an inverse, but not significant association with depressive symptoms (highest vs. lowest tertile: OR 0.73, 95 % CI 0.51–1.02). In another study using statistical dietary pattern analyses, Le Port et al. [22] conducted gender-stratified analyses: Firstly, a 'healthy diet' pattern was identified for both samples, which was inversely associated with depressive symptoms in men and in women; secondly, a 'traditional' pattern was identified in the female sample, which showed an even stronger inverse association with depressive symptoms.

Furthermore, two prospective studies [18, 19] focused on a specific depressive disorder and examined the association between dietary patterns during pregnancy and postpartum depression. Postpartum depression was assessed by EDPS in both studies, but the results were partly inconsistent. Both studies found no significant association between healthy dietary patterns and depressive symptoms measured as categorical outcome (Chatzi et al.: cut-off EDPS score $\geq$13; Okubo et al.: cut-off EDPS score $\geq$9), but Chatzi et al. found a significant inverse association between a 'health conscious' pattern and continuous EDPS scores ($\beta = -1.75$, 95 % CI -3.22 to -0.28; $p = 0.02$).

Cross-sectional studies

Kuczmarski et al. [30] investigated the association between the Healthy Eating Index-2005 (HEI-2005) and depressive symptoms assessed by CES-D. Their results showed that

Table 1 Characteristics of the included studies (cohort studies)

References, location	Study design, sample	Diet assessment	Depression assessment	Main results	Comments
Akbaraly et al. [29], United Kingdom	Prospective cohort study, based on the Whitehall II Study Baseline between 1997 and 1999 (phase 5), follow-up between 2002 and 2004 (phase 7), follow-up duration of about 5 years $n = 3{,}059$ (73.8 % male, 26.2 % female), office staff of civil service departments, white Europeans, aged 35–55 years at study start in 1985–1988 (phase 1)	Assessment method: Food frequency questionnaire, 127 items Dietary pattern analysis: principal component analysis Identified dietary patterns: whole food pattern, processed food pattern	Assessment of depressive symptoms Assessment method: Center for Epidemiologic Studies–Depression Scale (CES-D) Definition of depression: CES-D score ≥16	Odds ratios (95 % CI), highest versus lowest tertile (lowest = reference) for fully adjusted models Whole food pattern: OR 0.73 (0.51–1.02) Processed food pattern: OR 1.69 (1.10–2.60)	Adjusted for: gender, age, energy intake, marital status, employment grade, education, physical activity, smoking habits, hypertension, diabetes, stroke, cardiovascular disease, use of antidepressive drugs, cognitive functioning Exclusion of participants with antidepressant treatment or a score ≥4 on the General Health Questionnaire depression subscale at phase 5
Akbaraly et al. [9], UK	Prospective cohort study, based on the Whitehall II Study Baseline in 2003/2004 (phase 7), follow-up in 2008/2009 (phase 9), follow-up duration of 5 years $n = 4{,}215$ (3,155 male, 1,060 female), office staff of civil service departments, aged 35–55 years at study start in 1985–1988 (phase 1)	Assessment method: Food frequency questionnaire, 127 items Dietary pattern analysis: Alternative Healthy Eating Index (AHEI), based on 9 dietary components	Assessment of recurrent depression (=depressive symptoms at phase 7 and 9) Assessment method: Center for Epidemiologic Studies-Depression Scale (CES-D) Definition of depression: CES-D score ≥16 or self-reported use of antidepressant drugs	Odds ratios (95 % CI), highest versus lowest tertile (lowest = reference) for fully adjusted models Men: OR 0.95 (0.64–1.42) Women: OR 0.36 (0.20–0.64) Odds ratios (95 % CI) for each 1-SD increase in AHEI score (fully adjusted models) Men: OR 0.95 (0.80–1.13) Women: OR 0.59 (0.47–0.75)	Adjusted for: age, sex, ethnicity, total energy intake, socioeconomic status, retirement, living alone, smoking, physical activity, coronary artery disease, type 2 diabetes, hypertension, HDL cholesterol, use of lipid-lowering drugs, central obesity, cognitive impairment Exclusion of participants with antidepressant treatment at study phases 3 or 5
Chatzi et al. [18], Greece	Prospective cohort study, based on the mother–child cohort 'Rhea' Baseline in mid-pregnancy in 2007/2008, follow-up 8–10 weeks postpartum $n = 529$ women, Greek pregnant women with singleton pregnancies only	Assessment method: Food frequency questionnaire, 250 items Dietary pattern analysis: principal component analysis Identified dietary patterns: Western pattern, health conscious pattern	Assessment of depressive symptoms, postpartum depression Assessment method: Edinburg Postpartum Depression Scale (EPDS) Definition of depression: EPDS score ≥13	Relative risks (95 % CI) for categorical EDPS score (≥13), highest versus lowest tertile (lowest = reference) Western pattern: RR 1.14 (0.58–2.26) Health conscious pattern: RR 0.51 (0.25–1.05) β-Coefficients (95 % CI) for continuous EPDS scores, highest versus lowest tertile (lowest = reference) Western pattern: $\beta = 1.32$ (−0.19 to 2.76) Health conscious pattern: $\beta = -1.75$ (−3.22 to −0.28)	Adjusted for: maternal age, maternal education, parity, house tenure, depression in previous pregnancies, energy intake Exclusion of women with diagnosis of depression before pregnancy

