Dietary inflammatory index, sleep duration, and sleep quality: a systematic review

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Systematic Review

Dietary Inflammatory Index, Sleep Duration, and Sleep Quality: A Systematic Review

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Abstract: The inflammatory potential of the diet, as measured by the Dietary Inflammatory Index (DII®), has been repeatedly shown to be associated with various inflammatory markers and mental and physical health outcomes. Of specific importance, several cross-sectional studies revealed mixed results regarding the correlations between the DII and sleep outcomes. Hence, in the current paper, a systematic review that examines the associations between the DII, sleep duration, and sleep quality was performed. The PubMed database was systematically searched for studies published up to November 2023 following PRISMA guidelines. Only cross-sectional studies that assessed the DII, sleep duration, and sleep quality across healthy and unhealthy cohorts were included. Eleven and seven studies were included in the systematic review for sleep quality and duration, respectively. The results of the present systematic review show that pro-inflammatory diets may be associated with poor sleep outcomes (duration and quality); however, as the current literature is inconsistent and limited, further cross-sectional studies in larger cohorts are necessary to (i) explore this relationship to address this heterogeneity and (ii) explore populations that are more sensitive to diet-induced inflammation.

Keywords: sleep; dietary inflammatory index; nutrition; systematic review; inflammation

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1. Introduction

Poor diet, a leading risk factor for noncommunicable diseases, is linked to poor sleep outcomes [1]. For instance, previous studies have shown the benefits of fats; group B vitamins, magnesium, and l-tryptophan; foods containing tryptophan, melatonin, and phytonutrients(e.g., cherries, kiwifruit, milk) [2–4]; and dietary patterns such as the Mediterranean-style diet [5] and/or a high-quality diet [6] on sleep duration and sleep quality.

The aforementioned nutrients, food groups, and dietary patterns are also known to be associated with reduced systemic chronic inflammation (SCI) biomarkers, including platelet and leukocyte counts, neutrophil-to-lymphocyte ratios (NLRs), and C-reactive protein (CRP) levels [7–10]. For instance, large-cohort studies in healthy adults from Italy, the UK, and the US, assessing diet using food frequency questionnaires, found that adherence to a Mediterranean dietary pattern or higher healthy dietary scores was associated with lower markers of systematic chronic inflammation [7–9]. Additionally, a meta-analysis of five cross-sectional studies conducted in older adults (≥64 years)) revealed significant inverse associations between adherence to a Mediterranean dietary pattern and circulating CRP [10]. Moreover, evidence from meta-analyses of randomized controlled trials across various age groups have further supported the cross-sectional evidence above by showing reductions in CRP, interleukin-6 (IL-6), and interleukin-1 β (IL-1β) [11,12].

Additionally, an increasing body of research has highlighted connections between sleep patterns and SCI. For instance, previous studies have noted associations between (i) higher leukocyte counts and shorter sleep duration (<8 h/night) [13], (ii) higher levels of CRP and IL-6 and shorter sleep duration (<5 h/night) [14], and (iii) higher CRP levels, platelet counts, and NLR, and poorer sleep quality [8,15,16] was observed. Similarly, the inflammatory potential of the diet, namely the Dietary Inflammatory Index (DII®: a literature-derived estimation that is associated with circulating inflammatory biomarkers) [17] has also been shown to be related to sleep outcomes, such that more pro-inflammatory diets were correlated with shorter and longer sleep durations and lower sleep quality [18–24]. However, other studies observed null findings [25–30].

As evidenced above, the findings remain highly inconclusive, and to the best of our knowledge, this area of research has not been systematically reviewed. Despite the heterogeneity of the studies included in this review, our objective was to carry out a systematic review and assess the strength of the scientific evidence supporting the associations between sleep outcomes (namely sleep duration and sleep quality) and the DII.

2. Methods

2.1. Study Selection

The inclusion criteria were (1) the DII, a literature-based dietary score that quantifies the inflammatory potential of diet [17], being measured by 24-hour dietary recall, dietary survey data, or a food frequency questionnaire; (2) sleep duration or sleep quality, assessed by both subjective and objective measures; (3) cross-sectional studies; and (4) healthy or unhealthy (sleep and/or metabolic disorders) participants of any age or gender.

The exclusion criteria included (1) randomized controlled and quasi-experimental trials, case reports, letters to editors, conference papers, theses, personal opinions or commentaries, and (2) animal, in vitro, and ex vivo studies.

