

## Is there an association between diet and depression in children and adolescents? A systematic review

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### Abstract

This review critically evaluates previous studies investigating the association between dietary intake of children and young people and depression and related mental health problems. A systematic literature search was conducted using electronic databases such as PsycINFO, MEDLINE, PubMed and Cochrane. A total of twenty studies were identified that met inclusion criteria and were subsequently rated for quality. The studies used a range of methods to measure dietary intake and mental health. Important potential confounding variables (e.g. socio-economic status) were often not included or controlled. There were also inconsistencies in the use of key constructs, which made comparisons between studies difficult. Despite some contradictory results, overall there was support for an association between healthy dietary patterns or consumption of a high-quality diet and lower levels of depression or better mental health. Similarly, there was a relationship between unhealthy diet and consumption of low-quality diet and depression or poor mental health. However, where significant relationships were reported, effect sizes were small. Future research on the relationship between diet and mental health in young people should use more clearly defined constructs to define diet and include or control for important confounders.

**Key words:** Depression: Anxiety: Nutrition: Diet: Children: Adolescents

In any given year, approximately 20% of children and adolescents globally have mental health difficulties, including major depressive disorder. Depression has been ranked as the second most common cause of death in adolescents, via suicide<sup>(1,2)</sup>. As mental health problems often start in childhood or adolescence, they are strongly associated with other developmental and health conditions affecting quality of life, social, academic performance, personality disorders and substance abuse in adult life<sup>(3–6)</sup>. There are limited evidence-based treatment regimens for this age group, including therapy, and a single licenced pharmacological treatment, fluoxetine<sup>(7)</sup>. Both treatments are only moderately effective, with up to 50% of young people not responding to treatment or experiencing relapse and further episodes of depression<sup>(8–10)</sup>. An important area for development therefore is to prevent depression via public health interventions that can be delivered to an entire population of children and adolescents.

Over the past decade, several studies have suggested that diet could play an important role in treatment and prevention of depression. Two main approaches have been used to examine this relationship. A number of studies have investigated the impact of individual nutrients such as *n*-3 fatty acids<sup>(11,12)</sup>, vitamins such as B<sub>12</sub><sup>(13)</sup> and minerals such as Zn, Se and Fe<sup>(14–16)</sup>. In addition, several intervention studies have examined the effect of supplements containing more than one nutrient (e.g. multivitamins, EPA and DHA) on mood<sup>(17–19)</sup>. However, the

idea of investigating individual nutrients to ascertain whether that single ingredient is responsible for improving mood is problematic. Mood regulation is influenced by a number of different neurochemical pathways (e.g. serotonin and dopamine), with each requiring several nutrients to supply the metabolites necessary for production of the individual neurotransmitters involved in regulation of mood<sup>(20)</sup>.

An alternative approach has been to explore the effects of whole diet and eating patterns on mood. In correlational epidemiological studies of adults, an 'unhealthy' and 'Westernised' diet was associated with an increased likelihood of mental disorders and psychiatric distress<sup>(21–24)</sup>, whereas a 'healthy' or 'good-quality' diet was associated with better mental health<sup>(21,25–28)</sup>. However, several other factors such as socio-economic status (SES), household income and educational levels also influence dietary choice, and thus need to be included as potential confounders<sup>(29,30)</sup>.

Overall, studies with adults that have investigated the relationship between diet and mental health suggest that the relationship is complex and potentially bidirectional<sup>(31)</sup>. Given the development of the brain during childhood and adolescence, and the emergence of depression during adolescence, the impact of diet on mental health may plausibly be greater during this period than later in life<sup>(3,4,32)</sup>. In addition, adolescents typically become increasingly independent and make more decisions about the type and amount of food they

**Abbreviation:** SES, socio-economic status.

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consume, including 'junk' and 'fast' foods<sup>(33)</sup>. Therefore, the relationship between diet and mental health in young people and children warrants specific attention.

In a recent review, twelve epidemiological studies that examined the association between diet and mental health in young people were identified and reviewed<sup>(34)</sup>. It concluded that there was evidence for a significant relationship between an unhealthy diet and worsening mental health. Our review aims to advance knowledge in this field by (1) using a more sensitive measure of assessing methodological quality, and (2) assessing effect sizes across studies so that data can be compared on a single metric. Together, this will help describe the current status of the field, identify key methodological challenges facing researchers, synthesise and integrate existing research to highlight future research opportunities and implications for the development of dietary strategies to prevent childhood and adolescent depression.

## Methods

### Search strategy

A systematic literature search was conducted of social sciences, medical, health and psychiatric databases (i.e. PsycINFO, MEDLINE, PubMed, BIOSIS Cochrane Library and ScienceDirect). We identified relevant literature, published in the English language, from 1970 up to April 2016. Reference lists of related studies and reviews were also searched.

The search was carried out using the following combinations of key terms: internalising disorders or internali\* or mental health or depression or depr\* or depressive disorders or anxiety or anxi\* or anxiety disorders or affective disorders or mood or mood disorders or well-being **AND** diet or nutrition or diet quality or dietary patterns **AND** youth or young people or adolescents or adol\* or children or teen. As anxiety disorders commonly co-occur in children and adolescents with depression, with anxiety having an earlier age of onset, they were also included in the literature search<sup>(35–39)</sup>. However, diet and its relationship with depressive disorders was the primary objective of this review.

### Inclusion criteria

Studies eligible to be included in this review were as follows:

1. In English language.
2. Available as full text (including abstracts of meetings, etc.).
3. Included children and young people aged 18 years and below in the sample.
4. Study designs were case-control, cross-sectional, epidemiological cohort or experimental trials.
5. Examined the association between nutrition, dietary pattern, diet quality and internalising disorders (including low mood, depressive or anxiety symptoms and emotional problems).
6. Diet or nutritional intake measured via self-report (FFQ, diet records) or controlled weighed food records, observation or use of biological markers.

7. Diet quality measured by calculating scores from food frequency data or diet quality and diet patterns defined as overall habitual dietary intake.
8. Internalising disorders measured using self-report, doctor's diagnosis, medical records, interview or depression/anxiety rating scales.

### Exclusion criteria

Exclusion criteria were as follows:

1. Studies focused on disorders of eating or dietary restraint for weight-loss purposes.
2. Reported internalising disorder as a secondary problem to physical health problems (e.g. diabetes and heart disease).
3. Studies using only pregnant women as participants.
4. Animal studies.
5. Studies that focused on individual nutrients specifically.
6. Studies where all participants were over 18 years of age.
7. Mental health data limited to measures of behaviour or conduct (externalising problems).

The methodological quality of each study was assessed independently by S. K. and S. A. R., using the National Institutes of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. Disagreements were discussed with C. M. W. and a shared rating was given. Methodological criteria evaluated included the following: (a) bias in selection of participants, measurement or information with high risk of bias translating to a rating of poor quality and (b) study designs that could help determine a causal relationship between diet and mental health (Table 1).

