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Systematic Review

A 10-Year Systematic Review (2013 to 2022) on Effects of Diet on Migraine

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Abstract

Migraine, a type of headache characterized by moderate or severe throbbing pain on one side of the head, has sparked growing interest in relation to the role of diet. Although extensive research had been conducted throughout the years, few reviews have been done. Here, a systematic review is conducted to determine the diet, food, and dietary pattern that worsen or reduce migraine, as well as the mechanisms behind it. Using articles indexed in PubMed within the last 10 years, from 2013 to 2022, 190 articles were identified. Of which, 45 articles were included in this review. After analysis, two distinct themes emerged, namely (a) diet, food, and dietary pattern that worsen migraine, and (b) diet, food, and dietary pattern that reduce migraine. The current body of literature shows that diet assumes a critical role and exerts a notable influence in migraine. Diet that worsens migraine include pro-inflammatory diet, high-sodium diet, and high-fat diet. Food that worsens migraine include meat, milk, and dairy products, alcoholic beverages, and chocolate. Low meal frequency may also worsen migraine. On the other hand, diet that reduces migraine include ketogenic diet, Mediterranean diet, DASH diet, and MIND diet. Food that reduces migraine include fruits and vegetables, as well as cold-water fatty fish. High meal frequency may also reduce migraine. Interestingly, caffeinated beverages may worsen or reduce migraine, depending on consumption.

Keywords: *Diet; Migraine; Ketogenic Diet; Mediterranean Diet; DASH Diet; MIND Diet*

Introduction

According to the National Health Service (NHS) [1], migraine is a type of headache characterized by moderate or severe throbbing pain on one side of the head. Other symptoms include nausea, vomiting, as well as increased sensitivity to light, sound, and odor. Movement, coughing, and sneezing can worsen the pain [2].

There are mainly two types of migraine, namely migraine with aura and migraine without aura [3]. Firstly, migraine with aura involves sensory disturbances that occur shortly before the migraine, where individuals may experience numbness, weakness, and tingling sensations. Individuals may also see spots, flashes, and zigzags, or even lose sight for short periods of time [4]. Secondly, migraine without aura is the most common type of migraine, where it does not involve sensory disturbances [5]. Other types of migraine include vestibular migraine, abdominal migraine, and hemiplegic migraine. Vestibular migraine involves vertigo and dizziness. Abdominal migraine does not

involve the typical headache, instead, it involves abdominal pain, and it is more common in young children under 10 years old. Hemiplegic migraine involves aura or sensory disturbances, and weakness on one side of the body [6].

There are usually four stages of migraine; namely, pro-drome, aura, attack, and post-drome. Firstly, pro-drome refers to the period before the attack or headache, where individuals may develop increased food cravings, thirst, yawning, and urination. This phase can last for a few hours to days. Secondly, aura refers to sensory disturbances that occur shortly before the migraine. Individuals suffering from migraine with aura will go through this phase while individuals suffering from migraine without aura will not go through this phase. This phase can last for five to 60 minutes. Thirdly, attack refers to headache. The other symptoms can appear and peak during this phase. If left untreated, this phase can last for four to 72 hours. Lastly, post-drome refers to the period after the attack or headache, where individuals may experience non-headache symptoms; such as, fatigue, neck stiffness and cognitive impairment. This phase can last for 24 to 48 hours [7].

While there are no exact causes, migraine is associated with abnormal brain activity, which activates trigeminal nerve fibers and releases calcitonin gene-related peptide (CGRP). The amount of serotonin in the brain also decreases. This results in the relaxation of blood vessel walls and vasodilation in the brain, causing throbbing pain on one side of the head [8]. Also, migraine can be associated with certain risk factors. It has been reported that migraine is more common in adult females, individuals with a family history of migraine, individuals with depression, anxiety disorders, bipolar disorders, sleep disorders, and epilepsy [9]. Additionally, migraine can be associated with certain triggers. There are mainly five categories of migraine-associated triggers, namely menstruation, weather changes, emotional stress, sleep disturbance, as well as food and beverages [10].

According to the World Health Organization (WHO) [11], headache disorders is one of the most common neurological disorders worldwide. According to the Institute for Health Metrics and Evaluation (IHME) [12], the Global Burden of Disease (GBD) study that was conducted in 2019 reported that migraine was responsible for 88.2% of the burden of headache disorders worldwide. Furthermore, the global prevalence of migraine increased from 721.9 million in 1990 to 1.1 billion in 2019 and the global age-standardized years lived with disability (YLD) rate of migraine increased from 517.6 in 1990 to 525.5 in 2019.