2.2. Search Strategy and Data Sources

An electronic literature search was carried out on PubMed and Scopus in order to identify appropriate studies. The literature search was conducted until the beginning of November 2023. The search strings used in the search included (DII OR "dietary inflammatory index" OR "inflammatory diet" OR "anti-inflammatory diet") AND (sleep*). Manuscripts were selected according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram [31,32]. Papers were selected independently by one reviewer (PH) based on the inclusion and exclusion criteria specified above. Information regarding (1) Publication details (authors, year, journal), (2) Participant characteristics (number of participants recruited, number of participants included in the study, gender, age range, and health status), (3) Study design, (4) Measures (DII, sleep duration, and sleep quality), and (5) Notes (factors that might affect results and/or data quality) were extracted from all publications.

3. Results

3.1. Study Characteristics

We identified 45 publications and screened them for eligibility based on the inclusion and exclusion criteria. Thirty-two studies were excluded. Eleven and seven studies that met all the inclusion criteria were included in the current review for sleep quality and sleep duration, respectively (Figure 1).

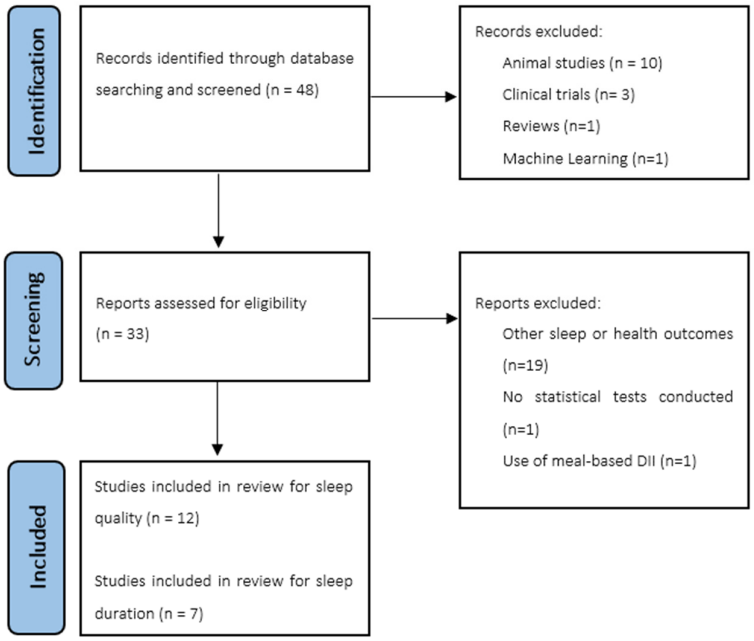

Figure 1. PRISMA flowchart.

3.2. DII and Sleep Duration

Seven studies assessed the association between sleep duration and dietary inflammation using the DII. Three studies assessed sleep duration by using objective methods (i.e., using actigraphy) [24,26,29]. Four studies assessed sleep duration subjectively using either the Pittsburgh Sleep Quality Index (PSQI) [19,20,33] or self-reported hours of sleep per night [21]. Summaries of all the studies are presented in Table 1.

Table 1. Summary of the studies involved in the review.

Authors	Participants	Design	Dietary Measures	Dependent Measures	Results: Sleep Duration	Results: Sleep Quality	Control Variables
[26]	427 (210 males) M_{age} = 27.6 SD_{age} = 3.8 $Range_{age}$ = 21–35	Cross-sectional	24 h dietary recall	Objective sleep duration (actigraphy), PSQI sleep quality	NS	NS	BMI, waist-to-hip ratio, blood pressure, blood composition, gender, age, education, income, employment status, marital status, children, race, physical and sedentary activity (monitor), and scores on Eating Attitudes Questionnaire, Perceived Stress Scale, Social Approval, Social Desirability
[30]	293 females exclusively breastfeeding for ≤6 months $Range_{age}$ = 25–45	Cross-sectional	Food frequency questionnaire (FFQ)	PSQI sleep quality		NS	Age, educational and occupational levels, number of babies and caregivers, level of social support
[29]	207 females with pre-pregnancy overweight or obesity M_{age} = 29.8 SD_{age} = 5.0 $Range_{age}$ = 18–44	Cross-sectional (longitudinal)	24 h dietary recall	Objective sleep duration (actigraphy)	NS		Age, race, education, marital status, income, employment, insurance type, statis for Special Supplemental Nutrition Program for Women, Infants, and Children, number of children in the household, parity, vitamin intake, fast food intake, smoking status prior to pregnancy, scores on Medical Outcomes Study Social Support Survey, Perceived Stress Scale, Social Support for Diet, Social Support for Physical Activity, physical activity (monitor)
[24]	401 police officers (295 males) M_{age} = 41.5 SD_{age} = 6.7	Cross-sectional (longitudinal)	Food frequency questionnaire (FFQ)	Objective sleep duration and sleep quality (actigraphy), PSQI sleep quality	NS	More pro-inflammatory diets are associated with better sleep quality	Age, race, education, sex, sleep medication, tobacco and alcohol consumption, work history, years employment, BMI, waist circumference, systolic blood pressure, scores

