Global Social Welfare (2022) 9:11–25
https://doi.org/10.1007/s40609-020-00199-9

Nutritional Deficiencies and Maternal Depression: Associations and Interventions in Lower and Middle-Income Countries: a Systematic Review of Literature

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Accepted: 13 November 2020 / Published online: 7 January 2021

Abstract

Background Nutrition deficiencies are common among pregnant and lactating women in middle- and low-income countries. At the same time, maternal mental disorders, mainly depression is highly prevalent during this period suggesting some connection between the two. The objective of this review is to determine the associations between nutritional deficiencies and maternal depression and identify the role of diet in depression to facilitate further research.

Methods A literature search included PubMed databases and Google Scholar search engine published from June 2008 to June 2019 and published in English. Medical subject heading terms was used to identify all relevant studies. All titles and abstracts identified by the search were screened then reviewed the full-text articles which were potentially eligible for inclusion.

Results The original search identified 1250 articles but with cascaded elimination, based on quality. Twenty five met the inclusion criteria, of which 13 were cross-sectional, eight were prospective cohort study, and four were intervention studies. Most (95%) of these studies reported positive associations between nutrition deficiencies, poor diet, and maternal depression; thus, only 5% did not show associations between nutrition and depression.

Conclusion Our review findings suggest that nutritional interventions are some of the most promising intercessions for mental health illnesses. Not all studies consistently associate poor diet quality with poor maternal and offspring mental health outcomes, and the majority of those that show are cross-sectional. Considering that most of these associations are cross-sectional, studies devoid of exposing causal relationship; thus, longitudinal studies are needed to confirm the associations towards sufficing as a window of opportunity for reducing the risk of mental disorders in mothers and offspring alike.

Keywords Nutritional deficiencies · Maternal depression · Dietary habits · Diet · Role and depression

Background

Maternal mental disorders are illnesses that occur during pregnancy or in the first year after childbirth; the most common mental illness during this period is maternal depression, also called perinatal depression (Gelaye et al. 2016; Sparling et al. 2017; Biratu and Haile 2015; World Health Organization (WHO) 2012). According to the World Health Organization, mental disorders worldwide have been documented as a top priority among the most dominant and neglected diseases (World Health Organization (WHO) 2012; Fisher et al. 2012; GBD 2017). It affects approximately 322 million people globally; out of those affected 29.19% comes from Africa (World Health Organization 2017) and its 50% higher in females than males (Saeed et al. 2016). Maternal depression is a major public health problem that affects mother's wellbeing and an attitude about life (Sparling et al. 2017; Stein et al. 2014). In low-

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and middle-income countries (LMICs), most maternal depression remains unnoticed and untreated; this may be due to the reason that depressive symptoms often cannot be differentiate between normal physiological changes during pregnancy and other pathological changes, and that screening of maternal depression is not part of service delivery in antenatal clinics in LMICs. It is documented that about 12.5–42% of pregnant women and 12–50% of mothers of newborns in LMICs screen positive for symptoms of depression (Shidhaye and Giri 2014); and also documented that about 76% and 85% of individuals suffering from mental illnesses in low- and middle-income countries do not receive treatment for the disorder (World Health Organization 2019). In pregnancy and early years of an infant's life, maternal depression and anxiety can cause substantial problems to the mother and her infant (Surkan et al. 2011). It can cause sadness and low energy, low motivation, and poor parenting (Guo et al. 2013). It can also lead to lack of hope, self-blame and doubt, confusion, and guilt of not being a good parent (Stein et al. 2014; Shidhaye and Giri 2014). Suicide is an ever-present risk with depression, along with adverse effects on infant growth and birth weight (Surkan et al. 2011; Qiao et al. 2012).

The social determinants of health explain the risk factors of depression which include social, psychological, and biological factors (World Health Organization (WHO) and Calouste Gulbenkian Foundation 2014). Nutrition and lifestyle measures are the biological bases of mental illness, and nutritional deficiency is a factor that has been given consideration, among other theories about the causes of depression; research-based evidence reveals that patients with depression have altered levels of monoamine neurotransmitters (Jacka et al. 2017; Leung and Kaplan 2009). According to Rechenberg and Humphries, the three mechanisms that bring about depression include (a) low dopamine, serotonin, and norepinephrine levels in the brain; (b) neuro-membranes that have been altered and the polyunsaturated fatty acids impact on the membranes; and (c) hormones, specifically hormonal changes which occur during and after pregnancy; all of these pathways are affected by particular nutrients and could be corrected by nutritional interventions (Rechenberg and Humphries 2013).

Nutritional Science, Brain, and Mental Health

Nutrition is a science of food and its relationship to health (Liu et al. 2015; Kaur et al. 2014). It is already known that nutrition is fundamental to brain health in regulating neurotransmitters to function well, and that the neurotransmitters failure has been identified as a key element that brings connection between nutrition and depression (Rechenberg and Humphries 2013). It is also true that perinatal mood disorders (depression), leads to unhealthy behavioral changes which have serious and lasting consequences to both mother and child, that is why there is no health without perinatal mental health (Stein et al. 2014). The relationship between nutrition and brain functions has been found to be intricately intertwined for long period of time in history almost 100 years back; strong connection between nutrition and mood has been identified for B-complex vitamins, including vitamin B6, and, vitamin B-12, folate, magnesium, calcium, iron, zinc, and omega-3 types (Kennedy 2016; Gómez-pinilla 2010; Bodnar and Wisner 2015). Other nutrients commonly associated with mental health include antioxidant vitamins, such as C and E22, and bioactive substances found in foods (Rechenberg and Humphries 2013; Larson and Yousafzai 2017; Opie 2017). These nutrients are mostly available in healthy diets, such as those that include dark green leafy and orange or red-colored vegetables and whole-grains and protein sources (Davison et al. 2012).

The properties and functions of these nutrients have been investigated with respect to their role in a number of ways in which they can affect neural and endocrine pathways, and understanding how their deficiencies may contribute to the pathophysiology of depression. For example, Leung and Kaplan review (Leung and Kaplan 2009) report folate as a vitamin that is required for the biosynthesis of the three monoamine neurotransmitters: the serotonin, dopamine, and norepinephrine; the deficiency of this vitamin may affect the production of the neurotransmitters leading to depression. A study by Kennedy reported vitamin B6 in the involvement of neurotransmitter pathways; it is a cofactor in the production of serotonin from tryptophan, and that low plasma level of B6 has been associated with depression (Kennedy 2016). Vitamin B-12 has neurological function, and it is also a cofactor in the production of neurotransmitters (Rechenberg and Humphries 2013; Ford et al. 2018; Meihua et al. 2017). Other functions of B12 include forming red blood cells and maintaining nervous system. Zinc, is an essential nutritional element which plays many key roles including enzyme catalysis, cell signaling, DNA replication, and transcription and therefore is essential for neural development in learning and memory function as well as mood stability (Meihua et al. 2017). Zinc has also been used as an anti-depressant (Ranjbar et al. 2013). Another important nutritional element is polyunsaturated fatty acids (PUFAs), particularly n-3 PUFAs, which are the building blocks for health brain function and development. Epidemiological evidence has established that low consumption of n-3 PUFA is associated with mood disorders (Reimers and Ljung 2019). This is due to the fact that brain has the highest concentration of lipids after the adipose tissue; the brain contains 50–60% lipids concentration which forms the dry weight of the brain, and the brain requires particularly PUFAs from the 6 and 3 PUFAs families; therefore, the decrease in their concentration leads to imbalances of neurotransmitters resulting to mood disorders (Larrieu and Layé 2018).