With these alarming rates, the need to develop effective treatment options for migraine increases. While there is currently no definitive cure, the focus lies on easing the symptoms of migraine. Several common treatment options include medications, acupuncture, cold compress, management of emotional stress, regulation of sleep patterns, and dietary changes [13]. As diet is related to both migraine-associated triggers and treatments for migraine, it is evident that diet is a major factor and plays a significant role in migraine. Current research suggests that certain diet, food, and dietary pattern can worsen or reduce migraine [14]. Recent research also suggests that diet can affect brain activity by influencing the activity of neuropeptides, neuroreceptors, ion channels, glucose metabolism, and sympathetic nervous system. Moreover, diet could trigger inflammation, release of nitric oxide, and vasodilation in the brain, all of which are involved in migraine development [15].

Systematic review refers to the methodical analysis of literature that employs clear and repeatable techniques to thoroughly investigate, evaluate and combine information from numerous articles that are interconnected. It also utilizes approaches to minimize biases. Hence, it is superior and plays an essential role in evidence-based practice [16]. Although extensive research on the role of diet in migraine had been conducted throughout the years, few reviews have been done. Therefore, there is a lack of comprehensive illustration and explanation. With the above reasons, it is important to review the articles about the role of diet in migraine. Here, articles from PubMed are systematically reviewed to determine the diet, food, and dietary pattern that worsen or reduce migraine, as well as the mechanisms behind it.

Methods

A literature search was conducted using PubMed to source for the articles from 1st January 2013 to 31st December 2022. The search term used was "diet[tiab] AND migraine[tiab]". The following exclusion criteria were applied: (A) articles that were not published in English were removed; (B) articles other than primary articles, such as secondary articles consisting of systematic reviews, narrative reviews, and meta-analyses, were removed; (C) articles without access to the full-text articles were removed; (D) articles without mention of "diet" and "migraine" were removed. After the exclusion criteria were applied, the articles remaining were included in this review. A qualitative data extraction was conducted. A summary table was used. Data extracted from the articles included authors, titles, journals, methods, results, strengths, and limitations. A narrative synthesis was then conducted.

Results and Discussion

A total of 190 articles identified from PubMed (Figure 1). 182 articles were published in English (exclusion criteria A); of which, 148 were primary articles (exclusion criteria B). Within the primary articles, 83 were articles with access to the full-text articles (exclusion criteria C). Within the full-text articles, 45 were articles with mention of "diet" and "migraine" (exclusion criteria D). Therefore, a total of 45 articles were included in this review.

Theme 1: Diet, food, and dietary pattern that worsen migraine

Out of the 45 articles, 13 articles analyzed the diet, food and dietary pattern that worsen migraine. Diet that worsens migraine include pro-inflammatory diet, high-sodium diet, and high-fat diet.

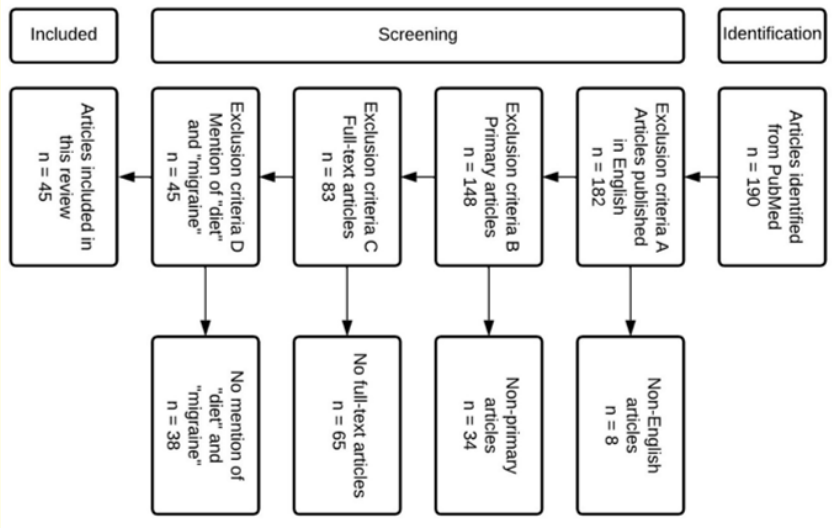

Figure 1: *Process flow using PRISMA.*

[1]https://pubmed.ncbi.nlm.nih.gov/?term=diet[tiab]+AND+migraine[tiab]&filter=dates.2013/1/1-2022/12/31

Themes	Number of Articles	References
Diet, food, and dietary pattern that worsen migraine	13	[17-29]
Diet, food, and dietary pattern that reduce migraine	41	[17,18,21-23,26-61]