							on Depression scale, Anxiety inventory, and Impact of events
[23]	5594 adults Age ≥ 30	Cross-sectional	Dietary survey NHANES 2005–2008	PSQI sleep quality		More pro-inflammatory diets are associated with poor sleep quality	
[19]	211 adults (103 males) $Range_{age}$ = 18–50	Cross-sectional	Food frequency questionnaire (FFQ)	PSQI sleep duration, PSQI sleep quality	More pro-inflammatory diet associated with shorter sleep duration	NS	Energy intake
[22]	219 females with overweight or obesity $Range_{age}$ = 17–58	Cross-sectional	Food frequency questionnaire (FFQ)	PSQI sleep quality		More pro-inflammatory diets are associated with poor sleep quality	Age, physical activity, energy, BMI
[18]	249 females with obesity M_{age} = 23.88 SD_{age} = 3.81 $Range_{age}$ = 18–35	Cross-sectional	Food frequency questionnaire (FFQ)	PSQI sleep quality		More pro-inflammatory diets are associated with poor sleep quality	Energy intake (Model 1), age, education, physical activity, energy intake (Model 2)
[21]	30,121 (14,488 males) M_{age} = 47.19 SE_{age} = 0.26	Cross-sectional	Dietary survey NHANNES 2005–2016	Self-reported sleep duration: categories short <6 h), recommended (6–9 h), long (>9 h)	E-DII scores significantly higher in short and long sleep duration participants		Age, sex, BMI, race/ethnicity, education, marital status, chronic medical condition.
[33]	379 students (136 males) $Range_{age}$ = 18–21	Cross-sectional	Food frequency questionnaire (FFQ)	PSQI sleep duration, PSQI sleep quality	NS	NS	Age, sex, nationality, marital status, living situation, income, smoking status, education, college type, BMI, and physical activity
[28]	278 females with obesity or overweight	Cross-sectional	Food frequency questionnaire (FFQ)	PSQI sleep quality		NS	

	M_{age} = 31.40 SD_{age} = 10.89						
[25]	95 females with FMS diagnosis; 98 women (menopause status matched) controls	Cross-sectional	24 h dietary recall	PSQI sleep quality		NS	Age, menopausal status, and overall energy levels
[20]	2044 (804 males) $Range_{age}$ = <30-≥70	Cross-sectional	Food frequency questionnaire (FFQ)	PSQI sleep duration, PSQI sleep quality	NS	Individuals who follow more pro-inflammatory dietary patterns are less likely to have adequate sleep quality	Age, sex, marital, educational, and occupational status, smoking and alcohol drinking habits, and physical activity level
[27]	296 Obstructive Sleep Apnea patients $Range_{age}$ = 18–60	Cross-sectional	Food frequency questionnaire (FFQ)	PSQI sleep quality		NS	Sex, BMI, circumferences of waist and neck, poor sleep quality, physical activity, daytime sleepiness, diastolic blood pressure, alcohol consumption, energy intake, household income, fatigue, shiftwork

Six studies were conducted in healthy adults across the lifespan [19–21,24,26,29,33]. Of these, two reported outcomes in younger participants [26,33], while four studies focused on middle-aged participants [19–21,24]. Across the six studies, only two studies reported an association between sleep duration and dietary inflammation, such that more inflammatory diets were associated with a shorter (less than 6 h) [19,21] and longer (more than 9 h) [21] sleep duration.

One study assessed the correlation between sleep duration and dietary inflammation in pregnant participants with overweight or obesity and showed no association between sleep duration and dietary inflammatory scores [29].

3.3. DII and Sleep Quality

Twelve studies assessed the link between sleep quality (as measured by the Pittsburgh Sleep Quality Index, where higher scores indicate poor sleep quality [34]) and the DII. Summaries of all the studies are presented in Table 1.

