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The effect of nutrition and physical activity on sleep quality among adults: a scoping review

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Abstract

Sleep quality and its effects have become a public concern over the last few years. While the prevalence of sleep disorders was increasing, several studies have linked diet and physical activity as a cause of it. Indeed, many people complain about their sleeping problems without considering their lifestyle as a cause. This leads the efforts to focus on these principal factors and find their specific effect. The study aims to map out the research on the effect of nutrition and physical activity on sleep quality. The literature search was conducted in electronic libraries and databases related to nutrition and medical literature – Google Scholar, PubMed, and ScienceDirect– using relevant selected keywords. Article inclusion and selection were made by excluding duplicates, analyzing titles and abstracts, and reviewing the articles' full text. This review included 61 articles. This literature study reinforces the importance of researching sleep and the lifestyle contributors to poor sleep, such as physical activity and nutrition.

Keywords Nutrition, Sleep disorder, Sleep quality, Physical activity

Introduction

Sleep is a fundamental biological process for physiological and biochemical functions in the human body, including immunity, metabolism, appetite regulation, emotional status, and cardiovascular and hormonal systems (Jyväkorpi et al. 2021). The body needs good quality and enough sleep, estimated to be 7–8 h minimum daily, to do all these essential functions. Sleep disorder is a condition with a high prevalence that damages the normal circadian rhythm, negatively impacting physical health and physiological well-being. Several types of sleep disorders are studied frequently, including obstructive sleep dyspnea and insomnia (Zhao et al. 2020).

Insomnia is the most widespread type of sleep disorder. It can be defined as difficulty in falling asleep or maintaining sleep initiation. Most insomnia is considered a public health problem and can be a life threat (Sacks, et al. 2017). Lack of sleep in quality or quantity negatively impacts health, work performance, and quality of life (Pereira et al. 2020). It is believed that insomnia contributes to many adverse health complications; hypertension and diabetes mellitus (DM) are some of the many complications (Fernandez-Mendoza, et al. 2012; Vgontzas et al. 2009).

The prevalence rates of sleep disorders in the Netherlands were studied and analyzed. The general sleep disturbance (GSD) was 32.1%, whereas sleep insufficiency was 43.2%. The restless legs disorder and limb movements during sleep rate were measured at 12.5%, insomnia at 8.2%, parasomnia at 6.1%, circadian rhythm sleep disorder at 5.3%, hypersomnolence at 5.9%, sleep-related breathing disorders at 7.1%, and the presence of two or

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more concurrent sleep disorders was 12.2%. Also, sleep duration and onset time revealed relationships with GSD, respectively, with the 22:00–24:00 period and seven to eight maintaining optimal associates (Kerkhof 2017). Hypersomnia, or Excessive Daytime Sleepiness (EDS), is described as increased demand for sleep significantly during activities or situations requiring attentiveness. Excessive daytime sleepiness is an indicator of sleep disorder and an indicator of severe chronic health problems. Besides, it is associated with social consequences. Primary factors associated with EDS include Low activity levels, ageing, short sleep duration, obesity, sleep apnea, DM, depression, and others (Adama Melaku et al. 2019). Obstructive sleep apnea (OSA) is a common but often unrecognized breath-related sleep disorder, and it is caused by pharyngeal collapse during sleep. Frequent awakenings characterized it waking headaches, night snoring, daytime sleepiness, and decreased cognitive performance (Guilleminault and Zupancic 2009).

The most significant risk factor for OSA syndrome is obesity. In contrast, the disposition of fat reduces the dimension of the upper airway, decreases muscles' activity, and the lunge volume reduced as a mechanical effect of obesity (Klykylo and Kay 2012). Many factors assist the human into slumber; nutrition is obtaining or providing the necessary food for growth, health, and all the physiological processes (Zhao et al. 2020). It is considered one of the significant factors that help with sleep and play an essential role in regulating bodily functions, such as hormones and neurotransmitters that seem essential in the human sleeping system. Epidemiological data show that the average night's sleep has declined by about 20 min, based on progressively stressful life, working long hours, and watching TV at night. Alcohol is still used as a sedative, but toleration is generated within three to seven days. Drinking alcohol late at night disturbs sleep quality, especially when alcohol is metabolized and left in the body. The association between alcohol, OSA, insomnia, and traffic accidents has been discussed. The study confirms a link between those alcohol-related deaths and deaths in both cases. The main effect of alcohol is the effect on sleep quality (Watson and Preedy 2020).

Melatonin is a hormone released from the pineal gland, usually at night. It has many roles in the human body, regulating circadian and sleep/wake cycles and enhancing sleep (Blask 2009). Melatonin can be found in many fruits (e.g., grapes and berries), vegetables (e.g., tomato), seeds (e.g., black and white mustard), cereals, and nuts (e.g., pistachio) (Meng, et al. 2017). However, magnesium is considered one of the critical elements in the human body that is believed to be a cofactor in several biochemical reactions. It has many benefits, such as ensuring sleep quality and regulating the human body's circadian rhythm. Sleep quality can be affected by the diet's food types, such as magnesium (Sanlier and Sabuncular 2020). Malnutrition and micronutrient deficiencies are risk factors for many negative consequences.

Caffeine has long been associated with a sleep disorder. Evidence has grown indicating the stimulating effect of caffeine and merely restoring normal functioning after abstinence from caffeine. Moreover, caffeine interrupts sleep, with sleep hygiene instructions calling for stopping caffeine consumption before bed. However, caffeine response at bedtime is variable, and withdrawal may confuse studies (Watson and Preedy 2020).