**Table 1.** National Institutes of Health criteria list for assessing study quality

	Criteria list
1	Was the research question or objective in this paper clearly stated?
2	Was the study population clearly specified and defined?
3	Was the participation rate of eligible persons at least 50 %?
4	Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were the inclusion and exclusion criteria for the study pre-specified and applied uniformly to all participants?
5	Were sample size justification, power description or variance and effect estimates provided?
6	For the analysis in this study, was the exposure(s) of interest measured before the outcome(s) measured?
7	Was the time frame sufficient, so that one could reasonably expect to see an association between exposure and outcome if it existed?
8	For exposure that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g. categories of exposure or exposure measured as a continuous variable)?
9	Were the exposure measures (independent variables) clearly defined, valid, reliable and implemented consistently across all study participants?
10	Was the exposure(s) assessed more than once over time?
11	Were the outcome measures (dependent variables) clearly defined, valid, reliable and implemented consistently across all study participants?
12	Were the outcome assessors blinded to the exposure status of participants?
13	Was loss to follow-up after baseline 20 % or less?
14	Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?



## Results

This section describes in detail the process of literature selection, quality ratings of the studies, methodology used and also a summary of results of these studies.

### Selection

A total of 3014 studies were identified as a result of the initial search. Further screening identified ninety-eight studies relating specifically to nutrition and mood. Of these, seventy-eight were excluded, typically because participants were not in the appropriate age range, depression and/or anxiety was not measured, depression/anxiety were secondary to physical health problems or studies included calorie restraint or binge eating.

Complete details of screening, filtering and our selection process for the studies included in this review are shown in Fig. 1. In total, twenty studies that met inclusion and exclusion criteria were identified. Study populations were from USA, UK, Australia, Canada, Germany, Norway, Spain, Malaysia, Pakistan, Iran and China. Even though the traditional diets of non-western countries may differ, most of these studies investigated the consumption of junk or Westernised foods. Two studies, one from China and another from Norway, examined both Westernised and their traditional diets. Key features of the selected studies are presented in Table 2.

Data were extracted from seventeen cross-sectional studies and from three prospective cohort studies with follow-up periods ranging from 2 to 4 years. No experimental studies or clinical trials were identified. The total number of participants recruited across the twenty studies was 110 857, although two studies used participants from the same data set (The Western Australian Pregnancy Cohort (Raine) Study; with  $n$  1324 and  $n$  1598, respectively)<sup>(40,41)</sup>; 109 533 unique individual participants were recruited in total to these studies. There were 51 834 males and 49 588 females, although some authors did not clearly state the number of boys and girls in their studies<sup>(42,43)</sup>. The age of participants ranged from 18 months to 18 years.

### Overall quality

Using the NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies, the quality of majority of studies was rated as 'fair' ( $n$  16), with three studies classified as 'good'<sup>(43–45)</sup> and one rated as 'poor'<sup>(42)</sup>. The key methodological features of each study are outlined in Table 2. Common methodological weaknesses included inadequate measurement of the key variables (diet and mental health), which will be discussed in more detail below.

### Measures of diet

Several different measures were used to measure dietary/nutritional intake across these studies. The most common and relatively reliable methods used were FFQ including Harvard Youth/Adolescent FFQ (YAQ FFQ; a widely used validated questionnaire) and Commonwealth Scientific & Industrial Research Organisation FFQ (semi-validated for use in adults). One particular study used 3-d food records, which are more

reliable than FFQ<sup>(46)</sup>. In addition, a single study calculated absolute food consumption (to nearest gram) under controlled laboratory conditions<sup>(47)</sup>, which is considered one of the most reliable methods to measure dietary intake.

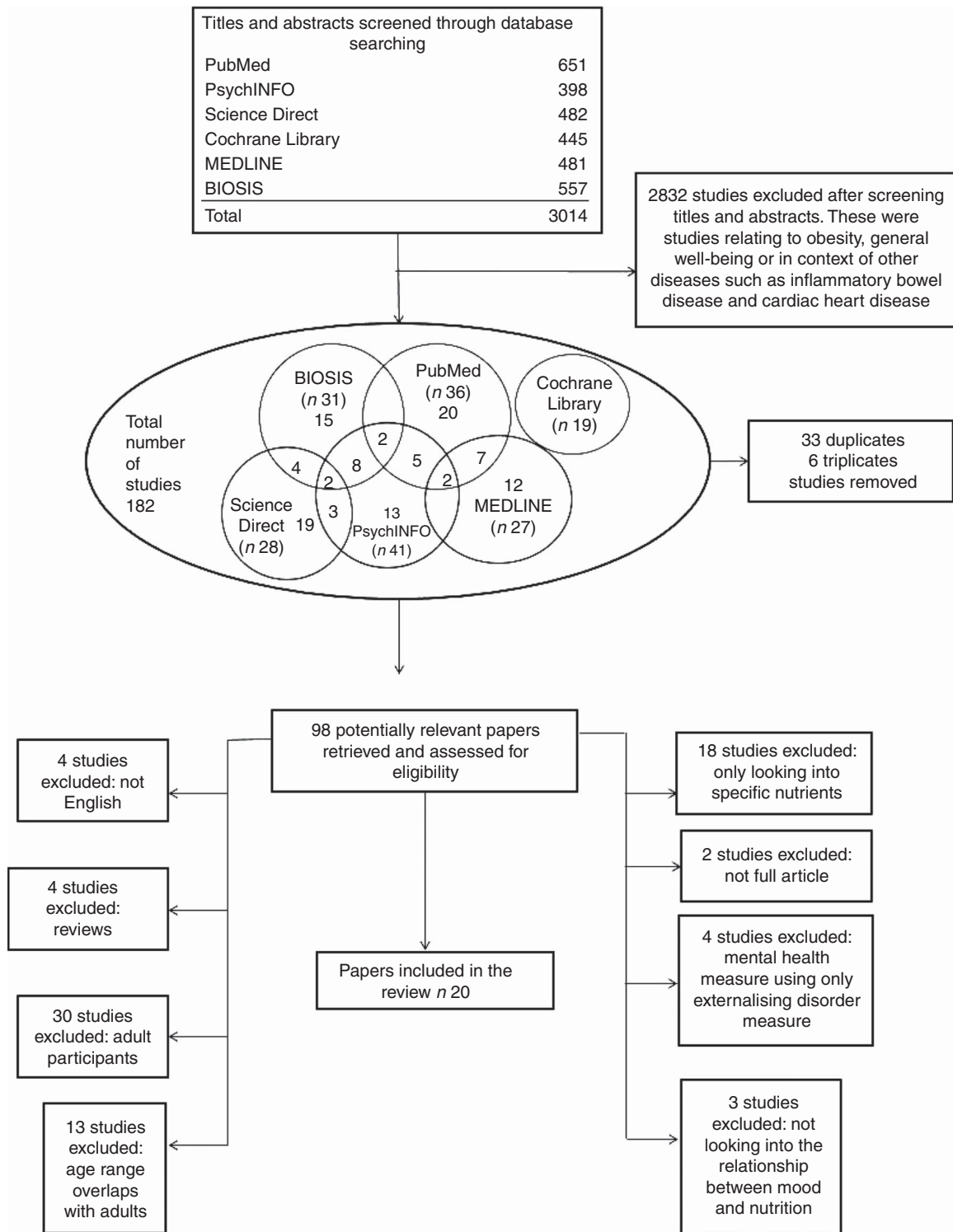
Diet quality was measured using questionnaires based on the FFQ in addition to National Healthy Eating Guidelines, Australian Guide to Healthy Eating, Amherst Health and Activity Survey of Child Habits, German Optimized Mixed Diet or Diet Quality Index-International scores. In each case, these consisted of components such as variety, adequacy, moderation and balance in the diet. None of these measures was validated. Other non-validated measures included questions on fruits, vegetables, sweets, snacks (including salty) and carbonated drinks consumption, in addition to regularity of breakfast consumption and skipping meals (Eating Behaviour Questionnaire). Simple questions with questionable validity such as 'do you eat a healthy diet?' were also used.

