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Review article

The association between diet and mood: A systematic review of current literature

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ABSTRACT

A number of studies have examined the association between diet and mood state, but the findings have been inconclusive. Herein, we conducted a systematic review to assess the association between different diet and mood state. PubMed, Cochrane's library, Science direct, Scopus, Google scholar and ISI web of science databases were searched for all available literature until December 2017 for studies assessing the association between diet and mood state. The Newcastle-Ottawa Scale and Jadad scale for reporting randomized clinical trials were used to assess study quality. A total of 18 studies out of 2857 met our inclusion criteria and included in our systematic review. Although there are not consistent findings between studies, it seems that DASH, vegetable-based, glycemic load-based, ketogenic and Paleo diets could improve mood more than the others. Further studies are needed to assess such relationship in a longer period to draw a firm link between diet and mood.

1. Introduction

Mood disorders such as major depressive and bipolar disorders are defined as psychology arousal conditions of which main features of them are mood disturbance. Mood disorders are one of the causes of disability and mortality worldwide. Approximately 7.4% of the total burden of the disease in 2010 was due to mental and substance use disorders (Lutz and Kieffer, 2013; Whiteford et al., 2013). At least 50% of the suicides is due to mood disorders (Isometsa, 2014). Non-drug approaches like nutrition interventions are effective in improving mental health and mood disorders and could be categorized in three levels, including nutrient, food and diet. Studies have shown that nutrients such as magnesium, vitamin E, C and D and omega-3 poly unsaturated fatty acids may affect the etiology of mood disorder such as depression (Wang et al., 2013; Banikazemi et al., 2015). Recent meta-analysis study showed that there is an association between hypomagnesemia and depression (Cheungpasitporn et al., 2015). Furthermore, omega-3 poly unsaturated fatty acids and their derivatives are found in the brain and involved in processes such as neurotransmission, neuro plasticity and signal protection, so they can affect the mood and cognition disorders (Su et al., 2015). Food intake can be involved in regulating of mood and emotions, and this can affect the food choice (Gibson, 2006). Comfort foods containing high-fat and carbohydrate were preferred to be consumed with depressed mood subjects (Tomiyama et al., 2012). A meta-analysis showed inverse association between vegetables and fruit's intake with depression mood (Liu et al., 2016). In addition, some study showed that nuts containing unsaturated fatty acids, polyphenols and vitamins may have protective effect against mood and cognitive disorders (Gomez-Pinilla, 2008; Pribis, 2016).

As people do not consume nutrients and foods separately, therefore, dietary patterns could be a better approach to understand the relationship between disease and diet, because they can be considered as total dietary intake as well as the interactions between nutrients and many foods and synergistic effects between them. Accordingly, attention has been drawn from nutrient and food to the dietary pattern over the past decade (Chahoud et al., 2004; Jacobs and Tapsell, 2007).

So far, different diets including Mediterranean diet (MD), dietary approach to stop hypertension (DASH), vegetable-based, glycemic load-based, ketogenic, zone and paleo diet have been studied in order to find a relationship between diets and mood. There are not consistent

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findings between these studies. Also each different diet consists of different components that should be addressed in this regard.

To address these issues, we carried out a systematic review to assess the relationship between different types of diet and mood states in general population through observational and interventional studies.

2. Methods and materials

The present systematic review was performed based on the Preferred Reporting Item for Systematic Review and Meta-analysis (PRISMA) statement and was registered on Prospero database (CRD42017082235).

2.1. Data source and search strategy

The comprehensive search was done through PubMed, Cochrane's library, Science direct, Scopus, Google scholar and ISI web of science databases for all available literature until October 2018 with no restriction of language. The search terms were “diet”, “diet type”, “dietary habit”, “dietary pattern”, “eating pattern”, “food”, “nutrition” combined with “mood”, “affect” and “well-being”. In order to find any related studies, the cited references of included articles were also examined too.

2.2. Inclusion criteria

The studies have met the following inclusion criteria: (1) studies evaluated the effect of diets or dietary patterns, analyzed by priori method, on the mood states; (2) studies that measured and reported mood state variables as an outcome of administered or exposed to diet; (3) articles written in English language. In addition to the above inclusion criteria, we did not limit the included studies to types of study population or study design.

2.3. Data extraction

The following information was extracted for each included study: author name, publication year, country, mean age, sex, sample size, study duration, participants’ health status, study design, dietary assessment and mood assessment method. The processes of data extraction and assessment were done by two independent reviewers.

2.4. Study quality

The Newcastle-Ottawa Quality Assessment Scale was used to assess the quality of observational studies (Peterson et al., 2011). This scale consisted of three variables, including: selection (5 points), comparability (2 points) and outcome (3 points) for a total score of 10 points. The studies that received 7–10, 3–6 and 0–3 point were identified as high, moderate and low quality. On the other hand, Jadad scale for reporting randomized clinical trial was used to assess the quality of interventional studies. In the recent scale, papers were evaluated based on randomization (mentioned as randomized gets 1 point and mentioned randomization methods gets another point), blinding (mentioned as double blind gets 1 point and mentioned blinding methods gets another point) and inclusion of participants (mentioned withdrawals and dropouts gets 1 point). In this scale, study that got 3 points or more ranked as high quality (Clark et al., 1999). (Table 2 and 3)

3. Results

3.1. The search results

Our initial search through databases identified 4321 papers. After removing duplicates, remaining 2857 articles were reviewed based on the title and abstract by two independent reviewers. Totally, 109 articles were retrieved and reviewed based on full-text availability and finally, 18 studies met our inclusion criteria and included in our systematic review. Flow diagram of search results is illustrated in Fig. 1.