Table 1: *Thematic classification of articles.*

Themes	Limitations	Potential Solutions
Diet, food, and dietary pattern that worsen migraine	Cross-sectional study design, prevents inference of causal relationship [17-20,24]	Perform longitudinal study, such as cohort study
	Recall bias and measurement errors [17-20,24-26]	Select suitable data collection approach and standardize measurement procedures
	Unmeasured confounding factors, lead to inaccurate results [17,18,28]	Perform more comprehensive study, such as prospective study
	Selection bias [17,18,25]	Determine and keep to selection criteria
	Small sample size [17,20,25]	Consider larger sample size
	Participants might not be headache-free during blood test, lead to inaccurate results [18]	Confirm with participants that they are headache-free before administering blood test
	Self-reporting bias [19,20,28]	Validate self-reported data
	Analyses used data from 1999 to 2004, lead to inaccurate representation of current situation [19]	Examine using data that are up to date
	Analyses used data of average food intake patterns, lead to vague results [20]	Examine using data of specific food intake
	Administered questionnaire as diagnostic method of migraine, lead to inaccurate results [25]	Conduct face-to-face interview with neurologist
	COVID-19 might have affected migraine in participants, lead to inaccurate results [28]	Test participants for COVID-19 and question about current or previous COVID-19 infection

Diet, food, and dietary pattern that reduce migraine	Lack of power to demonstrate statistically significant clinical effect compared to placebo [30]	Conduct well-designed randomized clinical trial
	Prescence of confounding factors, lead to inaccurate results [30]	Limit study to specific group of participants with migraine without aura who followed normal calorie diet and did not experience weight loss while on ketogenic diet
	Other mechanisms might have affected ketogenesis and ketosis, lead to inaccurate results [30,39]	Record multiple readings and investigate mechanisms of action using neurophysiology and neuroimaging techniques
	Cross-sectional study design, prevents inference of causal relationship [31,35]	Perform longitudinal study, such as cohort study
	Small sample size [31,35,38-40,42,45,54,55,57]	Consider larger sample size
	Short observation period [31,39,54]	Consider long-term observation and longer follow-up period
	Unable to establish actual presence of ketonemia in participants [31]	Use blood ketone meters that are able to store data and disable or cover its display to maintain blind nature of study
	Recall bias and measurement errors [35,42,55,60]	Select suitable data collection approach and standardize measurement procedures
	Self-reporting bias [35,55,56]	Validate self-reported data
	Social desirability bias [37]	Identify under-reporters and conduct sensitivity analysis
	Baseline dietary intake and caloric requirements of participants were not factored into analysis [38]	Instruct participants to complete food record or estimate total energy requirements before starting intervention
	Unable to conduct tightly controlled diet intervention trials in free living populations, lead to inaccurate results [40]	Consider food provision
	Used Headache Impact Test-6 (HIT-6) as measure of pain, lead to vague results [40]	Examine using data from headache diary
	Unmeasured confounding factors, lead to inaccurate results [41]	Perform more comprehensive study, such as prospective study
	Lack of control group [54,56,57,59,60]	Include well-selected control group
	Selection bias [54]	Determine and keep to selection criteria
	Lack of research on potential impact of polyphenols and phytochemicals on migraine prognosis [55]	Perform more comprehensive study, such as prospective study
	Cross-sectional study design, prevents inference of causal relationship [60]	Perform longitudinal study, such as cohort study

Table 2: *Limitations and potential solutions of articles.*

Ghoreishy., *et al*. [18] suggest that adhering to a pro-inflammatory diet is linked to an elevated likelihood of experiencing severe migraine. The study involved both women and men. The study showed that a pro-inflammatory diet that is associated with higher serum inflammatory markers, significantly correlated with an increased risk of severe migraine. A pro-inflammatory diet refers to the regular consumption of food that promotes inflammation within the body. It includes the consumption of food that is high in refined carbohydrates, added sugars, saturated fats, and trans fats. Some examples include red meat, processed meat, fried food, snack food, refined grains, sweetened beverages, and alcoholic beverages. Such food can lead to an imbalance in the body's inflammatory processes, triggering inflammation and worsening migraine [62].