Nutritional Needs During Pregnancy

Evidence from research shows that women of childbearing age are vulnerable hence suffer from nutritional deficiencies, becoming at high risk of developing depressive disorders among other complications (Bodnar and Wisner 2015). Pregnancy is a period in particular, that has attracted special attention with respect to the occurrence of depression (Gernand et al. 2016). This may be due to the reasons that during pregnancy, nutritional needs are upraised to meet the increased demands for fetus development and other metabolites during pregnancy; this may result in depletion of maternal nutrient stores, poor nutrients concentration in the blood and brain subsequently neurotransmitter imbalances and mood disorder (Sparling et al. 2017; Rechenberg and Humphries 2013). To mention few example, folate (folic acids) is important in the production of blood and protein; it reduces the risk of neural tube defects (which is the birth defect of the brain and spinal cord); it plays a crucial role in many metabolic reactions such as the biosynthesis of DNA and RNA, methylation of homocysteine to methionine, and amino acid metabolism (Mousa et al. 2019). The recommended intake of folate increases during pregnancy from 200 to 400 mcg per day (Lowensohn et al. 2016). When pregnant women do not meet their daily recommended allowance for this nutrient, they become deficient. A serious decrease in nutrient stores throughout pregnancy and a lack of immediate recovery after childbirth increase a woman's risk of developing depression (Bodnar and Wisner 2015). Thus, pregnancy represents a unique opportunity in life with considerable possibility to influence maternal health and the health of the next generation (O'Neil et al. 2014). Thus, to say optimal nutrition is necessary and the diets should be balanced, not only in terms of macronutrients proteins, carbohydrates, and fats, but also in terms of micronutrients vitamins and minerals, to reduce nutritional deficiencies and inadequacies (Rechenberg and Humphries 2013).

In LMICs, pregnant women are even at higher risk of poor nutritional deficiencies as a result of poverty, food insecurity, lack of adequate financial or family support, gender-based violence, frequent infections, and frequent pregnancies (Chaparro et al. 2014; Salam et al. 2015; Lindsay et al. 2012). Maternal malnutrition is evident and accounted for by the facts that between 5 and 20% of African women have a low body mass index (BMI), an outcome of long-lasting problems of lack of enough food, and across the continent, the prevalence of anemia ranges from 21 to 80%; similarly, high deficiencies in both vitamin A and Zn deficiency levels have been experienced (Lartey 2008). WHO estimates that globally, over two billion people are at risk of vitamin A, iodine, and iron deficiency; other micronutrients deficiencies of public health concern are zinc, folate, and B vitamins (Bailey et al. 2015). Studies from Kenya and Nigeria, for example, have revealed a high prevalence of both under- and over-nutrition, as well as nutrient deficiencies, including iron, folate, vitamin D, and vitamin A, that result in obstetric complications, hypertension, anemia, neural tube defects, night-blindness, low birth weight, and maternal and perinatal mortality (Lindsay et al. 2012; Obwocha et al. 2016). The micronutrients discussed above are very crucial to brain health, and their deficiencies increases the risks of mental disorders and other non-communicable diseases among women in the reproductive years. The double burden of malnutrition also co-exists in developing countries due to poverty poor eating behavior and eating habits, that lead to increased undernutrition and over nutrition (Kimani-Murage et al. 2015). Women are as twice vulnerable and susceptible to the double burden of malnutrition because of their high nutritional needs during pregnancy and lactation especially in the context of gender inequalities (Nguyen 2019). In LMICS where people lack enough food, there is a tendency of consuming high quantities of energy giving food due to the fact that they are cheap and easier to obtain as well as their capacity to satisfy hunger. These scenarios result in over consumptions of mostly carbohydrates, fats, and sweet drinks leading to growing rates of obesity among perinatal women that can be transferred to their off springs.

Objectives

Nutrition deficiencies are common among pregnant and lactating women in LMICs; at the same time, levels of maternal depression are extremely high among members of this group suggesting some connection between the two. The objective of this review is to determine the associations between nutritional deficiencies and maternal depression and identify the role of diet in depression to facilitate further research.

Methods

Search Strategy

A literature search included PubMed databases and Google Scholar search engine published from June 2008 to June 2019 and published in English. Medical subject heading terms were used to identify all relevant studies. The first search combined nutritional deficiency terms with maternal depression terms, while the second combined diet quality terms with depression terms and maternity terms separately. All titles and abstracts identified by the search were screened, then reviewed the full text, which were potentially eligible articles for inclusion.

Study Criteria

Studies considered for inclusion in this review were full-text articles and abstracts which consisted of cross-sectional study designs, cohort, studies, randomized control trials, and longitudinal studies that examined the association between nutrition and maternal depression, dietary practice, role of diet in preventing depression; and if they presented measures of association between nutritional biomarkers during or after pregnancy, and depression during pregnancy or up to 1-year postpartum. We excluded studies that examined nutrient deficiencies in animals, examined the effects of additives on mental health, examined emotional or binge eating, studies that were published in a language other than English, and studies that assessed hormones or other compounds synthesized by the body but not directly affected by dietary intake. There were no limitations placed on age due to known high rates of adolescent pregnancies across developing countries or the timing of pregnancy.

The Search Details

("malnutrition"[MeSH Terms] OR "malnutrition"[All Fields] OR ("nutritional"[All Fields] AND "deficiencies"[All Fields]) OR "nutritional deficiencies"[All Fields]) AND ("mothers"[MeSH Terms] OR "mothers"[All Fields] OR "maternal"[All Fields]) AND ("depressive disorder"[MeSH Terms] OR ("depressive"[All Fields] AND "disorder"[All Fields]) OR "depressive disorder"[All Fields] OR "depression"[All Fields] OR "depression"[MeSH Terms]) AND middle [All Fields] AND ("poverty"[MeSH Terms] OR "poverty"[All Fields] OR ("low"[All Fields] AND "income"[All Fields]) OR "low income"[All Fields]) AND countries [All Fields] AND Mesh Terms: Role; diet; mothers; depression; depressive disorders ("2009/06/28"[PDat]: "2019/06/25"[PDat]).