3.2. Overview of included studies

Among 18 studies included, three used DASH (Torres et al., 2008; Torres and Nowson, 2012; Valipour et al., 2017), four MD (Wardle et al., 2000; Hyyppä et al., 2003; McMillan et al., 2011; Lee et al., 2015), four vegetable-based (Beezhold et al., 2010; Beezhold and Johnston, 2012; Beezhold et al., 2015; Olabi et al., 2015), two glycemic load-based (Cheatham et al., 2009; Breymeyer et al., 2016), three ketogenic (McClernon et al., 2007; Lambrechts et al., 2012; IJff et al., 2016), one Paleo (Lee et al., 2017) and one Zone diets (Fontani et al., 2005). Based on the country, eight papers were from United States (McClernon et al., 2007; Cheatham et al., 2009; Beezhold et al., 2010; Beezhold and Johnston, 2012; Beezhold et al., 2015; Olabi et al., 2015; Breymeyer et al., 2016; Lee et al., 2017), four from Australia (Torres et al., 2008; McMillan et al., 2011; Torres and Nowson, 2012; Lee et al., 2015), two from The Netherlands (Lambrechts et al., 2012; IJff et al., 2016) and the others were obtained from United Kingdom (Wardle et al., 2000), Finland (Hyyppä et al., 2003), Italy (Fontani et al., 2005) and Iran (Valipour et al., 2017). Fourteen articles were interventional (Wardle et al., 2000; Hyyppä et al., 2003; Fontani et al., 2005; McClernon et al., 2007; Torres et al., 2008; Cheatham et al., 2009; McMillan et al., 2011; Beezhold and Johnston, 2012; Torres and Nowson, 2012; Lee et al., 2015; Olabi et al., 2015; Breymeyer et al., 2016; IJff et al., 2016; Lee et al., 2017) and four were observational (Beezhold et al., 2010; Lambrechts et al., 2012; Beezhold et al., 2015; Valipour et al., 2017). In order to assess the dietary pattern, seven studies used dietary record (Wardle et al., 2000; McMillan et al., 2011; Torres and Nowson, 2012; Lee et al., 2015; Olabi et al., 2015; Breymeyer et al., 2016; Lee et al., 2017), four food frequency questionnaire (FFQ) (Beezhold et al., 2010; Beezhold and Johnston, 2012; Beezhold et al., 2015; Valipour et al., 2017), one twenty four-hour recall (McClernon et al., 2007) and the remaining did not explain the dietary assessment method (Hyyppä et al., 2003; Fontani et al., 2005; Torres et al., 2008; Cheatham et al., 2009; Lambrechts et al., 2012; IJff et al., 2016). For ranking mood state, eleven studies filled in POMS (Wardle et al., 2000; Fontani et al., 2005; Torres et al., 2008; Cheatham et al., 2009; McMillan et al., 2011; Lambrechts et al., 2012; Torres and Nowson, 2012; Lee et al., 2015; Olabi et al., 2015; Breymeyer et al., 2016; IJff et al., 2016), two BECK questionnaire (Hyyppä et al., 2003; Lee et al., 2017), one Hospital Anxiety and Depression Scale (HADS) (Valipour et al., 2017), one Atkins Health Indicator Test (AHIT) (McClernon et al., 2007), one Depression Anxiety Stress Scales (DASS) (Beezhold et al., 2015) and the remaining used both POMS and DASS (Beezhold et al., 2010; Beezhold and Johnston, 2012). Based upon the Newcastle-Ottawa Quality Assessment Scale among four observational studies, three (Beezhold et al., 2010; Beezhold et al., 2015; Valipour et al., 2017) and one identified as high and low quality, respectively (Lambrechts et al., 2012). Among interventional studies, two categorized as high (Wardle et al., 2000; Fontani et al., 2005) and the others as low quality (Hyyppä et al., 2003; McClernon et al., 2007; Torres et al., 2008; Cheatham et al., 2009; McMillan et al., 2011; Beezhold and Johnston, 2012; Torres and Nowson, 2012; Lee et al., 2015; Olabi et al., 2015; Breymeyer et al., 2016; IJff et al., 2016; Lee et al., 2017). Finally, eleven studies recruited healthy (Fontani et al., 2005; McClernon et al., 2007; Cheatham et al., 2009; Beezhold et al., 2010; McMillan et al., 2011; Beezhold and Johnston, 2012; Beezhold et al., 2015; Lee et al., 2015; Olabi et al., 2015; Breymeyer et al., 2016; Valipour et al., 2017), two epileptic (Lambrechts et al., 2012; IJff et al., 2016), two hypercholesterolemic (Wardle et al., 2000; Hyyppä et al., 2003) and the others were hypertensive (Torres et al., 2008), postmenopausal (Torres and Nowson, 2012) and multiple sclerosis subjects (Lee et al., 2017).