Most of the studies used measures that relied on child/adolescent self-report. A few studies used a parent or caregiver report of their children's diet – this may affect the accuracy of the results because of social desirability factors or parents' lack of knowledge of what the child might be consuming away from home. Overall dietary intake was not measured in a coherent way, and most tools used to measure nutritional intake or quality were not validated, particularly for the age range of the sample. In addition, there was a lack of consistency between the studies with regard to the items of food used to define healthy or unhealthy diet and whether diet quality or dietary patterns should be used to best define an individual's dietary intake.

### Measures of mood

A number of studies used measures of adolescent mental health that were well-established, validated and suitable for young people. The most common measures were the Child Behaviour Checklist<sup>(40,41,48)</sup>, the Strengths and Difficulties Questionnaire<sup>(43,45,49–51)</sup>, Short Mood and Feelings Questionnaire<sup>(45,52)</sup> and Depression Self-Rating Scale for Children. The Center for Epidemiologic Studies Depression Scale for Children was also used by one study<sup>(46)</sup>. These were typically completed by parents of younger children or by adolescents themselves. Some studies measured depression only and others used measures that were composed of components measuring both depression and anxiety ('internalising' problems).

A wide range of other measures were also used. Some were generic measures of adolescent well-being that included elements of depression, for example, Paediatric Quality of Life, some were completed by professionals on the basis of an unstructured consultation, for example, International Classification of Disease (ICD-9/10), and others were specific to depression but not designed for use by children and adolescents, for example, the Beck Depression Inventory (II) and the Depression, Anxiety and Stress Scale (DASS-21). Additional *ad hoc* items such as 'during the past 12 months, how often have you been so worried about something that you could not sleep at night?', 'During the past 12 months, did you make a plan about how you would attempt suicide?' and questions on frequency of feeling depressed were also used but are of doubtful validity.



**Fig. 1.** Showing the selection process of studies included in this review.

### Study design

Most research studies used designs that were cross-sectional. This was a relatively weak design because it was not able to determine the direction of the relationship between diet and mood. Longitudinal studies were uncommon. Socio-economic variables

that are highly correlated with mood in children and young people and that are related to diet, such as SES, income and parents' educational level, were not measured consistently and were neither measured nor controlled by some studies<sup>(47,48,53–55)</sup>. The most common confounding variables that were controlled were age and sex of participants. Some important variables