Table 1 continued

References, location	Study design, sample	Diet assessment	Depression assessment	Main results	Comments
Hodge et al. [24], Australia	Prospective cohort study, based on the Melbourne Collaborative Cohort Study (MCCS) Baseline between 1990 and 1994, follow-up between 2003 and 2007, follow-up duration of about 12 years n = 8,660, healthy participants born in Australia, aged 50–69 years at baseline	Assessment method: Food frequency questionnaire, 121 items Dietary pattern analysis: (1) Mediterranean Diet Score (MDS), based on 9 components; (2) principal component analysis Identified dietary patterns: Mediterranean Diet Score, modified Mediterranean pattern, Australian pattern	Assessment of psychological distress (as a marker for depression) Assessment method: Kessler Psychological Distress Scale (K10) Definition of depression: K10 score ≥20	Odds ratios (95 % CI) for MDS categories MDS (0–3 points): reference MDS (4–6 points): OR 0.94 (0.77–1.13) MDS (7–9 points): OR 0.72 (0.54–0.95) Odds ratios (95 % CI), highest versus lowest quintile (lowest = reference) for fully adjusted models Modified Mediterranean pattern: OR 0.92 (0.69–1.24) Australian pattern: OR 0.61 (0.40–0.91)	Adjusted for: sex, age at baseline and follow-up, energy intake, physical activity, smoking, asthma, hypertension, arthritis, gallstones, kidney stones, education, socioeconomic status, number of relatives visited at least once a month, number of friends could visit without invitation, number of people in household, social activity Exclusion of participants who reported antidepressant drug use at baseline
Le Port et al. [22], France	Prospective cohort study, based on the GAZEL cohort Baseline in 1998, follow-up from 1999 up to 2008 n = 12,404 (9,272 male, 3,132 female), employees of France's National Gas and Electricity Company, aged 45–60 years at baseline	Assessment method: Food frequency questionnaire, 35 items Dietary pattern analysis: principal component analysis Identified dietary patterns Men: low-fat diet, healthy diet, Western diet, fat-sweet diet, high snacking pattern; Women: low-fat diet, healthy diet, traditional diet, high snacking pattern, high animal protein diet, high dessert pattern	Assessment of depressive symptoms Assessment method: Center for Epidemiologic Studies–Depression Scale (CES-D) Definition of depression: score of ≥17 in men, score of ≥23 in women	Odds ratios (95 % CI), highest versus lowest quartile (lowest = reference) for fully adjusted models Men Low-fat diet: OR 1.16 (1.02–1.31) Healthy diet: OR 0.72 (0.63–0.83) Western diet: OR 1.36 (1.19–1.54) Fat-sweet diet: OR 1.49 (1.30–1.71)Snacking pattern: OR 1.50 (1.32–1.71) Women Low-fat diet: OR 1.39 (1.22–1.73) Healthy diet: OR 0.75 (0.61–0.93) Traditional diet: OR 0.63 (0.50–0.80) Snacking pattern: OR 1.43 (1.16–1.76) Animal protein diet: OR 1.03 (0.84–1.26) Dessert pattern: OR 1.03 (0.84–1.26)	Adjusted for: age in 1989, employment position at 35 years, professional activity, body mass index, marital status, physical activity, smoking status, alcohol intake Sensitivity analysis: after exclusion of participants with CES-D ≥17/23 in 1996 and 1999 associations became non significant for the healthy diet patterns in men and women; the associations for the other patterns remained unchanged

Table 1 continued

References, location	Study design, sample	Diet assessment	Depression assessment	Main results	Comments
Okubo et al. [19], Japan	Prospective cohort study, based on the Osaka Maternal and Child Health Study (OMCHS) Baseline during pregnancy, follow-up took place at 2–9 month postpartum $n = 865$ women, Japanese pregnant women, mean age of 29.9 years at baseline	Assessment method: Diet history questionnaire, 150 items Dietary pattern analysis: factor analysis Identified dietary patterns: healthy pattern, Western pattern, Japanese pattern	Assessment of depressive symptoms, postpartum depression Assessment method: Edinburg Postnatal Depression Scale (EPDS) Definition of depression: EPDS score ≥9	Odds ratios (95 % CI), highest versus lowest quartile (lowest = reference) for adjusted models Healthy pattern: OR 0.94 (0.52–1.69) Western pattern: OR 0.73 (0.42–1.24) Japanese pattern: OR 0.96 (0.56–1.64)	Adjusted for: age, gestation, parity, smoking, change in diet in the preceding month, family structure, occupation, family income, education, season at baseline data collection, body mass index, time of delivery, medical problems in pregnancy, baby's sex, baby's birth weight
Rienks et al. [25], Australia	Prospective cohort study, based on the Australian Longitudinal Study on Women's Health Baseline in 2001 (survey 3), follow-up in 2004 (survey 4), follow-up duration of 3 years $n = 6{,}060$ women, aged 50–55 years at survey 3	Assessment method: Food frequency questionnaire, 80 items Dietary patterns analysis: factor analysis Identified dietary patterns: Cooked vegetables pattern, fruit pattern, Mediterranean style, meat and processed meat pattern, dairy pattern, high-fat and sugar pattern	Assessment of depressive symptoms Assessment method: Center for Epidemiologic Studies–Depression Scale (CES-D) (10 items version) Definition of depression: CES-D score ≥10	Odds ratios (95 % CI) per unit of factor score, for fully adjusted models Cooked vegetables pattern: OR 0.93 (0.84–1.02) Fruit pattern: OR 1.01 (0.91–1.11) Mediterranean style: OR 0.83 (0.75–0.91) Meat and processed meat pattern: OR 1.09 (0.98–1.21) Dairy pattern: OR 0.93 (0.84–1.02) High-fat and sugar pattern: OR 1.08 (0.96–1.20)	Adjusted for: energy intake, smoking, physical activity, ability to manage on available income, occupational status, education level, marital status, mean stress score, body mass index category Exclusion of participants with depressive symptoms (CES-D ≥10) at survey 3
Sanchez-Villegas et al. [28], Spain	Prospective cohort study, based on the University of Navarra Follow-up Project (SUN Project) Baseline started in 1999, follow-up questionnaires were mailed every 2 years, median follow-up duration of 4.4 years $n = 10{,}094$ (4,196 male, 5,898 female), healthy university graduates of the University of Navarra	Assessment method: Food frequency questionnaire, 136 items Dietary pattern analysis: Mediterranean dietary pattern (MDP), diet score based on 9 components	Assessment of (self-reported) depression Definition of depression: self-reported physician-made diagnosis of depression and/or use of antidepressant drugs	Hazard ratio (95 % CI) for adjusted model MDP (0–2 points): reference MDP (3 points): HR 0.74 (0.57–0.98) MDP (4 points): HR 0.66 (0.50–0.86) MDP (5 points): HR 0.49 (0.36–0.67) MDP (6–9 points): HR 0.58 (0.44–0.77) p for trend <0.001	Adjusted for: sex, age, smoking status, body mass index and its quadratic term, physical activity during leisure time, energy intake, employment status Exclusion of participants with antidepressant medication or physician-made diagnosis of depression at baseline