Table 1
Characteristics of included studies.

Study	Location	Age	Sample size (sex)	Duration	Population	Design	DA method	MA method	Adjustment	Result: Within group	Result: Between group
DASH Diet											
Torres and Nowson (2012)	Australia	59.3 ± 5.1	95 (F)	14 week	post menopause women	RCT	3-day food record	POMS	NM	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Vigor ↓ Global score ↓	Anger ↓
Valipour et al. (2017)	Iran	36.4 ± 8.03	3846 (1712M/ 2134F)	–	Healthy individuals	Cross-sectional study	FFQ	HADS	age, sex, energy intake, marital status, socioeconomic status, smoking, physical activity, chronic disease, antidepressant use, supplement use, pregnant or lactating women, and frequent spice consumers, and BMI	Higher adherence to dash associated with lower anxiety and depression	
Torres et al. (2008)	Australia	55.6 ± 9.9	94 (38F/ 56M)	4 week	Normal & hypertensive subjects	RCT-Cross over	NM	POMS	NM	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Vigor ↑ Global score ↓	Depression ↓ Tension ↓ Vigor ↑ Global score ↓
Mediterranean diet											
Wardle et al. (2000)	UK	53 ± 10	176 (85F/ 91M)	12 week	Hypercholesterolemic subjects	RCT	7-day food record	POMS	NM	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Vigor ↑	NS
McMillan et al. (2011)	Australia	21.12 ± 3.26	25 (F)	10 day	Healthy individuals	RCT	Food record	POMS	NM	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Vigor ↑ Global score ↓	Vigor ↑
Lee et al. (2015)	Australia	25.6 ± 5.1	24 (F)	10 day	Healthy individuals	RCT-Cross over	Food record	POMS	NM	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Vigor ↑ Global score ↓	Confusion ↓
Hyyppä et al. (2003)	Finland	48.2 ± 6.2	120 (M)	12 week	Hypercholesterolemic subjects	RCT-Cross over	NM	BECK	Age, weight, BMI, education, socioeconomic status, blood pressure	NS	NS
Vegetable-based diet											
Beezhold and Johnston (2012)	USA	NM	39 (82%F/ 18%M)	2 week	Healthy individuals	RCT	FFQ	POMS DASS	NM	Anxiety ↓ Stress ↓ Tension ↓ Confusion ↓ Fatigue ↓ Vigor ↑ Global score ↓	Stress ↓ Confusion ↓

(continued on next page)

Table 1 (*continued*)

Olabi et al. (2015)	USA	43 ± 1.7	31 (21F/10M)	4 week	Healthy individuals	RCT	Food record	POMS	sickness, physical activity, menses, initial weight, gender	Fatigue ↓ Vigor ↑	Fatigue ↓ Vigor ↑
Beezhold et al. (2010)	USA	43.03 ± 1.41	138 (77F/61M)	–	Healthy individuals	Cross-sectional study	FFQ	POMS DASS	age, sex, physical activity, BMI	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Vigor ↑ Global score ↓ Anxiety ↓ Stress ↓	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Global score ↓ Anxiety ↓
Beezhold et al. (2015)	USA	34.83 ± 10.2	620 (78.5% F/21.5%M)	–	Healthy individuals	Cross-sectional study	FFQ	DASS	age	Anxiety ↓ Stress ↓	Anxiety ↓ Stress ↓
Glycemic load-based diet											
Cheatham et al. (2009)	USA	34.75 ± 4.9	42 (31F/11M)	6 month	Healthy individuals	RCT	NM	POMS	Age, weight, BMI, % weight change, calorie restriction	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Vigor ↑ Global score ↓	Confusion ↓ Depression ↓
Breymeyer et al. (2016)	USA	28.85 ± 7.4	82 (41F/41M)	56 day (2 × 28)	Healthy individuals	RCT-Cross over	3-day food record	POMS	POMS scores, diet type, sex, body fat classification, diet order, and feeding period	Fatigue ↓ Vigor ↑ Global score ↓ Negative affect ↓	Fatigue ↓ Vigor ↑ Global score ↓
Ketogenic diet											
IJff et al. (2016)	Netherland	7.8 (1.6–16.1)	50 (21F/29M)	4 month	Epileptic subjects	RCT	NM	POMS	NM	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Vigor ↑	Vigor ↑
(McClernon et al., 2007)	USA	44.36 ± 9.03	120(89F/31M)	6 month	Healthy individuals	RCT	24-hour recall	AHIT	BMI	Fatigue ↓ Negative affect ↓	Fatigue ↓ Negative affect ↓
Lambrechts et al. (2012)	Netherland	28 (18–41)	15 (8F/7M)	12 month	Epileptic subjects	observational	NM	POMS	NM	Depression ↓ Fatigue ↓ Tension ↓ Anxiety ↓	NS
Paleo diet											
Lee et al. (2017)	USA	51 ± 6.5	19 (14F/5M)	12 month	Multiple Sclerosis	quasi-experimental	Food record	BECK	Age, disability, baseline fatigue	Depression ↓ Anxiety ↓	
Zone diet											
Fontani et al. (2005)	Italy	33 ± 7	33(20F/13M)	70 day (2 × 35)	Healthy individuals	RCT-Cross over	NM	POMS	NM	Anger ↓ Confusion ↓ Depression ↓ Fatigue ↓ Tension ↓ Vigor ↑	NS

DA: Dietary assessment, MA: Mood assessment, FFQ: Food frequency questionnaire, POMS: Profile of mood state, HADS: Hospital anxiety and depression scale, DASS: Depression anxiety stress scales, AHIT: Atkins health indicator test, NM: Not mentioned, NS: Non significant, BMI: Body mass index

Table 2
Quality assessment of observational studies.

