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REVIEW

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The effect of mediterranean diet and chrononutrition on sleep quality: a scoping review

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Abstract

Background The relationship between diet and sleep quality is intricate, with growing evidence suggesting that dietary patterns and meal timing (chrononutrition) can significantly influence sleep outcomes. This scoping review aims to compare the impact of Mediterranean diet and chrononutrition methods on sleep variables, including sleep quality, duration, and efficiency. While the Mediterranean diet is renowned for its health benefits in chronic diseases, chrononutrition focuses on how the timing of food intake affects health and circadian biology.

Methods Literature search following PRISMA guidelines using PubMed and Google Scholar focused on Mediterranean diet and chrononutrition effects on sleep quality. Studies assessed sleep quality using subjective methods like Pittsburgh Sleep Quality Index, analyzing data on study type, sample size, age group, diet, duration, sleep parameters, and outcomes.

Results Thirty three studies met inclusion criteria, 24 focusing on Mediterranean diet and 9 on chrononutrition. Among the 24 Mediterranean diet studies, most of which were observational studies, 17 reported a positive association between adherence to Mediterranean diet and improved self-reported sleep quality, while the remaining studies found no significant association. In contrast, evidence supporting the positive effects of chrononutrition on sleep quality was limited, with only two out of nine studies having found improvement in sleep quality.

Conclusions Mediterranean diet demonstrates a more consistent and positive influence on sleep quality compared to chrononutrition. However, a limitation of review is that the reviewed Mediterranean diet studies were mainly cross-sectional or observational, while the reviewed chrononutrition studies were mainly interventional trials. Larger interventional clinical trials are needed to determine optimal dietary strategies and meal timing for promoting healthy sleep.

Keywords Mediterranean diet, Chrononutrition, Time-restricted eating, Intermittent fasting, Alternate day eating, Sleep quality, Pittsburgh Sleep Quality Index (PSQI)

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Introduction

Epidemiologic evidence suggests that inadequate sleep quantity and quality are linked to higher risks of obesity, cancer, cardiovascular issues, diabetes, and mortality [1–3]. Long-term poor sleep quality has been associated with cognitive decline, including dementia and Alzheimer's disease [2]. The impact of diet and eating habits on sleep quality is profound, and when and what we eat can influence our sleep patterns. For example, consuming heavy or spicy meals and caffeine close to bedtime may lead to discomfort and indigestion, disrupting sleep [4, 5]. On the other hand, incorporating sleep-friendly foods, such as milk, fruit, fish, and vegetables and those rich in tryptophan and magnesium, can promote relaxation and better sleep [3, 6, 7]. Additionally, maintaining regular mealtimes helps regulate the body's internal clock, reinforcing a consistent sleep-wake cycle [8].

Although the relationship between diet and sleep quality is uncertain, adhering to healthy diets such as the Mediterranean diet (MD), the Dietary Approaches to Stop Hypertension (DASH) diet, and a whole food plant-based diet may yield positive outcomes for both sleep quality and daytime sleepiness while reducing insomnia symptoms [9–12]. Renowned for its rich flavors, the MD is considered one of the healthiest dietary patterns. It primarily includes whole grains, vegetables, legumes, nuts, fish, fruits, and plant-based fats while avoiding or having small amounts of red meat. MD has evolved into a fundamental diet in both the prevention and management of chronic noncommunicable diseases [13]. One review of meta-analyses examining the relationship between adherence to the MD and 37 different health outcomes identified reductions in the risk of overall mortality, cardiovascular diseases, coronary heart disease, myocardial infarction, overall cancer incidence, neurodegenerative diseases, and diabetes [14]. A recent comprehensive review study demonstrated that higher adherence to the MD is associated with a lower likelihood of experiencing poor sleep quality, inadequate sleep duration, excessive daytime sleepiness, or insomnia symptoms [1].

The complex relationship between diet and sleep underscores the importance of considering not only what we eat but also when we eat. The relationship between food and the circadian clock system, known as *chrononutrition*, explores how the timing of food intake contributes to maintaining health and rapidly resetting our internal clock [5, 15]. Chrononutrition posits that aligning mealtimes with the body's natural rhythms can improve health outcomes [5]. By understanding and applying the principles of chrononutrition, individuals can enhance their metabolic health, potentially prevent chronic diseases, and improve their quality of life [5]. Chrononutrition encompasses a range of dietary methods and terminologies, including time-restricted eating/feeding (TRE/TRF), intermittent fasting (IF), time-based nutrition, and temporal eating/nutrition. In recent years, IF has gained popularity as a viable dietary strategy for weight loss [16]. IF alternates between periods of eating and fasting, with fasting periods typically lasting anywhere from 10 to 24 hours . Similarly, TRE focuses on eating during specific period daily (typically within a 4- to 12-hour window) and abstaining from food for the remainder of the day; this time restricted diet method has gained popularity in recent years [16]. In contrast, Alternate Day Fasting (ADF) involves alternating between a 'fast day,' where intake is limited to 0–600 kcal, and a 'feast day,' where one can eat freely [17].

Meanwhile, chronotype refers to an individual's natural inclination toward being a morning person, evening person, or somewhere in between. This biological predisposition influences daily activity patterns, sleep-wake cycles, and overall energy levels throughout the day. Morning types are early risers who function best in the morning, while evening types are more active and alert later in the day. Intermediate types fall between these two preferences. Chronotype is not only associated with sleep-wake preferences but also impacts lifestyle behaviors, dietary habits, and health outcomes. For instance, one cross-sectional study investigated the association between chronotype and adherence to the MD in middle-aged Italian adults found that evening chronotypes were more likely to follow unhealthy lifestyles, engage in less physical activity, and have lower adherence to the MD compared to morning and intermediate chronotypes [18]. These findings emphasize the importance of incorporating chronotype considerations into dietary and lifestyle interventions to promote healthier behaviors across diverse populations.

In a pioneering study, Gill and Panda [19] reported improvements in sleep quality associated with TRE. However, subsequent investigations have presented mixed results regarding the strength of this association. For instance, while some studies supported TRE's potential benefits for sleep [20–28], others, like Fitzgerald et al. [29], indicated no significant difference between the effects of IF and daily calorie restriction on sleep quality. While some studies proposed no direct link between diet and sleep, others indicate that stronger compliance to MD correlates with various markers of improved sleep quality and duration [13, 30].