Several studies also suggest that having a high-sodium diet is linked to an increased risk of severe migraine [18,20,26]. Generally, these studies involved both women and men. The studies exhibited a consensus among their findings, showing that a high-sodium diet significantly correlated with an increased risk of severe migraine. A high-sodium diet refers to the regular consumption of high-sodium food, such as table salt, processed meat, sauces, and salad dressings. There are a few possible reasons. Firstly, sodium is pro-inflammatory. As suggested by Ghoreishy., *et al*. [18], pro-inflammatory food can lead to an imbalance in the body's inflammatory processes, triggering inflammation and worsening migraine. Secondly, excessive intake of sodium can lead to dehydration through several mechanisms, including increased water excretion, altered thirst sensation, impaired water absorption, and increased water loss through sweat. This can then result in changes in blood flow to the brain, and disruptions in electrolyte and neurotransmitter levels, triggering migraine [63]. Thirdly, high amounts of sodium can lead to an increase in blood pressure through several mechanisms, including water retention, constriction of blood vessels, impaired kidney function, and activation of the renin-angiotensin-aldosterone system. This can then result in changes in the blood vessels, and thus, changes in blood flow to the brain, triggering migraine [64]. However, Brown., *et al.* [65] discovered an inverse relationship between sodium intake and migraine. The probability of having a migraine decreased by 7% with increasing sodium intake. It is worth noting that this inverse relationship is only limited to women with a lower body mass index (BMI) and men. These individuals may have a different brain extracellular sodium regulation system, which could be a potential factor for this phenomenon. As there is limited research available, more studies must be conducted to determine the underlying mechanisms and potential factors contributing to the conflicting association between a high-sodium diet and migraine.

There is also evidence suggesting that following a high-fat diet is linked to a heightened risk of severe migraine. According to Ghoreishy., *et al.* [18], a high-fat diet that is associated with higher dietary inflammatory index (DII), significantly correlated with an increased risk of severe migraine. The study involved both women and men. A high-fat diet refers to the regular consumption of high-fat food, such as fatty meat, processed meat, fried food, snack food, and full-fat dairy products. There are a few possible reasons. Firstly, saturated fat, trans fat, and omega-6 fatty acid are pro-inflammatory. As suggested by Ghoreishy., *et al*. [18], pro-inflammatory food can lead to an imbalance in the body's inflammatory processes, triggering inflammation and worsening migraine. Secondly, excessive intake of fat can lead to an increase in prostaglandin production. This can then result in the relaxation of blood vessel walls, and thus, vasodilation in the brain, triggering migraine [66]. In addition, women with migraine reported a higher omega-6 fatty acid to omega-3 fatty acid ratio compared to women without migraine [19]. This indicates that women with migraine tend to consume a higher proportion of omega-6 fatty acid relative to omega-3 fatty acid in their diet. Since omega-6 fatty acid is known to be pro-inflammatory, it can trigger inflammation and worsen migraine. However, it is worth noting that these findings are only limited to women and focus solely on the ratio of omega-6 fatty acid to omega-3 fatty acid. Due to the limited research available, further studies are needed to investigate the effects of both omega-6 and omega-3 fatty acids in both women and men. It is also necessary to explore the specific effects of omega-6 and omega-3 fatty acids individually.

Food that worsens migraine include meat, milk, and dairy products, as well as caffeinated beverages, alcoholic beverages, and chocolate. Multiple studies suggest that the consumption of meat, milk, and dairy products can act as dietary triggers for migraine

[17,21,22,25,27,29]. In general, these studies encompassed both women and men, and their findings demonstrate a consensus, indicating that meat, milk, and dairy products have been identified as potential dietary triggers for migraine. Red meat, milk, egg, and cheese are one of the most reported triggers for migraine in individuals, indicating its significant impact on a large population. There are a few possible reasons. Firstly, meat, milk, and dairy products are known to contain high amounts of protein, calcium, and phosphorus. These nutrients can increase potential renal acid load (PRAL), where the body produces more acid during metabolism, disrupting the acid-base equilibrium in the body. This can then result in the constriction of blood vessels, changes in blood flow to the brain, and disruptions in neurotransmitter levels. Thus, contributing to migraine development. Secondly, the study by Durham., *et al.* [8] indicate that migraine is associated with increased levels of CGRP. Meat, milk, and dairy products can increase nitric oxide levels and production of inflammatory markers, which stimulates the release of CGRP. Hence, contributing to migraine development. Thirdly, meat, milk and dairy products can increase cortisol levels. Cortisol is a stress hormone that may interfere with the pain management and healing processes in the body, therefore prolonging the duration and impeding the recovery of migraine [67]. Also, for individuals with lactose intolerance, consumption of milk and dairy products can cause migraine. Lactose intolerance refers to the inability to properly digest lactose, a type of sugar mainly found in milk and dairy products. When individuals with lactose intolerance consume milk and dairy products, the undigested lactose can reach the large intestine, disrupting the gut microbiota and releasing inflammatory substances, therefore triggering migraine. Furthermore, lactose intolerance is associated with gastrointestinal symptoms, such as abdominal pain and bloating, which have the potential to trigger and exacerbate migraine [68].