**Table 2.** Key features determining the quality ratings of the included studies (Mean values and standard deviations)

Citation Country	Participants		Diet		Mental health		Respondent	Confounding variables	Quality rating
	Numbers	Age (years)	Measure	Validated	Measure	Validated			
Brooks <i>et al.</i> <sup>(53)</sup> USA	2224	Mean 16.2 (sd 1.6)	Do you eat a healthy diet? Yes/No	No	Frequency of depression or 'stress' in the past 30 d	No	Adolescents	Age, race and sex	Fair
Fulkerson <i>et al.</i> <sup>(54)</sup> USA	4734	Mean M 14.9 (sd 1.7) Mean F 14.7 (sd 1.7)	Meal, junk food, snacking frequency, YAQ	Yes-YAQ	Kandel & Davies' 6-item scale	No	Adolescents	Race and grade level. Sex-specific analysis	Fair
Jacka <i>et al.</i> <sup>(52)</sup> Australia	7114	Range 10–14 Mean 11.6 (sd 0.81)	Unhealthy diet score based on dietary questionnaire	No	SMFQ – 13 items	Yes	Adolescents	Age, sex, SES, eating attitudes, PA, BMI and smoking	Fair
Jacka <i>et al.</i> <sup>(44)</sup> Australia	2915	Range 11–18	Healthy/unhealthy diet based dietary questionnaire	Yes – in adults	PedsQL	Yes	Adolescents	Age, sex, SES, PA, dieting behaviours and BMI	Good
Jacka <i>et al.</i> <sup>(45)</sup> UK	2789	Range 11–14	Unhealthy diet score: frequency of fruit, vegetable, fast food snacks and breakfast	No	SMFQ and SDQ	Yes	Adolescents	Sex, age, ethnicity, religion, SES, PA, BMI, dieting behaviour, alcohol, cigarette and drug use	Good
Kohlboeck <i>et al.</i> <sup>(49)</sup> Germany	3361	Range 9.9–12.7 Mean 11.15 (sd 0.5)	Diet quality based on 82-item FFQ	Yes FFQ	SDQ	Yes	Caretaker	Sex, SES, BMI, PA, television/PC use and total energy intake	Fair
McMartin <i>et al.</i> <sup>(57)</sup> Canada	3757	Range 10–11	YAQ used to calculate DQI-I scores	Yes YAQ	ICD-9 or 10	Yes	Child	Sex, energy intake, SES, weight, PA	Fair
McMartin <i>et al.</i> <sup>(60)</sup> Canada	6528	Range 10–11	YAQ used to calculate DQI-I scores	Yes YAQ	EuroQoL for youth	Yes	Child	SES, height, weight, PA, sex and energy intake	Fair
Mooreville <i>et al.</i> <sup>(47)</sup> USA	Study 1: 228 Study 2: 204	Range 8–17 Mean 13 (sd 2.8)	Energy (kcal) consumed after an overnight fast	Yes	21-item BDI-II	Yes	Adolescents	Age, race, height, % fat mass and fat free mass	Fair
Oddy <i>et al.</i> <sup>(40)</sup> Australia	1324	Range 13–15 Mean 14 (sd 0.2)	CSIRO FFQ used to identify healthy/Western dietary patterns	Semi-validated in adults	CBCL (4–18 years)	Yes	Caretaker	Total energy intake, PA, television/PC use, BMI, SES and sex	Fair
Oellingrath <i>et al.</i> <sup>(51)</sup> Norway	1095	Range 12–13	FFQ covering 40 food items	No	SDQ (parental version)	Yes	Caretaker	SES, PA, BMI and sex	Fair
Rao <i>et al.</i> <sup>(42)</sup> Pakistan	4583	Range 13–15	Frequency of carbonated drinks and fast food consumed	No	Anxiety, suicidal ideation measured using 1 item each	No	Adolescents	Age, sex, BMI, SES, parental check, understanding and close friends	Poor
Renzaho <i>et al.</i> <sup>(50)</sup> USA	3370	Range 0–12	Frequency of fruit and vegetable consumed	No	SDQ	Yes	Caretaker	SES, age, sex, food security, social support	Fair
Rubio-López <i>et al.</i> <sup>(46)</sup> Spain	710	Range 6–9	3-d food diary	Yes	CES-DC	No	Caretaker	Age, sex, BMI, SES and nationality	Fair
Robinson <i>et al.</i> <sup>(41)</sup> Australia	1598	Mean 14 (sd 0.2)	CSIRO FFQ	Semi-validated in adults	CBCL	Yes	Caretaker	Sex, family income, maternal employment	Fair
Tajik <i>et al.</i> <sup>(55)</sup> Malaysia	1568	Range 13–14 Mean 13 (sd 0.8)	Eating Behaviour Questionnaire	No	DASS-21	Yes	Adolescents	No confounding variable identified	Fair
Vollrath <i>et al.</i> <sup>(48)</sup> Norway	40 266	1-5	Frequency of sweet food and drinks	No	CBCL and EAS	Yes	Caretaker	Sex, weight, height and breast-feeding	Fair
Weng <i>et al.</i> <sup>(58)</sup> China	5003	Range 11–16 Mean 13.2 (sd 0.99)	38-item comprehensive FFQ	No	DSRS Chinese version for children	Yes	Adolescents	SES, age, sex, PA and BMI	Fair
Wiles <i>et al.</i> <sup>(43)</sup> UK	4000	Range 3–4.5 Follow-up age 7 years	FFQ: junk, health conscious and traditional	No	SDQ	Yes	Caretaker	Sex, SES, maternal depression and anxiety	Good
Zahedi <i>et al.</i> <sup>(59)</sup> Iran	13 486	Range 6–18 Mean 12.47 (sd 3.36)	Frequency of junk food, sweets, beverages, fast foods and salty snacks	No	Questions on depression insomnia confusion anxiety and aggression	No	Trained personal	Age, sex, family history of chronic diseases, mothers education, screen time, PA, SES and BMI	Fair

M, male; F, female; YAQ, Youth and Adolescent Questionnaire; SMFQ, Short Mood and Feeling Questionnaire; SES, socio-economic status; PA, physical activity; PedsQL, Paediatric Quality of Life Inventory; SDQ, Strengths and Difficulties Questionnaire; PC, personal computer; DQI-I, Diet Quality Index-international; ICD, International Classification of Diseases; EuroQoL, European Quality of life scale; BDI-II Beck Depression Inventory; CSIRO, Commonwealth Scientific and Research Organisation; CBCL, Child Behaviour Checklist; CES-DC, Center for Epidemiological Studies Depression Scale for Children; DASS, Depression, Anxiety and Stress Scale; EAS, Emotionality Activity and Sociability Questionnaire; DSRS, Depression Self-Rating Scale.



including medical conditions such as hypothyroidism, diabetes and food allergies, which may be correlated to mood or food choices, were not considered by any study.

### Effect sizes

The association between diet and mental health was reported in a number of different ways. The most common method of evaluating the relationship between diet and mental health was to calculate the increased risk of depression given different types of diet. Other methods of analysis were univariate associations between the variables, multivariable linear regression and negative binomial regression with results reported as incidence rate ratio.

To allow the results of different studies to be compared on the same metric, we calculated effect sizes for all key variables where data were provided using the Practical Meta-Analysis Effect Size Calculator<sup>(56)</sup>. Two studies did not report data in a way that made this possible<sup>(40,57)</sup>.

### Relationship between nutrition and mood

The main results of the twenty studies, including the effect sizes, are shown in Table 3. Owing to the heterogeneity of the constructs, measurements and definitions of both internalising (depression and anxiety) symptoms and dietary intake, for example, quality, patterns, food groups and eating behaviours, the key results were grouped and described into the following broad categories.

#### Healthy diet

**Overall healthy diet.** A 'healthy' diet was broadly defined as positive eating behaviours and consumption of fruits and vegetables, health-promoting behaviours and avoiding 'unhealthy' food. However, there were inconsistencies regarding food items such as grains and legumes being part of a healthy diet. The relationships between a healthy diet or a healthy diet pattern and depression were investigated by eight studies<sup>(40,44–46,52–54,58)</sup>. Five studies reported a significant association between a healthy diet and lower depression with effect sizes ranging from small to medium ( $d=0.5^{(52)}$ ). There were a few exceptions<sup>(40,45,46)</sup>, where there was a weak evidence for an association between a healthy diet pattern and internalising symptoms. One study<sup>(53)</sup> reported that the association between 'healthy' diet and mood was significant only for females ( $d=0.14$ ). One research group explored the relationship between mental health and diet in a longitudinal design at two time points<sup>(44,45)</sup>. Jacka *et al.*<sup>(44)</sup> found that a healthy diet predicted depression 2 years later ( $d=0.43$ ) but that depression at baseline did not predict healthy diet consumption ( $d=0.02$ ) 2 years later. In contrast, Jacka *et al.*<sup>(45)</sup> found no association between a healthy diet and mental health 3 years later ( $d=0.11$ ).

**Fruits and vegetables.** There were conflicting results regarding fruit and vegetable intakes, and their association with mood. The studies that explored this association<sup>(40,41,49,50,54,57)</sup> all measured fruits and vegetables separately, except for two studies<sup>(49,57)</sup>, who grouped these variables into a single category.

Only one study<sup>(50)</sup> investigated whether mental health was associated with fruit and vegetable consumption. The majority of studies found no significant association between consumption of fruits and vegetables and mood. However, one study reported that compared with healthy individuals, individuals with emotional problems consumed significantly less fruit (in both males and females, average  $d=0.185$ ) and vegetables (only in females,  $d=0.1$ )<sup>(50)</sup>. Another study reported that consumption of fruits and leafy green vegetables (only) was significantly associated with lower odds of internalising symptoms<sup>(40)</sup>. Other vegetables such as cruciferous and yellow/red vegetables were not associated with internalising problems<sup>(40)</sup>.

