

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

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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 research 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. Twenty studies were identified that met the 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 confounds.

## 1. Introduction

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 is 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 a whole 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 omega-3 fatty acids<sup>(11, 12)</sup>, vitamins such as B12<sup>(13)</sup> and minerals such as zinc, selenium and iron<sup>(14-16)</sup>. Additionally, several intervention studies have examined the effect of supplements containing more than one nutrient (for example multivitamins, eicosapentaenoic acid and docosahexaenoic acid) 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 the 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>, whilst a ‘Healthy’ or ‘good’ quality diet was associated with better mental health <sup>(21, 25-28)</sup>. However, several other factors such as socioeconomic status (SES), household income and educational levels also influence dietary choice and thus need to be included as potential confounds <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>. Additionally, adolescents typically become increasingly independent and make more decisions about the type and amount of food they consume, including ‘junk’ and ‘fast’ foods <sup>(33)</sup>. Therefore, the relationship between diet and mental health in young people and children therefore warrants specific attention.

In a recent review, 12 epidemiological studies were identified and reviewed that examined the association between diet and mental health in young people <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.

## **2. Methods**

### **2.1 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 SCIENCE DIRECT). 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 wellbeing **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 adolescent with depression, 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 is the primary objective of this review.

### **2.2 Inclusion criteria**

Studies eligible to be included in this review were:

1. In English language

2. Available as full text (including abstracts of meeting etc.)
3. Included children and young people 18 years and younger in the sample.
4. Study designs were case control, cross sectional, epidemiological cohort, 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 (food frequency questionnaires, 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.

## **2.2 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



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.R, using the National Institutes of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. Disagreements were discussed with C.W and a shared rating was given. Methodological criteria evaluated included: (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).

### **3. 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.

#### **3.1 Selection**

A total of 3,014 studies were identified as a result of the initial search. Further screening identified 98 studies relating specifically to nutrition and mood. Of these, 78 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.

Full details of screening, filtering and our selection process for the studies included in this review are shown in Figure 1. Twenty studies that met the inclusion and exclusion criteria were identified. Study populations were from United States, United Kingdom, 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 a Westernised and their traditional diets. Key features of the selected studies are presented in Table 1.

Data was extracted from 17 cross-sectional studies and 3 prospective cohort studies with follow up periods ranging from 2-4 years. No experimental studies or clinical trials were identified. The total number of participants recruited across the 20 studies was 110857, although, two studies used participants from the same data set (RAINE; with n=1324 and n=1598 respectively) <sup>(40, 41)</sup>; 109533 unique individual participants were recruited in total to these studies. There were 51834 males and 49588 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.

### **3.2 Overall quality**

Using the NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies, the quality of the 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>. Key methodological features of each study are outlined in Table 1. Common methodological weaknesses included inadequate measurement of the key variables (diet and mental health) which will be discussed in more detail below.

### **3.3 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 food frequency questionnaires including Harvard Youth/ Adolescent Food Frequency Questionnaire (YAQ FFQ; a widely used validated

questionnaire) and Commonwealth Scientific & Industrial Research Organisation FFQ (semi-validated for use in adults). Three-day food records, which are more reliable than FFQs, were used by one study<sup>(46)</sup>. Additionally, a single study calculated absolute food consumption (to nearest gram) under controlled lab 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 (DQI-I) scores. In each case these consisted of components such as variety, adequacy, moderation and balance in the diet. None of these measures were validated. Other non-validated measures included questions on fruit, vegetable, sweets, snacks (including salty) and carbonated drink consumption, in addition to regularity of breakfast consumptions 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 their children’s diet – this may affect the accuracy of the results due to 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. Additionally, there was a lack of consistency between the studies with regards 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.

### **3.4 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 (CBCL) <sup>(40, 41, 48)</sup>, the Strengths, Difficulties Questionnaire (SDQ) <sup>(43, 45, 49-51)</sup>, Short Mood & Feelings Questionnaire (SMFQ) <sup>(45, 52)</sup> and Depression self-rating Scale for Children (DSRS). The Center for Epidemiologic Studies Depression Scale for Children (CES-DC) 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 measure of adolescent well-being that included elements of depression e.g. Paediatric Quality of Life (PedsQL), some were completed by professionals on the basis of an unstructured consultation, e.g. International Classification of Disease (ICD-9/10), others were specific to depression but not designed for use by children and adolescents e.g. the Beck Depression Inventory (II), and the Depression Anxiety & 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.