Data Extraction

The data extraction was conducted by two reviewers (a data collector and the first author (BM)), who independently extracted the data addressing the criteria of the study. We extracted the following key information from those articles that were eligible for inclusion: the author, sample size, screening instruments (dietary measure, and mental health measure), key findings, and the limitations of the study. All the information of the eligible articles was put into a spreadsheet as indicated in Table 1 Additional file 1

Quality Assessment

Quality assessments of all of the eligible studies were evaluated for methodological quality and appropriateness for inclusion, based on a set of pre-determined criteria derived from the National Institutes of Health (NIH) Quality Assessment Tool of Systematic Reviews and Meta-Analyses in PRISMA guidelines.

Search Outcomes

The initial search strategy identified 1250 citations; out of these, 42 were excluded because of duplication, leaving 1,208 relevant studies. Out of those studies, 1,132 were excluded based on information available in the abstract and title that did not fit the objective of this review; the remaining 76 articles were assessed for eligibility. On examination of the full-text articles, 51 studies did not fulfill inclusion criteria and were afterward excluded; only 25 studies were eligible for final analysis, as indicated in Fig. 1.

Data Analysis

Studies that were included for analysis were separated by study design, sample size, objectives, screening instruments, outcomes, and limitations of the study. Using these stratifications, we calculated proportions of studies that demonstrated positive and negative associations between diet and maternal depression.

Results

Overview of Studies

A total of twenty-five studies were eligible for final analysis. Of the twenty-five studies that were reviewed, thirteen studies were cross sectional, eight were prospective cohort studies, and four studies were intervention studies. About 95% of these studies reported positive associations between nutrition deficiencies, poor diet, and maternal depression; only 5% reported that there were no associations between nutrition and depression. Much of these associations were cross-sectional which represented 52%; prospective cohort studies were 32%, and intervention studies were 16%.

Screening Instruments: Depression Measures

Previous researches have used different tools to measure maternal mental disorders. Out of all the tools used, Edinburgh Postnatal Depression Scale (EPDS) was the most commonly used tool for screening of maternal depression, where eight studies out of the reviewed twenty-five, used it. Other assessment tools that were used included the Perceived Stress Scale and the Prenatal Distress Questionnaire (Singh et al. 2017); The Expanded Mini-International Neuropsychiatric Interview (Abrahams et al. 2018); General Health Questionnaire (GHQ-12) (Jacka et al. 2010); Clinical interview (SCID-I/NP),

Table 1 Studies included in the review on the role of diet in the prevention of maternal depression

N	Author, year	Design, objective, and sample size	Measurements	Outcomes	Limitations
1	Fowles et al. 2012	A cross-sectional study that investigated diet quality and its relationship with stress, depression, social support, and eating habits, low-income women in Austin, Texas. (n = 71)	The Edinburgh Postnatal Depression Scale was used to measure depression and the Prenatal Psychosocial Profile was used to assess stress and social support. The Dietary Quality Index–Pregnancy (DQI-P) was used to assess overall diet quality and three 24-h dietary recalls	Results revealed that women with diet quality scores below the median (n = 35) had more depression (9.6 ± 5.1 vs 6.7 ± 5.1) and stress (22.1 ± 5.4 vs 19.3 ± 4.8) and less control over meal preparation (5.0 ± 1.5 vs 4.2 ± 1.5) and support from others (52.0 ± 12.0 vs 57.4 ± 7.2) than did women with high-diet quality scores (n = 36).	This study was conducted targeting only low-income women; this may limit the application of these findings to wealthier women. 24-h recall has a weakness that it includes the under- or over-reporting of intake, which may limit the validity of the results and because it is a cross section study, it limits the causal relationship
2	Singh et al. 2017	A cross-sectional study to evaluate the prevalence of nutritional deficits in pregnant teenagers and the associations among micronutrient dietary intake, stress, and depression (n = 108) in Latina	Automated Self-Administered 24-h dietary recall (ASA24) in the 2nd trimester Stress was measured using the Perceived Stress Scale and the Prenatal Distress Questionnaire.	Mood and dietary factors were associated. More than 50% of pregnant teenagers had an inadequate intake of folate, vitamin A, vitamin E, iron, zinc, calcium, magnesium, and phosphorous thiamin, riboflavin, niacin, vitamin B6, vitamin B12, vitamin C, copper, and selenium.	The cross-sectional nature of the study affects the establishment of a causal relationship between dietary factors and mood. One 24-h food recall was done in this study, which may reduce the validity of the findings. Depression scale used in this study was not validated in a Latina population, limiting the reliability and validity of their findings.
3	Paskulin et al. 2017	A cross-sectional study that evaluated the association between dietary patterns and mental disorders among pregnant women in southern Brazil. (n = 712).	Food Frequency Questionnaire.(FFQ) The Primary Care Evaluation of Mental Disorders (PRIME-MD)	High prevalence of major depressive disorder was observed among women with low fruit intake (43%, PR 1.43, 95% CI 1.04–1.95) and high sweets and sugars intake (91%, PR 1.91, 95% CI 1.19–3.07). Low intake of beans was significantly associated with generalized anxiety disorder (PR 1.40, 95% CI 1.01–1.93).	It is a cross-sectional design which prevents a conclusive inference on the direction of the relationship. FFQ has poor capability to estimate the actual ingestion -This results cannot be generalized to the entire universe of Brazilian pregnant
4	Nana and Zema (2018)	A community-based cross-sectional study that assessed dietary practices and associated factors during pregnancy in Northwest Ethiopia. (n = 616)	Sociodemographic and socioeconomic questionnaire, dietary knowledge, dietary practices, and mid-upper arm circumference (MUAC).	60.7% of pregnant women reported poor dietary practices, while 38.6% had poor dietary knowledge.	There was no standardized questionnaire in Ethiopia at national level to assess food intake in terms of specific nutrients consumed.
5	Jacka et al. 2010	A cross-sectional study to examine the extent to which the high-prevalence mental disorders are related to habitual diet (N = 1,046) Australian	Food frequency questionnaire FFQ and General Health Questionnaire (GHQ-12) to measure psychological symptoms	Results demonstrate an association between habitual diet quality and the high-prevalence mental disorders	This is a cross-sectional study; it cannot establish the causal relationship between mental disorders and habitual diet.
6	Melaku Desta et al. 2019	An institution-based cross-sectional study to assess dietary diversity, on pregnant women attending antenatal clinic of Shashemane town Ethiopia (n = 315)	24-h dietary recall method and the dietary diversity score were computed for ten food groups.	About 74.6% of mothers did not consume an adequate diet. Only a quarter (25.4%) of pregnant mothers consumed adequate dietary diversity.	- Exposure and outcome are difficult to be determined, due to the cross-sectional nature of the study. -Results cannot be to generalize to the entire population. - The 24-h recall bias may have occurred due to the reason that it was self-reported.
7	Khalid et al. 2016	A cross-sectional study that investigated the association between mood disorders and socioeconomic status (SES). (N = 1095), Australian	Clinical interview (SCID-I/NP), psychiatric history; SES was determined by cross-referencing residential with Australian Bureau of Statistics 2006 census	The low SES group had a 2.0-fold increased odds of a current mood disorder compared to the mid group, (OR = 2.0, 95% CI 1.0–4.1, p = 0.05).	It is a cross-sectional relationship so it cannot establish the causal relationship.