First author, year of publication (reference)	1. Selection: Representativeness of the sample	Sample size	Non-respondents	Ascertainment of the exposure (risk factor)	2. Comparability: The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled	3. Outcome: Assessment of the outcome	Statistical test	Total qualityscores
Dash diet								
Valipour et al. (2017)	*	*	*	**	**	**	*	10
Vegetable-based diet								
Beezhold et al. (2010)	–	–	*	**	*	**	*	9
Beezhold et al. (2015)	*	*	*	*	*	**	*	8
Ketogenic diet								
Lambrechts et al. (2012)	*	–	–	–	–	–	*	2

* Indicates 1 points.
** Indicates 2 points.

Table 3
Quality assessment of interventional studies.

First author	Randomization	Blinding	An accounts of all patients	Total score
Dash diet				
Torres and Nowson (2012)	1	0	1	2
Torres et al. (2008)	2	0	0	2
Mediterranean diet				
Wardle et al. (2000)	2	0	1	3
McMillan et al. (2011)	1	0	1	2
Lee et al. (2015)	1	0	1	2
Hyyppä et al. (2003)	1	1	0	2
Vegetable-based diet				
Beezhold and Johnston (2012)	1	0	1	2
Olabi et al. (2015)	0	0	0	0
Glycemic load-based diet				
Cheatham et al. (2009)	1	0	0	1
Breymeyer et al. (2016)	1	0	1	2
Ketogenic diet				
IJff et al. (2016)	1	0	1	2
McClernon et al. (2007)	1	0	1	2
Paleo diet				
Lee et al. (2017)	0	0	1	1
Zone diet				
Fontani et al. (2005)	1	2	1	4

3.3. Findings from systematic review

3.3.1. DASH diet

In the first study, Torres et al. recruited 95 post-menopausal healthy women (59.3 ± 5.1, years old) which were assigned to either DASH-type or healthy diet for 14 weeks. After intervention, both groups showed significant improvement ($p < 0.01$) in overall mood and also six domains of mood (anger, confusion, depression, fatigue, tension and vigor). When the results of dependent variables considered separately and analyzed by diet × time interaction, only anger showed significant improvement ($p < 0.05$) in DASH group compared with controls (Torres and Nowson, 2012).

In 2008, Torres et al. evaluated the effects of two forms of DASH diet (US DASH and very low sodium DASH) and high calcium diet on 94 (55.6 ± 9.9 years old) normal and hypertensive subjects. In this cross over study, 4 weeks intervention revealed that following very low sodium DASH diet resulted in greater reduction in depression, tension and the POMS global score, and increase in vigor in comparison to US DASH diet. This relationship confirmed by 24-h urinary electrolyte excretion indicating lower sodium and higher potassium were significantly correlated with a better mood score (Torres et al., 2008).

In the last study, Valipour et al. investigated the association between adherence to DASH diet and psychological health among Iranian adults. In this cross-sectional study, 3846 healthy men and women (36.4 ± 8.03 years old) were categorized based on DASH score. Moderate (compared to low) adherence to DASH diet showed an association with lower odds of depression (OR 0.73; 95% CI 0.59–0.90) in whole participants and anxiety (0.63; 0.42–0.95) in overweight or obese individuals but adherence to DASH diet did not show any significant improvements in another psychological distress (Valipour et al., 2017).

3.3.2. Mediterranean diet

In the first study, Wardle et al. randomly assigned 176 hypercholesterolemic subjects (53 ± 10 years old) into three groups to receive low fat, MD or control diet for 12 weeks. Although the mood state (anger, confusion, depression, fatigue, tension and vigor) improved in the intervention group, however, it did not show any significant improvements compared with the controls (Wardle et al., 2000).