The relationship between diet and sleep is bidirectional; poor sleep negatively affects dietary habits, and an unhealthy diet adversely impacts sleep. Circadian misalignment due to irregular sleep and poor dietary choices has also been observed and can increase risk of chronic diseases [31]. Both dietary patterns and meal timing have emerged as factors that can influence sleep quality. This scoping comparative review examines the effects of MD and chrononutrition on sleep variables, including duration, efficiency, and architecture.

Materials and methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement and flow diagram were used to describe the study selection process for this article [32]. We conducted the systematic electronic literature search in PubMed and Google Scholar from their inception of the research to December 31, 2023. The following keywords were used individually and in combination: "Sleep" OR "Sleep quality" OR "Mediterranean Diet" OR "Chrononutrition" OR "Time-restricted diet" OR "Time-restricted feeding" OR "Intermittent fasting" OR "Alternate day eating" OR "Temporal eating" accompanied by "Sleep Deprivation" OR "Sleep efficacy" OR "Sleep duration" OR "Sleep disturbance" OR "Sleep quality index" OR "Sleep impairment". All keywords were based on MeSH and non-MeSH terms, ensuring comprehensive coverage of the relevant topics. The combination of terms was based on a systematic approach aimed at capturing all possible variations in the literature related to the intersection of diet, time-restricted eating, and sleep quality. Prospective/retrospective clinical trials, and cross-sectional studies were considered for the review. The articles found using these methods were chosen based on specified inclusion criteria: (1) studies exploring the effects of MD and chrononutrition on sleep as both exposure and outcome comprised both observational and interventional studies with controlled trials or single-arm studies without a control group; (2) studies assessing subjective sleep quality using self-reported questionnaires, such as the Pittsburgh Sleep Quality Index (PSQI); and (3) studies examining 10 or more healthy participants of all age groups (adolescents, young adults, adults, and older adults). The selection of exclusion criteria ensured that the selected articles were controlled and validated. Articles meeting any of the following criteria were excluded: 1) studies including participants with known sleep disorders, such as obstructive sleep apnea, insomnia, narcolepsy, restless leg syndrome, and parasomnia; 2) studies exclusively evaluating a single sleep parameter (e.g., sleep duration, sleep latency, sleep efficacy or symptoms of insomnia); 3) studies with incomplete interventions or durations of less than 1 week; 4) studies assessing sleep quality via objective methods; and 5) non-peer-reviewed, non-English, and theoretical articles.

We extracted information about study type, sample size, age group, diet (type and frequency), study duration, sleep parameters, and study outcomes. Manual data extraction was done using Excel spreadsheet software (Microsoft Corporation). The investigators did not use blind methods when collecting and examining data.

Results

In this scoping review, we focused on studies assessing the effects of MD and chrononutrition on sleep quality. As shown in Fig. 1, initial database searches yielded 17,369 studies on MD and 24,032 studies on chrononutrition. Once duplicates and irrelevant articles were excluded and titles and abstracts were reviewed, 389 full-text articles were retrieved for further evaluation, with 47 articles meeting inclusion criteria. A further 14 articles were excluded due to improper intervention protocol ($n = 5$) and lack of sleep quality data ($n = 9$), leaving 33 studies for review (24 on MD and 9 on chrononutrition).

Table 1 [33–56] and 2 [20–28] contain details about the characteristics of the studies included. MD research spanned Italy, Greece, UAE, Spain, Iran, Turkey, Chile, and Sweden, while chrononutrition studies were conducted in Australia, USA, and Germany, showing diverse study populations. Included studies consisted of parallel-arm randomized controlled trials (RCTs; $n = 7$), cross-sectional studies ($n = 17$), and single-group clinical trials ($n = 5$). Sample sizes ranged from 22 to 23,829 for MD studies and 19 to 116 for chrononutrition studies. Intervention duration ranged from 16 weeks to 2.8 years (median years for follow up) for MD studies and 4 weeks to 24 weeks for chrononutrition studies.

Many studies predominantly utilized the PSQI to measure sleep quality, yet alternatives like other self-reported questionnaires were also employed. One particular study measured sleep quality using a visual analogue scale (VAS) that spans from 0 (representing the poorest sleep quality) to 100 (indicating optimal sleep quality), whereas another employed the myCircadianClock (mCC) app to evaluate morning sleep quality [24, 28]. Another study utilized the Sleep Index II, comprising 12 self-reported items, with scores ranging from 1 to 54; here, higher scores denote more severe sleep issues [41]. Various studies have opted for different self-reported questionnaires instead of the PSQI [34, 52, 54, 55].

Mediterranean Diet (MD) adherence was quantified using scores based on scientific literature, encompassing various scoring systems like the MedDiet Score and the Mediterranean diet Quality Index for children and adolescents (KIDMED). Higher scores indicate stronger compliance with MD guidelines or the MD pyramid [57].

Research consistently shows that MD is associated with improved sleep quality across different demographics (Table 1). Out of 19 cross-sectional MD studies, 14 observed a significant positive correlation between MD adherence and enhanced self-reported sleep metrics such as reduced PSQI scores across diverse study cohorts where higher scores on the PSQI are indicative of poorer sleep quality [33, 36–38, 41, 42, 44, 45, 49–53, 55]. The remaining studies present a spectrum of findings: three detected no significant connection [39, 40,