#### Other food categories considered 'healthy'.

1. Cereal and grains: two studies<sup>(41,49)</sup> examined the effect of cereal consumption, whereas one<sup>(40)</sup> examined the effect of whole and refined 'grains' on mood. There was no evidence that cereals or grains were significantly associated with depression.
2. Dairy products: all three studies<sup>(40,41,49)</sup> reported no significant association between dairy products and depression.
3. Fish: four studies<sup>(40,41,49,57)</sup> explored fish intake and its association with depression. However, only one<sup>(57)</sup> study reported higher fish consumption to be significantly associated with decreased odds of developing mental health difficulties.

#### Unhealthy diet

**Overall unhealthy diet.** Six studies investigated the relationship between unhealthy diet and mental health<sup>(40,42,44,52,54)</sup>. An 'unhealthy' diet was broadly defined as one comprised of fast foods or take-aways, foods containing high fat and sugar levels, confectionery, sweetened beverages, snacking, Western dietary patterns and unhealthy food preferences. Typically, 'unhealthy' diets were reflected in a continuous score with higher levels indicating an unhealthier diet. Each of the studies reported a significant cross-sectional association between unhealthy diets and depression, with small-to-moderate effect sizes ( $d=0.1$  to  $0.39$ ). Jacka *et al.*<sup>(45)</sup> explored the link between mental health and an unhealthy diet in a longitudinal design. They found that unhealthy ( $d=0.26$ ) diet at baseline significantly predicted the occurrence of depression 2 years later but did not predict depression at 3 years ( $d=0.097$ )<sup>(47)</sup>. They also reported no association between depression at baseline and unhealthy diet consumption over time ( $d=0.06$ )<sup>(44)</sup>.

**Fast food/take away/eating away from home/junk food.** Seven studies investigated junk food or fast food consumption and mental health in adolescents<sup>(40,41,43,46,54,55,59)</sup>. Food items within this category consisted of Western food items or processed foods such as hamburgers, pizzas, meat pies, savoury pastries, fried food, hot chips, coated poultry and soft drinks. The food items included were more or less similar for different countries and cultures. Four studies<sup>(40,41,55,59)</sup> reported an association between high take-away/fast food consumption and increased odds of mental health problems. Overall, the effect sizes of these studies were small, with the exception of one study<sup>(41)</sup> that included confectionery and snacking as a part of junk/fast food consumption, and therefore reported a large effect size of junk food on mental health (Table 3).