### **3.5 Study design**

Most research studies used designs that were cross sectional. This is a relatively weak design because it is 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 which are related to diet, such as SES, income and parents' educational level were not measured consistently and were not measured or not controlled by some <sup>(47,48,53-55)</sup>. The most common confounding variables that were controlled were the age and gender of participants. Some important variables such as medical conditions like hypothyroidism, diabetes and food allergies, which may be correlated to mood or food choices, were not considered by any study.

### **3.6 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 (IRR).

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>.

### **3.7 Relationship between nutrition and mood**

The main results of the 20 studies, including the effect sizes, are shown in Table 3. Due to the heterogeneity of the constructs, measurements and definitions of both internalizing

(depression and anxiety) symptoms and dietary intake e.g. quality, patterns, food groups and eating behaviours, the key results were grouped and described in to the following broad categories:

### **3.7.1 Healthy Diet**

#### ***3.7.1.1 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 relationship between healthy diet or 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 was exception<sup>(40, 45, 46)</sup>, where there was a weak evidence for an association between healthy diet pattern and internalizing 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. (2011)<sup>(44)</sup> found that that a healthy diet predicted depression two years later ( $d=0.43$ ) but that depression at baseline did not predict healthy diet consumption ( $d=0.02$ ) two years later. In contrast, Jacka et al., (2013)<sup>(45)</sup> found no association between a healthy diet and mental health 3 years later ( $d=0.11$ ).

#### ***3.7.1.2 Fruits & 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<sup>(50)</sup>, investigated if

mental health was associated with fruit and vegetable consumption. The majority of studies found no significant association between consumption of fruit and vegetable and mood. However, one study reported that compared to 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>. One other study reported that consumption of fruit 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>.

### ***3.7.1.3 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' effect on mood. There was no evidence that cereal or grains were significantly associated with depression.
2. Dairy: 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> reported higher fish consumption to be significantly associated with decreased odds of developing mental health difficulties.

## **3.7.2 Unhealthy Diet**

### ***3.7.2 .1 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 away, 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 and colleagues 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 two years later<sup>(45)</sup> 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>.

### **3.7.2 .2 *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 hamburger, pizza, meat pie, savoury pastry, meat pies, 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> which included confectionary and snacking as a part of junk / fast food consumption and therefor reported a large effect size of junk food on mental health (Table 3). One study<sup>(43)</sup> used a longitudinal design, with dietary consumption measured by parental report at 4.5 years and parent reported mental health problems at the age of 7. Consumption of junk food at 4.5 years did not predict emotional problems at 7 years.

### **3.7.2 .3 *Snacking***



Snacking was defined as the consumption of the following food items between meals: preserved fruits, confectionery, crisps, ready to eat savouries, salty snacks and 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  $0.12$ ).

#### **3.7.2 .4 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 3 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 food and drink.

#### **3.7.2 .5 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, one<sup>(58)</sup> 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.

### **3.7.2 .6 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 3 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>.

### **3.7.3 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>.

### **3.7.4 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>.

### 3.7.5 Overall Dietary Intake

A recent study investigated the association between self-reported depressive symptoms and 29 different nutrients (including macro, micro nutrients and minerals) <sup>(46)</sup>. Intake of protein, carbohydrates, pantothenic acid, biotin, vitamin B12, vitamin E, zinc, manganese, cobalt, aluminium and bromine was significantly lower in children with depressive symptoms. Whilst consumption of thiamin and vitamin K was high in children with depressive symptoms when compared to non-symptomatic peers. However, the effect sizes for the significant results were small ranging from  $d=0.18-0.21$ , with the exception of biotin ( $d=0.99$ ). The list of all the nutrients and their effect sizes is reported in table 3.

Additionally, two further studies have investigated a few specific nutrients in addition to exploring overall 'diet'. Fulkerson and colleagues investigated, calcium, iron, sucrose, vitamin D, folate, vitamin B6 and B12 <sup>(54)</sup>, whilst McMartin investigated the intake of omega-3 fatty acid and the ratio between omega-3 and omega-6 <sup>(57)</sup>. Neither study found an association between consumption of any of these nutrients and mental health problems.