Table 1 continued

References, location	Study design, sample	Diet assessment	Depression assessment	Main results	Comments
Skarupski et al. [26], USA	Prospective cohort study, based on the Chicago Health And Aging Project (CHAP) Baseline: 1993–1996, follow-up interviews were conducted at 3-year intervals, average follow-up duration of 7.2 years $n = 3{,}502$ (41 % male, 59 % female), black and white community-dwelling Americans living in Chicago, aged 65 years or older	Assessment method: Food frequency questionnaire, number of items not mentioned Dietary pattern analysis: Mediterranean Diet Score (MDS), based on 11 components	Assessment of depressive symptoms Assessment method: Center for Epidemiologic Studies-Depression Scale (CES-D) (10 items version) Definition of depression: CES-D score ≥4	Parameter estimate (standard error) for fully adjusted model: −0.002 (0.001), $p = 0.04$ β (SE) for basic adjusted model Tertile 1 (T1): $\beta = 0.03$ (0.01), $p = 0.05$ Tertile 2 versus T1 (slope difference): $\beta = -0.01$ (0.01), $p = 0.25$ Tertile 3 versus T1 (slope difference): $\beta = -0.03$ (0.01), $p < 0.001$	Adjusted for: age, sex, race, education, income, widowhood, calories, body mass index, Mediterranean Diet Score, time lag, smoking, alcohol use, medical conditions and interactions of each variable with time lag Exclusion of participants with depressive symptoms (CES-D ≥4) at baseline

diet quality was inversely associated with depressive symptoms ($p < 0.0001$ for continuous CES-D scores; $p = 0.0002$ for categorical CES-D score ≥16). Using statistical dietary pattern analyses, Sugawara et al. [23] identified a 'healthy' pattern in a Japanese sample, which showed no association with depressive symptoms. Likewise, Samieri et al. [27] identified a 'healthy' pattern in a French sample and also found no significant association with depressive symptoms, neither in men ($\beta = -0.12$, 95 % CI −0.31 to 0.07) nor in women ($\beta = -0.16$, 95 % CI −0.33 to 0.007). In contrast, Jacka et al. [20] observed that higher diet quality scores were significantly associated with less depressive symptoms in men as well as in women. In the same sample, a 'healthy' pattern was identified derived from principal component analysis, which was inversely associated with depressive symptoms in women, but not in men.

In two further studies, Jacka et al. [4, 21] examined the diet–depression relationship in women, using structured clinical interviews for the assessment of major depression/dysthymia as well as bipolar disorder. The diet quality scores showed no significant association with both disorders. Additionally, both times 'traditional' patterns were identified by factor analysis that in contrast showed inverse associations with major depression as well as bipolar disorder.

Western/unhealthy dietary patterns and depression

The second common pattern that became apparent in several studies was mainly characterized by a high consumption of processed foods, such as fast food, (processed) meat, refined grains, salty snacks, sweets, desserts and soft drinks. These patterns were labeled 'Western' or 'processed food' patterns. In comparison with predominant dietary recommendations, such patterns reflect a rather unhealthy diet behavior. The association between Western patterns and depression was investigated in eight studies, all of them using statistical dietary pattern analyses only. The results of the studies reporting proper risk estimates as well as the results of the heterogeneity tests are presented in Fig. 3.

Prospective studies

In their study from 2009, Akbaraly et al. [29] identified a 'processed food' pattern. This dietary pattern showed a significant association with depressive symptoms after exclusion of participants with depressive symptoms at baseline (highest vs. lowest tertile: OR 1.69, 95 % CI 1.10–2.60). Le Port et al. [22] conducted gender-stratified analyses and identified a 'Western' pattern in a male sample, which also showed a significant positive association with depressive symptoms.