**Table 3.** Key results (Interval risk ratios (IRR), *b* values and 95 % confidence intervals)

Citation	Study design	Key results: description and effect sizes
Brooks <i>et al.</i> <sup>(53)</sup> Fulkerson <i>et al.</i> <sup>(54)</sup>	Cross-sectional Cross-sectional	Healthy diet negatively correlated with depression only in females: <sup>males</sup> <i>d</i> =0.016, <sup>females</sup> <i>d</i> =0.028* Health-promoting attitude negatively correlated with depression <sup>males</sup> <i>d</i> =0.51*, <sup>females</sup> <i>d</i> =0.28* Health compromising attitude positively correlated with depression <sup>males</sup> <i>d</i> =0.34*, <sup>females</sup> <i>d</i> =0.19* Breakfast consumption negatively correlated with depression <sup>males</sup> <i>d</i> =0.32*, <sup>females</sup> <i>d</i> =0.30* Lunch, <sup>males</sup> <i>d</i> =0.29*, <sup>females</sup> <i>d</i> =0.39*, and dinner, <sup>males</sup> <i>d</i> =0.25*, <sup>females</sup> <i>d</i> =0.30*, negatively correlated with depression Daily consumption of soft drinks positively correlated with depression in males only <sup>males</sup> <i>d</i> =0.25*, <sup>females</sup> <i>d</i> =0.09 Caffeine intake positively associated with depression <sup>males</sup> <i>d</i> =0.41*, <sup>females</sup> <i>d</i> =0.33* Not significantly associated with depression: snacking in between meals <sup>males</sup> <i>d</i> =0.085, <sup>females</sup> <i>d</i> =0.084, fast food consumption <sup>males</sup> <i>d</i> =0.12, <sup>females</sup> <i>d</i> =0.10, daily vegetable intake <sup>males</sup> <i>d</i> =0.06, <sup>females</sup> <i>d</i> =0.11, daily fruit intake <sup>males</sup> <i>d</i> =0, <sup>females</sup> <i>d</i> =0.1, Ca <sup>males</sup> <i>d</i> =0.031, <sup>females</sup> <i>d</i> =0.04, Fe <sup>males</sup> <i>d</i> =0.05, <sup>females</sup> <i>d</i> =0.011, <sup>males</sup> <i>d</i> =0.15, <sup>females</sup> <i>d</i> =0.044, vitamin D <sup>males</sup> <i>d</i> =0.051, <sup>females</sup> <i>d</i> =0.068, folate <sup>males</sup> <i>d</i> =0.049, <sup>females</sup> <i>d</i> =0.069, vitamin B <sub>6</sub> <sup>males</sup> <i>d</i> =0, <sup>females</sup> <i>d</i> =0 and vitamin B <sub>12</sub> <sup>males</sup> <i>d</i> =0.06, <sup>females</sup> <i>d</i> =0.034
Jacka <i>et al.</i> <sup>(52)</sup>	Cross-sectional	Healthy diet negatively correlated with depression <i>d</i> =0.55* Unhealthy diet positively associated with depression: <i>d</i> =0.39*
Jacka <i>et al.</i> <sup>(44)</sup>	Cross-sectional Longitudinal	Healthy diet negatively correlated with depression <i>d</i> =0.286* Unhealthy diet negatively associated with depression <i>d</i> =0.181* Diet predicted mental health at 2-year follow-up: healthy diet score <i>d</i> =0.43*, unhealthy diet scores <i>d</i> =0.26* Mental health did not predict diet at 2-year follow-up: healthy diet score <i>d</i> =0.02, unhealthy diet scores <i>d</i> =0.06
Jacka <i>et al.</i> <sup>(45)</sup>	Cross-sectional Longitudinal	Healthy diet was not correlated with psychological distress SDQ ( <i>d</i> =0*) and SMFQ ( <i>d</i> =0.001*) Unhealthy diet positively correlated with psychological distress SDQ (0.178*) and SMFQ ( <i>d</i> =0.099*) Unhealthy ( <i>d</i> =0.097) and healthy diet scores ( <i>d</i> =0.111) did not significantly predict mental health at 3 years
Kohlboeck <i>et al.</i> <sup>(49)</sup>	Cross-sectional	Higher diet quality significantly negatively associated with emotional problems ( <i>d</i> =0.03*) Confectionery significantly positively associated with emotional problems ( <i>d</i> =0.04*) Not associated with emotional problems: bakery wares ( <i>d</i> =0.01), fats and oils ( <i>d</i> =0.05), dairy products ( <i>d</i> =0.025), meat and meat products( <i>d</i> =0.03), cereals( <i>d</i> =0.013), eggs ( <i>d</i> =0.012), fruit and vegetables ( <i>d</i> =0.012), fish ( <i>d</i> =0.002), ready to eat savouries ( <i>d</i> =0.009) and beverages ( <i>d</i> =0.005)
McMartin <i>et al.</i> <sup>(57)</sup>	Cross-sectional	Not enough information to calculate effect size. Variety and increased adequacy in diet significantly associated with internalising disorder (IRR 0.45*; 95 % CI 0.25, 0.82 and IRR 0.64*; 95 % CI 0.34, 1.2, respectively). Not associated with emotional problems: overall diet quality not significantly associated with internalising disorder (IRR 1.09; 95 % CI 0.73, 1.63) Moderation in diet not associated with internalising disorder (IRR 1.07; 95 % CI 0.66, 1.73) Balance in diet not associated with internalising disorder (IRR 1.06; 95 % CI 0.66, 1.73) Fruit and vegetables (IRR 1.25; 95 % CI 0.80, 1.99), folate (IRR 1.21; 95 % CI 0.64, 2.32), vitamin B <sub>6</sub> (IRR 1.05; 95 % CI 0.56, 1.99), vitamin B <sub>12</sub> (IRR 0.77; 95 % CI 0.5, 1.17), fish intake (IRR 0.59; 95 % CI 0.41, 1.55), <i>n</i> -3 fatty acid (IRR 0.97; 95 % CI 0.61, 1.55), <i>n</i> -3: <i>n</i> -6 ratio (IRR 0.9; 95 % CI 0.67, 1.21), percentage energy from fat (IRR 0.82; 95 % CI 0.55, 1.22)
McMartin <i>et al.</i> <sup>(60)</sup>	Cross-sectional	Diet quality negatively associated with worrying, sad or unhappy feelings ( <i>d</i> =0.025*) Higher variety in diet negatively associated with worrying, sad or unhappy feelings ( <i>d</i> =0.012*) Increased adequacy in diet negatively associated with worrying, sad or unhappy feelings ( <i>d</i> =0.028*). Balance in diet was significantly associated with worrying, sad or unhappy feelings ( <i>d</i> =0.012*) Moderation in diet not associated with worrying, sad or unhappy feelings ( <i>d</i> =0.01)
Mooreville <i>et al.</i> <sup>(47)</sup>	Cross-sectional	Study 1: depressive symptoms not associated with consumption of sweet snacks ( <i>d</i> =0.26) Study 2: depressive symptoms associated with consumption of sweets snack ( <i>d</i> =0.52*)
Oddy <i>et al.</i> <sup>(40)</sup>	Cross-sectional	Not enough information to calculate effect size Leafy green vegetables <i>b</i> = -1.98* (95 % CI -3.80, -0.16) and fruit: <i>b</i> = -2.16* (95 % CI -3.92, -0.41) associated with lower internalising score Western dietary pattern overall significantly associated with 'internalising' symptoms <i>b</i> = 1.25* (95 % CI 0.15, 2.35) Takeaway (Q4: <i>b</i> = 1.89* (95 % CI 0.07, 3.71)); confectionery (Q4: <i>b</i> = 2.63* (95 % CI 0.87, 4.39)) and red meat (Q4: <i>b</i> = 1.98* (95 % CI 0.20-3.76)) significantly associated with higher internalising scores Not associated with emotional problems: healthy diet pattern overall not significantly associated with internalising symptoms <i>b</i> = 1.25 (95 % CI -0.54, 0.88) Tomato, yellow/red <i>b</i> = -0.51 (95 % CI -2.24, 1.23), cruciferous, other vegetables, legumes, whole grains and fish steamed grilled or tinned not associated with internalising symptoms Refined grains, processed meat, potato fried, crisps, soft drinks, cakes/biscuits, sauces/dressings and full fat dairy products not associated with internalising symptoms
Oellingrath <i>et al.</i> <sup>(51)</sup>	Cross-sectional	Not associated with problems: junk/convenient ( <i>d</i> =0.097), varied Norwegian ( <i>d</i> =0.053) and snacking ( <i>d</i> =0.025)
Rao <i>et al.</i> <sup>(42)</sup>	Cross-sectional	Positive correlation between anxiety and three ( <i>d</i> =0.14*) or four or more ( <i>d</i> =0.21*) unhealthy behaviours Positive correlation between suicidal ideation and two ( <i>d</i> =0.10*), three ( <i>d</i> =0.27*) or four or more ( <i>d</i> =0.36*) unhealthy behaviour