Seven of these studies were conducted in healthy adults across the lifespan [19,20,23,24,26,30,33]. Studies that have been conducted mainly in young adults found null associations between sleep quality and the DII [19,26,30,33]. However, in middle-aged adults, Wirth, Fekedulegn, et al. (2022) [24] showed that more pro-inflammatory diets were correlated with higher improved subjective sleep quality. By using representative samples across age groups (but by mainly recruiting young-to-middle-aged adults), Godos, Ferri, Caraci, Cosentino, Castellano, Shivappa, et al. (2019) [20] showed that individuals in the highest quartile of the DII (i.e., individuals who follow more pro-inflammatory dietary patterns) were less likely to have adequate sleep quality and, similarly, Wang et al. (2022) [23] showed that more pro-inflammatory diets were linked with poor sleep quality (in individuals with poor sleep quality).

The remainder of the studies were conducted in young-to-middle-aged unhealthy adults [18,22,25,27]. While studies conducted in overweight and/or obese individuals found significant associations between higher scores on the DII and poor sleep quality [18,22] (apart from Tabrizi and Farhangi, 2021 [28]), other studies showed no significant association between the DII and sleep quality in individuals with sleep apnea [27] and fibromyalgia [25].

3.4. Risk of Bias

The quality of the studies included in this review was evaluated by one reviewer (PH) using the Agency for Healthcare Research and Quality (AHRQ) checklist [35]; Table 2. The 11-item AHRQ checklist has "yes", "no", or "unclear" classifications. The studies are classified as "high quality" (8–11 items with a "yes" response); moderate quality (4–7 items with a "yes" response); and "low quality" (0–3 items with a "yes" response). The applied quality appraisal revealed eleven studies to be of high quality, one study to be of moderate quality, and two studies to be of low quality.

Table 2. Risk of bias assessment by using the Agency for Healthcare Research and Quality checklist [35].

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Total
[26]	+	+	-	-	?	+	+	+	+	+	+	8
[30]	+	+	-	+	+	+	+	-	+	+	+	9
[29]	+	+	-	+	+	+	+	+	NA	+	+	9
[24]	+	+	-	+	+	+	+	+	NA	+	+	9
[23]	+	+	+	+	+	+	+	+	+	+	?	10
[19]	+	+	-	-	+	+	+	+	+	+	?	8
[22]	+	+	-	-	?	+	+	+	NA	+	-	6
[18]	+	+	-	-	+	+	+	+	-	+	+	8
[21]	+	+	+	+	+	+	+	+	NA	+	+	10

[21]	+	?	-	+	?	+	+	+	+	-	-	6
[28]	+	?	+	+	?	+	+	+	NA	-	+	7
[25]	+	+	-	+	+	+	+	+	+	+	-	9
[20]	+	+	+	+	?	+	+	+	+	+	-	9
[27]	+	+	-	+	+	+	+	+	+	+	-	9

Please see the Supplementary Material for the questions included in the checklist. Green/+: Yes; Red/-: No; Amber/?: Unclear; NA: Blue/Not applicable. Total column denotes the number of Green/+ responses (≤3: Low quality; 4–7: Moderate quality; ≥8: High quality).

4. Discussion

In terms of sleep duration, small cross-sectional studies in healthy adults (n < 500), reported no significant correlation between DII scores and sleep duration [20,24,26,33]. Similar findings were reported in pregnant participants with overweight or obesity [29]. One study reported an association between higher DII scores and shorter sleep duration amongst university employees in Iran [19]; however, it is important to highlight that the majority of participants (i.e., 85% and above) reported a short sleep duration of less than 6 h, which may not represent the broader population [36]. Hence, this limitation raises concern for the generalizability of their findings. A large-scale survey (n > 30,000) conducted by Kase et al. (2021) [21], on the other hand, revealed that higher dietary inflammation scores, indicative of a pro-inflammatory diet, were associated with both shorter (less than 6 h) and longer (more than 9 h) sleep durations. Notably, this study utilized data from the National Health and Nutrition Examination Survey, where sleep duration was assessed through self-reported hours of sleep at night on weekdays or workdays. In contrast, the study by Behbahani et al. (2022) [19] utilized the Pittsburgh Sleep Quality Index (PSQI) to evaluate self-reported sleep duration, although specific details about variable information are not clarified in the study. Given that different sleep assessments (e.g., actigraphy, diary, and retrospective questionnaires) are known to yield different estimates of sleep duration [37], findings should be interpreted with caution.

Taken together, the observed discrepancies across studies may be attributed to variations in study size, sample representation, and different methods used to assess sleep duration, with some studies relying on subjective self-report measures. Notably, studies involving both healthy and unhealthy participants that measured sleep objectively using actigraphy reported no significant link between sleep duration and dietary inflammatory scores [24,26,29]. This highlights the importance of standardized methodologies in future research.