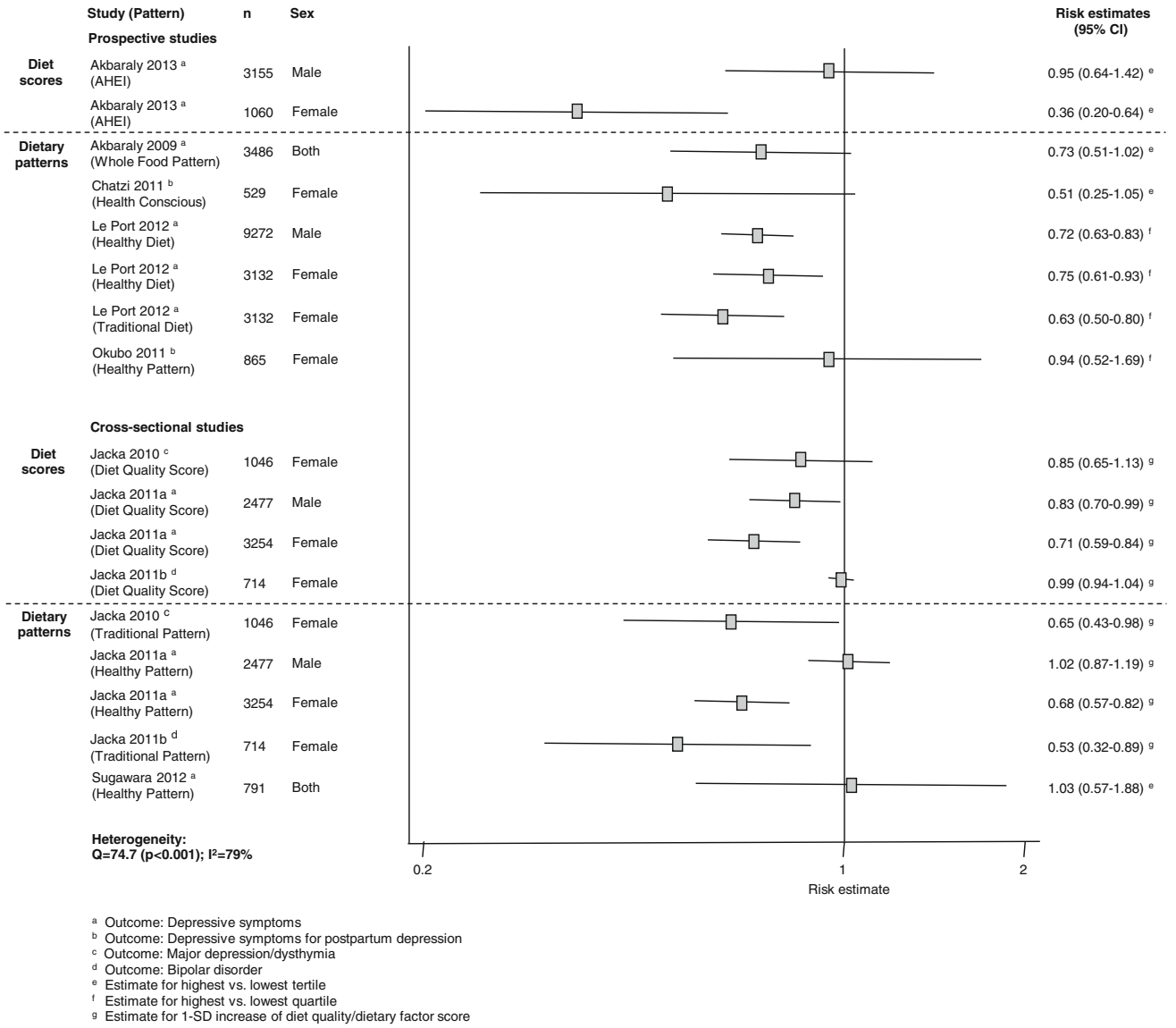

Fig. 2 Forest plot of the associations between traditional/healthy dietary patterns and depression risk (without pooled effect estimate): Results are presented stratified by study design, each *line* shows an individual study result for one dietary pattern, the *horizontal lines* represent 95 % CIs, the *boxes* represent individual point estimates, the *dotted lines* separate studies using diet scores (*above the line*) and studies using statistical dietary pattern analyses (*beneath the line*)

As already noted in the last section, two prospective studies investigated the association between dietary patterns during pregnancy and postpartum depression [18, 19]. Both studies identified a 'Western' pattern, but none of them found an association with postpartum depression, neither for categorical outcomes nor for continuous EDPS scores.

Cross-sectional studies

In contrast to the results of the prospective studies, all cross-sectional studies failed to detect an association between Western patterns and depression. Sugawara et al. [23] examined the relationship between a 'Western' pattern and depressive symptoms in a Japanese population, but found no significant association. Similarly, Jacka et al. [20] conducted gender-stratified analyses and identified 'Western' patterns in men as well as in women, again showing no significant association with depressive symptoms.

In their studies using structured clinical interviews for depression assessment in female samples, Jacka et al. [4, 21] identified 'Western' patterns both times. These dietary patterns showed increased but not statistically significant ORs for the association with major depression/dysthymia [4] as well as bipolar disorder [21] in the adjusted models.