Table 1 (continued)

N	Author, year	Design, objective, and sample size	Measurements	Outcomes	Limitations
8	Baskin et al. 2017	A cross-sectional study that explored the predictive role of antenatal diet quality for antenatal and postnatal depressive symptoms. Pregnant women (n = 167). New Zealand	Edinburgh Postnatal Depression Scale (EPDS); a food frequency questionnaire (FFQ). Diet quality was determined by extracting dietary patterns	Two dietary patterns were identified; unhealthy diet was associated with increased rates of depressive symptoms	The predictive nature of either dietary patterns or depressive symptoms cannot be concluded
9	Dadi and Desyibelew 2019	A community-based cross-sectional study that determined the extent of undernutrition among pregnant mothers in Gondar town, Northwest Ethiopia. (n = 940)	A face-to-face interview was administered using an Online kit (ODK). Mid Upper Arm Circumference (MUAC)	Results indicate 14.4% (95% CI: 12.3–16.7) of pregnant mothers were undernourished. Age of the pregnant mothers increased the odds of being undernourished by 10% and having a poor marital condition	It is a cross-sectional nature of the study which affects the establishment of a causal relationship between identified risk factors and undernutrition
10	Jacka et al. (2010)	A cross-sectional study examined the association between diet quality and bipolar disorder in a randomly selected, population-based women aged 20–93 years (n = 33)	Food Frequency Questionnaire (FFQ) Mental health was assessed using the. Structured Clinical Interview for DSM-IV (SCID-I/NP.)	Results indicate that a 'traditional' dietary pattern was associated with reduced odds for Depression (OR = 0.53 95% CI 0.32–0.89) after adjustments for overall energy intake.	The small sample size is small in this study that can limit representation, and the cross-sectional study design prevents the direction of the relationships between diet quality and unipolar depressive illness
11	Abrahams et al. 2018	A cross-sectional study in a low-income suburb in Cape Town. to assess factors associated with food insecurity and depression (N = 376).	US Household Food Security Survey Module was used to measure food insecurity. The Expanded Mini-International Neuropsychiatric Interview was used to diagnose depression	Results show 42% of households were food insecure and that 21% of participants were depressed. The odds of depression was greater in women who were food insecure (5.30; 1.63–17.30),	The relationship between food insecurity and depression is complex and requires further investigation.
12	Obwocha et al. 2016	A cross-sectional study to assess the dietary patterns, nutrient intake, and nutrition education information among pregnant mothers attending Ante-Natal Clinic at Kisii Level 5 Hospital- Kenya n = 102	Data on food and nutrient intake were collected using pretested 24-h diet recall and Food Frequency Questionnaires	Results showed a deficit in consumption of folic acid, calcium, and iron with respect to the Recommended Dietary Allowances (RDA).	-Its across-sectional design eliminates the possibility of identifying the causal relationship between eating patterns and health. -The information obtained was self-reported data, that depends on one's honesty and accuracy of responses and, might be a source of recall bias
13	Poorrezaeian et al. 2017	**A** cross-sectional study was performed to determine the relationship between the dietary diversity score (DDS) and stress and depression in women. (n = 360 women aged 20–49 years) in the south of Tehran	The dietary intake and score of depression, anxiety, and stress were measured using a 24-h dietary recall and the 42-item depression, anxiety, stress scales questionnaire, respectively.	Results indicate a total of 31.4 and 25.8% of the subjects suffered from depression and stress, respectively. After adjusting for confounders, a one-unit increase in DDS was associated with a 39% reduction in the risk of severe depression.	24-h dietary recall result in failure in recalling diet and portions consumed, and no cause-and-effect relationship between DDS and stress and depression could be inferred in this cross-sectional study.
14	Lukose et al. 2014	A prospective cohort study that examined the association between depressive symptoms and nutrients intake	The Kessler Psychological Distress Scale (K-10). Nutritional, clinical, and biochemical factors were also assessed. food frequency questionnaire (FFQ)	Nutrient intakes, serum vitamin B12, methylmalonic acid, homocysteine, and red cell folate levels were not associated with measures of depression	This study did not assess the severity of medical symptoms; vomiting was found to have a positive association with depressive symptoms.
15	Chatzi et al. 2015	A cohort of pregnant women, that investigated whether dietary patterns during pregnancy are related to postpartum depression (n = 529) Women, In Greece, 2007–2010.	Food Frequency Questionnaire (FFQ) in mid-pregnancy and the Edinburg Postpartum Depression Scale (EPDS) at 8–10 weeks postpartum	High adherence to a 'health-conscious' diet, characterized by vegetables, fruit, pulses, nuts, dairy products, fish, and olive oil, was associated with lower EPDS scores (highest v. lowest tertile: β-coefficient = − 1.75, p = 0.02).	During pregnancy, dietary intake is complicated because of various factors in the period of pregnancy. Depression symptoms were assessed with the self-administered EPDS, so it can lead to bias. There was a low participation rate only (57%).

Table 1 (continued)