In 2011, McMillan et al. randomly assigned 25 healthy females

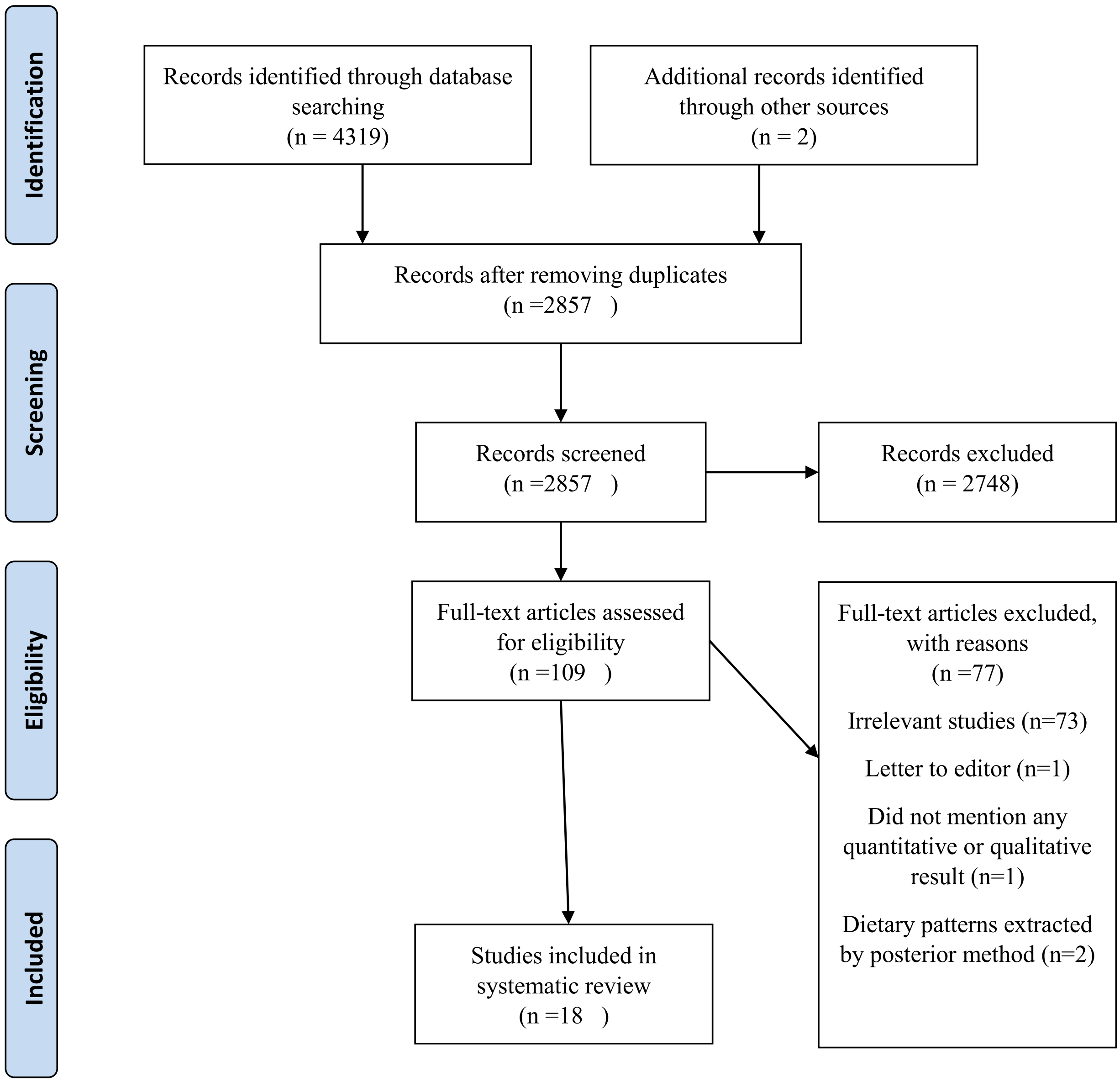

Fig. 1. The flow diagram of study selection.

(21.12 ± 3.26 years old) into MD or control diet group to receive dietary intervention for ten days. Although After dietary intervention scores of mood domains improved, only the score of vigor significantly increased ($p = 0.006$) in the diet group (McMillan et al., 2011).

Another study was carried out as a cross over design to evaluate the effects of MDfor ten days. In this study 24 healthy individuals (25.6 ± 5.1years old) were randomly allocated to intervention (MD) or control (usual diet) group. Results revealed that factors in the POMS questionnaire (anger, confusion, depression, fatigue, tension and vigor) did not show any significant changes except for confusion ($p = 0.02$). Additionally, subjects in the usual diet at the beginning, showed greater reduction in confusion following MD than those in the MD (Lee et al., 2015).

In the last study, Hyyppa et al. investigated the effects of MD or simvastatin alone or in combination on mood scores of hypercholesterolemic men (48.2 ± 6.2 years old). In this randomized double blind cross over trial, 12 weeks intervention with MD did not change variables of mood state significantly (Hyyppä et al., 2003).

3.3.3. Vegetable-based diet

First study conducted by Beezhold et al. in 2012 in order to examine the effect of meat, fish and poultry restriction (as vegetarian diet) on mood state. In this trial, 39 healthy individuals randomly assigned to either control (omnivores) or diet groups (vegetarian diet) for two weeks intervention. Although, the results revealed that vegetarian diet improved mood state, only stress and confusion declined significantly (Beezhold and Johnston, 2012).

In 2015, Olabi et al. assessed the effect of vegan diet on 16 non-vegetarian healthy individuals (43 ± 1.7 years old) in three repeated 10 days (30 days). The results of mood questionnaires revealed that vegan diet improved two components of mood, including vigor ($p < 0.05$) and fatigue ($p < 0.001$) (Olabi et al., 2015).