Physical activity (PA) is a well-known approach to relieving stress and improving mood and depression. It also proved that physically active people participate more in social activities (Stewart, et al. 2003; Amarantos et al. 2001). Sleep quality is proportional to PA; if one increases, the other follows. PA positively impacts sleep quality, as demonstrated in many studies. The American sleep disorders association has listed standard PA as a non-pharmacological cure to enhance sleep quality (Norman et al. 2000). Studies have shown that PA improvement is an essential factor for sleep quality. Apart from many kinds of PA, what matters is that elevated fitness will decrease sleeping complications and improve sleeping quality (Lee and Lin 2007). However, a low level of PA has been associated with insomnia and sleep-disordered breathing. People with obesity have behavioural problems such as low activity levels, which in turn affects sleeping quality and causes more complications in sleep (Vasquez et al. 2008; Paparrigopoulos et al. 2010).

This review aims to map out the existing literature on targeting the effect of nutrition and PA on sleep quality and examine if the studies consider the inter-relationships between PA and nutrition. This paper aims to review and illustrate this existing research in an integrated manner, show gaps in the work done, and determine future research directions.

Methods

Search strategy

This review followed specified methodological methods for scoping reviews operating the framework proposed by Arskey and O'Malley for scoping reviews (Arksey and O'Malley 2005). The framework has five components, i.e., specifying the research question, specifying related studies, studies selection, charting data (collating, mapping, and summarizing), and reporting results. The protocol for this review has not been registered. The presented review was thoroughly researched through various databases: Saudi Digital Library (SDL), PubMed, Google Scholar, ScienceDirect, and Harvard Medical School were the primary ones used to find recent articles about sleep quality, nutrition, and PA and what links them together. The research was conducted electronically from February–March 2021.

The Boolean operators "AND" and "OR" for published peer-reviewed studies were undertaken by three researchers (M.H.A, B.S.A. and M.S.A) within the electronic databases that were published between 2000–2021. In determining the keywords related to the research question, the keywords used were "diet OR nutrition" AND "sleep quality OR sleeping disorders" AND "physical activity OR exercise." Sentences such as physical activity AND nutrition, sleep AND nutrition, physical activity AND sleep, and all three dimensions were searched for relevant results.

Selection criteria

The criteria depended on selecting the articles included in the review: (1) they revolved around three main topics (sleep quality, nutrition, and PA). (2) specific diets and behavioural changes were suggested as treatments. (3) it was focused on adults and older adults. (4) it was in English. (5) it was available in full text. Articles were only included if they fulfilled the inclusion criteria and were presented as an abstract or an article in the press.

Selection process

Three reviewers (M.H.A, B.S.A and M.S.A) independently screened titles and abstracts and assessed full-text articles to establish eligibility for inclusion. A fourth reviewer (N.W.A.) was consulted for discrepancies. The selected articles were exported and collected in the Mendeley Desktop (version 1.19.8) reference software to manage and resort to the articles as references. The content of all files would be at the level of relevance in the search. Then the information will be relied upon in the basic research.

Data extraction

The authors (N.A, N.A, M.A, B.A, M.A and O.G) agreed that the data would be extracted from the full text to be reviewed. Then it would be verified by them. The data were extracted to describe the main topics, the study design, aim, age group, intervention, PA, sleep, nutrition, and other primary outcomes.

Results and discussion

Initially, 175,767 records were found through databases, and three records were from other sources (Fig. 1). Only 413 records were retrieved, as their topics seemed appropriate to include in the review. After screening the records, 218 records were included, and 112 were only concerned with nutrition or PA or only sleeping problems. Other articles needed the appropriate recommendations or solutions, while some were concerned with different age groups. After that, 106 full-text articles were assessed for eligibility, and 45 were excluded because they only had nutrition, PA, and some needed further research. Finally, 61 articles were included in the review.

Of the 61 studies, 13 were cross-sectional studies, 11 were randomized control trials, 4 were experimental studies, 5 were clinical trials, and the other 28 were studies and articles to collect general information concerning the three dimensions. Of the 61 studies, ten focused on sleep and sleep disorders, 37 focused on nutrition and its relation to sleep quality, 13 focused on PA and sleep quality, and one focused on the three dimensions altogether.

The extensive review results in an interrelated connection between sleep quality and diet, and sleep quality and PA was found by conducting the actual results found in many studies. Those studies reported that if the individuals followed a healthy diet, did the regular physical activity, and got enough sleep; it would help them avoid the risk of chronic conditions that may interrupt their sleep quality (Watson and Preedy 2020). Other studies showed that the quantity of food could affect sleep quality, but even the food in the diet had effects.

Sleep disorders

Several studies indicate that sleep patterns, such as short sleep periods (<7 h) and long (>9 h), can influence the risk of developing chronic disease (St-Onge et al. 2016a). Short sleep duration has become more scrutinized and associated with an increased risk of type 2 DM, obesity, and cardiovascular disease (St-Onge et al. 2016b). Also, it impairs glucose metabolism, which increases the risk of type 2 DM (Arora et al. 2015). Researchers found a possibility that a short sleep period might impede those body-rebuilding processes usually done during sleep and may lead to behavioural and biological risk factors for developing chronic disease (Broussard and Brady 2010). Biologically, sleep affects circulating levels of the hunger hormones that indicate hunger, leptin, and ghrelin. Ghrelin indicates hunger, while leptin indicates satiety. Sleep deprivation leads to high ghrelin levels and low levels of leptin. Accordingly, the hormonal imbalance of leptin and ghrelin might lead to overconsumption (Arora et al. 2015; Broussard and Brady 2010). Adiponectin, a secretory product of adipose tissue found at low levels in the plasma of obese individuals, is inversely associated with adolescent girls' sleep duration. However, sleep deprivation causes neurons to be activated more in response to food stimuli, which increases the urge to search for food with a high amount of energy, especially those energy-dense foods rich in sugar and fat (Sacks, et al. 2017). Another pathway in which sleep disturbances and