### 3.7.6 Diet and Anxiety

Three studies <sup>(42, 585, 59)</sup> explored the association between diet and anxiety alone, with one <sup>(58)</sup> also exploring the relation between comorbid 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 of these studies was small ( $d=0.21$  and  $d=0.21$  Table 2). Higher consumption of ‘animal’ food types and ‘snacking’ dietary patterns was associated with anxiety and comorbid depression<sup>(58)</sup>. A traditional dietary pattern, consisting 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.

#### **4. Discussion**

This systematic literature review identified and evaluated research examining the relationship between diet and mental health in children and adolescents. Currently, the first line treatment for depression is psychological therapy and a single antidepressant that act through dopaminergic, serotonergic and monoaminergic mechanisms. These however fail to decrease the burden of depression due to 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 agomelatin, that synchronizes 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 20 studies were identified, a range of different ways of defining and conceptualising diet quality were 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 study design, all the studies identified in this review were correlational. Only 3 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 socio-economic status, culture, and age <sup>(33,66-69)</sup>. 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 socio-economic status 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 Type 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 association 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 e.g. 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 to 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, 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 minimized to at least

establish the strength of any association between diet and mental health.

### **Authorship**

The authors declare no conflicts of interest arising from the conclusions of this work. All authors contributed to the literature search, analysis of the data published, manuscript writing and revisions of the article.

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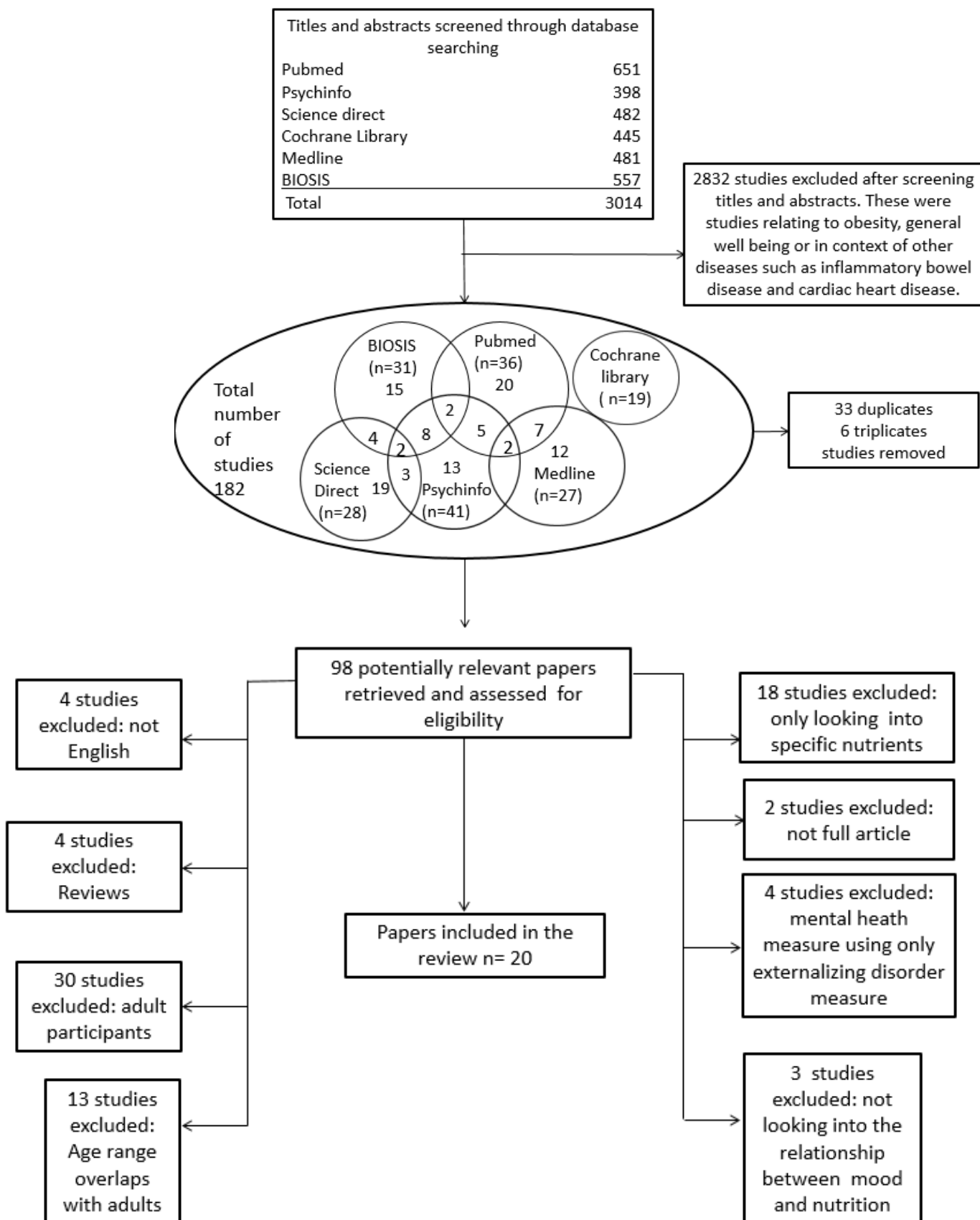
Table 1: NIH Criteria list for assessing study quality