N	Author, year	Design, objective, and sample size	Measurements	Outcomes	Limitations
16	Akbaraly et al. 2009	A prospective cohort that examined the association between dietary patterns and depression using an overall diet approach (n = 3486).	Epidemiologic Studies-Depression scale (CES-D) scale Two dietary patterns were identified: 'whole food' (heavily loaded by vegetables, fruits, and fish) and 'processed food' (heavily loaded by sweetened desserts, fried food, processed meat, refined grains, and high-fat dairy products).	Whole food patterns had lower odds of CES-D depression (OR = 0.74, 95% CI 0.56–0.99). In contrast, high consumption of processed food was associated with an increased odd of CES-D depression (OR = 1.58, 95% CI 1.11–2.23).	CES–D excluded prior depression as it was only introduced at phase 7 of the study. There may be some bias due to the selective retention of participants. A semi-quantitative food questionnaire coved only specific foods and is recognized to be less precise than dietary assessment by diary questionnaire.
17	Jacka et al. 2012	A randomly selected, population-based sample of women, to examine the relationship between the dietary intakes of these three (magnesium, folate, and zinc) micronutrients and clinically determined depressive and anxiety disorders	Food frequency questionnaire. The General Health Questionnaire-12 measured psychological symptoms, and a clinical interview (Structured Clinical Interview for DSM-IV-TR.	Increase in the intake of zinc, magnesium, and folate was associated with reduced odds ratio (OR) for major depression/dysthymia (zinc: OR = 0.52, 95% confidence interval (CI) 0.31 to 0.88; magnesium: OR = 0.60, 95% CI 0.37 to 0.96; folate: OR = 0.66, 95% CI 0.45 to 0.97).	Reverse causality and confounding cannot be ruled out as explanations.
18	Jacka et al. 2017	A 'SMILES' a 12-week, parallel-group, single-blind, randomized controlled trial that investigated the efficacy of a dietary improvement program for the treatment of major depressive episodes (diet intervention, n = 33; control, n = 34)	Depression was assessed using the Montgomery–Åsberg Depression Rating Scale (MADRS) and 12-week diet intervention	The dietary support group demonstrated greater improvement between baseline and 12 weeks on the MADRS than the social support control group, $t(60.7) = 4.38$, $p < 0.001$	The study sample was a fairly small group, with a short duration of 12 weeks only Expectation bias is observed due inability to blind the participants to their intervention group. Small sample size increases the possibilities that the sample was not representative
19	Null et al. 2017	A cohort of a lifestyle modification study involving individuals suffering mainly from depression, cognitive decline, Parkinson's disease, or anxiety. (N = 27)	Diet prescribed was an alkalizing anti-inflammatory vegan diet with 75% raw and 25% lightly cooked foods and elimination of certain foods and a letter from an medical doctor confirming the conditions.	Results demonstrate that an intervention of diet, juicing, supplements, exercise, and lifestyle may provide considerable benefits for all conditions addressed.	The study was a relatively small group, with a short duration
20	Pina-Camacho et al. 2015	A prospective birth cohort study of mother-child pairs to examine the inter-relationships between maternal depressive symptoms and unhealthy diet with child emotional–behavioral dysregulation (n = 7814)	Edinburgh Postnatal Depression Scale (EPDS) and food frequency questionnaire (FFQ and Infant Temperament Scale	Results indicated that higher prenatal maternal depression symptoms were prospectively associated with a higher unhealthy diet, both during pregnancy and the postnatal	The prospective association between maternal depression, unhealthy nutrition, and child dysregulation was not large. Dietary pattern analysis using factor analysis can only detect a small percentage of the variance in dietary intakes. There may be measurement error because measures were based on maternal self-reports rather than on clinical observations.
21	Saeed et al. 2016	A cohort study that investigated the relationship of antenatal depression with maternal dietary intake and neonatal outcome in Pakistan on 94 middle class antenatal (hospital-based	Edinburgh Postnatal Depression Scale (EPDS) and Healthy Eating Index Rates	Results indicated that antenatal depression increased the risk of poor healthy eating index rates, and neonatal outcomes consist of fetal growth retardation, preterm birth low apgar score (and low birth weight)	The study population also belonged to the middle class; therefore, results cannot be generalized to the entire universe
22	Naem et al. (2014)	A randomized-controlled trial to assess the zinc status and dietary intake of zinc and other macronutrients among	24-h recalls method and a food frequency questionnaire. The blood hemoglobin level, serum zinc level, and fasting blood sugar were determined.	Zinc deficiency was identified among 53.5% of the sample, and three iron intakes were below 50% of the RDA.	24-h dietary recall includes under- or over-reporting of intake, variations between foods eaten, and honesty of

Table 1 (continued)

N	Author, year	Design, objective, and sample size	Measurements	Outcomes	Limitations
		pregnant women in Alexandria, Egypt (*n*=100)		Protein intake was less than 70% of the RDA.	the participants to provide wrong answers.
23	Tsai et al. (2016)	Longitudinal data collected from 1,238 pregnant women during a 3-year cluster-randomized trial	Single-item food insufficiency measure was used to inquire the number of days of hunger in the past week. Depression symptom was measured using the Xhosa version of the 10-item Edinburgh Postnatal Depression Scale	Food insufficiency had a strong and statistically significant association with depression symptom severity ($\beta = 0.70$; 95% CI, 0.46–0.94), suggesting a 6.5% relative difference in depression symptom severity per day.	Findings may not generalize beyond the study population.
24	Francis et al. (2018)	A randomized controlled trial (RCT) has been conducted to examine whether young adults with elevated depression symptoms would comply with a brief, 3-week diet intervention and whether this can improve symptoms of depression	Depression tool: Centre for Epidemiological Studies Depression Scale; CESD-R; and Depression Anxiety and Stress Scale 21 depression subscale; DASS-21-D. Diet compliance was measured via self-report questionnaires and spectrophotometry.	The diet change group ($n = 38$) was significantly lower than the habitual diet ($n = 38$) group following 3 weeks of diet improvement, controlling for baseline scores (effect size: Cohen's $d = 0.65$).	The study lacks an active control group as a comparison, the reason being that you cannot tell people to eat unhealthy diet to be a comparison group.
25	Teo et al. (2018)	A prospective cohort examined the associations of dietary patterns during confinement period in a multi-ethnic Asian cohort with postpartum depression (PPD) and anxiety (PPA) in Singapore (*n* 490)	Dietary intakes 3-day food diaries and dietary patterns And depression was measured using Edinburgh Postnatal Depression Scale (EPDS	Four dietary patterns were identified: There were no associations observed between traditional-Chinese-confinement diet, and eat-out diet with maternal mental health, only the traditional-Indian-confinement diet and soup-vegetables-fruits diet were positively associated with reduced depression symptoms	The dietary patterns were specific to Asia's context and cannot be generalized to the entire population

psychiatric history (Khalid et al. 2016); The Kessler Psychological Distress Scale (K-10) (Lukose et al. 2014); Depression (CES-D) Scale (Akbaraly et al. 2009); Clinical interview (Structured Clinical Interview for DSM-IV-TR (Jacka et al. 2012); Montgomery–Åsberg Depression Rating Scale (MADRS) (Jacka et al. 2017) and Xhosa version of the 10-item Edinburgh Postnatal Depression Scale (Tsai et al. 2016); and lastly Depression Anxiety and Stress Scale 21 depression subscale; DASS-21-D (Francis et al. 2018).