Another study conducted by Beezhold et al. in 2010 to assess the relationship between vegetarian diet and mood. In this cross-sectional study, mood state of 139 healthy women (43.03 ± 1.41 years old) examined as a result of adherence to vegetarian or omnivorous diets. Vegetarian diet showed better total scores of DASS ($p < 0.001$) and also two subscales of DASS (depression and anxiety) ($p < 0.001$) than those of the omnivorous group. Mean total POMS scores of the vegetarian group were significantly lower than omnivorous as well as the domain scores (tension, depression, anger and fatigue) but not confusion and vigor (Beezhold et al., 2010).

In the last study, Beezhold et al. in 2015 surveyed the relation between mood and diet in 620 healthy subjects (34.83 ± 10.2) in which participants were categorized into three groups, including vegetarian, vegan and omnivorous based on their diets. The vegan diet showed significant reduction for anxiety ($P < 0.05$) and stress ($P < 0.01$) and also it was inversely correlated with recent subscale of DASS ($p < 0.001$). Vegetarian diet did not show any beneficial effects on mood (Beezhold et al., 2015).

3.3.4. Glycemic load-based diet

Cheatham et al. in 2009 investigated the effects of high and low glycemic load diet on mood and cognition. In this randomized controlled trial study, 42 healthy overweight adults (age 35 ± 5 years; BMI 27.8 ± 1.6 kg/m^2) were randomly assigned to high ($n = 20$) or low glycemic load ($n = 22$) diet. Among subscales of POMS, score of depression increased in a high glycemic load diet compared with low glycemic after six months of intervention ($p = 0.04$). There was also a trend towards confusion when hunger added as a covariate ($p = 0.05$) indicating that score of confusion decreased more in the low glycemic load diet than the high glycemic one (Cheatham et al., 2009).

Another study was done by Breymeyer et al. in 2016 to investigate the efficacy of low and high glycemic load diet on components of mood. In this randomized cross over controlled study, eighty-two healthy subjects (28.85 ± 7.4 years old) randomly allocated to high or low glycemic load diet for 28 days. Based upon the results, in the high glycemic load diet vigor was lower and the both total mood disturbance ($p = 0.05$) ($p = 0.01$) and fatigue were higher ($p = 0.04$) (Breymeyer et al., 2016).

3.3.5. Ketogenic diet

In the first study, IJff et al. recruited 50 epileptic patients (mean 7.8 years old) to investigate the impact of ketogenic diet on mood state. In this randomized clinical trial, participants were randomly allocated to ketogenic diet or as usual care group for four months. The results revealed that only vigor improved significantly ($p = 0.005$) in the intervention group (IJff et al., 2016).

Another study done by McClernon et al. in 2007 to examine the effects of ketogenic and low-fat diets on mood state of 120 healthy individuals (44.36 ± 9.03 years old). After 6-month intervention, negative affect ($p < 0.0001$) and fatigue ($p <$ 0001) showed significantly better scores in ketogenic group (McClernon et al., 2007).

In the last study, Lambrechts et al. in 2012 conducted an observational study to assess the impact of ketogenic diet on mood state of 15 epileptic patients with mean age of 28 years old. After 12 months of ketogenic diet therapy, mood variables did not change significantly (Lambrechts et al., 2012).

3.3.6. Paleo diet

Lee et al. examined the efficacy of Paleo diet on mood variables in patients with multiple sclerosis. In this quasi-experimental study, 19 patients (51 ± 6.5 mean age) were enrolled to receive intervention for 12 months. The results revealed anxiety and depression scores improved significantly ($p < 0.05$) at the end of trial (Lee et al., 2017).

3.3.7. Zone diet

The only study that used zone diet carried out by Fontani et al. in 2005. In this cross-over trial, 33 healthy subjects (33 ± 7 years old) were randomly assigned to zone or control diets for 35 days. Then, each group sub-divided into omega-3 supplement or placebo. Zone diet could improve the mood state (vigor, anger, anxiety, confusion and depression) but supplementation with omega-3 made this improvement significant ($p < 0.05$) except the fatigue which omega-3 supplementation increased the score (i.e. became worse) (Fontani et al., 2005).

4. Disscussion

To the best of our knowledge, no systematic review has been published to assess the relationship between diet and mood. We, therefore, gathered all types of diets, including: DASH, MD, vegetable-based, glycemic load-based, ketogenic, Paleo and Zone diet.