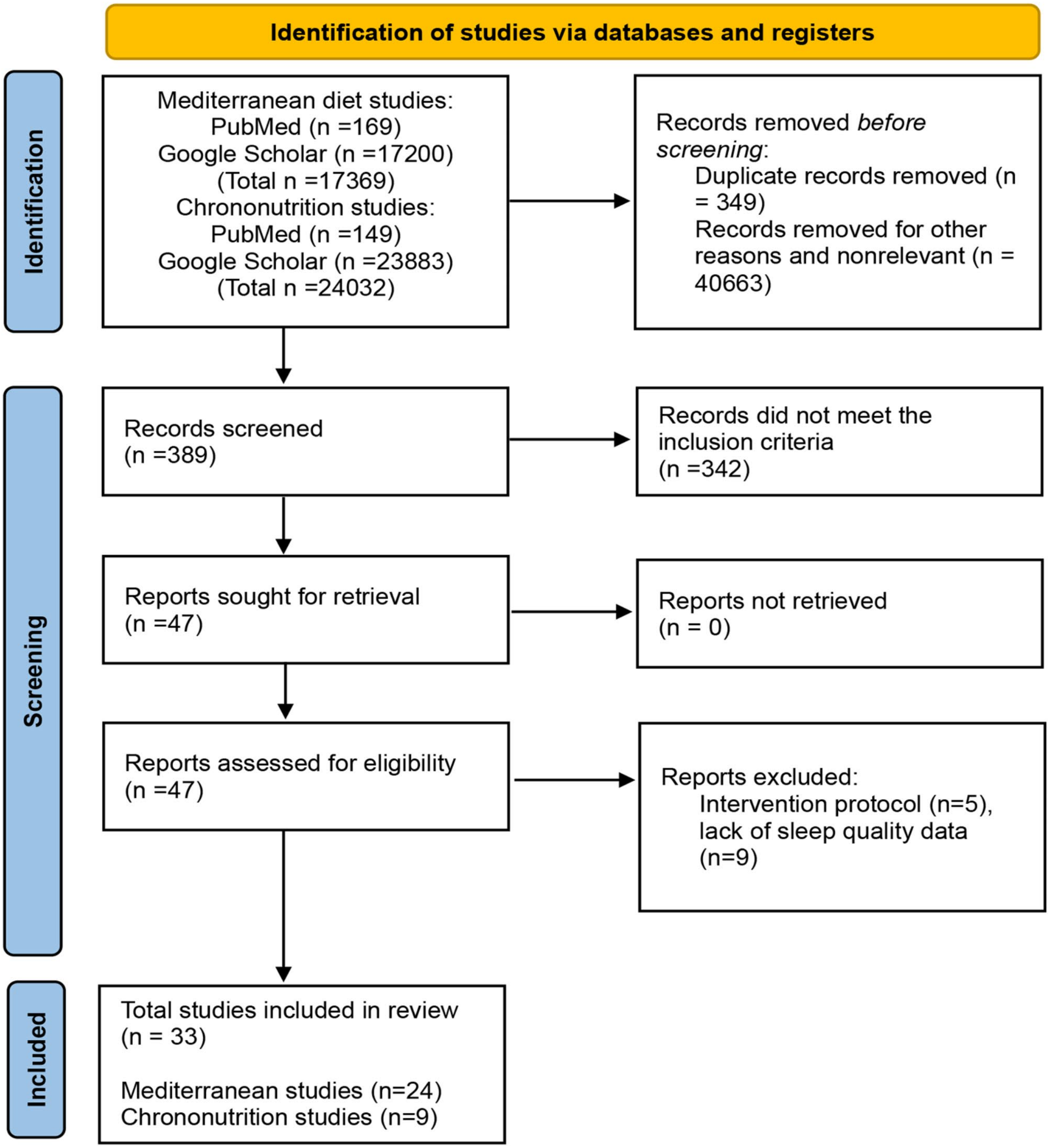

Fig. 1 PRISMA flow diagram depicting the search strategy and study selection process

54], one identified improvement in subjective sleep quality only [46], and another found MD benefits were significant in men but not in women [48]. Among three RCTs, only one—focusing on pregnant women—demonstrated a decrease in poor sleep quality within the MD group compared to a control group receiving standard prenatal care [43]; the other two showed no benefits [47, 48]. Additionally, two longitudinal studies documented sleep quality improvements after extended follow-up periods [34, 56].

While most MD-related research was cross-sectional, a few explored the diet's impact in different adult demographics [34, 35, 43, 47, 56]. One study contrasted two MD patterns with varying red meat intakes—500 g

Table 1 Mediterranean diet and sleep quality

Reference	Study design (duration)	Participants (sex)	Age group	MD assessment tool/interventions	Sleep assessment tools	Results[a]
Mediterranean Cross-Sectional Studies						
Mamalaki et al. (2018) [41]	Cross-sectional study	1,639 (M, F)	72.7 ± 5.7 years	MedDietScore	Sleep Index II	• Sleep quality was positively associated with MD adherence ($p < 0.001$). • Participants with low MD adherence reported worse sleep quality compared to those with high MD adherence in those ≤ 75 years of age, but not in those > 75 years of age.
Godos et al. (2019) [38]	Cross-sectional study (MEAL study)	1,936 (M, F) urban population	≥ 18 years	MEDI-LITE	PSQI	• Higher MD adherence significantly improves sleep quality, increasing odds by 82% (OR 1.82, 95% CI 1.32–2.52, $p < 0.001$).
van Egmond et al. (2019) [54]	Cross sectional study (Uppsala Longitudinal Study of adult Men)	970 (M)	71.0 ± 1.0 years	mMDS	Self-made questionnaire	• There was nosignificant link between MD adherence and subjective sleep initiation/maintenance ($p = 0.32$ and $p = 0.57$, respectively).
Adelantado-Renau et al. (2019) [33]	Cross-sectional study	269 (M, F)	13.9 ± 0.3 years	KIDMED	PSQI	• MD adherence was positively correlated with sleep quality ($p < 0.05$)
Fernández-Medina et al. (2020) [36]	Cross-sectional study	334 (M, F) university students	21.84 years (mean)	MEDAS	PSQI	• There was a significant negative correlation ($r = -0.28$; $p < 0.05$) between MD adherence and poor sleep quality.
Theorell-Haglow et al. (2020) [52]	Cross-sectional study	23,829 (M, F)	45–75 years	Modified MD score (mMED)	Self-reported questionnaire	• Short sleepers had lower adherence to a healthy diet compared to normal sleepers. Poor sleep quality among short sleepers further decreased adherence.
Muscogiuri et al. (2020) [45]	Cross-sectional study	172 (M, F)	51.8 ± 15.7 years	MEDAS	PSQI	• Good sleepers (PSQI < 5) had significantly higher MD adherence compared to poor sleepers (PSQI > 5)
Flor-Alemany et al. (2020) [37]	Cross-sectional study	150 (F) pregnant population	32.9 ± 4.6 years	MFP (evaluation procedures were carried out at the 16th and 34th gestational week)	PSQI	• High MFP scores are linked to better PSQI scores ($p = 0.005$), while increased red meat consumption worsens sleep quality at the 34th gestational week ($p = 0.032$).
Jurado-Fasoli et al. (2020) [39]	Cross-sectional study	70 (M, F)	40–65 years	MEDAS	PSQI, wrist accelerometer	• There was no observable association between MD adherence and sleep quality or additional sleep parameters.