Screening Instruments: Dietary Measures

The tool that was mostly used for dietary intake measure was Dietary 24-h recalls method and Food Frequency Questionnaire (FFQ); other tools included Automated Self-Administered 24-hour dietary recall (ASA24) (Singh et al. 2017); dietary knowledge and practices questionnaire (Nana and Zema 2018); dietary patterns questionnaires (Akbaraly et al. 2009); 7-day food diary; and Dietary Quality Index–Pregnancy (DQI-P) (Fowles et al. 2012); Nutrition clinical and biochemical (Lukose et al. 2014); dietary intakes 3-day food diaries and dietary patterns (Teo et al. 2018); single-item food insufficiency measure (Tsai et al. 2016); and the CM-700D Konica-Minolta Spectrophotometer, which measures the light in the participant's skin reflected and skin yellowness and the quantity of flavonoids (chemicals from fruit and vegetables) in their diet to predict plasma carotenoid levels following diet intervention (Francis et al. 2018).

Discussion

Association Between Nutrition and Maternal Depression

Most studies in this review consistently associated poor quality prenatal diet with poor maternal mental health. A study by Paskulin and colleagues in Brazil found a high prevalence of major depressive disorder among women with low fruit intake (43%, PR 1.43, 95% CI 1.04–1.95) and high sweets and sugars intake (91%, PR 1.91, 95% CI 1.19–3.07) (Paskulin et al. 2017). A study by Singh and colleagues, in Latina, evaluated the prevalence of nutritional deficits in pregnant

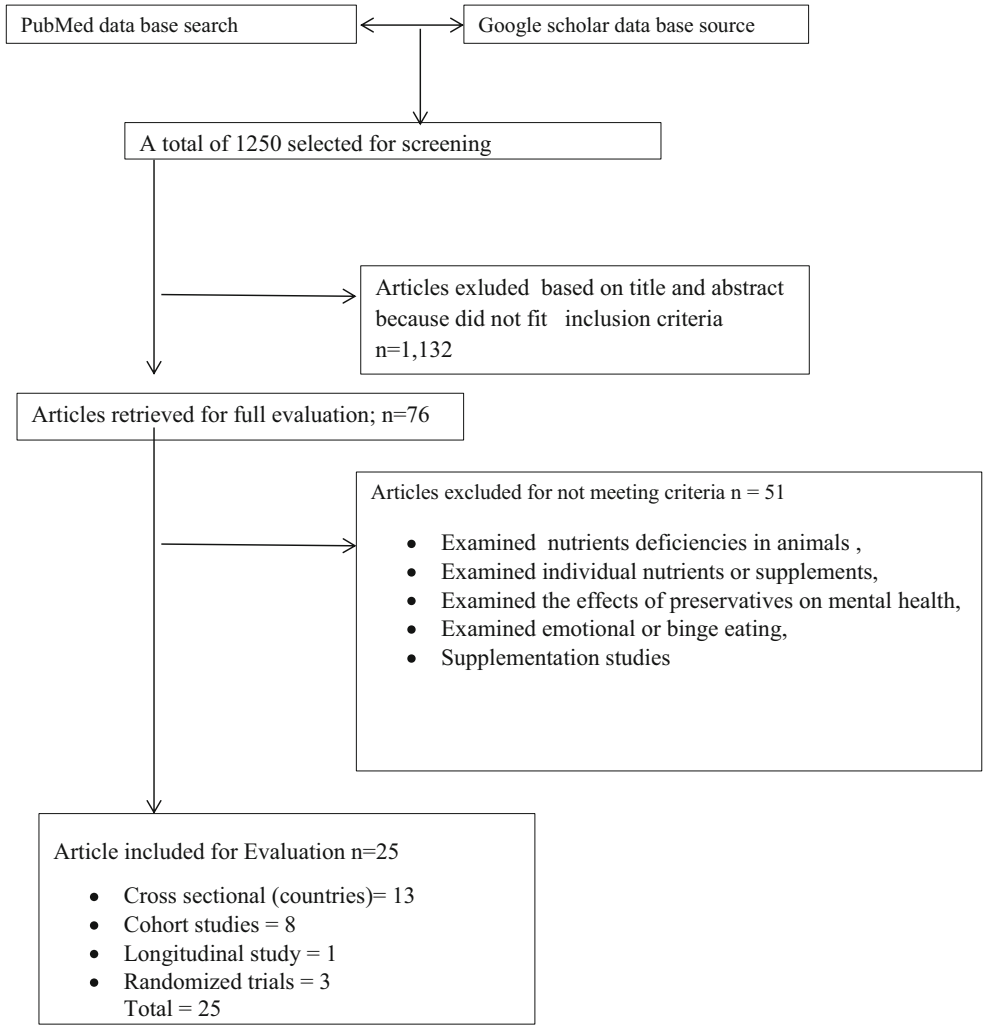

Fig. 1 Flow chart of study selection. Flow diagram: study selection process on the role of diet in prevention of maternal depression

teenagers and assessed the associations among micronutrient dietary intake and depression; results show that more than 50% of pregnant teenagers had an inadequate intake of folate, vitamin A, vitamin E, iron, zinc, calcium, magnesium, and phosphorous; these are micronutrients that are very crucial to brain health (Singh et al. 2017). In Ethiopia, Nana and Zema (Nana and Zema 2018) reported that more than half of the pregnant women (60.7%) in the study had poor dietary practices which they attributed to maternal poor health. In a study by Jacka and colleagues, in Australian, the relationship between high-prevalence mental disorders and habitual diet was studied; the results demonstrated an association between habitual diet quality and high-prevalence mental disorders (Jacka et al. 2010). Again, Williams and colleagues in Australian reported that low socioeconomic status group had a 2.0-fold increased odds of a current mood disorder compared to the secure food group (Khalid et al. 2016). Baskin and colleagues (Baskin et al. 2017) in New Zealand found that unhealthy diet was associated with increased rates of depressive symptoms. Fowles and colleague (Fowles et al. 2012) in Austin, Texas examined the relationships among distress social support and eating habits with dietary quality in low-income pregnant women and found that poor eating habits had a direct effect on psychosocial distress, and poor eating habits contributed to inadequate dietary quality. A study by Dad and Desyibelew (Dadi and Desyibelew 2019) determined the extent of undernutrition among pregnant mothers in Gondar town, Northwest Ethiopia; Results indicate 14.4% (95% CI: 12.3–16.7) of pregnant mothers were undernourished.

Role of Diet in Understanding Maternal Depression

A well-balanced diet contains thousands of nutrients that are helpful to our bodies and all nutrients are normally consumed from various sources of food in meals (Cetin and Laoreti 2015). Diets with abundance of vegetables, alongside with animal protein, legumes, fruits, nuts, and whole grains, have been evaluated in research and were found to contain nutrients that improve mental health (Jacka et al. 2017). A cohort study of pregnant women by Chatz and colleagues in Greece (Chatzi et al. 2015) investigated dietary patterns and depression

during pregnancy and found that high adherence to a health-conscious diet, which is high in vegetables, fruit, pulses, nuts, dairy products, fish, and olive oil, was associated with lower EPDS scores β-coefficient = − 1.75, p = 0.02). Prospective cohort study by Akbaraly and colleague (Akbaraly et al. 2009) examined the association between dietary patterns and depression using an overall diet approach, and found an association between an unhealthy diet and mental health problems; unhealthy diet score, were two times likely to be more symptomatic (OR 2.10, 95% CI: 1.38–3.20).