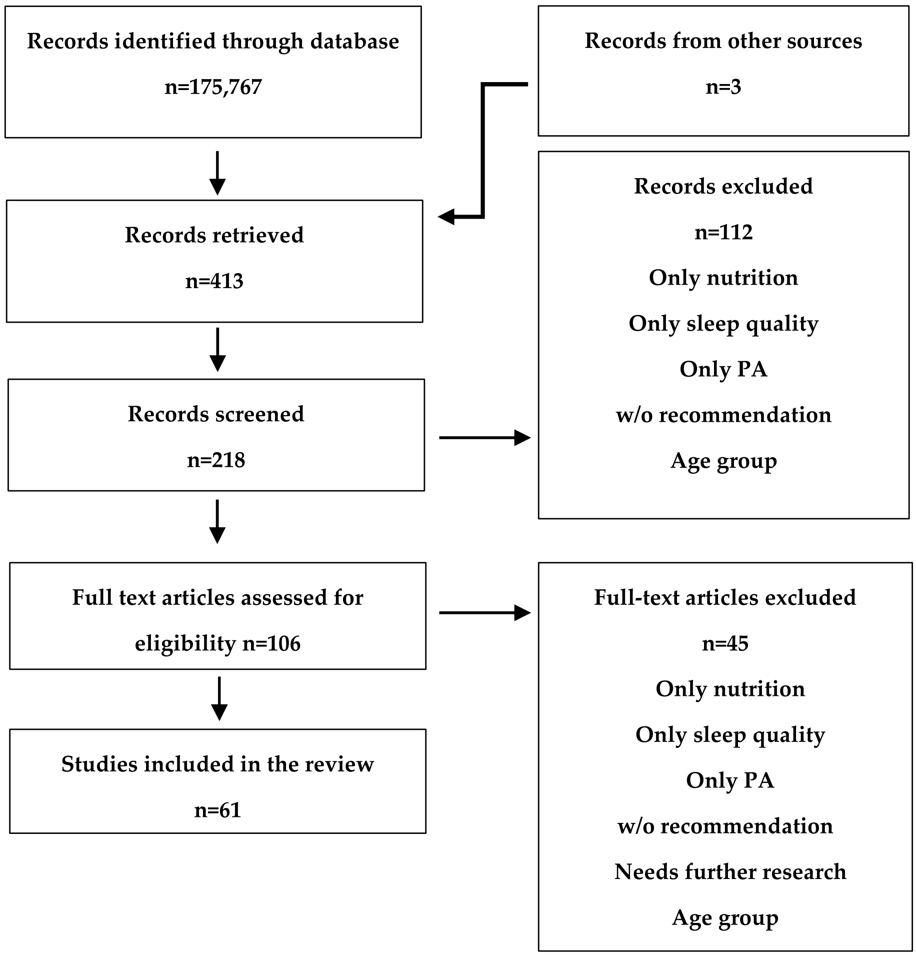

Fig. 1 PRISMA flow diagram

deprivation are caused by metabolic dysregulation over the activation of the hypothalamic–pituitary–adrenal (HPA) axis; it liberates neuroendocrine parameters such as cortisol, resulting in increased glucose and insulin and decreased levels of adiponectin (Frank et al. 2017).

Short sleep duration shows additional irregular consuming habits, including energy-dense, smaller, and more frequent meals through irregular mealtime (Dashti et al. 2015). Suggested behaviour includes more opportunities and time to eat, being psychologically stress-free, increased perceptiveness to dietary meals reward, unrestricted eating, more additional energy required to maintain extended alertness, and shifts in hunger hormones (Bartel et al. 2015). As a result, lack of sleep may stimulate extra energy intake by influencing consumer behaviour and nutritional composition. A well-established relationship exists between higher total energy, fat intake, and short sleep time. The relationship between overeating and sleep has also been well-examined and appears strong (Patel and Hu 2008).

Moreover, longer sleep duration is associated with an increased risk of type 2 DM, obesity, cardiovascular diseases (CVD), depression, and chronic renal diseases in observational studies. In a cross-sectional study, sleep disturbances, such as sleep apnea, are also related to prolonged sleep duration. Indeed, coping with an inferior quality of sleep and longer sleep duration is associated with increased cortisol activity in adolescents (Mrug et al. 2016). Evidence from prospective studies indicates that sleep period changes may increase the risk of CVD, type 2 DM, and metabolic syndrome mortality (Ferrie, et al. 2007; Song et al. 2016). Studies have also revealed that employees encounter regular changes in their work shifts; their sleep patterns cause a lack of physical activity, weight gain, sleep deprivation, increased cortisol production, and increased inflammation (Frank et al. 2017).

In 2014, researchers conducted a cross-sectional study at King Abdul-Aziz Medical City to identify the association between sleep duration and common health issues. The results show that 33.8% reported a short sleep period of fewer than seven hours. The results show that 33.8% reported a short sleep period of fewer than seven hours in the nighttime. The short sleep period was higher in females than males (37.3% vs. 31.4%, $p < 0.01$). The most common health conditions reported were DM (20.8%), BMI of > 30 kg/m^2 (39.1%), depression (4.3%), hypertension with (33.9%), asthma with (17.3%), COPD with (6.6%), and hyperlipidemia with (2.7%). DM was associated with sleep longer than 9 h per night (25.4%, $p = 0.011$) and hypertension (54.2%, $p < 0.01$) (Ahmed, et al. 2017).