Table 1 (continued)

Reference	Study design (duration)	Participants (sex)	Age group	MD assessment tool/interventions	Sleep assessment tools	Results[a]
Mediterranean Cross-Sectional Studies						
Kolokotroni et al. (2021) [40]	Cross-sectional study	745 (M, F)	39 years (median)	MEDAS	PSQI	• There was no significant correlation between MD adherence and sleep quality during COVID lockdown.
Prete et al. (2021) [48]	Cross-sectional study	604 (M, F)	26–35 years	Modified MD score (QueMD)	PSQI	• MD adherence showed a significant correlation with sleep quality in men ($p < 0.05$), but not in women ($p = 0.84$).
Naja et al. (2022) [46]	Cross-sectional study	503 (M, F) students	22.1 ± 4.2 years	KIDMED	PSQI	• MD was not linked to general PSQI score but was associated with subjective sleep quality (OR, 0.48; 95% CI, 0.31–0.67) sleep latency, sleep disruption, and daytime functioning ($p < 0.001$).
Rostami et al. (2022) [49]	Cross-sectional study	400 (M)	38.67 years (mean)	MIND diet	PSQI	• High MIND diet adherence was associated with lower odds of poor sleep quality (OR for Tertile-3 vs. Tertile-1, 0.56; 95% CI, 0.34–0.92; p-trend = 0.023).
Mohammadi et al. (2023) [44]	Cross-sectional study	535 (M, F)	42.6 years (mean)	MDS	PSQI	• Participants in highest MDS tertile had reduced odds of short sleep (OR = 0.44; 95% CI, 0.21–0.91) and poor sleep quality (OR = 0.48; 95% CI, 0.22–0.96) compared to the lowest tertile.
Shiraseb et al. (2023) [51]	Cross-sectional study	266 (F) overweight and obese population	18–48 years	MD and DASH	PSQI	• Higher MD adherence in overweight/obese women linked to better sleep quality (OR, 1.05; 95% CI, 1.00-1.08; $p = 0.02$) even after controlling for potential confounders ($p = 0.04$).
Tryfonos et al. (2023) [53]	Cross-sectional study	279 (M, F) with MS	72.6 ± 12.3 years	MedDietScore	PSQI	• High MD adherence in patients with MS linked to 75% higher odds of adequate sleep quality (OR, 1.75; 95% CI, 1.52–2.03; $p = 0.0033$).
Mantzorou et al. (2023) [42]	Cross-sectional study	3,254 (M, F) urban, rural, and island population	≥65 years	MedDietScore	PSQI	• Older adults with moderate or high MD adherence had 2.1-fold better sleep quality than those with very low/low MD adherence (OR, 2.11; 95% CI, 1.79–2.44; $p = 0.0018$)

Table 1 (continued)

Reference	Study design (duration)	Participants (sex)	Age group	MD assessment tool/interventions	Sleep assessment tools	Results[a]
Mediterranean Cross-Sectional Studies						
Zapata-Lamana et al. (2023) [55]	Cross-sectional study	265 (M, F) school students	13.5 ± 1.8 years	KIDMED	Sleep and Rest Sect. 6 of Questionnaire on Lifestyle and Adolescence: *Sleep Hygiene*	• Poor sleep hygiene indicators were associated with lower MD adherence ($p < 0.05$).
Şahin-Bodur et al. (2024) [50]	Cross-sectional study	1,031 (M, F)	28.6 ± 8.3 years	MEDAS	PSQI	• Low and moderate MEDAS scores were associated with poor sleep quality (PSQI: 6.1 ± 2.8 and 5.1 ± 2.5, respectively) compared to high MEDAS scores (PSQI: 4.7 ± 2.3; $p < 0.001$).
Interventional and Observational Mediterranean Studies						
Campanini et al. (2017) [34]	Prospective study (2.8 years median follow-up)	1,596 (M, F)	≥ 60 years	MEDAS	Self-reported questionnaire	• High MD adherence reduced the risk of significant sleep duration changes and poor sleep quality by 56% (OR, 0.44; 95% CI, 0.29–0.68; $p < 0.001$)
O'Connor et al. (2018) [47]	RCT, crossover, investigator-blinded (16 weeks: two 5-week interventions with ≥ 4-week washout period)	41 (M, F) [39 completed the sleep questionnaire]	46 ± 2 years	MEDAS MDs with ∼500 g/wk (Med-Red Pattern) or ∼200 g/wk (Med-Control Pattern) of lean, unprocessed beef or pork (5 weeks)	PSQI and actigraphy	• MD had no impact on sleep quality or patterns, with sleep score changes of Med-Red − 0.7 ± 0.4 SE and Med-Control − 0.2 ± 0.3 SE. • No significant time x pattern effect was observed in global sleep score for both diet patterns ($p = 0.16$ and $p < 0.05$).
Martínez-Rodríguez et al. (2020) [43]	RCT (16 weeks)	22 (F) with fibromyalgia	Intervention group (48 ± 4 years) vs. Control group (50 ± 5 years)	Intervention group ($n = 11$), MD enriched with high doses of TRY and MG (60 mg each) vs. Control group ($n = 11$), standard MD	PSQI	• MD did not affect sleep quality in either group. • There was no significant group x time effect on global sleep quality for both groups ($p = 0.08$). Post-intervention PSQI scores: Control 7.55 ± 2.46, Experimental 10.00 ± 3.55.