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**Criteria list**


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- 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 being in the study pre-specified and applied uniformly to all participants?
  - 5** Was a sample size justification, power description, or variance and effect estimates provided?
  - 6** For the analysis in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?
  - 7** Was the timeframe 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 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 base line 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).
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1 Figure 1: Showing the selection process of studies included in this review.

Table 2: Key features determining the Quality ratings of the included studies

Citation	Participants		Diet		Mental Health		Respondent	Confounding Variables	Quality Rating
	Country	Number	Age/year	Measure	Validated	Measure			
Brooks et al., 2002 United states	2224	Mean: 16.2 (1.6)	Do you eat a healthy diet? Y/N.	No	Frequency of depression or 'stress' in the past 30 days.	No	Adolescents	Age, race and gender.	Fair
Fulkerson et al., 2004 United states	4734	Mean M: 14.9 (1.7) F:14.7 (1.7)	Meal, junk food, snacking frequency, YAQ.	Yes- YAQ	Kandel & Davies' 6-item scale.	No	Adolescents	Race and Grade level. Gender specific analysis.	Fair
Jacka et al., 2010 Australia	7114	Range: 10-14 Mean: 11.6 (0.81)	Unhealthy diet score based on dietary questionnaire.	No	SMFQ - 13 items.	Yes	Adolescents	Age, gender, SES, eating attitudes, PA, BMI and smoking.	Fair
Jacka et al., 2011 Australia	2915 After 2yrs: 2054	Range: 11-18	Healthy/unhealthy diet based Dietary questionnaire.	Yes - in adults	PedsQL	Yes	Adolescents	Age, gender, SES, PA, dieting behaviours and BMI.	Good

Citation	Participants		Diet		Mental Health		Respondent	Confounding Variables	Quality Rating
	Country	Number	Age/year	Measure	Validity	Measure			
Jacka et al., 2013 United kingdom	2789	Range: 11-14	Unhealthy diet score: Frequency of fruit, vegetable, fast food snacks and breakfast.	No	SMFQ and SDQ	Yes	Adolescents	Gender, age, ethnicity, religion, SES, PA, BMI, dieting behaviour, alcohol, cigarette and drug use.	Good
Kohlboeck et al., 2012 Germany	3361	Range: 9.9-12.7 Mean: 11.15 (0.5)	Diet quality based on 82-item FFQ.	Yes FFQ	SDQ	Yes	Caretaker	Gender, SES, BMI, PA, television/PC use and total energy intake.	Fair
McMartin et al., 2012 Canada	3757	Range: 10-11	YAQ used to calculate DQI-I scores	Yes YAQ	ICD- 9 or 10	Yes	Child	Gender, energy intake, SES, weight, PA	Fair
McMartin et al., 2013 Canada	6528	Range: 10-11	YAQ used to calculate DQI-I scores	Yes YAQ	EuroQoL for youth.	Yes	Child	SES, height, weight, PA, gender and energy intake.	Fair