Caffeinated beverages play a complex yet interesting role in migraine, as it can have both negative and positive effects. On one hand, it can serve as dietary triggers for migraine, while on the other hand, it can reduce migraine. In this section (Theme 1: Diet, Food, and Dietary Pattern that Worsen Migraine), the focus is on the discussion of its negative effects. Subsequently, in the next section (Theme 2: Diet, Food, and Dietary Pattern that Reduce Migraine), the focus is on the discussion of its positive effects. Numerous studies suggest that the consumption of caffeinated beverages can serve as dietary triggers for migraine [21,22,24,27]. Across the range of studies involving both women and men, there is a notable consensus among their findings, pointing towards caffeinated beverages being recognized as potential dietary triggers for migraine. Coffee and tea are one of the most reported triggers for migraine in individuals, highlighting its significant impact on a large population. There are a few possible reasons. Firstly, caffeine acts as a diuretic, causing an increase in urine production. Inadequate fluid intake to compensate for the diuretic effect can result in dehydration. This can then result in changes in blood flow to the brain, and disruptions in electrolyte and neurotransmitter levels, triggering migraine. Secondly, for individuals who consume caffeine regularly, abrupt discontinuation can cause caffeine withdrawal. For instance, an individual has a habit of having a cup of coffee every morning before work. If circumstances arise that cause him or her to be late for work; thus, unable to have his or her usual cup of coffee, this sudden deprivation can cause caffeine withdrawal. Caffeine withdrawal can increase blood flow and vasodilation in the brain, triggering migraine [69].

Several studies also suggest that the consumption of alcoholic beverages can act as dietary triggers for migraine [21,22,25,27,29]. These studies included both women and men, and their findings showed a shared agreement, highlighting that alcoholic beverages have been recognized as potential dietary triggers for migraine. Alcoholic beverages are one of the most reported triggers for migraine in individuals, underscoring its substantial influence on a considerable portion of the population. Additionally, Lisicki., *et al.* [25] suggest that wine is one of the most reported food items consumed in the hours leading up to a migraine. There are a few possible reasons. Firstly, much like caffeine, alcohol acts as a diuretic, causing an increase in urine production. Inadequate fluid intake to compensate for the diuretic effect can result in dehydration. This can then result in changes in blood flow to the brain, and disruptions in electrolyte and neurotransmitter levels, triggering migraine. Secondly, certain alcoholic beverages, such as wine and beer, are known to contain higher amounts of histamine and tannin. Histamine is a natural occurring compound that plays a role in various physiological processes within

the body, including immune response, while tannin is a natural occurring compound known as polyphenol. These substances can increase blood flow and vasodilation in the brain, triggering migraine [70].

Various studies also suggest that the consumption of chocolate can serve as a dietary trigger for migraine [21,22,24,25,27]. Inclusive of both women and men, the findings from these studies establish a consensus, underscoring the identification of chocolate as a potential dietary trigger for migraine. Chocolate ranks among the most reported triggers for migraine in individuals, emphasizing its considerable impact on a broad segment of the population. There are a few possible reasons. Firstly, certain chocolate, such as dark chocolate, are known to contain higher amounts of caffeine. As indicated in the studies on caffeine, caffeine can serve as dietary triggers for migraine [21,22,24,27]. Secondly, certain chocolate, such as dark chocolate, are known to contain higher amounts of tyramine, phenylethylamine (PEA), and flavanols. Tyramine is a natural occurring compound that is produced by the breakdown of an amino acid known as tyrosine, while PEA is a natural occurring compound that acts as a central nervous system stimulant. These substances can cause disruptions in neurotransmitter levels, initiating migraine. Durham., *et al.* [8] suggest that migraine is associated with increased levels of CGRP. Flavanols are a type of flavonoids, which are natural occurring compounds that can encourage production of nitric oxide by the endothelial cells lining the blood vessels. This increase in nitric oxide levels stimulates the release of CGRP; thus, initiating migraine [71].

Dietary pattern that worsens migraine include low meal frequency. In recent years, the potential impact of unhealthy and irregular dietary patterns on migraine have been a topic of interest in scientific research. Several studies have explored the relationship between low meal frequency and migraine, and the findings from these studies are in consensus that low meal frequency can contribute to the worsening of migraine [23,24,28]. Low meal frequency refers to the practice of consuming fewer meals than recommended or prolonged periods of fasting between meals. For instance, having one or two meals instead of three or four meals per day. One of the key factors behind this association is dehydration, which can then result in changes in blood flow to the brain, and disruptions in electrolyte and neurotransmitter levels, triggering migraine. Another factor to consider is hypoglycemia. Skipping meals can lead to fluctuations in blood sugar levels, causing blood sugar levels to be below the healthy range, also known as hypoglycemia. Hypoglycemia can increase cortisol levels. Witbracht., *et al.* [67] suggest that cortisol is a stress hormone that may interfere with the pain management and healing processes in the body, therefore prolonging the duration and impeding the recovery of migraine. Hypoglycemia can also reduce energy supply in the brain, which can result in changes in brain function and blood flow to the brain; thus, making individuals more susceptible to migraine [72].