Sleep duration of more or less than seven to eight hours a day is associated with DM, CVD, depression, obesity, work failure, car accidents, learning and memory issues, and an increased mortality rate (Sanlier and Sabuncular 2020). Foods and nutrients consumed before bed have a substantial effect on it. Assessing the relationship between sleep quality and nutrient intake is crucial to improve the nutritional factors that quickly affect sleep quality. Some researchers revealed that dietary modification could lead to better sleep quality. Moreover, it has been proposed that macronutrients impact sleep quality and duration. Getting enough hours of sleep may lead to eating healthy choices. However, sleep quality is more important than quantity, indicating that good sleep is a prerequisite for better food consumption (Sanlier and Sabuncular 2020).

Recent epidemiological and cross-sectional studies showed an association between nutrition and sleep period. Nearly most studies have shown that unhealthy choices of foods are associated with shorter sleep periods and inconsistent sleep patterns (Sanlier and Sabuncular 2020). Acceptable sleep periods have been completely associated with health-behavioural patterns such as compliance with a healthy diet among children, adolescents, and adults. Whereas a negative association between short sleep periods and health-related behavioural patterns (Quick, et al. 2014).

Macronutrients

The relationship between macronutrient and sleep duration have been reported in many previous studies; it is known that both meal timing and overall nutrient content affect sleep. Food eaten before bed is linked to sleep disturbances, and the effect of the macronutrient content in the diet on sleep quality is also evident (Arnulf, et al. 2002; Yajima, et al. 2014). Epidemiological studies reveal a positive relationship between food habits and sleep quality (Grandner et al. 2013; Santana 2012). A high intake of fat is related to sleep disturbances, and the Mediterranean diet is associated with fewer insomnia symptoms (St-Onge et al. 2016b). Furthermore, a randomized study about the relationship between a short sleep period and increased dietary intake was conducted on 30 participants, 15 healthy women, and 15 healthy men. Their ages were between 30 to 49 years old; sleep was assessed for two weeks by sleep log and actigraphy, and the result showed that an increase in energy and fat intake caused a reduction in sleep duration (St-Onge, et al. 2011).

Poor sleep experience might be associated with irregular dietary patterns such as consuming energy-rich foods, fats, or refined carbohydrates that meet most energy requirements. They consume fewer vegetables and fruits but more snacks (Sanlier and Sabuncular 2020). Besides sleep duration, bedtime is closely related to food intake (Grandner et al. 2013). Late sleepers have shorter sleep periods, significantly more dietary consumption, and fewer servings of vegetables at night. Regarding macronutrients, people who are late to sleep consume more carbohydrates, fats, and protein at night. Both high and low carbohydrates diets might be associated with changes in sleep periods. The dietary changes in carbohydrates also primarily affect rapid eye movement (REM) sleep (Afaghi et al. 2007). A study of the effects of high carbohydrates diets low in fat or deficient in carbohydrates concerning slow-wave sleep in fourteen healthy men found that low carbohydrates diets could induce increases in slow-wave sleep in the short term ($p < 0.05$) and found similar changes in slow-wave sleep after subjects ate a high carbohydrates diet (Yajima, et al. 2014). After a high carbohydrate diet, slow-wave sleep dropped at the start of the sleep cycle, so the difference in sleep patterns between test meals during the entire sleep period ($p < 0.01$). The researchers report that this drop in sleep at the start of the sleep cycle is connected to carbohydrate oxidation (Sanlier and Sabuncular 2020).

Accordingly, carbohydrate oxidation was found to be more elevated after consuming high-carbohydrate diets than after a high-fat diet, and carbohydrate oxidation was found to be lower during slow-wave sleep and higher during REM sleep. Some researchers have shown that diets with high carbohydrates positively affect delaying sleep, and researchers have found that a diet rich in carbohydrates leads to a shorter latency time than a controlled diet. Furthermore, those diets high in protein had less wakefulness (Lindseth et al. 2013). Several studies showed that subjects with short sleep duration get more additional calories from refined carbohydrates or fat (Grandner et al. 2013). It is believed that after consuming meals low in fat and high in carbohydrates, there is an upsurge in slow-wave sleep duration and a drop in the duration of sleep spent during the REM phase. In this study, drinks with a high level of carbohydrates raised the tendency to sleep duration compared to those with a low level of carbohydrates (Sanlier and Sabuncular 2020). The effect of some foods and drinks on sleep appears due to their content and amount consumed. Foods that contain protein make it easier to fall asleep. Carbohydrates are responsible for a sense of ease and comfort by impacting the level of serotonin. Foods that affect tryptophan availability are two of the most promising sleep-inducing foods in synthesizing serotonin and melatonin. Melatonin synthesis is initiated through the synthesis of 5-hydroxy-tryptophan from tryptophan by tryptophan-5-hydroxylase. Then serotonin is synthesized from 5-hydroxy-tryptophan by 5-hydroxy-tryptophan decarboxylase. Another study revealed a link between lack of sleep associated with eating energy-rich foods (for example, foods high in fats and refined carbohydrates), insufficient consumption of vegetables and fruits, and irregular eating habits (Sanlier and Sabuncular 2020).