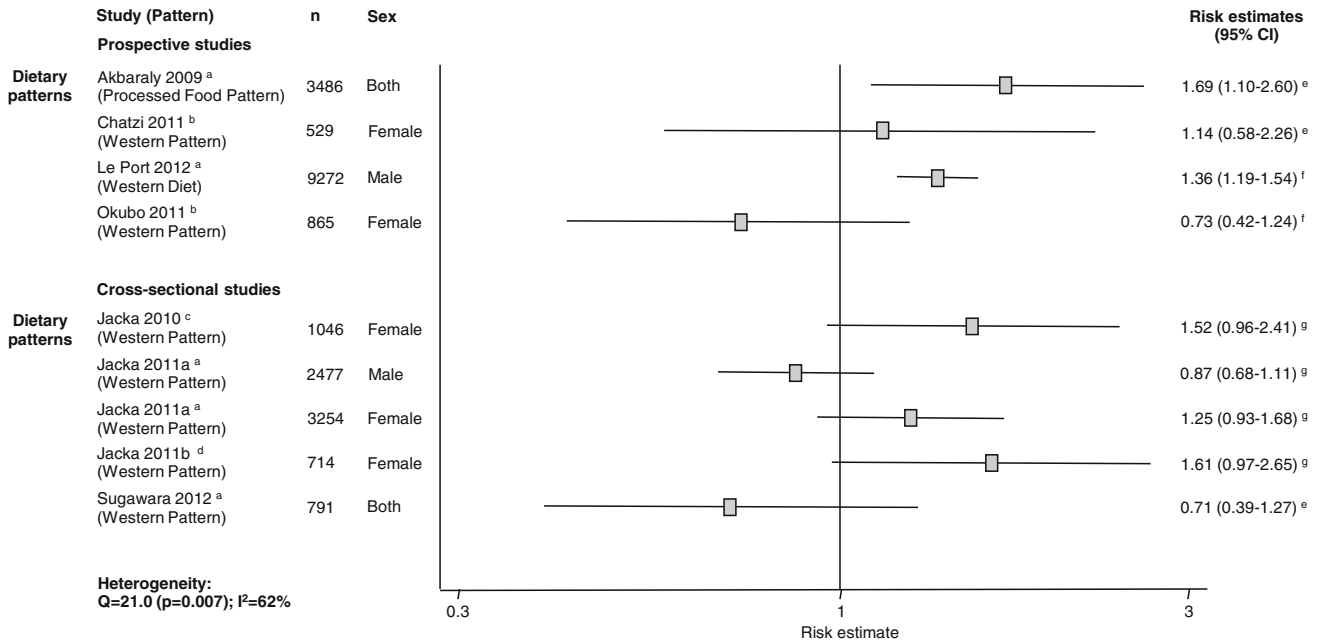

Fig. 3 Forest plot of the associations between Western/unhealthy patterns and depression risk (without pooled effect estimate): Results are presented stratified by study design, each *line* shows an individual study result for one dietary pattern, the *horizontal lines* represent 95 % CIs, the *boxes* represent individual point estimates

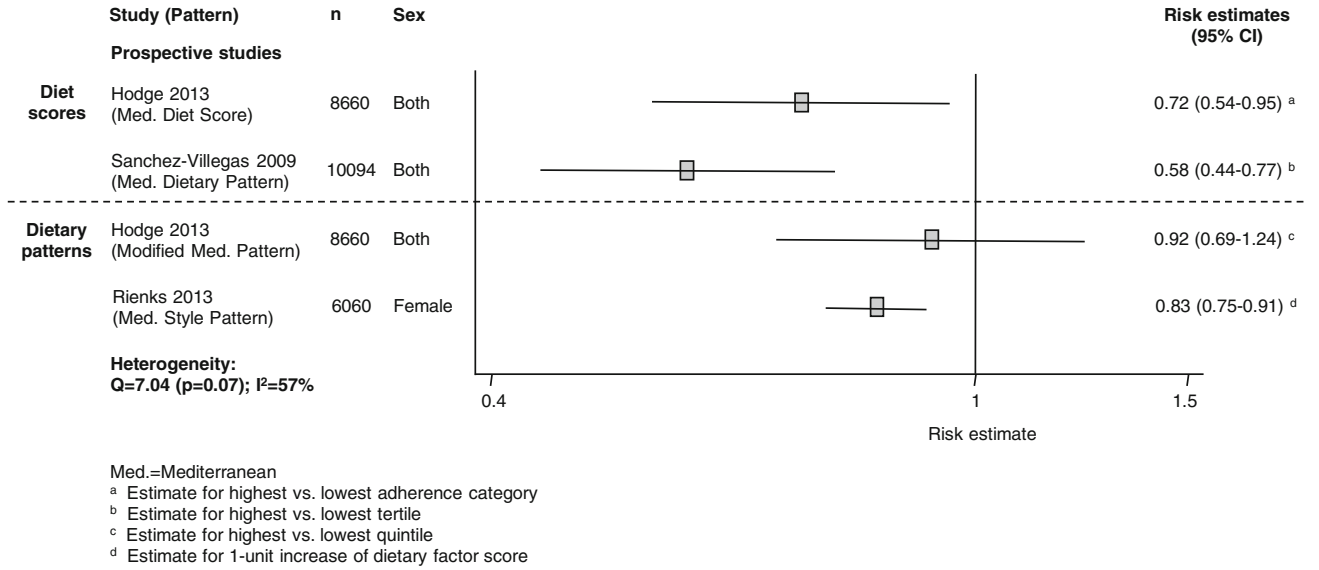

Fig. 4 Forest plot of the associations between Mediterranean dietary patterns and depression risk (without pooled effect estimate): Each *line* shows an individual study result for one dietary pattern, the *horizontal lines* represent 95 % CIs, the *boxes* represent individual point estimates, the *dotted line* separates studies using diet scores (*above the line*) and studies using statistical dietary pattern analyses (*beneath the line*)

Table 2 Characteristics of the included studies (cross-sectional studies)

References, location	Study design, sample	Diet assessment	Depression assessment	Main results	Comments
Jacka et al. [4], Australia	Cross-sectional analysis, based on the Geelong Osteoporosis Study (GOS) $n = 1{,}046$ women, randomly selected women aged 20–93 years	Assessment method: Food frequency questionnaire, 80 items Dietary pattern analysis: (1) Diet quality score, based on the Australian national guidelines for healthy eating; (2) principal component analysis Identified dietary patterns: Diet quality score, Western pattern, traditional pattern, modern pattern	Assessment of major depressive disorder and dysthymia Assessment method: structured clinical interview for DSM-IV-TR, research version	Odds ratios (95 % CI) for each 1-SD increase in diet quality/dietary factor score, adjusted models: Diet score: OR 0.85 (0.65–1.13) Western pattern: OR 1.52 (0.96–2.41) Traditional pattern: OR 0.65 (0.43–0.98) Modern pattern: OR 1.29 (0.96–1.73)	Adjusted for: age, socioeconomic status, education, physical activity, smoking, alcohol consumption, (energy intake)
Jacka et al. [20], Norway	Cross-sectional analysis, based on the Hordaland Health Study $n = 5{,}731$ (2,477 male, 3,254 female), participants aged 46–49 or 70–74 years	Assessment method: Food frequency questionnaire, 169 items Dietary pattern analysis: (1) Diet quality score, based on 6 components; (2) principal component analysis Identified dietary patterns: diet quality score, healthy pattern, Western pattern, traditional (Norwegian) pattern	Assessment of depressive symptoms Assessment method: Hospital Anxiety and Depression Scale (HADS)-Depression subscale (7 items) Definition of depression: HADS-D score ≥ 8	Odds ratios (95 % CI) for each 1-SD increase in diet quality/dietary factor score, fully adjusted models Men Diet quality score: OR 0.83 (0.70–0.99) Healthy pattern: OR 1.02 (0.87–1.19) Western pattern: OR 0.87 (0.68–1.11) Traditional Norwegian pattern: OR 0.77 (0.61–0.96) Women Diet quality score: OR 0.71 (0.59–0.84) Healthy pattern: OR 0.68 (0.57–0.82) Western pattern: OR 1.25 (0.93–1.68) Traditional Norwegian pattern: OR 0.99 (0.76–1.29)	Adjusted for: age, income, education, physical activity, smoking, alcohol, energy intake
Jacka et al. [21], Australia	Cross-sectional analysis, based on the Geelong Osteoporosis Study (GOS) $n = 714$ women, randomly selected women aged 20–93 years	Assessment method: Food frequency questionnaire, 80 items Dietary pattern analysis: (1) diet quality score, based on the Australian national guidelines for healthy eating; (2) principal component analysis Identified dietary patterns: diet quality score, Western pattern, traditional pattern, modern pattern	Assessment of bipolar disorder Assessment method: structured clinical interview for DSM-IV-TR, research version	Odds ratios (95 % CI) for each 1-SD increase in diet quality/dietary factor score, adjusted models Diet score: OR 0.99 (0.94–1.04) Western pattern: OR 1.61 (0.97–2.65) Traditional pattern: OR 0.53 (0.32–0.89) Modern pattern: OR 1.47 (1.04–2.09)	Adjusted for: energy intake Limited number of cases ($n = 23$) didn't allow for multivariate analyses with adjustment for further potential confounders Exclusion of participants with depressive disorders other than bipolar disorder