Theme 2: Diet, food, and dietary pattern that reduce migraine

Out of the 45 articles, 41 articles analyzed the diet, food and dietary pattern that reduce migraine. Diet that reduces migraine include ketogenic diet, Mediterranean diet, DASH diet, and MIND diet.

Ample studies suggest that adhering to a ketogenic diet is linked to a reduced risk of migraine [30,31,34,38,39,44,46,49,54,58,59,61]. Generally, these studies involved both women and men. The studies exhibited a consensus among their findings, showing that a ketogenic diet significantly correlated with a reduced risk of migraine. A ketogenic diet refers to a strict low-carbohydrate, moderate-protein, and high-fat diet. It involves reducing carbohydrate intake and replacing it with fat. This allows the body to enter a state known as ketosis, where the body burns fat instead of carbohydrate from food, producing ketones. Food commonly consumed while on a ketogenic diet include fruits, vegetables, legumes, nuts, fish, and shellfish. There are a few possible reasons. Firstly, ketogenic diet can mitigate any glucose metabolism deficiencies, allowing a more stable and sustained energy supply to the brain, therefore improving mitochondrial energy metabolism and lowering the incidence of migraine. Secondly, ketogenic diet has anti-inflammatory effects. The low-carbohydrate, moderate-protein, and high-fat nature of the diet can reduce inflammation and oxidative stress, therefore alleviating migraine. However, it is important to note that while ample studies suggest that adhering to a ketogenic diet is linked to a reduced risk of migraine, the association between a high-fat diet and a heightened risk of severe migraine should also be taken into consideration.

Some studies also suggest that following a Mediterranean diet is linked to a reduced risk of migraine [17,36]. Inclusive of both women and men, the studies contributed to a consensus among their findings, demonstrating a significant association between a Mediterranean diet and a reduced risk of migraine. A Mediterranean diet refers to a diet consisting of traditional food eaten in countries surrounding the Mediterranean Sea, such as Greece, Italy, and Spain. It is characterized by its high amounts of nutrients, including monounsaturated fat, fiber, and antioxidants. It emphasizes on the consumption of fruits, vegetables, wholegrains, fish, legumes, nuts, and olive oil, while limiting the consumption of red meat, processed meat, fried food, and snack food. Much like ketogenic diet, Mediterranean diet has anti-inflammatory effects. The high amounts of nutrients, including monounsaturated fat, fiber, and antioxidants in the diet can reduce inflammation and oxidative stress; therefore, alleviating migraine [73].

Several studies also suggest that having a DASH diet is linked to a reduced risk of migraine [17,36]. In general, these studies encompassed both women and men, and their findings demonstrate a consensus, indicating that a DASH diet significantly correlated with a reduced risk of migraine. DASH diet stands for Dietary Approaches to Stop Hypertension and it is designed to lower blood pressure and promote overall heart health. It is characterized by its high amounts of nutrients, including potassium, magnesium, and fiber. It emphasizes on the consumption of fruits, vegetables, wholegrains, lean proteins, legumes, nuts, and low-fat dairy products, while limiting the consumption of saturated fat, processed meat, fried food, and snack food. There are a few possible reasons. Firstly, much like ketogenic and Mediterranean diet, DASH diet has anti-inflammatory effects. The high amounts of nutrients, including potassium, magnesium, and fiber in the diet can reduce inflammation and oxidative stress, therefore alleviating migraine. Secondly, DASH diet can lead to a reduction in blood pressure. Reduction in blood pressure can ensure normal blood flow to the brain and balance of neurotransmitters, therefore alleviating migraine [74].