The DASH diet is a healthy eating pattern rich in plant proteins from nuts and legumes, fruits, vegetables, low-fat dairies, and restricted amounts of red meat, sweets, and sugar-sweetened beverages (Vollmer et al., 2001). DASH diet has shown a beneficial impact on anger, depression, anxiety, tension, vigor and POMS global score (Torres et al., 2008; Torres and Nowson, 2012; Valipour et al., 2017). In the view of quality, 2 interventional studies (Torres et al., 2008; Torres and Nowson, 2012) are low quality, which makes it difficult to draw a firm link between mood and DASH diet based on the results of these studies. On the other hand, another study of this group is a high-quality paper, but the cross-sectional design of this study makes it impossible to draw a causal link between mood and DASH diet (Valipour et al., 2017). The underlying mechanism of mood elevation by DASH diet could be due to its high amount of potassium, magnesium, calcium and low sodium content (O'Brien et al., 1980; Torres et al., 2008). High serum sodium: potassium ratio results in secretion of progesterone, which may change the neural activity of the brain possibly leading to mood deterioration (O'Brien et al., 1980; Toffoletto et al., 2014). This finding is in contrast with previous literature indicating that dietary low sodium intake results in a negative mood (Wassertheil-Smoller et al., 1991). Reduced sodium levels could activate renin-angiotensin system, which is, therefore, resulted in aldosterone secretion and high aldosterone level reported in patients with clinical depressive disorder (Jürgens and Graudal, 2004; Emanuele et al., 2005). An explanation for this controversy might be high load of magnesium alongside with low sodium content of DASH diet (Torres et al., 2008). Based on previous studies, magnesium supplementation could be an effective treatment of depression (Eby and Eby, 2006), so it requires more studies to clarify exact relationship between sodium-magnesium and mood state. Moreover, DASH diet includes the high amounts of antioxidant rich fruits and vegetables, that could be another mechanism of its mood elevating action (Torres and Nowson, 2012). It was shown that elements with high antioxidant capacity could restore antioxidant enzyme's activity in the brain cortex which results in mood elevation (Martín-Aragón et al., 2016).

Second subgroup belongs to MD, that could exert beneficial effects on vigor and confusion (McMillan et al., 2011; Lee et al., 2015). The MD largely consists of fish, a variety of fruits and vegetables, olive oil, whole grains and legumes. This diet is rich in nutrient such as essential fatty acids, magnesium, lean protein, and antioxidants, including vitamins E and C, which might link MD to brain function (Solfrizzi et al., 2003). MD is variable through different locations, cultures, and population. For example, the French type of MD included less fat, probably more fruit and vegetables, more wine, but it may be different from Minnesota type of MD in where there are more meat and potatoes, fewer vegetables and more dairy. Thus, this could be a reason for the different results of the studies from different regions (Singh et al., 2014). Moreover, three out of four studies (Hyyppä et al., 2003; McMillan et al., 2011; Lee et al., 2015) have low quality and the only high-quality study (Wardle et al., 2000) didn't find any beneficial effects for MD. High content of omega-3, and magnesium could be a possible link between MD and mood state (Eby and Eby, 2006). Dietary intake of omega-3 fatty acids can reduce the production of pro-inflammatory cytokines, including interleukin-1, interleukin-6 and tumor necrosis factor (TNF)-alpha that, in turn, play role in stabilizing brain cell's membrane and, therefore, improve the mood state (Kiecolt-Glaser et al., 2011). Another mechanism is related to increasing the brain-derived neurotrophic factor (BDNF) expression as a result of omega-3 consumption (Giles et al., 2013). BDNF is a protein that mostly found in the brain and has a role in growth and differentiation of the brain neurons and also supports survival of existing neurons (Acheson et al., 1995). It has been shown that omega-3 fatty acids consumption could increase the expression of BDNF in the cortex and hippocampus of rats, resulting in beneficial impact on mood state (Vines et al., 2012). There are plenty of suggested roles for magnesium, which link this element to the brain and mood (Eby and Eby, 2010). Magnesium could increase expression of BDNF, moreover; it could block the activity of N-Methyl-D-aspartate (NMDA) receptor. NMDA receptor is a glutamate receptor found in nerve cells and is important in nerve plasticity and memory function. Antagonizing activity of magnesium on NMDA receptor could induce antidepressant action of this element and boost our mood (Szewczyk et al., 2008).

Third subgroup belongs to vegetable-based diet, including vegetables and vegan diets. Vegetarian diets are defined as diets without meat, fish and poultry, but it included animal-derived foods: eggs, honey, milk and dairy products. On the other hand, vegan diets are defined as diet without animal or animal-derived foods (Piccoli et al., 2015). This diet could improve tension, depression, anger, fatigue, stress and anxiety (Beezhold et al., 2010; Beezhold and Johnston, 2012; Beezhold et al., 2015; Olabi et al., 2015). In this Section 2 study with interventional design (Beezhold and Johnston, 2012; Olabi et al., 2015) have low quality score and the others two studies have cross-sectional design (Beezhold et al., 2010; Beezhold et al., 2015) which all of these limitations make it difficult to draw a firm link between vegetable-based diet and mood. This diet is fulfilled with different types of vegetables and fruits, that are good sources of phytochemicals and vitamins with antioxidant capacity (Beezhold et al., 2010). Phytochemicals are chemical compounds completely synthesized by plants in order to protect them against pathogens. These compounds are categorized into two major groups, including carotenoids and polyphenol (Baxter et al., 1998). Increasing brain serotonin level and expression of BDNF, reduction of mono amine oxidases (MAO) A and B and inflammatory biomarkers (IL-6 and TNF-α) might be probable reasons for mood elevating activity of polyphenols (Bahramsoltani et al., 2015). Another element is ascorbic acid mostly found in fresh fruits and vegetables. This vitamin interacts with serotonergic, dopaminergic and noradrenergic system and also could block NMDA receptors, which might be the mood elevation mechanism of vitamin C (Bahramsoltani et al., 2015).