A randomized controlled trial named "The SMILES trial" tested the efficacy of a 12-week dietary intervention in the treatment of major depressive disorders, and results demonstrated that dietary improvement was a viable treatment strategy for treating major depression (Jacka et al. 2017). Francis and colleagues (Francis et al. 2018) conducted a RCT to examine whether young adults with elevated depression symptoms would comply with a brief, 3-week diet intervention and whether this can improve symptoms of depression; results indicated that Diet Change (DC) group improved from the elevated range (i.e., > 16) to the no clinical significance range, in the Centre for Epidemiological Studies Depression scale-Revised (CESD-R) score, but remained elevated in the habitual diet (HD) group across baseline and day 21. This difference was significant, with the DC group having significantly lower CESD-R scores on day 21 compared to the HD group, controlling for baseline CESD-R scores (F[1,75] = 7.792, p = 0.007, Cohen's d = 0.65. Additionally, when the ANCOVA was rerun, controlling for age, gender, physical activity, and baseline BMI, the significant group difference at day 21 remained (F[1,71] = 7.091, p = 0.010. A study by Jacka and colleague (Jacka et al. 2012) examined the relationship between the dietary intakes of three elements (magnesium, folate, and zinc) and found that increase in the intake of these three was associated with reduced odds for major depression (zinc: OR = 0.52, 95% CI: 0.31 to 0.88; magnesium: OR = 0.60, 95% CI 0.37–0.96; folate: OR = 0.66, 95% CI 0.45–0.97). A study by Saeed and colleague (Saeed et al. 2016) found that antenatal depression increases the risk of poor Healthy Eating Index rates on the mothers and neonatal outcomes consisted of fetal growth retardation, preterm birth, and low Apgar score. Another study by Pina (Pina-Camacho et al. 2015) found prospective association between higher prenatal maternal depression symptoms to be with higher unhealthy diet, both during pregnancy and the postnatal period, which was also associated with higher child dysregulation up to the age of 7 years. A study by Poorrezaeian and colleague (Poorrezaeian et al. 2017) determined the relationship between the dietary diversity score (DDS) and stress and depression in women. Results indicate that a total of 31.4 and 25.8% of the subjects suffered from depression and stress, respectively, and a one-unity dietary diversity score increase was associated with a 39% reduction in the risk of severe depression.

However, not all studies have shown an association between nutrition and maternal depression clearly. A prospective study by Teo and colleagues (Teo et al. 2018) examined the associations of dietary patterns during the confinement period in a multi-ethnic Asian cohort with postpartum depression) and anxiety. The study identified four dietary patterns: traditional-Indian-confinement diet; soup-vegetables-fruits diet; traditional-Chinese-confinement diet; and eat-out diet with maternal mental health. The results did not show an association between traditional-Chinese-confinement diet and eat-out diet with maternal mental health, but the association was detected between traditional-Indian-confinement diet and soup-vegetables-fruits diet, with reduced depression symptoms. This may be due to the reason that the traditional-Indian-confinement diet comprises legumes and pulses; these foods are rich in B-group vitamins that are crucial for the synthesis of monoamine neurotransmitters and may have helped to establish protection against depression symptoms. A prospective cohort study by Lukose and colleagues (Lukose et al. 2014) examined the associations between maternal depression and nutrients intake using biochemical measurements and food frequency questionnaire; the results showed that nutrient intakes, serum vitamin B12, methyl malonic acid, homocysteine, and red cell folate levels were not associated with measures of depression.

Methodological Strengths and Limitations

Study Design

Most of the studies in this review were cross sectional; the strength of these cross-sectional studies is that they established relationship between maternal mental disorders and the role of diet intervention in preventing the disorders. However, as a limitation, cross-sectional study design does not facilitate the establishment causal relationship between dietary factor and mood. On the other hand, interventional and prospective longitudinal studies are recommended as they have the capacity to establish causal relationship between the dietary factor and mood disorders (Singh et al. 2017; Paskulin et al. 2017). The strengths of these designs are that they give an opportunity to account for the effect of exposures during pregnancy and early life measures prospectively within the cohort that enables establishment of the relationship between exposures and outcomes. Bias issues were also observed in some cohort studies in this review, where there was failure to blind the participant in the intervention group and comparison group, which may affect on the results of the interventions (Jacka et al. 2017).

Sample Size Limitations

Sample size and short duration of the study were among the limitations found among the study reviewed in this review. For

example, the study by Jack FN and Null et al. (Jacka et al. 2017; Null et al. 2017) had small sample size which reduces the ability of the sample to be representative and cannot be generalized to the general population. Low participation rate was another limitation observed in a cohort study by Chatzi and colleague (Chatzi et al. 2015) in which a big number of participants did not participate in the follow-up. This resulted in a final sample that could not meet the representative threshold.

Screening Instrument Limitations

Although EPDS is an established and widely used screening tool for maternal depression with high specificity and sensitivity, it is not a definitive diagnosis, hence, the inherent limitation of using this tool. Assessments of depression symptoms with self-administered EPDS, rather than definite case based on clinician-administered structured diagnostic interview, have its limitations, that cause unreliability in results. (Chatzi et al. 2015). Another limitation found was using tools that are not validated in a given population; this may lead to unreliable results, and an example is the study by Singh and colleague (Singh et al. 2017) who used Reynolds Adolescent Depression Scale, Second Edition (RADS-2), the psychosocial measures tool which was not validated in a Latina population.

Dietary Measures Strength and Their Limitations

The 24-h recall method is considered to be cheaper and easier than other techniques and has been found to yield reliable information if carefully planned and implemented (Gibson et al. 2017). This review supports such observations albeit limitations to be considered when using this tool. According to Naem and colleague (Naem et al. 2014), a 24-h dietary recalls resulted in under- or over-reporting of food intake and possibilities of participants to provide their desire responses. A study by Singh (Singh et al. 2017) indicated that conducting only one 24-h dietary recall in a study can reduce the internal validity of the findings; however, it has been noted that a one-time 24-h recall reduces errors compared to the longer interval of recollection. On the other hand Automated Self-Administered 24-h dietary recall (ASA24) method is more accurate than administered 24-h recall. On the other hand, most of the information obtained through 24-h recall may be a source of both recall and social desirability bias when self-reported because the data does not take into account issues concerning accuracy of responses (Obwocha et al. 2016). The Food frequency questionnaire (FFQ) was used often among the studies reviewed; this tool is designed to assess habitual diet by asking about the frequency with which food items or specific food groups are consumed over a reference period; however, FFQ has poor capability to estimate the actual ingestion which is one of the limitations of the instrument. Chatzi et al (Chatzi et al. 2015) observed that the assessment of dietary intake in pregnant women is complicated because of various factors depending on the period of pregnancy. According to Desta and colleagues (Desta et al. 2019), FFQ may not give the exact figure of the dietary diversity due to a recall bias and being self-reported. According to Nana and Zema (Nana and Zema 2018), lack of standardized FFQ questionnaires at national level, where the study is conducted, is a limitation that can lead to failure in assessing food intake in terms of specific nutrients consumed hence results may be unreliable.