Table 2 continued

References, location	Study design, sample	Diet assessment	Depression assessment	Main results	Comments
Kuczmarski et al. [30], USA	Cross-sectional analysis, based on the Healthy Aging in Neighborhoods of Diversity across the Life Span Study (HANDLS Study) $n = 1{,}118$ (495 male, 623 female), African Americans and white Americans (with low socioeconomic status), living in Baltimore, aged 30–64 years	Assessment method: 24 h-dietary recalls Dietary pattern analysis: Healthy Eating Index-2005, diet score based 12 components	Assessment of depressive symptoms Assessment method: Center for Epidemiologic Studies–Depression Scale (CES-D) Definition of depression: CES-D score ≥ 16	Diet quality was significantly and inversely associated with depressive symptoms (unadjusted models) Linear regression (continuous CES-D): $p < 0.0001$ Logistic regression (CES-D ≥ 16): $p = 0.0002$; after adjustment the inverse effect was attenuated but remained statistically significant	Adjusted for: education, income, sex, race
Nanri et al. [31], Japan	Cross-sectional analysis, based on a Japanese health survey $n = 521$ (309 male, 212 female), Japanese employees of two municipal offices, aged 21–67 years	Assessment method: Diet history questionnaire, 65 items Dietary pattern analysis: principal component analysis Identified dietary patterns: Healthy Japanese pattern, animal food pattern, westernized breakfast pattern	Assessment of depressive symptoms Assessment method: Center for Epidemiologic Studies-Depression Scale (CES-D) Definition of depression: CES-D score ≥ 16	Odds ratios (95 % CI), highest versus lowest tertile (lowest = reference) for fully adjusted models Healthy Japanese pattern: OR 0.44 (0.25–0.78) Animal food pattern: OR 0.97 (0.61–1.55) Westernized breakfast pattern: OR 1.27 (0.77–2.10)	Adjusted for: age, sex, workplace, marital status, body mass index, job position, occupational physical activity, non-job physical activity, current smoking, history of hypertension, history of diabetes, total energy intake
Samieri et al. [27], France	Cross-sectional analysis, based on the Three-City Study $n = 1{,}724$ (647 male, 1,077 female), not institutionalized, community-dwelling French elderly living in Bordeaux, aged 65 years or older	Assessment method: Food frequency questionnaire, 148 items, and 24 h-dietary-recalls Dietary pattern analysis: cluster analysis, mixed method combining hybrid clustering and research for stable groups Identified dietary patterns Men: small eaters, biscuits and snacking, healthy, charcuterie/meat/alcohol, pasta eaters; Women: small eaters, biscuits and snacking, healthy, charcuterie/starchy food, pizza/sandwich eaters	Assessment of depressive symptoms Assessment method: Center for Epidemiologic Studies-Depression Scale (CES-D) For statistical analyses CES-D scores were root transformed and used as continuous variable	β-Coefficients (95 % CI) for adjusted models Men Small eaters: $\beta = -0.11$ (-0.29 to 0.07) Biscuits and snacking pattern: $\beta = -0.06$ (-0.35 to 0.23) Healthy pattern: $\beta = -0.12$ (-0.31 to 0.07) Charcuterie/meat/alcohol pattern: $\beta = 0.03$ (-0.20 to 0.26) Pasta eaters: $\beta = 0.26$ (0.06–0.46) Women Small eaters: $\beta = -0.03$ (-0.19 to 0.13) Biscuits and snacking pattern: $\beta = 0.13$ (-0.07 to 0.33) Healthy pattern: $\beta = -0.16$ (-0.33 to 0.007) Charcuterie/starchy food pattern: $\beta = -0.15$ (-0.32 to 0.02) Pizza and sandwich eaters: $\beta = 0.21$ (-0.11 to 0.53)	Adjusted for: age, education, income, marital status