A cross-sectional study showed that dietary protein intake relates to sleep quality, period, and pattern. Protein intake has a positive association with sleep period, and those who consumed less protein have more insomnia episodes than those who consumed more (Zhou et al. 2016). One study studied the effect of a diet consisting of high carbohydrates, fat, and protein compared to a control diet consumed daily for four days. The high protein diet lowered the number of awakenings compared to the control diet. The effect of macronutrients on sleep is demonstrated by tryptophan, the precursor to serotonin and a sleep-inducing agent. High glycemic index carbohydrates can increase tryptophan turnover. So, foods with high glycemic indexes are expected to stimulate sleep by increasing tryptophan and serotonin levels in the brain. Different pathways metabolize tryptophan to serotonin, melatonin, and niacin in the brain. It is also known that sleep deprivation reduces inhibitory control, stimulates negative moods, and affects the hormones that regulate appetite (Sanlier and Sabuncular 2020).

A high glycemic index (GI) diet is linked to stroke, cancer, and some chronic diseases (Yu, et al. 2016; Kabat, et al. 2008; Barclay, et al. 2008). Tryptophan competes with large natural amino acids in transport to the brain, so this change in the ratio may increase tryptophan in the brain. It is possible to notice the increase of serotonin levels in the brain after consuming carbohydrates; this mechanism explains the observations that a high-glycemic-index diet aids the sleep cycle (Afaghi et al. 2007). Also, it has been shown that diets with a high GI content stimulate inflammatory immune responses and lead to a rotation of the gut microbiome that may have an excellent effect on sleep quality (Zhou et al. 2016).

The essential amino acid tryptophan has a direct and essential impact on brain neurotransmitters. It functions as a precursor to melatonin and serotonin, which means it has a connection to improving sleep quality and regulating circadian rhythms, and it can be obtained from the diet (Lindseth and Murray 2016). Moreover, tryptophan intake in breakfast may be required for enhancing sleep initiation due to a high amount of serotonin-synthesized plasma melatonin in the pineal gland, which is synthesized again in the pineal gland during the day after the breakfast is consumed for several hours (Watson and Preedy 2020).

A comparative study was conducted to assess the impact of tryptophan-enriched cereal intake on improving sleep and showed that it is a facilitating and effective tool to improve sleep (Bravo, et al. 2013). Another study showed a modest but significant impact of tryptophan ($p < 0.01$) and niacin ($p < 0.01$) on sleep quality and insomnia (Verster et al. 2015). Although, an experimental study about the effect of light exposure and tryptophan-rich breakfast during the daytime on the secretion of melatonin at night was conducted on 40 males aged 22–31 years old and lasted for five days and four nights. The results showed that bright light exposure and a tryptophan-rich breakfast during the daytime encouraged melatonin secretion at night (Fukushige, et al. 2014).

Additionally, a study of 40 patients with insomnia who had received gamma-aminobutyric acid (GABA), which is a bioactive amino acid, for four weeks reported declined sleep latency and improved sleep efficacy. Glutamine is a nonessential amino acid involved in GABA synthesis and is considered a sleep inducer. Tyrosine is also a nonessential amino acid; its metabolite is norepinephrine. A study reported that 150 mg/kg of tyrosine supplementation following sleep enhances vigilance, working memory, and reasoning (Zhao et al. 2020). However, the association between tyrosine supplementation and sleep quality must be well studied. Two randomized controlled diet studies were conducted to evaluate the effect of a high-protein diet on sleep quality in obese and overweight adults revealing that excellent portion intake from protein enhances their sleep quality ($p < 0.01$) (Zhou et al. 2016). On the contrary, another study conducted to assess the influence of a low-calorie, high-protein diet on OSA symptoms and severity in obese adults, which increases the protein intake while following a low-calorie diet, showed no further positive impacts on OSA ($p < 0.001$) (Melo 2021).

Snacks rich in branched-chain amino acids (BCAA) are helpful for cirrhotic patients who do not have explicit encephalopathy but have sleep problems. BCAA supplementation improves sleep trouble; amino acid supplementation without BCAA-induced sleep disturbance. Neurosteroids, which have been proposed to be associated with hepatic encephalopathy, have been known to cause substantial sleep/wake cycle changes. BCAAs can work as psychotropic substances directly working on the central nervous system. OSA and restless legs syndrome are also known as causes of sleep trouble in patients with chronic liver disease (Watson and Preedy 2020).

Dietary fat showed great importance in regulating the body system. Several studies have shown the effect of different kinds of fat on the sleep–wake cycle. It has been proven for the first time that a high-fat diet affects the circadian cycle among mice. The study was conducted on mice. Their objective was to show that alterations in diet affected the circadian clock. This study showed that mice on a high-fat diet had longer and higher activity levels, resulting in less sleep (Kohsaka, et al. 2007).

Similarly, a study on humans was conducted to determine whether there was an association between fat diet intake and sleep period. A study was conducted in 2002 in Jiangsu, China, by collecting data through a national survey. It concluded that individuals with higher fat consumption had fewer hours to sleep (less than seven hours) and suffered decreased sleep duration (Shi et al. 2008). On the contrary, a study has shown that individuals who consumed a high-fat diet had better sleep quality. The study aimed to evaluate the relationship between serum fat on sleeping disturbances. A negative correlation was found between the fat concentrations and the level of sleep disturbances (Irmisch et al. 2007). Even though previous studies showed positive and negative results regarding fat consumption, they claimed no relation between fat content in food and sleep (Landström et al. 2000).