Citation	Participants		Diet		Mental Health		Respondent	Confounding Variables	Quality Rating	
	Country	Number	Age/year	Measure	Validity	Measure				Validity
Mooreville et al., 2014	United states	Study 1: 228	Range: 8-17	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 et al., 2009	Australia	1324	Range: 13-15 Mean: 14 (0.2)	CSIRO FFQ used to identify healthy/western dietary patterns	Semi validated in adults	CBCL (4-18yrs)	Yes	Caretaker	Total energy intake, PA, television/PC use, BMI, SES, and gender.	Fair
Oellinrath et al., 2013	Norway	1095	Range: 12-13	FFQ covering 40 food items	No	SDQ (parental version)	Yes	Caretaker	SES, PA, BMI and gender	Fair
Rao et al., 2015	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, gender, BMI, SES, parental check, understanding, and close friends.	Poor

Citation	Participants		Diet		Mental Health		Respondent	Confounding Variables	Quality Rating
	Country	Number	Age/year	Measure	Validity	Measure			
Renzaho et al., 2011 United states	3370	Range: 0-12	Frequency of Fruit & vegetable consumed.	No	SDQ	Yes	Caretaker	SES, age, gender, food security, social support.	Fair
Rubio-Lopez et al., 2016 Spain	710	Range: 6-9	3 day food diary.	Yes	CES-DC	No	Caretaker	Age, gender, BMI, SES and Nationality.	Fair
Robinson et al., 2011 Australia	1598	Mean: 14 (0.2)	CSIRO FFQ	Semi validated in adults	CBCL	Yes	Caretaker	Gender, family income, maternal employment.	Fair
Tajik et al., 2015 Malaysia	1568	Range: 13-14 Mean: 13 (0.8)	Eating Behaviour Questionnaire	No	DASS-21	Yes	Adolescents	No confounding variable identified.	Fair
Vollrath et al., 2011 Norway	40,266	1.5	Frequency of sweet food and drinks.	No	CBCL and EAS	Yes	Caretaker	Gender, weight, height and breastfeeding.	Fair

Citation	Participants		Diet		Mental Health		Respondent	Confounding Variables	Quality Rating
	Country	Number	Age/year	Measure	Validated	Measure			
Weng et al., 2012 China	5003	Range: 11-16 Mean: 13.2 (0.99)	38-item comprehensive FFQ	No	DSRS Chinese version for children.	Yes	Adolescents	SES, age, gender, PA and BMI.	Fair
Wiles et al., 2009 United Kingdom	4000	Range: 3-4.5 Follow up age 7	FFQ: junk, health conscious & traditional	No	SDQ	Yes	Caretaker	Gender, SES, maternal depression & anxiety.	Good
Zahedi et al., 2014 Iran	13,486	Range: 6-18 Mean: 12.47 (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, gender, family history of chronic diseases, mothers education, screen time, PA, SES and BMI.	Fair

Note: BDI-II Beck Depression Inventory; BMI= body mass index; CBCL= Child Behaviour Checklist; CES-DC= Center for Epidemiological Studies Depression Scale for Children; CSIRO= Commonwealth Scientific and Research Organisation; DASS= Depression, Anxiety and Stress Scale; DQI-I= Diet quality index-international; DSRS= Depression Self-rating Scale ; EAS= Emotionality Activity and Sociability Questionnaire; F= female; FFQ= Food frequency Questionnaire; ICD= International Classification of Diseases; M= male; PA= Physical Activity; PedsQL=Paediatric Quality of Life Inventory; SDQ= Strengths and Difficulties Questionnaire; SES= Socio-economic status; SMFQ= Short Mood and Feeling Questionnaire; YAQ=Youth and Adolescent Questionnaire.



Table 3: Key results.