There is also evidence suggesting that MIND diet is linked to a reduced risk of migraine. A study conducted by Askarpour., *et al.* [35] show that women with a higher score of the MIND diet exhibited a lower likelihood of experiencing severe migraine compared to women with a lower score of the MIND diet. Moreover, women with a higher score of the MIND diet also reported a shorter duration and less frequent occurrence of migraine compared to women with a lower score of the MIND diet. MIND diet stands for Mediterranean-DASH intervention for neurodegenerative delay and it is designed to promote overall brain health and reduce the risk of neurodegenerative diseases, such as Alzheimer's disease. It focuses on the consumption of nutrient-rich food, such as fruits, vegetables, wholegrains, fish, lean proteins, legumes, nuts, olive oil, low-fat dairy products, and berries, while limiting the consumption of red meat, saturated fat, processed meat, fried food, snack food, pastries, butter, and margarine. There are a few possible reasons. Firstly, much like ketogenic, Mediterranean, and DASH diet, MIND diet has anti-inflammatory effects. Consuming a diet rich in nutrient-dense food can reduce inflammation and oxidative stress, therefore alleviating migraine. Secondly, MIND diet can lead to a reduction of CGRP production. As indicated by Durham., *et al.* [8], migraine is associated with increased levels of CGRP. Therefore, by following a MIND diet, it can lead to a reduction of CGRP production, potentially resulting in a decrease in migraine severity, duration, and frequency. However, it is worth noting that these findings are only based on a small sample size and limited to women. Due to the restricted research available, additional studies with a larger and more diverse sample size are required to investigate the effects of a MIND diet in both women and men.

Food that reduces migraine include fruits and vegetables, as well as cold-water fatty fish, and caffeinated beverages. Multiple studies suggest that the consumption of a diet rich in fruits and vegetables can reduce migraine [17,18,32,36,41,42,50,52,59]. In general, these studies encompassed both women and men, and their findings demonstrate a consensus, indicating that fruits and vegetables have a beneficial effect on migraine development. Berries, citrus fruits, banana, avocado, spinach, kale, and chard are commonly cited as particularly beneficial for migraine. There are a few possible reasons. Firstly, fruits and vegetables are known to contain high amounts of magnesium, potassium, phytate, glutamate, and B-group vitamins. Magnesium, potassium, phytate, and B-group vitamins have anti-inflammatory effects, which can reduce inflammation and oxidative stress, therefore alleviating migraine. Secondly, fruits and vegetables,

due to its high amounts of magnesium and potassium, are known to be alkaline, which can lead to a reduction of PRAL. Reduction of PRAL can ensure acid-base equilibrium in the body, normal blood flow to the brain and balance of neurotransmitters. These effects can contribute to the alleviation of migraine and overall well-being. Thirdly, fruits and vegetables, due to its high amounts of glutamate and B-group vitamins, can regulate the release of neurotransmitters, including serotonin and dopamine. It can also regulate pain signaling in the brain. Collectively, these effects have the potential to shorten the duration and expedite the recovery of migraine, providing a promising avenue for alleviating migraine.

Numerous studies also suggest that the consumption of a diet rich in cold-water fatty fish can reduce migraine [32,41,59]. Across the range of studies involving both women and men, there is a notable consensus among their findings, indicating that cold-water fatty fish has a beneficial effect on migraine development. Salmon, mackerel, tuna, and sardine are commonly cited as particularly beneficial for migraine. Cold-water fatty fish is known to contain high amounts of omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These omega-3 fatty acids have anti-inflammatory effects, which can reduce inflammation and oxidative stress, therefore alleviating migraine. In addition, according to Mann., *et al.* [33] and Ramsden., *et al.* [40], individuals with a higher intake of EPA and DHA exhibited a lower likelihood of experiencing severe migraine compared to individuals with a lower intake of EPA and DHA. Moreover, individuals with a higher intake of EPA and DHA also reported a less frequent occurrence of migraine compared to individuals with a lower intake of EPA and DHA. However, Barbosa., *et al.* [43] discovered that even though omega-3 fatty acids can reduce the production of inflammatory markers, it does not have any significant effect on migraine. It is important to note that the study utilized male rats and the administration of omega-3 fatty acids was limited to a duration of only one month, which may be contributing factors to this phenomenon. As the available research is limited, there is a need for further investigation to determine the effects of omega-3 fatty acids in humans, both women and men. It is also necessary to explore the effects of omega-3 fatty acids over a longer duration.

As previously discussed, caffeinated beverages play a complex yet interesting role in migraine, as it can have both negative and positive effects. In this section (Theme 2: Diet, Food, and Dietary Pattern that Reduce Migraine), the focus is on the discussion of its positive effects. There is evidence suggesting that the consumption of caffeinated beverages can reduce migraine. Nowaczewska., *et al.* [75] found that individuals found caffeine to be effective in the acute treatment of migraine. The study involved both women and men. Coffee is commonly cited as particularly beneficial for migraine. There are a few possible reasons. Firstly, caffeine can lead to a reduction in blood flow and promote vasoconstriction in the brain, therefore relieving migraine. Secondly, when caffeine is consumed along with certain painkillers, it can increase absorption and effectiveness of the painkillers; therefore, accelerating migraine recovery. Hence, the role of caffeinated beverages is ambiguous. While it can serve as dietary triggers for migraine, it can also reduce migraine. It is important for individuals with migraine to be mindful of their caffeine consumption levels. Due to the limited research available, further investigation is required to fully understand the underlying mechanisms and potential factors contributing to the ambiguous association between caffeinated beverages and migraine.