The limitation of this review includes shortage of available literature and indexed articles on the association between nutritional deficiencies and maternal depression, the role of dietary protective power to prevent depressive disorders in lower income countries; due to this reason, this Systematic review was conducted on only the current available limited literature that associated nutrition and perinatal depression. Also in this review, the study population of the articles reviewed comprised mostly the women from low- and middle-income contexts; now, the focus on low-income women and middle class limits the application of the findings to women living in high socioeconomic contexts. However, focusing on low-resource contexts is important as these women are most likely to suffer most from nutritional deficiencies and experiences of adverse pregnancy outcomes.

Conclusion

Results demonstrate an association between diet quality and maternal mental outcomes. Research has provided evidence that food and nutrition interventions are some of the most promising intercessions for mental health illnesses. The findings derived from this review suggest that nutritional interventions should be tested to determine their efficacy in prevention and treatment of maternal mental health conditions as it is a major public health issue today. This can offer a window of opportunity to reduce the risk of maternal mental disorders in mothers and offspring alike. Therefore, as a recommendation to substantiate these associations between diet quality and mental health, longitudinal studies need to be conducted to confirm the preventive nature of nutrition to prevent mental disorders and other chronic diseases.

Acknowledgments We thank all authors of the studies included in this systematic review.

Availability of Data and Material Not applicable.

Authors' contributions BM was involved in designing, conducting a literature search, analysis, interpretations, and writing of the manuscript. WKM, a primary mentor helped in conceptualization, writing up and participated in designing, interpretations, and drafting the manuscript.

SN assisted in planning of the research concept and MK, assisted in designing the study, editing, and reviewing the paper for submission. All authors read and approved the final manuscript.

Compliance with ethical standards

Ethics Approval and Consent to Participate Not applicable.

Consent for Publication Not applicable

Competing Interests The authors declare that they have no competing interests.

Abbreviations *ASA24,* automated self-administered 24-h recall; *BMI,* body mass index; *CI,* confidence interval; *DC,* diet change; *HD,* habitual diet; *DNA,* deoxyribonucleic acid; *EPDS,* Edinburgh Postnatal Depression Scale; *FFQ,* food frequency questionnaire; *LMCIs,* low- and middle-income countries; *PUFA,* polyunsaturated fatty acids; *RCT,* randomized controlled trial; *RNA,* ribonucleic acid

Appendix 1: The literature search process

1. A literature search included PubMed database and Google Scholar search engine; to identify papers published from June, 2009 to June 2019. Medical subject heading terms was used to identify relevant studies.
2. The first PubMed search combined medical terms (nutritional deficiencies terms, with maternal depression terms). The second search in PubMed combined key words (diet role and maternal depression). The search result one and search results two were generated by the search engine.

PubMed database:
The Search result 1:- ("malnutrition"[MeSH Terms] OR "malnutrition"[All Fields] OR ("nutritional"[All Fields] AND "deficiencies"[All Fields]) OR "nutritional deficiencies"[All Fields]) AND ("mothers"[MeSH Terms] OR "mothers"[All Fields] OR "maternal"[All Fields]) AND ("depressive disorder"[MeSH Terms] OR ("depressive"[All Fields] AND "disorder"[All Fields]) OR "depressive disorder"[All Fields] OR "depression"[All Fields] OR "depression"[MeSH Terms]) AND middle [All Fields] AND ("poverty"[MeSH Terms] OR "poverty"[All Fields] OR ("low"[All Fields] AND "income"[All Fields]) OR "low income"[All Fields]) AND countries [All Fields] ("2009/06/28"[PDat]: "2019/06/25"[PDat]).
The Search result 2:- ("diet"[MeSH Terms] OR "diet"[All Fields]) AND quality[All Fields] AND ("mothers"[MeSH Terms] OR "mothers"[All Fields] OR "maternal"[All Fields]) AND ("depressive disorder"[MeSH Terms] OR ("depressive"[All Fields] AND "disorder"[All Fields]) OR "depressive disorder"[All Fields] OR "depression"[All Fields] OR "depression"[MeSH Terms]) AND ("depressive disorder"[MeSH Terms] OR "depressive"[All Fields] AND "disorder"[All Fields]) OR "depressive disorder"[All Fields] OR "depression"[All Fields] OR "depression"[MeSH Terms]) ("2009/06/28"[PDat] : "2019/06/25"[PDat]).

Search strategy. MeSH, medical subject headings

3. The initial combined search in PubMed identified 1200 citations
4. Google Scholar was also utilized to locate open access articles. The following search terms were used to locate articles specific studies (nutritional deficiencies, dietary role, and maternal depression). The google search results from June 2009 to June 2019 identified 92 citations of which 42 were also found in PubMed.
5. We screened relevant articles based on abstracts. If considered eligible, the full-text publication was retrieved and reviewed.
6. Additionally, hand searching was used through the reference lists of the articles identified which were reviewed to identify relevant additional studies.
7. Study Eligibility**: -** We considered studies that examined the association between nutritional deficiencies and maternal depression, and studies that examined the role of diet for depression, and if they presented measures of association.
8. Study Population: - Population included women of childbearing, pregnant, and lactating women. There were no limitations placed on age due to known high rates of adolescent pregnancies across developing countries or the timing of pregnancy.
9. Exclusion Criteria: - We excluded studies that examined nutrient deficiencies in animals, examined the effects of additives on mental health, examined emotional or binge eating, studies that were published in a language other than English, and studies that assessed hormones or other compounds synthesized by the body but not directly affected by dietary intake.
10. Data Extraction: - the data extraction was conducted by two authors (BM and MK), who independently extracted the data addressing the criteria of the study, where areas of uncertainty arose co-authors were consulted (WKM, SN).
11. Search Outcomes: **-** The initial search strategy identified 1250 citations; where 42 were excluded because of duplication, leaving 1,208. Out of those studies, 1,132 were excluded upon initial screening for not meeting inclusion criteria based on information available in the titles and abstracts. Of the remaining seventy-six articles, fifty one were excluded due to the reasons that, some were not the target group or examined individual nutrients or supplements, or some examine nutrients deficiencies in the general population, some focused on children mental health, and some emotional or binge eating. Only 25 studies were eligible for data charting and final analysis.

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