Table 1 (continued)

Reference	Study design (duration)	Participants (sex)	Age group	MD assessment tool/interventions	Sleep assessment tools	Results[a]
Mediterranean Cross-Sectional Studies						
Zuraikat et al. (2020) [56]	Prospective study (1-year follow-up)	432 (F)	20–76 years	aMED	PSQI	• Higher MD adherence improved sleep quality and efficiency, with PSQI scores reducing from 5.5 ± 3.6 to 5.1 ± 3.3 at 1-year follow-up ($p < 0.01$, $p < 0.001$).
Casas et al. (2023) [35]	RCT (baseline visit, 19–23 weeks of gestation, to final visit, 34–36 weeks of gestation)	1,221 (F) high-risk pregnant population	Intervention group (34.7–40.4 years) vs. Control group (33.3–40.5 years)	Intervention group ($n = 331$), PREDIMED trial diet intervention vs. Control group ($n = 349$), usual prenatal care	PSQI	• Intervention group had less poor sleep quality (16.8% vs. 21.8%) and better PSQI scores (7.0 vs. 7.9, $p = 0.001$) compared to the control group.

Abbreviations: aMED, alternate Mediterranean Diet score; DASH, Dietary Approaches to Stop Hypertension; F, female; KIDMED, Mediterranean Diet Quality Index for children and adolescent; M, male; MD, Mediterranean diet; MDS, Mediterranean dietary score; MEAL, Mediterranean healthy Eating, Aging, and Lifestyles; MEDAS, Mediterranean Diet Adherence Score; MedDietScore, Mediterranean Diet Score; MEDI-LITE, Mediterranean Diet adherence score based on the literature; MFP, Mediterranean Food Pattern; MG, magnesium; MIND, Mediterranean-DASH Intervention for Neurodegenerative Delay; mMDS, modified Mediterranean dietary score; MS, multiple sclerosis; OR, odds ratio; PSQI, Pittsburgh Sleep Quality Index; RCT, randomized control trial; SE, standard error; TRY, Tryptophan

[a] Data presented in mean ± SD or 95% CI

weekly (typical US intake) versus 200 g (recommended in heart-healthy diets)—but found no significant impact on sleep quality or characteristics, potentially due to the study's brief duration and limited statistical power [47]. Another RCT involving pregnant women showed that those in the MD group experienced better sleep quality than those receiving standard prenatal care [35]. A prospective study with a follow-up of nearly three years linked steady MD adherence with a reduced risk of significant sleep duration changes and a lower likelihood of poor sleep quality [34], underscoring the importance of long-term dietary adherence for substantial sleep benefits.

Chrononutrition studies summarized in Table 2 revealed that eight studies out of total nine studies which involved PSQI detected no significant enhancements in PSQI scores within the intervention groups [20–23, 25–28]; however, one study showed notable improvements in sleep quality measured through the mCC app, despite no changes in PSQI scores [28]. Another reported significant improvement in sleep quality assessed by VAS, though PSQI was not utilized [24]. One study noted a considerable PSQI decrease from baseline at three months, but this was not maintained by six months [23].

Discussion

A review of 33 studies, including 24 on the Mediterranean diet and 9 on chrononutrition, found that following the MD generally correlated with improved sleep quality. This includes enhancements in PSQI scores, reductions in insomnia symptoms, and improvements in sleep duration, latency, and efficiency. Fourteen of 19 cross-sectional studies reported a significant positive association between MD adherence and better self-reported sleep quality [33, 36–38, 41, 42, 44, 45, 49–53, 55]. However, two [43, 47] out of three randomized trials showed no significant improvements [35]. Most studies used the PSQI to assess sleep quality.

In contrast, evidence supporting the positive effects of chrononutrition on sleep quality is limited when measured by PSQI, but it may contribute positively to weight loss which may indirectly contribute to improved sleep if an appropriate level is achieved. While none of the chrononutrition studies showed an association with sleep quality using the PSQI, two TRE studies demonstrated improvement in sleep quality using alternative sleep survey tools like mCC and VAS which are validated tools commonly used to assess sleep quality [24, 28]. The variations in findings between the studies using mCC and VAS versus PSQI could be because these tools evaluated sleep quality daily, potentially reducing the impact of recall bias.

Sleep quality, efficacy, and duration

Sleep quality and efficacy are essential for overall health. Sleep quality is a multifaceted concept that encompasses various components, including sleep duration, efficiency, and timing. Together, these components play a critical role in determining overall sleep quality, influencing both physical and mental health outcomes. Limited research has investigated the impact of the MD on sleep latency and efficiency. Studies by Naja et al. [46] linked higher