In terms of sleep quality, small-scale (n < 430) cross-sectional studies in healthy adults did not show an association between sleep quality and DII [19,30,33] (apart from Wirth, Fekedulegn, et al., 2022 [24]). However, it is important to note that, in the Wirth, Fekedulegn, et al., 2022 study [24], participants (i.e., police officers) were exposed to several stressors that can affect sleep, including working night and evening shifts, shift changes, and higher depression and anxiety levels (which is in line with previous work showing health disparities in this population [38]). Hence, their inconsistent results could be attributable to these confounding factors. On the other hand, in large-cohort studies (n > 2000) with healthy adults, an association between reduced sleep quality and adherence to pro-inflammatory dietary patterns was found [20,23]. Therefore, null results reported above could be explained by the lack of power and sample representatives. Nevertheless, a correlation between reduced sleep quality and following pro-inflammatory dietary patterns may reflect the mediatory role of inflammation in the associations between diet quality and sleep quality. In fact, a previous study shows the mediating role of various inflammatory markers (such as platelet and neutrophil counts, CRP levels, and NLR) on the diet and sleep quality relationship in generally healthy older adults [8]. Hence, reducing dietary and/or circulating pro-inflammatory biomarkers via dietary interventions may offer a promising primary and/or alternative approach to improving sleep quality.

Additionally, studies conducted in obese and/or overweight individuals showed an association between reduced sleep quality and adherence to pro-inflammatory dietary patterns [18,22] (apart from Tabrizi and Farhangi, 2021 [28]; in which the null finding could be driven by the different statistical analysis technique, namely, the structural equational modeling, used). However, a similar pattern of results was not observed in studies conducted in populations with pain-related disorders or sleep-related breathing disorders (Correa-Rodríguez et al., 2019; Lopes et al., 2019). Given that (i) obesity and/or being overweight are states of low-grade systemic chronic inflammation [39] and (ii) systemic chronic inflammation (i.e., elevated pro-inflammatory biomarkers such as CRP) is associated with poor sleep quality [8], the results could reflect that the DII could be linked to sleep quality only in individuals with compromised inflammatory status. However, more research that elucidates the relationship between the DII and sleep quality in other metabolic conditions (such as non-communicable diseases) that are characterized by persistently high concentrations of circulating pro-inflammatory biomarkers is warranted.

The biological mechanisms regarding the association between the DII score and sleep duration and sleep quality could involve (i) cytokine responses, (ii) the neuroendocrine and autonomic pathways that link sleep with the immune system, and (iii) the role of inflammatory peptides in the homeostatic regulation of sleep (for a review, please see [40]). However, it is also important to highlight that various sociodemographic factors (such as low socioeconomic status and reduced access to healthy food and healthcare) could also contribute to the DII and sleep association, as they have all been shown to be associated with poor dietary choices (hence leading to anti-inflammatory dietary patterns) and poor sleep outcomes [41,42].

There are various limitations of the current review. Firstly, the studies involved in this review had no standard way of utilizing the DII and/or PSQI, such that these measures were used in a categorical and/or continuous manner. Therefore, due to the heterogeneity of the extracted data, no quantitative meta-analysis could be performed. Secondly, FFQ, dietary recall, and PSQI measures are subject to response/recall bias, as both sleep outcomes and dietary intakes are known to be under-reported [43,44]. Thirdly, there was heterogeneity in terms of DII score calculations, such that the number of food parameters included for estimating the DII differed substantially across studies. Fourthly, seven studies were conducted in female-only samples, limiting the generalizability of the findings. Fifthly, it is important to note that the studies included in this review did not systematically account for factors that may contribute to poor sleep (such as caffeine intake, lack of exercise, poor diet, stress, etc.); hence, it is highly possible that the results could be driven by the impact of these factors on sleep duration and quality. Finally, due to the cross-sectional nature of the studies, causality cannot be assumed.

5. Conclusions

The current review offers a thorough assessment of the literature on the association between sleep duration and quality and the DII and shows that pro-inflammatory diets may be associated with poor sleep outcomes (duration and quality). However, as the current literature is heterogenous, future studies are required to (i) replicate previous findings in large cohorts across age groups, utilizing all 45 food parameters that are required to estimate the DII, preferably by using objective sleep outcomes, and (ii) examine the potential benefits of adhering to anti-inflammatory diets on sleep outcomes and beyond.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/nu16060890/s1.

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