**Table 3.** *Continued*

Citation	Study design	Key results: description and effect sizes
Renzaho <i>et al.</i> <sup>(50)</sup>	Cross-sectional	Fruit consumption negatively associated with emotional problems in males ( $d=0.16^*$ ) and females ( $d=0.21^*$ ) Vegetable consumption negatively associated with emotional problems in females ( $d=0.1^*$ ) not, males ( $d=0.03$ )
Robinson <i>et al.</i> <sup>(41)</sup>	Cross-sectional	Takeaway and snacks positively associated with higher internalising symptoms ( $d=1.0$ ) Cereals ( $d=0.27$ ), fruits ( $d=0.27$ ), dairy products ( $d=0.33$ ), meat/meat alternatives ( $d=0.03$ ) and vegetables ( $d=0.42$ ) not significantly associated with internalising symptoms
Rubio-López <i>et al.</i> <sup>(46)</sup>	Cross-sectional	Nutrients lower in depressed group: proteins ( $d=0.215^*$ ), carbohydrates ( $d=0.185^*$ ), pantothenic acid ( $d=0.188^*$ ), biotin ( $d=0.994^*$ ), vitamin B <sub>12</sub> ( $d=0.222^*$ ), vitamin E ( $d=0.229^*$ ), Zn ( $d=0.280^*$ ), Mn ( $d=0.209^*$ ), Co ( $d=0.249^*$ ), Al ( $d=0.216^*$ ) and Br ( $d=0.182^*$ ) Nutrients higher in depressed group: thiamine ( $d=0.185^*$ ) and vitamin K ( $d=0.282^*$ ) Not associated with depression: lipids ( $d=0.0005$ ), fibre ( $d=0.149$ ), riboflavin ( $d=0.08$ ), niacin ( $d=0.105$ ), vitamin B <sub>6</sub> ( $d=0.165$ ), folic acid ( $d=0.128$ ), vitamin C ( $d=0.181$ ), vitamin A ( $d=0.181$ ), vitamin D ( $d=0.089$ ), Ca ( $d=0.026$ ), P ( $d=0.013$ ), Fe ( $d=0.143$ ), I ( $d=0.163$ ), F ( $d=0.106$ ) and Se ( $d=0.077$ )
Tajik <i>et al.</i> <sup>(55)</sup>	Cross-sectional	Eating out of home 4–7 times a week positively associated with higher levels of depressive symptoms ( $d=0.08^*$ ) Breakfast more than 4 d a week associated with lower depressive symptoms ( $d=0.03^*$ ) Lunch ( $d=0.03$ ) and dinner ( $d=0.048$ ) not significantly associated with depressive symptoms
Vollrath <i>et al.</i> <sup>(48)</sup>	Cross-sectional	Internalising problems are positively associated with being fed more high energy drinks at night ( $d=0.26^*$ ), sweet food ( $d=0.09^*$ ) and sweet drinks ( $d=0.14^*$ )
Weng <i>et al.</i> <sup>(58)</sup>	Cross-sectional	Snacking pattern positively associated with depression ( $d=0.12^*$ ) and anxiety ( $d=0.15^*$ ) Traditional dietary pattern negatively correlated with depression ( $d=0.23^*$ ) but not with anxiety ( $d=0.04$ ) Animal dietary pattern not associated with depression ( $d=0.05$ ), but associated with anxiety ( $d=0.15$ )
Wiles <i>et al.</i> <sup>(43)</sup>	Longitudinal	Junk food ( $d=0.002$ ) and sugar intake ( $d=0.0$ ) at age of 4.5 years not associated with emotional problems at age 7 years
Zahedi <i>et al.</i> <sup>(59)</sup>	Cross-sectional	Consumption of sweets (weekly $d=0.03^*$ , daily $d=0.01^*$ ), sweetened beverages (weekly $d=0.01^*$ , daily $d=0.08^*$ ), fast food (weekly $d=0.02^*$ , daily $d=0.095^*$ ) and salty snacks (weekly $d=0.01^*$ , daily $d=0.05^*$ ) positively associated with depression Consumption of sweets (weekly $d=0.05^*$ , daily $d=0.03^*$ ), sweetened beverages (weekly $d=0.03^*$ , daily $d=0.09^*$ ), fast food (weekly $d=0.02^*$ , daily $d=0.08^*$ ) and salty snacks (weekly $d=0.005^*$ , daily $d=0.05^*$ ) positively associated with anxiety

SDQ, Strengths and Difficulty Questionnaire; SMFQ, Short Mood and Feelings Questionnaire.  
\* Significant results.

One study<sup>(43)</sup> used a longitudinal design, with dietary consumption measured by a parental report at 4.5 years and parent-reported mental health problems at the age of 7 years. Consumption of junk food at 4.5 years did not predict emotional problems at 7 years.

**Snacking.** Snacking was defined as the consumption of the following food items between meals: preserved fruits, confectionery, crisps, ready-to-eat savouries, salty snacks, carbonated beverages, etc. Five studies examined the relationship between snacking and depression<sup>(40,46,49,58,59)</sup>. Only two studies<sup>(58,59)</sup> reported a significant association between snacking and depression, with small effect sizes ( $d=0.05$  and  $0.12$ ).

**Confectionery/sweets.** This category is divided into sweet foods such as confectionery, cakes, biscuits and sweet drinks such as soft drinks and sweet beverages. Four studies examined the relationship between confectionery or sweet foods and depression in a cross-sectional design<sup>(40,43,47,49)</sup>, of which three<sup>(43,47,49)</sup> found a significant cross-sectional association. In a longitudinal study, there was no significant association between sugar consumption and mental health after 3.5 years<sup>(43)</sup>. One study<sup>(40)</sup> found no association between consumption of baked goods and depression, but reported a significant association between confectionery consumption and increased odds of depression; the effect size was, however, very small ( $d=0.04$ ). Three studies<sup>(40,54,59)</sup> also investigated the effects of sweet

drinks on mood. Daily consumption of sweet drinks was significantly associated with increased depressive symptoms in all three studies; the effect sizes of these studies were small ( $d=0.09–0.25$ ), and in one study<sup>(54)</sup> the effect was significant only in males ( $d=0.25$ ). One study<sup>(48)</sup> explored the association between mental health on consumptions of sweet foods and drinks, and reported that individuals with poorer mental health were more likely to consume sweet foods and drinks.

**Meat.** The association between meat consumption and mental health was investigated in four studies<sup>(40,41,49,58)</sup>. Three<sup>(40,41,49)</sup> investigated the effects of red meat and meat products, and one<sup>(58)</sup> study explored the effect of ‘animal’ dietary pattern, consisting of processed meat and other meats on mental health. Only one of these four studies<sup>(40)</sup> reported that high meat consumption was significantly associated with poorer mental health.

*Other food categories considered unhealthy.*

1. Fats: three studies investigated fat intake, one explored intake of fats and oils<sup>(49)</sup> and two<sup>(54,57)</sup> reported total percentage fat intake. These three studies did not find a significant association between fat consumption and depression.
2. Caffeine: only one study examined the relationship between caffeine and mood and found that caffeine was significantly associated with depression (average  $d=0.37$ )<sup>(54)</sup>.



**Overall diet quality.** In addition to 'healthy' and 'unhealthy' diet being investigated separately, the association between overall diet quality and depression has also been explored<sup>(49,57,60)</sup>. Two studies<sup>(49,60)</sup> reported an association between higher diet quality scores and depression with a small effect size ( $d=0.025$  and  $0.03$ , respectively). One study reported no significant association between depression and overall diet quality; however, they did report that greater variety and adequacy of the diet was significantly associated with a lower level of emotional problems (unable to calculate effect size)<sup>(57)</sup>.

**Eating behaviours.** The relationship between depression and 'eating behaviours' such as having breakfast, lunch, dinner and skipping meals was explored in two studies<sup>(54,55)</sup>. Both reported significant associations between having breakfast and lower depressive symptoms ( $d=0.31$ <sup>(54)</sup>,  $d=0.03$ <sup>(55)</sup>). However, there were conflicting results regarding lunch and dinner consumption. One study showed an association between higher depression symptoms and individuals who skipped dinner (average  $d=0.28$ ) or lunch (average  $d=0.34$ )<sup>(54)</sup>. The second study found no significant association between depressive symptoms and having lunch ( $d=0.03$ ) or dinner ( $d=0.048$ )<sup>(55)</sup>.