Fourth subgroup, includes glycemic load-based diets that are categorized into a low or high glycemic load based upon the score of glycemic load formula. Dietary glycemic load (GL) is a measure of blood-glucose response to food influenced by carbohydrate type and quality and calculated as: GL = ([glycemic index of individual food x g carbohydrate per serving of food]/100). Depression, confusion, vigor, fatigue and total mood disturbance were improved in low glycemic load diet followers compared with high glycemic ones (Cheatham et al., 2009; Breymeyer et al., 2016). Two studies included in this subgroup which their results are inconsistent and have low quality (Cheatham et al., 2009; Breymeyer et al., 2016). So these limitations reduce their impact on the overall conclusion about glycemic load-diet and mood state. Previous studies have shown that high GL diet could interfere with hormonal change and availability of metabolic fuels such as free fatty acids and glucose, that exacerbate hunger and hunger sensation, therefore, negatively impact on vigor (Cheatham et al., 2009). Another related mechanism is blood-glucose fluctuations seen in high GL diet more than low GL and could exert negative effects on mood state (Cheatham et al., 2009; Penckofer et al., 2012). Rapid elevation of post-prandial blood glucose, main characteristics of high glycemic load diet, could produce pro-inflammatory cytokines and also free radicals. It has been reported by a recent analysis of Nurses' Health Study that inflammatory diet pattern could elevate the risk of mood disorders like depression (Kiecolt-Glaser 2010; Lucas et al., 2014).

Ketogenic diet belongs to the fifth subgroup, as a high-fat, low-protein, low-carbohydrate diet that reproduces the metabolic state of fasting (Lambrechts et al., 2012). This diet could exert a beneficial impact on vigor, fatigue and negative mood (McClernon et al., 2007; Lambrechts et al., 2012; IJff et al., 2016). This subgroup consisted of two interventions (McClernon et al., 2007; IJff et al., 2016) and one cross-sectional study (Lambrechts et al., 2012) which all of them have low quality and also there is not any consistency regard the association between their impacts on mood parameters. Ketogenic diet could stabilize blood-glucose level and also reduce hunger, which might be its link with mood (Boden et al., 2005). Moreover, this diet plays a role as mood stabilizer and antidepressant (Murphy et al., 2004).

The next subgroup belongs to Paleo diet that could improve depression and anxiety based on results of included study (Tarantino et al., 2015; Lee et al., 2017) but it should be taken into account that the only study in this subgroup did not use control group. Hunter gatherer, stone age, Paleolithic or simply Paleo diet is defined as a diet rich in meat, organ meats, roots, green vegetables, seasonal fruit, nuts and seeds (Tarantino et al., 2015). This diet is fulfilled with fruits and vegetables, and they could be a reason for elevating mood by this diet (Lee et al., 2017). Another underlying mechanism of Paleo diet is related to meat group which has a high amount of zinc (Amani et al., 2010; Tarantino et al., 2015). Recent evidence has shed light on the possible role of zinc in the serotonergic and glutamatergic system, as well as neurotrophic factors (BDNF) and antioxidant mechanisms that may play a role in mood regulation (Cope and Levenson, 2010). Administration of zinc could increase the density of serotonin receptor in hippocampus and the frontal cortex (Cichy et al., 2009). In addition, zinc can block NMDA receptors, which are the key mechanism of antidepressant drugs (Szewczyk et al., 2010).

The last subgroup belongs to Zone diet, which failed to show any beneficial impacts on mood state (Fontani et al., 2005). Zone diet characterized as low carbohydrate, high-protein diet and is linked to mood because of its antioxidant activity (Urso and Clarkson, 2003; Fontani et al., 2005).

There are some reports on association between low cholesterol levels and depressive mood disorders (Papakostas et al., 2004) which makes a paradox because most studies presented in this review including DASH, MD and vegetable-based diets are low in cholesterol or have hypocholesterolemic effects. In order to clear these discrepancies two points should be taken into account. First, not all studies suggested the association between mood disorders and low cholesterol levels (McCallum et al., 1994; Freedman et al., 1995). Second, cholesterol levels are mainly regulated by de novo synthesis (Stone et al., 2014).

Some limitations of this study are as follows. There are inconsistencies among included studies related to different diet, population, sample size and study duration. The number of studies in each category was not enough to conclude that a specific diet could be associated with mood states. Moreover, the methodologies of included studies were different, which makes it difficult to draw a firm link between diet and mood. Another limitation of our study is related to the nature of interventions in which it was impossible for blinding regarding the effects of different diets. Therefore, intervention group could be aware that they were changing to a healthier diet, and this might, directly or indirectly, influence the mood. Lastly, the taste and pleasure of diets were not mentioned in different studies that could impact on mood states of consumers.

5. Conclusion

According to all mentioned above, we found that diet could improve the mood states, but differences between the diets should be taken into account. Although there is not a consistent finding between studies, it seems that DASH, vegetable-based, glycemic load-based, ketogenic and Paleo diets could improve mood more than the others. Further studies are needed to assess such relationship in a longer period to draw a firm link between diet and mood.

Conflict of interest

None

Author contribution

R. Amani: contributed in concept of manuscript and edited the draft.
A. Arab, S. Moradi, S. Mehrabani contributed in writing and revising the manuscript.

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