Table 2 continued

References, location	Study design, sample	Diet assessment	Depression assessment	Main results	Comments
Sugawara et al. [23], Japan	Cross-sectional analysis, based on the Iwaki Health Promotion Project $n = 791$ (303 male, 488 female), Japanese community-dwelling population, aged 22–86 years	Assessment method: Diet history questionnaire, 65 items Dietary pattern analysis: principal component analysis Identified dietary patterns: healthy pattern, Western pattern, bread and confectionery pattern, alcohol and accompanying pattern	Assessment of depressive symptoms Assessment method: Center for Epidemiologic Studies-Depression Scale (CES-D) Definition of depression: CES-D score ≥16	Odds ratios (95 % CI), highest versus lowest tertile (lowest = reference) for fully adjusted models Healthy pattern: OR 1.03 (0.57–1.88) Western pattern: OR 0.71 (0.39–1.27) Bread and confectionery pattern: OR 1.02 (0.59–1.78) Alcohol and accompanying pattern: OR 0.94 (0.55–1.59)	Adjusted for: age, gender, exercise-habit, body mass index, education, marital status, current smoking, history of hypertension, history of diabetes mellitus

Mediterranean dietary patterns and depression

Four of the included studies examined the relationship between a Mediterranean diet and depression [24–26, 28]. In general, a Mediterranean diet is characterized by a high intake of fruit, vegetables, legumes, whole grain products and fish, a low to moderate consumption of meat, dairy products and alcohol (in particular red wine) and olive oil as the main source of fat [32, 33]. In the four studies, five 'Mediterranean' patterns were examined that in most parts were concordant with the typical characteristics of a Mediterranean diet. All of the studies showed a prospective study design and had relatively high sample sizes, which differed between $n = 3{,}504$ and $n = 10{,}094$ participants. The results of the studies that reported proper risk estimates as well as the results of the heterogeneity tests are presented in Fig. 4.

Hodge et al. [24] as well as Sanchez-Villegas et al. [28] investigated the association using a Mediterranean diet score. Both studies found significant inverse associations with depressive symptoms. In line with that Skarupski et al. [26] observed a significant inverse association linking a high adherence to a Mediterranean diet score with decreased depressive symptoms ($\beta = -0.03$; ± 0.01 SE; $p < 0.001$).

The data-driven dietary patterns found by Hodge et al. [24] ('Modified Mediterranean' pattern) and Rienks et al. [25] ('Mediterranean style' pattern) showed diverse results. Rienks et al. showed a significant inverse association with depressive symptoms, whereas Hodge et al. found no significant association with psychological distress. Rienks et al. could strengthen their results by examining the trend over the quintiles and showing a clear dose–response relationship between a 'Mediterranean style' pattern and depressive symptoms.

Other dietary patterns and depression

Some included studies identified further dietary patterns that focused on certain food groups or other specific diet characteristics instead of the above-mentioned diets. These individual dietary patterns showed only little concordance with each other and, therefore, were not grouped into any further pattern groups. The results of these dietary patterns will not be presented or discussed in detail because there was only limited evidence. For the sake of completeness, all results are noted in Table 1 and 2.

Discussion

The aim of the present systematic review was to give an overview of the current state of research examining the

relationship between dietary patterns and depression in healthy adults. Sixteen eligible studies were identified and included in the present review, in which three main dietary patterns became apparent: (1) traditional/healthy patterns, (2) Western/unhealthy patterns and (3) Mediterranean patterns. The majority of these studies suggest a protective effect of healthy or traditional dietary patterns in regard to depression. However, the results are not entirely consistent; some studies failed to detect a protective effect. Similarly, the results support a protective effect of a Mediterranean diet: Four of the five identified Mediterranean patterns showed a significant inverse association with depression. In contrast, the Western patterns may be associated with higher odds of depression: Two prospective studies observed significant positive associations of Western dietary patterns and depressive symptoms; however, all cross-sectional studies failed to detect such an effect.

Two studies investigated the link between dietary patterns during pregnancy and postpartum depression, both reporting no significant associations. Pregnancy itself is often associated with intentional as well as unintentional dietary modifications, which may influence the diet–depression relationship. Therefore, the results for postpartum depression should be interpreted with caution.

Due to major differences in study characteristics such as study design, assessment methods, presentation of effect estimates and adjustment for potential confounders, a comparison of results was difficult. With respect to these differences, the lack of homogeneity as well as additional methodological limitations, it was decided to omit the performance of meta-analyses and the calculation of pooled effect estimates. At this point, it should also be noted that research on the diet–depression relationship came, at least to some degree, from a relatively small number of authors/research groups—for instance, three of the included studies were performed by Jacka and colleagues.

Recently, another systematic review examining the relationship between dietary patterns and depression was published by Quirk et al. [34]. The authors concluded that there is limited evidence for an association between 'traditional' diets (including Mediterranean and Nordic diets) and depression as well as conflicting evidence for 'healthy,' 'Western,' 'traditional Japanese' and further individual dietary patterns and depression [34]. The results of Quirk et al. are concordant with the results of this review in some parts: Quirk et al. as well as the present review found some high-quality studies that indicate a possible relationship between healthy patterns and depression, but the available literature still is not entirely consistent. Additionally, both reviews reported that the results for the effects of Western patterns were in some way conflicting at this point. For the association between a Mediterranean diet and depression, Quirk et al. [34] considered only one study that reported no association. In contrast to this, the present review included five analyses, whereof four reported an inverse association between Mediterranean patterns and depression. The review of Quirk et al. [34] included studies published until October 2011. Since then, several new studies have been published adding new evidence to the current state of research, e.g., five new cohort studies.

In another recent systematic review and meta-analysis, Psaltopoulou et al. [35] investigated the effects of a Mediterranean diet on stroke, cognitive impairment and depression. Concordant with the findings of the present review, Psaltopoulou et al. [35] observed a protective effect of a Mediterranean diet: Their pooled analyses showed that a high as well as a moderate adherence to a Mediterranean diet was associated with reduced risks for depression, possibly indicating a dose–response relationship (high adherence: RR 0.68, 95 % CI 0.54–0.86; moderate adherence: RR 0.77, 95 % CI 0.62–0.95) [35]. However, there was considerable heterogeneity across the studies ($I^2 = 53$ %, 54 %) [35]. Thus, the pooled results should be interpreted with caution.