Saturated fatty acids (SFAs) have a particular effect on body weight and health conditions. It has been proven in many studies that SFAs are a risk factor for many diseases, mainly cardiovascular disease (Sacks, et al. 2017). Consuming sugars and saturated fat have been associated with short sleep duration and fewer recovery and ad libitum diets by the inpatient sleep interruption study (Frank et al. 2017). However, studies examining the relationship between SFAs and sleep quality are rare—a randomized clinical trial of patients with 26 normal body weight adults on a controlled diet. The study's objective was to find the dietary patterns that affect sleep if sleep differs from a controlled diet. They discovered that SFAs with a low-fiber diet are associated with less restorative sleep ($p < 0.05$) (St-Onge et al. 2016a).

Cholesterol also affects sleep quality, as a study has shown that a high cholesterol-containing diet can cause non-restorative sleep (Grandner et al. 2014). Although, more studies have shown that high and low cholesterol consumption can negatively affect the duration and quality of sleep (Santana 2012; Gangwisch, et al. 2010).

Polyunsaturated fatty acids (PUFA) have a good reputation for health in general, and it is known that omega-3 PUFA helps prevent cardiovascular disease (Aung, et al. 2018), and stroke (Saber, et al. 2017). A previous study on hamsters examined the role of omega-3 regarding melatonin rhythms; the aim was to find the effect of an omega-3 PUFA deficit diet on melatonin levels. They concluded that deficiency in omega-3 PUFA caused a disturbance in sleep by affecting the melatonin rhythm (Lavialle, et al. 2008). Additionally, fatty acids have shown several effects on sleep quality. A clinical study about the association between fatty acids and sleep quality was conducted on 63 obese patients (54 male and 9 female) aged 18 to 65. The unsaturated fatty acid was positively correlated with total sleep time. The study showed a positive effect of omega-3 PUFA on sleep quality among obese individuals with OSA. This study aimed to determine the relationship between sleep quality and gluteal adipose tissue fatty acids. It resulted in a significant positive relation ($p < 0.05$) between omega-3 PUFA and sleep quality, REM sleep, and slow-wave sleep (Papandreou 2013).

On the other hand, a case report suggested the opposite regarding omega-3 PUFA. The study claimed that high eicosapentaenoic acid (EPA) fish oil supplements are a possible cause of sleep disturbance in successfully depression-treated patients. Sleep disturbances were diminished once the supplements were stopped (Blanchard and McCarter 2015). Table 1 summarizes some studies with various methods in different age groups that were conducted to examine the relationship between sleep quality and energy intake.

Micronutrients

Micronutrient intake has additionally been suggested to affect sleep patterns (Frank et al. 2017). Vitamins and minerals affect the quality of sleep and are interconnected to the effect on melatonin production. Exogenous melatonin is safe and beneficial in enhancing quality and sleep–wake cycles (Sanlier and Sabuncular 2020). Based on many studies, vitamin B12 and vitamin B12 (thiamine) have been consumed at higher levels in people who sleep regularly than those with insomnia. Besides, several well-designed studies support valerian (A herb that is mostly used to treat sleeping disorders, especially insomnia) as an effective supplement for improving sleep patterns (Watson and Preedy 2020).

Pyridoxine deficiency is thought to increase the risk of mental disorders and disturb sleep. Vitamin B12 is also believed to affect the shortening of sleep duration, wakefulness rhythm, and sleep propensity's circadian rhythm. Additionally, it is believed to reduce night-time leg cramps. Some minerals and vitamin deficiencies can disturb sleep (Sanlier and Sabuncular 2020).

The development of daytime neurocognitive impairment may be related to Vitamin D deficiency. It may advance the risk of developing OSA by promoting chronic rhinitis, decreased airway pressure, and enlarged

Table 1 Summary of studies examined the relationship between sleep quality and energy intake

Study Design	n	Age (years)	Results	References
Hormones and glucose samples of 24 h were collected, six days of four hours of sleep followed by six days of 12 h of sleep. Energy intake was evaluated	11 males	18—27	No significant difference in energy intake between long and short sleep duration. A lower level of leptin	(Spiegel et al. 2004)
Sleep laboratory 5.5 or 8.5 h/day sleep for 14 days, ghrelin levels, calories of consumed foods, serum leptin levels, and total energy expenditure (TEE) were measured	11 individuals	35 – 49	No significant differences in the serum leptin levels, ghrelin levels, and TEE	(Nedeltcheva et al. 2009)
24 h food recall was documented and compared to sleeping less than eight hours or more	240 adolescents	16—19	Those who had more energy, fat, and snacks intake had less than eight hours of sleep	(Weiss et al. 2010)
Sleep was evaluated for two weeks by sleep log and actigraphy. The first week was four hours of sleep, the second week was nine hours of sleep, and the fifth-day food intake was documented	15 females, 15 males	30 – 49	Participants consumed more calories during the short sleep duration	(St-Onge, et al. 2011)
The participants self-reported eating behavior, sleep duration, and alcohol consumption	703 individuals	18—64	Higher calorie intakes from alcohol were recorded during sleep of fewer than six hours	(Chaput et al. 2012)
Obesity therapy was used for six months, the 24-h recall conducted the nutrition assessment, and sleep was evaluated at baseline and post-therapy	41 obese children	20—50	More extended sleep time results in less calorie intake. Each one-hour sleep increase resulted in 186 cal less calorie intake	(Clifford, et al. 2012)
Five-day, five-hours, and 9-h sleep duration were used. The calorimeter method calculated energy expenditure according to carbon dioxide production and oxygen consumption	16 individuals	Mean age 22.4	Insufficient sleep increased TEE by 5%. It was reported that insufficient sleep impacts hunger by changing the peptide YY, ghrelin, and leptin hormone levels	(Markwald, et al. 2013)

adenoid tonsils. More research is required to determine the complex relationship between regular sleep duration and vitamin D (Watson and Preedy 2020).