Citation	Study Design	Key results: Description and Effect sizes
<b>Brooks et al., 2002</b>	Cross sectional	Healthy diet negatively correlated with depression only in females: $d_{males}=0.016$ $d_{females}=0.028^*$
<b>Fulkerson et al., 2004</b>	Cross sectional	Health promoting attitude negatively correlated with depression $d_{males}=0.51^*$ , $d_{females}=0.28^*$ . Health compromising attitude positively correlated with depression $d_{males}=0.34^*$ , $d_{females}=0.19^*$ . Breakfast consumption negatively correlated with depression $d_{males}=0.32^*$ $d_{females}=0.30^*$ . Lunch, $d_{males}=0.29^*$ , $d_{females}=0.39^*$ , and dinner, $d_{males}=0.25^*$ , $d_{females}=0.30^*$ , negatively correlated with depression. Daily consumption of soft drinks positively correlated with depression in males only $d_{males}=0.25^*$ , $d_{females}=0.09$ . Caffeine intake positively associated with depression $d_{males}=0.41^*$ , $d_{females}=0.33^*$ . Not significantly associated with depression: Snacking in between meals $d_{males}=0.085$ , $d_{females}=0.084$ , fast food consumption $d_{males}=0.12$ , $d_{females}=0.10$ , daily vegetable intake $d_{males}=0.06$ , $d_{females}=0.11$ , daily fruit intake $d_{males}=0$ , $d_{females}=0.1$ , calcium $d_{males}=0.031$ , $d_{females}=0.04$ , iron $d_{males}=0.05$ , $d_{females}=0.011$ , $d_{males}=0.15$ , $d_{females}=0.044$ , Vitamin D $d_{males}=0.051$ , $d_{females}=0.068$ , Folate $d_{males}=0.049$ , $d_{females}=0.069$ , Vitamin B6 $d_{males}=0$ $d_{females}=0$ and Vitamin B12 $d_{males}=0.06$ , $d_{females}=0.034$ .
<b>Jacka et al., 2010</b>	Cross sectional	Healthy diet negatively correlated with depression $d=0.55^*$ Unhealthy diet positively associated with depression: $d=0.39^*$
<b>Jacka et al., 2011</b>	Cross sectional	Healthy diet negatively correlated with depression $d=0.286^*$ Unhealthy diet negatively associated with depression $d=0.181^*$
	Longitudinal	Diet predicted mental health at 2 year follow up: Healthy diet score $d=0.43^*$ , Unhealthy diet scores $d=0.26^*$ Mental health did not predict diet at 2 year follow up: Healthy diet score $d=0.02$ , Unhealthy diet scores $d=0.06$

Citation	Study Design	Key results: Description and Effect sizes
<b>Jacka et al., 2013</b>	Cross sectional	Healthy diet was not correlated with psychological distress SDQ (d=0*) and SMFQ (d=0.001*) Unhealthy diet positively correlated with psychological distress SDQ (0.178*) and SMFQ (d=0.099*)
	Longitudinal	Unhealthy (d=0.097) and healthy diet scores (d=0.111) did not significantly predict mental health at 3 years.
<b>Kohlboeck et al., 2012</b>	Cross sectional	Higher diet quality significantly negatively associated with emotional problems (d=0.03*) Confectionary significantly positively associated with emotional problems (d=0.04*) Not associated with emotional problems: Bakery wares (d=0.01), Fats and oils (d=0.05), Dairy products (d=0.025), Meat and meat products(d=0.03), Cereals(d=0.013), Eggs (d= 0.012), Fruit and vegetables (d=0.012), Fish (d=0.002), Ready to eat savouries (d=0.009) and Beverages (d=0.005)
<b>McMartin et al.,2012</b>	Cross sectional	Not enough information to calculate effect size. Variety and increased adequacy in diet significantly associated with internalising disorder (IRR=0.45* CI=0.25, 0.82 and IRR=0.64* CI=0.34, 1.2 respectively). Not associated with emotional problems: Overall diet quality not significantly associated with internalising disorder (IRR=1.09 CI=0.73, 1.63) Moderation in diet not associated with internalising disorder (IRR=1.07 CI=0.66, 1.73). Balance in diet not associated with internalising disorder (IRR=1.06 CI=0.66, 1.73). Fruit and vegetables (IRR=1.25 CI=0.80, 1.99), Folate (IRR=1.21 CI=0.64, 2.32), Vitamin B6(I RR=1.05 CI=0.56, 1.99), Vitamin B12 (IRR=0.77CI=0.5, 1.17), Fish intake (IRR=0.59 CI=0.41, 1.55), n-3 fatty acid (IRR=0.97 CI=0.61, 1.55), n3:n6 ratio (IRR=0.9 CI=0.67, 1.21), percentage energy from fat(I RR=0.82 CI=0.55, 1.22).