Table 2 Chrononutrition and sleep quality

Reference	Study design	Participants (sex)	Age group	Intervention group	Diet length	Sleep assessment tool	Results[a]
TRE Studies							
Gabel et al. (2019) [21]	Single-arm clinical trial	23 (M, F) obese population	25–65 years	8-hour TRE (10 am-6 pm)	12 weeks	PSQI	• Mean PSQI score was below 5 at week 1 (4.7 ± 0.5) and week 12 (4.8 ± 0.7), indicating good sleep quality. • Poor sleepers (PSQI > 5, n = 10) showed no significant changes after 12 weeks of TRE (6.3 ± 0.8 vs. 7.2 ± 1.0)
Parr et al. (2020) [26]	Single-arm clinical trial	19 (M, F) overweight, obese, and DM-2 population	35–65 years	9-hour TRE (10 am-7 pm)	4 weeks	PSQI	• PSQI scores did not significantly change from pre- (7.00 ± 4.29) to postintervention (6.68 ± 3.84; p = 0.79).
Cienfuegos et al. (2020) [20]	Parallel-arm RCT	58 (M, F) obese population	18–65 years	1: 4-hour TRE (3–7 pm) 2: 6-hour TRE (1–7 pm) 3: Control (no mealtime restrictions)	8 weeks	PSQI	• PSQI did not change after 4-hour TRE (baseline: 5.9 + 0.7 vs. week 8: 4.8 + 0.6) or 6-hour TRE (baseline: 6.4 + 0.8 vs. week 8: 5.3 + 0.9) compared to controls.
Lowe et al. (2020) [25]	Parallel-arm RCT	116 (M, F) overweight and obese population	18–64 years	1: 8-hour TRE (12 – 8 pm) 2: Control (3 meals and snacks each day)	12 weeks	PSQI	• Mean difference in pre- and post-TRE group was – 0.018 (95% CI, – 0.455 – 0.420; p = 0.94 for ΔTRE). There were no significant changes in PSQI between either group (p = 0.28).
Wilkinson et al. (2020) [28]	Single-arm clinical trial	19 (M, F) overweight, obese, and prediabetes population	59 ± 11.14 years	10-hour TRE (self-selected)	12 weeks	PSQI and mCC app	• There was a minor, but not significant, tendency towards better sleep on the PSQI (mean change, – 0.68 ± 2.06; p = 0.164). • Daily morning sleep quality reported via mCC app improved by as much as 23% (16.28 ± 24.88; p = 0.019) after 10-hour TRE.
Kesztyus et al. (2020) [24]	Secondary analysis of 2 pilot studies in a pre-post design	99 (M, F) overweight and obese population	48.9 ± 1.1 years	8–9–hour TRE (self-selected)	12 weeks	EQ- 5D VAS	• Sleep quality changed significantly by 9.6 ± 13.9 points(p < 0.001), but sleep duration was not extended on VAS.
Jayakumar et al. (2023) [22]	Parallel-arm RCT	Total 42 Control (n = 15), TLE (n = 27)	14–18 years Adolescents	3 groups: 8-hour TLE (participants self-selected their eating window) + real-time continuous glucose monitor, 8-hour TLE + blinded continuous glucose monitor, or a prolonged eating window.	12 weeks	PSQI	• No significant difference seen in total PSQI score change between TLE and control over the study period (p > 0.05). • Median PSQI total score decreased from 6 at week 0 (IQR, 5–10) to 5 at week 12 (IQR, 2–7), suggesting improvement in sleep quality in the TLE group.
ADF Studies							
Kalam et al. (2021) [23]	Single-arm clinical trial	31 (M, F) obese population	18–65 years	ADF with fast day (600 kcal) and feast day (ad libitum) + low carb/high protein diet	24 weeks	PSQI	• Among poor sleepers, PSQI significantly decreased from baseline (9.3 ± 0.9) to month 3 (7.2 ± 0.7; p < 0.05). • However, by month 6, the PSQI score (8.0 ± 0.9) showed minor reduction with no significant difference compared to baseline or month 3.

Table 2 (continued)

Reference	Study design	Participants (sex)	Age group	Intervention group	Diet length	Sleep assessment tool	Results[a]
TRE Studies							
IF Studies							
Teong et al. (2021) [27]	Secondary analysis of open label RCT	46 (F) [CR group = 24, IF group = 22] overweight and obese population	35–70 years	IF group fasted for 24 h on 3 non-consecutive days/week, from breakfast to the following day's breakfast.	8 weeks	PSQI	• No significant changes were seen in PSQI score postintervention in either group. • The difference in mean PSQI between baseline and after 8-week intervention following 12-hour overnight fast in IF group was − 1.1 ± 2.2 ($p = 0.293$)

Abbreviations: ADF, alternate day fasting; CR, calorie restriction; DM-2, type 2 diabetes mellitus; F, female; IF, intermittent fasting; IQR, interquartile range; M, male; mCC app, myCircadianClock application; OR, odds ratio; PSQI, Pittsburgh Sleep Quality Index; RCT, randomized control trial; TLE, time-limited eating; TRE, time-restricted eating; EQ-VAS, EuroQol-visual analogue scale

[a] Data presented in mean ± SD or 95% CI

MD adherence to shorter sleep latency and fewer awakenings. Zuraikat et al. [56] found that higher adherence resulted in better sleep efficiency and quality. While the MD has consistently demonstrated beneficial effects on sleep [13], studies on chrononutrition have produced inconsistent results. Early research [19] indicated improvements, whereas numerous subsequent studies [20–23, 25–28] have shown no significant impact on sleep quality. Short-term improvements in sleep latency and efficiency can result from consuming melatonin-rich foods [58]. Over time, the MD enhances sleep by lowering inflammation and reducing the risk of conditions such as obesity and cardiovascular disease, which are linked to poor sleep [59, 60]. Chrononutrition, an emerging field, explores how the timing of food intake impacts health, with disruptions, such as irregular meal timing, increasingly linked to poor sleep quality [61]. Long-term adherence to strategies like time-restricted eating supports circadian rhythms and metabolic health, further boosting sleep quality [62].

Sleep duration findings are mixed. Some research connects higher MD adherence with longer sleep times [63], while others see no such association [41]. Campanini et al. [34] reported a 56% reduction in sleep duration variability with strong MD adherence. Chrononutrition studies typically show no change in sleep duration, as participants generally slept over 7 hours per night [19–21, 23–26, 28, 64]. In time-restricted eating (TRE) studies, except for one randomized control trial that reported earlier sleep onset by about 34.5 ± 15.8 min generally, and 56.1 ± 18.1 min among adherents in late sleepers [65], no improvements in sleep quality or duration were observed.

Most MD research is cross-sectional or observational, and it is essential to consider baseline sleep characteristics when evaluating the impact of MD on sleep quality. We emphasize that understanding the initial sleep patterns of the target population is critical prior to any intervention. Muscogiuri et al. [45] observed that good sleepers tended to follow MD closely, whereas poor sleepers with higher PSQI scores were less compliant. In chrononutrition research, four studies indicated poor sleep (PSQI > 5) prior to dietary interventions [20, 22, 26, 28], while two TRE trials showed relatively good initial sleep quality (PSQI < 5) [21, 25]. In two TRE studies, improvements in sleep quality were recorded through daily self-reported measures, despite heterogeneous baseline sleep profiles [24, 28].