Dietary pattern that reduces migraine include high meal frequency. In recent scientific research, there has been a growing interest in the potential influence of healthy and regular dietary patterns on migraine. Several studies have examined the relationship between high meal frequency and migraine, and the findings from these studies are in consensus that high meal frequency can contribute to the reduction of migraine [23,28,53]. High meal frequency refers to the practice of consuming small frequent meals throughout the day. For instance, having five or six small meals instead of three or four meals per day. In addition, according to the American Migraine Foundation [76], one of its recommendations include eating five or six small and calorie-controlled meals per day for the optimal management of migraine. One of the key factors behind this association is the prevention of hunger. Hunger can act as a trigger for migraine in individuals. By preventing hunger, individuals can avoid this trigger and reduce the likelihood of experiencing migraine. Another factor to consider is the regulation of blood sugar levels. Consuming small frequent meals throughout the day can ensure a steady source of carbohydrates and maintain stable blood sugar levels; thus, making individuals less susceptible to migraine.

Principal findings of this review

This review highlights the pivotal role of diet as a prominent and influential factor in migraine. It reveals that certain diets, including pro-inflammatory, high-sodium, and high-fat diets, can contribute to the worsening of migraine. Specific food items, including meat, milk, dairy products, caffeinated beverages, alcoholic beverages, and chocolate, have also been identified as potential dietary triggers for migraine. Furthermore, dietary pattern characterized by low meal frequency have been associated with an exacerbation of migraine.

On the other hand, certain diets, including ketogenic, Mediterranean, DASH, and MIND diets, have shown potential in reducing migraine. Incorporating fruits, vegetables, cold-water fatty fish, and caffeinated beverages into the diet have also been associated with a reduction of migraine. Additionally, dietary pattern characterized by high meal frequency have been linked to a reduced risk of migraine.

Given that specific dietary triggers for migraine may vary among individuals, identifying and eliminating them can also be a valuable strategy to effectively manage migraine. However, the associations between a high-sodium diet and migraine, omega-6 and omega-3 fatty acids and migraine, MIND diet and migraine, as well as the ambiguous association between caffeinated beverages and migraine might need to be investigated and studied further for a more comprehensive understanding of the role of diet in migraine.

As observed in table 2, substantial constraints were identified across the studies, with the primary concern being inherent bias in the participants' responses. Moreover, the absence of standardized protocols and procedures was also evident. All of these could have contributed to measurement errors and potentially compromised the accuracy of the findings.

Main Strengths and Limitations of this Review

The main strength of this review lies in its meticulous adherence to a clear pre-specified eligibility criteria and systematic search strategy that aligns with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). This rigorous approach enhances the credibility and reliability of this review, making it a valuable resource for evidence-based practice. Another strength of this review is its comprehensive assessment of the limitations and potential solutions identified within the individual themes. This review not only provides a transparent evaluation of the existing research, but also offers valuable insights for future researchers. This approach facilitates a deeper understanding of the gaps in the literature and can guide future investigations in different directions, potentially contributing to the advancement of knowledge in the field. A notable limitation of this review is the limited use of databases to source for the articles. By relying solely on PubMed as the database, this review might have missed out relevant articles available in other databases. This approach might have resulted in insufficient coverage for this review.

Conclusion

Review of 45 articles out of 190 articles yielded two distinct themes, namely (a) diet, food, and dietary pattern that worsen migraine, and (b) diet, food, and dietary pattern that reduce migraine. Diet that worsens migraine include pro-inflammatory diet, high-sodium diet, and high-fat diet. Food that worsens migraine include meat, milk, and dairy products, alcoholic beverages, and chocolate. Low meal frequency may also worsen migraine. On the other hand, diet that reduces migraine include ketogenic diet, Mediterranean diet, DASH diet, and MIND diet. Food that reduces migraine include fruits and vegetables, as well as cold-water fatty fish. High meal frequency may also reduce migraine. Interestingly, caffeinated beverages may worsen or reduce migraine, depending on consumption. This allows individuals with migraine to make informed choices about their dietary habits; therefore, potentially alleviating the burden of migraine.

Supplementary Materials

Data files for this study can be downloaded at https://bit.ly/Diet_Migraine.

Conflict of Interest

The authors declare no conflict of interest.

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