Citation	Study Design	Key results: Description and Effect sizes
<b>McMartin et al., 2013</b>	Cross sectional	<p>Diet quality negatively associated with worrying, sad or unhappy feelings (d=0.025*).</p> <p>Higher variety in diet negatively associated with worrying, sad or unhappy feelings (d=0.012*).</p> <p>Increased adequacy in diet negatively associated with worrying, sad or unhappy feelings (d=0.028*). Balance in diet was significantly associated with worrying, sad or unhappy feelings (d=0.012*).</p> <p>Moderation in diet not associated with worrying, sad or unhappy feelings (d=0.01).</p>
<b>Mooreville et al., 2014</b>	Cross sectional	<p>Study 1: Depressive symptoms not associated with consumption of sweet snacks (d=0.26).</p> <p>Study2: Depressive symptoms associated with consumption of sweets snack (d=0.52*)</p>
<b>Oddy et al., 2009</b>	Cross sectional	<p>Not enough information to calculate effect size.</p> <p>Leafy green vegetables b=-1.98*(CL= -3.80 to -0.16] and fruit: b=-2.16*(CI= -3.92 to -0.41)] associated with lower internalising score.</p> <p>Western dietary pattern overall significantly associated with ‘internalising’ symptoms b=1.25*(CI=0.15-2.35).</p> <p>Takeaway [Q4: b=1.89*(CI0.07-3.71)]; Confectionary [Q4: b=2.63*(CI0.87-4.39)] and Red meat [Q4: b=1.98*(CI=0.20-3.76)] significantly associated with higher internalising scores.</p> <p>Not associated with emotional problems:</p> <p>Healthy diet pattern overall not significantly associated with Internalising symptoms b=1.25 (CI= -0.54,0.88).</p> <p>Tomato, yellow/red b= -0.51(-2.24, 1.23), cruciferous, other vegetables, legumes, whole grains and fish steamed grilled or tinned not associated with internalising symptoms.</p> <p>Refined grains, processed meat, potato fried, crisps, soft drinks, cakes/biscuits, sauces/dressings and full fat dairy products not associated with internalising symptoms.</p>
<b>Oellinrath et al., 2013</b>	Cross sectional	<p>Not associated with problems:</p> <p>Junk/convenient (d=0.097), Varied Norwegian (d=0.053) and Snacking (d= 0.025).</p>

Citation	Study Design	Key results: Description and Effect sizes
<b>Rao et al., 2015</b>	Cross sectional	Positive correlation between anxiety and three [d= 0.14*], or four or more [d= 0.21*] unhealthy behaviours. Positive correlation between suicidal ideation and two (d=0.10*), three (d=0.27*) or four or more (d=0.36*) unhealthy behaviour.
<b>Renzaho et al., 2011</b>	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).
<b>Robinson et al., 2011</b>	Cross sectional	Takeaway and snacks positively associated with higher internalising symptoms (d = 1.0*). Cereals (d=0.27), fruits (d= 0.27), dairy (d = 0.33), meat/meat alternatives (d=0.03) and vegetables (d=0.42) not significantly associated with internalising symptoms.
<b>Rubio-Lopez et al., 2016</b>	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 B12 (d=0.222*), vitamin E (d=0.229*), zinc (d=0.280*), manganese (d=0.209*), cobalt (d=0.249*), aluminium (d=0.216*) and bromine (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 B6 (d=0.165), Folic acid (d=0.128), Vitamin C (d=0.181), Vitamin A (d=0.181), Vitamin D (d=0.089), Calcium (d=0.026), Phosphorus (d=0.013), Iron (d=0.143), Iodine (d=0.163), Fluoride (d=0.106) and Selenium (d=0.077).
<b>Tajik et al., 2015</b>	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 days 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.

Citation	Study Design	Key results: Description and Effect sizes
<b>Vollrath et al., 2011</b>	Cross sectional	Internalising problems are positively associated with being fed more high calorie drinks at night (d=0.26*), sweet food (d=0.09*) and sweet drinks(d=0.14*).
<b>Weng et al., 2012</b>	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).
<b>Wiles et al., 2009</b>	Longitudinal	Junk food (d=0.002) and sugar intake (d=0.0) at age of 4.5 not associated with emotional problems at age 7.
<b>Zahedi et al., 2014</b>	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

Note: C = Category, CI = Confidence Interval, IRR = Interval Risk Ratio, OR = Odds Ratio, PedsQL = Paediatric Quality of Life Inventory, Q = Quartile, SDQ = Strengths and Difficulty Questionnaire, SMFQ = Short Mood and Feelings Questionnaire, \* = Significant Result