A double-blind clinical trial study with 89 adult participants with sleep disorders, aged between 20–50-year-old, divided into two groups: intervention with 50 000-unit of vitamin D supplement and placebo. The study showed that vitamin D improved sleep quality and reduced sleep latency with ($p<0.05$) instead of increasing sleep duration (Majid et al. 2018). Moreover, vitamin C, found in citrus fruits and vegetables, protects the brain from the memory loss associated with sleep deprivation. Also, vitamin B6 (pyridoxine) is widely found in food items that act as an enzyme in hundreds of enzymatic reactions (Zhao et al. 2020).

Iron plays a significant role in many enzymatic processes. An adequate amount of iron in the central nervous system is essential for dopamine receptors' normal functioning, where tyrosine hydroxylase controls dopamine synthesis. Iron and tetrahydrobiopterin are tyrosine hydroxylase cofactors. Also, iron is associated with the functions of opioid peptides, GABA, and serotonin (Partinen et al. 2014).

Several studies have reported that magnesium enhances melatonin secretion in the pineal gland by promoting the N-acetyltransferase activity of serotonin as the central enzyme in melatonin synthesis, which can enhance sleep quality. Lack of vitamins such as B vitamins or minerals such as magnesium might negatively impact sleep. Physiologically, this relies on the synthesis impacts of melatonin and serotonin (Sanlier and Sabuncular 2020) (Table 2).

Physical activity

The impact of PA on sleep duration and quality studies conflicted on this subject. Some concluded that PA positively affected relieving stress and improved sleep quality (Hori et al. 2016). In contrast, other studies have concluded negative results (Choi and Sohng 2018). It is well known that PA affects sleep quality positively (Benloucif, et al. 2004). Most people reported sleeping better if they did any activity during the day. Several studies have shown that people with medium to high PA levels had better sleep quality (Benloucif, et al. 2004; Yang et al. 2012).

Moreover, A prospective open-label study has shown that there is evidence that daily walking was beneficial in improving subjective sleep quality in both active and inactive individuals. This study's samples were 490 healthy individuals; they were sectioned into two groups, 214 were active, and 276 were inactive. After four weeks of walking intervention, it was found that the Pittsburgh Sleep Quality Index (PSQI) had improved along with sleep duration and latency (Hori et al. 2016).

A study examined whether exercise training improved sleep quality for adults and older adults with sleeping disorders. The study targeted 305 adults over 40 years old with sleeping disorders using self-reported PSQI or polysomnography. The study intervened with a formal aerobic or resistance training program. It was conducted significantly reduce sleep latency for the exercise group. However, the results did not differ in sleep efficiency, sleep disturbance, or daytime functioning (Yang et al. 2012).

Although, a prospective open-label study concerning improving subjective sleep by walking intervention examined a sample of 490 healthy workers and divided them into two groups; 276 subjects without PA habits and 214 subjects with PA habits. A walking intervention with a target of 10,000 steps every day for a month was completed. PSQI measurements were administered twice, before and after the study. The results showed that the walking intervention improved the subjects' PSQI scores in both groups. It also improved sleep latency and duration (Hori et al. 2016).

More studies were interested in finding a positive effect on subjective and objective sleep quality. An experimental study aimed to observe the impact of a 12-month moderate to intense PA intervention on subjective and objective sleep quality. A sample of 66 inactive participants aged 55 or older with mild to moderate sleeping problems was given a 12-month program to increase their PA. The study improved some subjective and objective sleep dimensions. It resulted in less impaired PSQI global sleep quality scores ($p=0.01$) (King, et al. 2008). However, a systematic study demonstrated in 2019 showed no effect of PA on sleep quality or quantity, and the researchers studied the latest eight years of publications. They reviewed and analyzed the selected researchers systematically and concluded 14 studies. Comparing the PA and sleep quality was based on moderate to vigorous PA levels. They found that some studies had a negative result with no effect of PA on sleep quality. They also concluded that PA could be a modifiable risk factor for improving sleep in further studies (Wang and Boros 2021).

Many studies have agreed upon the positive effect of PA on sleep quality. However, negative results still existed. A study has shown no noticeable effect of PA on sleep quality. A floor-seated exercise program (FSEP) was implemented on 77 older adult participants. Sleep quality had no significant effects (Choi and Sohng 2018).

Table 2 Shows studies that were conducted to assess and analyze the effect of macro- and micronutrients as interventions for sleep disorders