In the past, two other systematic reviews examined the association between single dietary factors and depression risk. Murakami and Sasaki [6] reported that most studies found no association between single dietary factors and depression. In contrast, Sanhueza et al. [7] concluded that some nutrients have protective effects (i.e., folate, ω-3 fatty acids, olive oil, fish, fruits and vegetables), while others have negative effects (i.e., processed foods such as sweets, processed meat, fried foods and refined grains). In addition, the review of Sanhueza et al. [7] also included two studies reporting on dietary patterns. The authors were mentioning a possible link between dietary patterns and the risk of depression and recommended the strengthening of dietary pattern analysis in future research.

While there are some hypotheses how diet and depression might be related, the underlying mechanisms are not sufficiently understood. Diet as a long-term exposure might influence the development of depression, because special nutrients are essential substances for several brain functions. Suggested biological mechanisms include, for instance, the effects of polyunsaturated fatty acids on membrane fluidity in the brain and on inflammation [36], the protective effect of antioxidants against oxidative stress [37, 38] and the negative effect of folate deficiencies that result in increased homocysteine concentrations which in turn are suggested to play a role in the pathogenesis of psychiatric disorders [39]. On the basis of these suggested mechanisms, the possible protective effect of healthy and Mediterranean dietary patterns (characterized by a high consumption of fish, fruit and vegetables, providing a wide diversity of nutrients including essential fatty acids and

antioxidants) could be based on the synergetic combination of the protective effects mentioned above.

Nevertheless, it has to be considered that diet is just one component in the multifactorial origin of mental disorders. However, given the increasing prevalence of depression as well as the negative effects on quality of life, health and economy, even small protective effects can be important [40]. In contrast to other risk factors, diet represents a modifiable environmental factor and may be one of the easiest to modify [3, 4]. In addition, the general guidelines for a healthy diet have preventive potential in relation to other chronic diseases such as adiposity, cardiovascular disease or certain cancers. Therefore, incorporating the risk factor diet in evidence-based strategies for primary prevention of depression would go along with already existing public health strategies in regard to other lifestyle-related diseases [4, 7].

Compared to the traditional approach with focus on single nutrients or foods, the new concept of dietary patterns analysis has several strengths and advantages [10]. As already discussed before, the investigation of dietary patterns may have the potential to detect the cumulative impact of several dietary components at once [10]. Another strength of the present review is the restriction to samples of healthy free-living humans by excluding studies examining samples at high risk or with already existing diseases, because these participants may be more susceptible to depression than healthy subjects [41].

Despite these strengths, results should be interpreted with caution because of some methodological limitations. First of all, the literature search was limited to articles published in English or German. Secondly, there is always the difficulty to identify all existing research data. In the present review, it was tried to discover unpublished research by further searching for congress papers or meeting abstracts. Nevertheless, these methodological issues can result bias.

Notably, there was a wide diversity of assessment methods in relation to diet as well as depression. For dietary assessment, tools such as food frequency questionnaires, diet history questionnaires or 24 h-dietary-recalls were used. For nutritional epidemiological studies using assessment methods that rely on self-reported information, the possibility of dietary measurement errors has always to be considered. These factors may have impact on the identification of dietary patterns and, therefore, on the detection of potential effects [10, 11]. Similarly, the studies used different depression assessment methods, such as structured clinical interviews, self-reported information on a previous depression diagnosis or antidepressant medication, as well as depression scales to assess depressive symptoms. The vast majority of the included studies used depression scales. It has to be considered that depression scales represent just a rough indicator of depressive symptomatology instead of a clear clinical diagnosis of depression. Only two included studies, both of cross-sectional design, used structured clinical interviews, which are known to be the gold standard method for depression assessment [42]. This issue has to be noted as a clear limitation of the identified studies. All in all, most of the included studies used well-established and validated methods rather than not validated ones. However, the diversity of diet and depression assessment methods might have some effects on the final results.

The present systematic review is based on observational studies, which always imply the possibility of bias and confounding. Two further aspects have to be considered. Firstly, the relationship between diet and depression may be present in both ways: Diet quality can have an effect on the development of depression and depression may lead to a poor diet quality [3]. Due to their study design, the results of cross-sectional studies can be influenced by this reverse causation problem. Exposure and outcome are assessed at the same point in time and, therefore, cause and effect cannot be separated clearly. This is a limitation of cross-sectional studies and should be considered when interpreting the results. Secondly, 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. In the context of confounding, it is discussed that diet is only one component of an overall lifestyle and that other lifestyle factors, e.g., physical activity or smoking, possibly act as confounders with regard to the diet–depression relationship, as healthy dietary patterns were often reported in combination with other healthy lifestyle behaviors [11, 29]. It is conceivable that individuals who maintain an overall healthy lifestyle are highly motivated when it comes to their health. This attitude may be accompanied by a higher discipline and willpower of these individuals in general, which in turn may protect against the onset of mental disorders [28].

Prior research on the diet–depression relationship has commonly treated depression as a homogeneous entity. Up to now, there is no study considering distinct depressive subtypes, for instance, atypical or melancholic depression. However, in current research, it has been suggested that there are subtype-specific biological mechanisms that might be involved differently in the pathogenesis of depression and related morbidities [43–45]. For an improved understanding of underlying biological pathways and causal effects, the heterogeneity of depression should be considered [43–46]. Future research should differentiate between subtypes of depression in assessment as well as analysis [42].

Conclusion

In summary, the available literature suggests a possible association between dietary patterns and depression: Healthy and Mediterranean dietary patterns seem to be associated with lower odds of depression, whereas Western dietary patterns may be associated with higher odds of depression. But with respect to the major differences in study characteristics, the high level of heterogeneity and some methodological limitations of the included studies, no firm conclusion can be drawn at this point. To clarify the diet–depression relationship, further research particularly through prospective studies is needed that uses homogenous methods and takes different subtypes of depression into account.

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