**Overall dietary intake.** A recent study investigated the association between self-reported depressive symptoms and twenty-nine different nutrients (including macronutrients, micronutrients and minerals)<sup>(46)</sup>. Intakes of protein, carbohydrates, pantothenic acid, biotin, vitamin B<sub>12</sub>, vitamin E, Zn, Mn, Co, Al and Br were significantly lower in children with depressive symptoms. However, consumption of thiamin and vitamin K was high in children with depressive symptoms when compared with non-symptomatic peers. However, the effect sizes for the significant results were small ranging from  $d=0.18$  to  $0.21$ , with the exception of biotin ( $d=0.99$ ). The list of all the nutrients and their effect sizes is reported in Table 3.

In addition, two further studies have investigated a few specific nutrients in addition to exploring overall 'diet'. Fulkerson *et al.*<sup>(54)</sup> investigated Ca, Fe, sucrose, vitamin D, folate, vitamin B<sub>6</sub> and B<sub>12</sub> intakes, whereas McMartin *et al.*<sup>(57)</sup> investigated the intake of *n-3* fatty acid and the ratio between *n-3:n-6*. Neither study found an association between consumption of any of these nutrients and mental health problems.

**Diet and anxiety.** Three studies<sup>(42,58,59)</sup> explored the association between diet and anxiety alone, with one<sup>(58)</sup> also exploring the relationship between co-morbid depression and anxiety. There was a significant association between anxiety and three or more unhealthy behaviours such as consumption of fast food and sweet beverages<sup>(42)</sup>. Another study<sup>(59)</sup> reported that consumption of sweets, sweet beverages, fast food and salty snacks was associated with increased odds of anxiety. However, the effect sizes of both these studies were small ( $d=0.21$  and  $d=0.21$ ; Table 3). Higher consumptions of 'animal' food types and 'snacking' dietary patterns were associated with anxiety and co-morbid depression<sup>(58)</sup>. A traditional dietary pattern, consisting of typically healthy foods such as fruits, vegetables, oatmeal and wholegrain, was negatively associated with

coexisting depression and anxiety ( $d=0.04$ ) but not with anxiety alone.

## Discussion

This systematic literature review identified and evaluated studies examining the relationship between diet and mental health in children and adolescents. At present, the first-line treatment for depression is psychological therapy, and a single antidepressant that acts through dopaminergic, serotonergic and monoaminergic mechanisms. These, however, fail to decrease the burden of depression because of people's lack of response to these medications, especially the younger population<sup>(61)</sup>. This suggests that there may be an alternative mechanism through which depression can be targeted. Any possible method of preventing the development of depression symptoms or reducing existing symptoms has great potential as a public health intervention. In addition to potential nutritional interventions, other possible therapies that are being investigated include the use of other psychoactive compounds such as agomelatine, which synchronises circadian rhythms, targeting inflammation and gut microbes<sup>(62-65)</sup>. Review of these other potential treatments is beyond the scope of this review.

Despite the importance of the topic, we found relatively few studies that examined diet and mental health in adolescents, especially when compared with the large number of studies with adult participants.

Our review highlights several important issues, both methodological and substantive. From a methodological perspective, there are significant problems in the design and conduct of epidemiological studies. Although only twenty studies were identified, a range of different ways of defining and conceptualising diet quality was used that could not be easily compared or integrated. Even well-established measures of diet quality relied on retrospective self-report of food consumption, which is of dubious reliability and validity. The more intrusive but reliable use of daily food diaries was rarely reported. The measurement of depression and associated mental health difficulties was somewhat more satisfactory in that some well-standardised and validated measures with good psychometric qualities were used.

Of more concern, however, is the related problem of the study design; all the studies identified in this review were correlational. Only three included a longitudinal element, and thus most could not help determine the direction of the causal relationship between diet and mood<sup>(43-45)</sup>. Intervention studies, using an overall diet strategy, are the only robust way to establish causality; if these are impractical or impossible to conduct, then it is essential to conduct careful longitudinal studies with adequate methods of measuring key constructs of diet and mood. Further adding to the difficulty in understanding any causal relationship between diet and mental health is that both diet and mood are influenced by many other factors including SES, culture and age<sup>(33,66-69)</sup>. A few studies attempted to control the impact of important confounds, and thus any observed relationships between diet and mental health must be interpreted cautiously. It is entirely plausible that low mood and poor diet are both caused by the same third variable, low SES or



social exclusion, both of which would act to restrict access to a varied healthy diet and to increase adverse life and other environmental causes of poor mental health.

These methodological problems made it difficult to integrate the studies and to make inferences regarding the association between mood and dietary pattern. Most studies included multiple measures of 'diet' quality or content and included multiple significant testing, thus increasing the likelihood of types I and II errors. To impose some consistency on the results of multiple statistical tests using different measures of diet and mental health, we calculated the effect sizes for each study. Given the caveats outlined above relating to methodological and conceptual problems, there was a general tendency to report small associations between diet and mental health, with 'unhealthy' diet associated with increased odds of mental health difficulties and 'healthy' diet having the opposite effect. Similar conclusions were drawn in the studies investigating whether a healthy or unhealthy diet is associated with depression in adults<sup>(21–28)</sup>. The conclusion that there is an association between unhealthy dietary pattern and worsening of mental health observed in this review was consistent with the recent review<sup>(34)</sup>. However, the consistent association between unhealthy dietary pattern and worsening of mental health found in this review contradicted the observations of the previous review<sup>(34)</sup>.

No inferences could be made about the associations between fast food, vegetables and fruits and mental health. Therefore, because causality cannot be determined, it is important to note that there is a plausible alternative causal pathway, whereby low mood leads to increased consumption of unhealthy 'junk' food – for example, chocolate and decreased consumption of 'healthy' foods. These conflicting and heterogeneous findings regarding the association between fruit, vegetables, fast food and mental health are similar to those found in adult studies. Indeed, a recent review of adult literature also identified similar problems regarding method quality and the inconsistencies between the constructs<sup>(70)</sup>.

Given the inherent limitations of cross-sectional research designs and the demands of large community intervention studies, another tactic may be to focus on observational and intervention studies with 'at-risk' or clinical populations. This could involve comparisons of nutritional intake between healthy adolescents and those with anxiety and depressive disorders. However, in order to make confident causal statements about the effects of diet on mental health, intervention studies are required, and these can be best informed by theory about mechanisms and better designed correlational studies.

Overcoming the methodological problems discussed in this review will require greater collaboration and communication between researchers. This will help establish clearer and more consistent definitions and constructs, and more shared use of reliable and valid instruments that can be used consistently across cultures, communities and cohorts.

### Conclusion

Research regarding dietary pattern or diet quality and its association with mental health in children and adolescents is at an early stage. This review highlighted some conceptual and

methodological problems that, if not addressed, will impede future research and public health interventions. It is therefore essential to make sure that further methodological problems are minimised to at least establish the strength of any association between diet and mental health.

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