Subgroup analysis

Several studies found that factors like age, sex, body weight, and pregnancy played a role in how MD and chrononutrition affect sleep. According to self-reported questionnaires on sleep quality, MD was associated with lower insomnia symptoms (i.e. trouble falling asleep, difficulty maintaining sleep, early morning awakening) in women but not in men [66]. Prete et al. [48] stated that MD was associated with better sleep in men ($p < 0.05$) but not in women ($p = 0.84$), while Godos et al. [38] reported improved sleep quality in non-obese women. According to two studies, MD enhanced sleep quality and reduced sleep latency in individuals of normal or overweight status, but this effect was not observed in participants classified as obese [38, 44]. This difference may be due to MD's positive effects on metabolic health, body fat levels, and weight status, which may influence the relationship between adherence to MD and better sleep quality [2]. While most of the chrononutrition studies with participants classified as overweight or obese showed no significant change in sleep quality, the initial study by Gill and Panda [19] stated participants in the 10-hour TRE group classified as overweight experienced improvement in sleep quality after 16 weeks of intervention. Sleep quality worsens with gestational age, but pregnant women who followed MD tended to experience better sleep quality throughout gestation [35]. Another study with pregnant women showed that the group with the highest adherence to the Mediterranean diet (Tertile 3) showed better sleep quality than the lowest adherence group (Tertile 1) at the 16th and 34th gestational weeks (both, $p < 0.05$). Higher adherence to the diet, including more fruits, olive oil, and less red meat, was linked to better sleep quality, particularly in sedentary women [37]. Future studies should investigate how factors such as age, sex, and preexisting health conditions might moderate the relationship between dietary patterns and sleep quality.

Impact of dietary components

MD focuses on plant-based foods, whole grains, healthy fats (like olive oil, nuts, and seeds), and lean proteins such as fish and poultry [13]. It encourages moderate red wine consumption for its antioxidants and limits red meat. Herbs and spices replace excess salt, enhancing flavor. Regular physical activity is crucial in this lifestyle for health and well-being. Although the impact of macro- and micronutrients on sleep is not fully understood, St-Onge et al. [3] suggest that abnormal nutrient levels can disrupt sleep quality. High carbohydrate intake correlates with poor sleep, while low carbohydrate consumption (< 50% energy) may cause sleep maintenance issues [23, 67]. Inadequate protein (< 16% energy) reduces sleep quality and causes trouble falling asleep, whereas too much protein (> 19% energy) is associated with difficulty staying asleep [3, 67]. Intervention studies further illustrate these dynamics. A high-protein diet (35% energy) improved sleep in a 12-week ADF trial but not at 24 weeks [23]. One RCT showed that overweight adults might enhance sleep with higher protein diets while losing weight, excluding the ADF approach [68]. Zhou et al. [68] noted better sleep quality in overweight individuals with a high-protein diet (> 25% energy), but Castro et al. [69] observed no significant sleep improvements after four months on such a diet. Carbohydrate intake also appears to influence sleep differently depending on the context. Low carbohydrate diets (10-20% energy) is associated with sleep maintenance issues [67], yet a very low carbohydrate diet (10% energy) is related to increasing deep sleep percentage compared to a mixed diet, per Afaghi et al. [70]. These findings underscore the importance of considering both the broader dietary patterns, such as the Mediterranean diet and chrononutrition, and the specific macronutrient compositions that may mediate their effects on sleep.

High dietary fiber from fruits, vegetables, whole grains, and legumes in MD links to better sleep quality and adequate sleep duration, reducing daytime sleepiness [71]. Higher fiber intake is associated with more deep sleep and less light sleep [71]. Studies show that increased fruit and vegetable consumption correlates with longer sleep duration and less daytime sleepiness. Women following MD with higher fruit and vegetable intake experienced better sleep, indicated by lower PSQI scores and fewer sleep interruptions [56]. Oliveira and Marques-Vidal [30] found no consistent nutritional markers linked to sleep quality but noted that MD components like dairy, fruits, and vegetables could enhance sleep, whereas sugary foods or meat might worsen it.

Mechanisms

While the mechanism which underlies the MD's impact on sleep remains unclear, several interconnected and overlapping pathways have been proposed, including enhancements in metabolism and vascular function, lowering inflammation and oxidative stress, neuroprotection, melatonin biosynthesis, and modulation of the microbiota [13]. The MD dietary pattern is composed of a balanced levels of proteins, fats, and carbohydrates as well as vitamins and polyphenols/antioxidants [13]. One mechanism may involve the tryptophan-serotonin-melatonin system. Tryptophan serves as a precursor to serotonin, a neurotransmitter that promotes feelings of relaxation and sleepiness, and melatonin, a hormone that regulates sleep and alertness [13, 43, 58]. MD, rich in tryptophan and other essential nutrients supports this biosynthesis pathway, enhancing sleep quality. Consuming tryptophan-enriched foods is associated with an increase in sleep efficiency, total sleep time, and reduced sleep latency [13]. However, in a RCT involving women with fibromyalgia, the intervention group following MD with tryptophan and magnesium (60 mg of each) did not result in significant modifications to sleep quality compared to the control group following a standard MD [43]. Chronic inflammation has been associated with disruptions in sleep architecture, leading to shorter sleep durations and reduced sleep quality [3]. High content of polyunsaturated fatty acids (PUFA) and phytochemicals, such as polyphenols, found in the MD have been reported to have a beneficial effect on inflammatory parameters [1]. Therefore, the anti-inflammatory properties of PUFA and polyphenols present in the Mediterranean diet may contribute to improved sleep health.

Investigations on chrononutrition thus far have not shown significant enhancements in sleep quality, despite the metabolic advantages of TRE and IF, including weight management and improved glucose regulation [24, 26]. The interplay between nutrients, dietary habits, and sleep quality remains largely unclear, given the complexity of the factors that can influence sleep quality. The mechanisms by which chrononutrition patterns, such as TRE and IF, may improve sleep quality are not yet fully understood. It has been suggested that IF could enhance sleep by strengthening the peripheral circadian rhythm through restricting food consumption in the evening and at night [72]. Despite allowing unrestricted energy intake, TRE involves aligning energy consumption with the normal diurnal rhythms of metabolic hormones and energy regulation [73]. This can help regulate the internal clock, potentially improving sleep in individuals with irregular sleep patterns. A study by Lowe et al. [25] on TRE found no significant improvements in sleep quality, suggesting that the timing of food intake alone may not be sufficient to influence sleep parameters. Future research should explore whether specific chrononutrition approaches are more effective for improving sleep quality.