Study Design	Participants	Component	Outcomes	Reference
Laboratory sleep evaluation	Young males	low-fat / High-carbohydrate vs. high-fat / low-carbohydrate or balanced isocaloric diets	Less none-REM sleep	(Phillips, et al. 1975)
Laboratory sleep evaluation	Young males	Low-glycemic-index vs. high-glycemic-index meals	Sleep onset shortening	(Afaghi et al. 2007)
Cross-sectional	Adults	High-fat intake	Reduced sleep period	(Shi et al. 2008)
A parallel, randomized, controlled trial	Obese males and moderate to severe OSA	Liquid, very low-calorie diet pursued by gradual normal diet vs. usual diet	Improved OSA	(Johansson, et al. 2009)
Randomized clinical trial, crossover intervention	In-patient normal BMI adults	High-sugar intake, low-fiber, and high-saturated fat vs. ad libitum	Wakefulness and less restorative sleep	(St-Onge et al. 2016a)
Clinical trial, double-blind	Young adults	High tryptophan diet vs. low tryptophan diet	Less level of sleepiness and sustained attention the next morning	(Markus et al. 2005)
Clinical trial, double-blind	Elderly with insomnia in a long-term care	Diets supplement with zinc, magnesium, and melatonin vs. placebo	Improved sleep time and quality	(Rondanelli et al. 2011)
Cross-sectional	Adults	Deficiency in the following: selenium, vitamin B1, magnesium, phosphorus, iron, zinc, and folate	Short sleep period	(Grandner et al. 2013)
Cross-sectional	Adults	Deficiency in the following: vitamin C, alpha-carotene, lycopene, vitamin D, calcium, and selenium	Difficulty to sleep and sleep maintenance	(Grandner et al. 2014)
Clinical trial	Adults with sleep troubles	Vitamin D supplement vs. placebo	Enhanced sleep period and quality	(Majid et al. 2018)
Randomized trial, double-blinded	Adults	High zinc food vs. astaxanthin zinc food or placebo supplemented with astaxanthin oil and zinc-enriched yeast or placebo	Improved sleep quality	(Saito et al. 2017)
Randomized trial, placebo-controlled	Elderly	Fermented milk drink vs. placebo	Improved sleep quality	(Yamamura, et al. 2009)
Randomized trial	Elderly with chronic insomnia	Tart cherry juice drink vs. placebo	Decline in insomnia severity	(Pigeon et al. 2010)
Laboratory sleep evaluation	Adults and elderly	Jerte Valley cherry cultivars	Improved sleep time	(Garrido, et al. 2010)
Self-controlled diet	Adults with self-reported sleep disruption	Kiwi	Improved sleep onset and quality	(Lin et al. 2011)
Randomized trial, placebo-controlled	In-patient adult males	Atlantic salmon vs. alternative meal, i.e., beef, chicken, and pork	Better functioning life	(Hansen, et al. 2014)
Cross-sectional	Adults and elderly	Oily fish foods	Improved sleep quality	(Brutto et al. 2016)

Conclusions

Studies showcasing the association between nutrition, sleep quality, and PA have been discussed in this review. These associations were concerned with the positive and negative correlations that were regarded with those studies. Several studies examined the effect of macro- and micro-nutrients on sleep parameters. Some studies proved that there was a positive correlation between nutrient intake and quality of sleep.

Nutrients such as tryptophan-rich foods, antioxidants, melatonin, micronutrients, and fruits positively affect sleep quality. Moreover, the leading cause of sleep restriction was excessive energy intake. Specifically, short sleep duration was mainly correlated with excessive energy intake of carbohydrates and fat. Nevertheless, to what extent diet can impact sleep remains to be seen. For this reason, some diet nutrients and models can be utilized as sleep modulators. More studies about the effect of eating habits and the timing of meals should be conducted to understand the precise impact of nutrition on sleep quality.

In conclusion, the results were mainly positive in PA's effect on sleep duration and sleep onset regarding physical activity. The relationship was as follows: wherever the exercise rate increased, the amount of sleep improved. However, some studies claimed that PA did not affect sleep enhancement. Those studies needed further investigation on their side.

Strengths and limitations

The primary strength comes from its focus on diet and PA as an intervention to enhance sleep quality by focusing on diet and PA intervention rather than searching broadly for all sleep quality interventions to enhance (such as medication and other therapy). The lifestyle changes "nutrition and PA" generally have more long-term benefits than the different solutions and minor or no side effects. It also benefits life quality, mental health, work performance, and social life. Moreover, no national study shows that the prevalence of sleep disorders in Saudi Arabia can be generalized. The limitations of this work were the focus on the studies that involved adults as samples. Besides, the BMI value was not considered in the studies' inclusion and exclusion.

Suggestions for future research

The main gap found during the research process was the significant need for studies reporting the relationship between those three dimensions (nutrition, PA, and sleep quality). There was even no questionnaire conducted to assess the relationship between the dimensions. Moreover, there needed to be more clinical trials with restricted instructions and with accurate outcomes. This was a scoping review aimed at identifying the beadth and scope of research on the topic. It also opens new avenues for future research and may serve as a source of hypotheses for future quantitative research.

Abbreviations

BCAA	Branched-Chain Amino Acids
BMI	Body Mass Index
COPD	Chronic Obstructive Pulmonary Disease
CVD	Cardiovascular Diseases
DM	Diabetes Mellitus
EDS	Excessive Daytime Sleepiness
EPA	Eicosapentaenoic Acid
FSEP	Floor-Seated Exercise Program
GABA	Gamma-Aminobutyric Acid
GI	Glycemic Index
GSD	General Sleep Disturbance
HPA	Hypothalamic-Pituitary-Adrenal
OSA	Obstructive Sleep Apnea
PA	Physical Activity
PSQI	Pittsburgh Sleep Quality Index
PUFA	Polyunsaturated Fatty Acids
REM	Rapid Eye Movement
SDL	Saudi Digital Library
SFA	Saturated Fatty Acid
TEE	Total Energy Expenditure

Authors' contributions

N.W.A designed the review and performed the literature analysis. N.W.A, N.A, M.H.A, B.S.A, and M.S.A wrote the manuscript. N.W.A and O.M.G critically revised the text and gave a substantial scientific contribution. N.W.A and O.M.G review and formatting. All authors have read and agreed to the published version of the manuscript.

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