Another way IF can enhance sleep quality is by lowering overall body weight. Current evidence indicates that slight decreases in body weight is associated with enhanced sleep quality and length [20]; while obesity has been linked to shorter sleep duration as well as lower sleep quality. Losing weight has been proven to enhance various aspects of sleep, such as sleep quality, duration, and reducing likelihood of obstructive sleep apnea (OSA). TRE results in a modest reduction in body weight of 1–4% for adults classified as overweight or obese within a period of 1 to 16 weeks [20, 21, 74]. In contrast, ADF typically leads to a slightly higher reduction in weight (3-7%) compared to TRE within the same timeframe. Combining these results indicate that both TRE and ADF lead to slight to moderate weight reduction (1-6%) but their impact on sleep is still uncertain. Many participants identified hunger, stress, and emotional fluctuations as primary obstacles to adhering to chrononutrition interventions [26]. One explanation for the lack of effect on sleep quality by chrononutrition intervention could be the insufficient amount of weight loss attained. Losing 5–10% of body weight is recommended for better sleep [16]. Participants in 5 of the TRE studies lost only 2–3% of body weight which may explain why sleep variables did not change. Interestingly, Kalam et al. [23] found that quality of sleep improved significantly by week 12 of ADF, but this improvement decreased by week 24 despite maintaining 6% weight loss achieved during the program. Furthermore, prolonged adherence to chrononutrition may yield positive outcomes, considering that included studies had durations ranging from 4 to 24 weeks. This highlights the need for extended and more comprehensive clinical trials to evaluate sleep-related outcomes.

The relationship between dietary patterns and the gut microbiome is an emerging area of research. Diets high in plant-based foods, such as those based on the MD, have been suggested to positively influence gut microbiome composition [75]. For example, a study involving 106 male patients with coronary heart disease found that following the MD, alongside a low-fat regimen, led to decreased gut dysbiosis and improved metabolic status [76]. Additionally, chrononutrition, such as TRE, aligns eating patterns with circadian rhythms, optimizing metabolic and immune responses. This alignment has been shown to promote gut health by reducing dysbiosis [77]. The gut–brain axis is essential for maintaining overall health, with the gut microbiome playing a critical role in regulating neurotransmitters such as glutamate. While glutamate is vital for brain function, its dysregulation can lead to neurotoxicity, potentially contributing to sleep disturbances [78]. Although more research is needed to fully understand these connections, it is important to consider the role of gut health in dietary interventions aimed at improving sleep quality.

Practical Implications

In sleep clinics, incorporating the MD and chrononutrition into treatments for OSA and other sleep disorders show considerable promise. Chrononutrition, which coordinates eating patterns with the body's natural rhythms, may enhance metabolic health, support weight loss, and decrease sleep interruptions from late-night meals. On the other hand, the MD reduces markers of inflammation and oxidative stress, potentially lessening OSA symptoms and improving sleep quality (1, 78–79), as well as mitigating the risk of developing metabolic disorders, often exacerbated by OSA. As suggested by Georgoulis in a RCT, a combined MD and lifestyle intervention, in addition to standard CPAP therapy, significantly improves OSA severity, symptomatology, and sleep quality, surpassing the benefits of standard care alone, regardless of continuous positive airway pressure (CPAP) use and weight loss (78–79). Such a holistic dietary strategy complements traditional treatments, likely leading to better patient compliance and overall outcomes (3, 78–79). For effective clinical application, sleep clinics should incorporate dietary counseling that promotes the MD alongside guidance on meal timing to improve patient outcomes in OSA and other sleep disorders. Adopting these integrative strategies may not only alleviate sleep disruptions but also enhance overall health and well-being for individuals affected by sleep disorders.

Limitations

This review has several limitations. One major limitation is that the studies reviewed here related the MD and chrononutrition dietary patterns were heterogenous in study designs, including RCTs, single-group clinical trials, cross-sectional studies, and observational studies. Most MD studies were cross-sectional, preventing the ability to determine directionality and causality of the relationship. On the other hand, most chrononutrition studies adopted a clinical trial study design, providing a higher level of evidence but with smaller sample sizes. As highlighted by Ioannidis (80–81), observational studies may be more prone to confounding factors and bias compared to randomized controlled trials, which should be considered when interpreting our findings. This heterogeneity in study design introduces a potential source of bias and makes drawing direct comparisons and generalizing findings challenging, necessitating cautious interpretation of the observed results. Furthermore, differences in study participants, questionnaires, and assessment methods for measuring adherence to MD and sleep outcomes may also contribute to inconsistent findings. Godos et al. [2] noted in their systematic review that MD studies often had larger sample sizes and longer follow-up periods compared to chrononutrition studies, potentially influencing the strength of observed associations. There may be potential synergies between MD principles and chrononutrition practices. For example, the emphasis on earlier, lighter evening meals in both approaches could positively influence sleep onset and quality. However, strict time-restricted eating might conflict with the social aspects of traditional Mediterranean dining. A notable limitation of this review is the potential variability in the interpretation and implementation of the MD across different studies. The traditional MD may differ significantly from contemporary Westernized versions influenced by processed and high-calorie foods. These variations may contribute to inconsistencies in observed outcomes related to sleep quality and other health benefits. Future studies should account for these dietary shifts to better understand the specific effects of the traditional MD compared to its modern adaptations. Another limitation is the subjective nature of sleep quality assessments, which may introduce recall bias. To pave the way for evidence-based dietary recommendations for sleep, future research should consider large prospective cohort studies with longer duration and RCTs, as well as incorporating objective sleep assessments such as with actigraphy and polysomnography alongside subjective tools like the PSQI, for a comprehensive evaluation of outcomes. Additionally, research into the potential synergistic effects of combining these dietary approaches could provide valuable insights, suggesting that an optimal dietary pattern may require incorporating elements from both dietary and temporal eating patterns.

Conclusions

This comparative review highlights ways in which MD and chrononutrition differ in their effects on sleep quality. While MD studies consistently demonstrate positive associations, the evidence for chrononutrition is less robust currently. This encourages future research to further elucidate various dietary interventions on sleep outcomes, with a goal to identify optimal dietary strategies for promoting healthy sleep.

Abbreviations

ADF Alternate day fasting
IF Intermittent fasting
MD Mediterranean diet
PSQI Pittsburgh Sleep Quality Index
TRE Time-restricted eating
TRF Time-restricted feeding

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Not applicable.

Author contributions

AP and JC led the study conception and design of the study, performed data extraction, analysis and interpretation of results. AP and JC led manuscript writing and record screening. All authors contributed to assessment of the risk of bias and revision of the manuscript. The authors read and approved the final manuscript.

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Data availability

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Declarations

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