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Relationship Between DASH Diet Adherence and Sleep Patterns, Inflammatory Markers, and Oxidative Stress in Iranian Adults

Lucia Francesca Marino[1]*, Alessandro Pietro Galli[1], Marco Lorenzo Vitale[1]

[1]Department of Management, University of Naples Federico II, Naples, Italy.

***E-mail** ✉ l.marino.unina@yahoo.com

Abstract

This study aimed to investigate the association between adherence to the Dietary Approaches to sleep quality and Stop Hypertension diet (DASH), sleep duration, as well as markers of oxidative stress and inflammation in Iranian adults. This cross-sectional study, conducted in 2021, included 535 participants. Dietary intake was evaluated using a validated 168-item food frequency questionnaire, and participants' adherence to the DASH diet was estimated via a DASH score. Sleep quality and duration were assessed using the Pittsburgh Sleep Quality Index (PSQI). Fasting blood samples were collected to measure serum biomarkers of inflammation and oxidative stress. Individuals with higher levels of DASH diet adherence (relative to those with lower adherence) showed lower risks of experiencing poor sleep quality and short sleep duration [fully-adjusted model for for short sleeping: ORT3 vs. T1 = 0.66; 95%CI: 0.45–0.96; poor sleep quality: ORT3 vs. T1 = 0.64; 95%CI: 0.44–0.94]. Such associations appeared stronger among female participants [fully-adjusted model for for short sleeping: ORT3 vs. T1 = 0.12; 95%CI: 0.03–0.55; poor sleep quality: ORT3 vs. T1 = 0.14; 95%CI: 0.04–0.56]. Additionally, moderate adherence was associated with reduced likelihood of delayed sleep onset [fully-adjusted model: ORT2 vs. T1 = 0.39; 95%CI: 0.15–0.98], while higher adherence correlated with lower odds of sleep disturbances [fully-adjusted model: ORT3 vs. T1 = 0.26; 95%CI: 0.08–0.84]. After full adjustment, DASH diet adherence displayed no significant relationship with markers of oxidative or inflammation stress ($p \geq 0.05$).Among middle-aged Iranian adults, greater adherence to the DASH diet was related to enhanced sleep quality and longer sleep duration, particularly in women. The examined biomarkers did not mediate these associations

Keywords: Sleep duration, Sleep quality, Adults, Dietary Approach to Stop Hypertension (DASH) diet

Introduction

Sleep disorders rank among the top health concerns in adults, with prevalence increasing with age [1]. Poor sleep can negatively affect health, reduce quality of life, and impair daily functioning [2]. Chronic insufficient or low-quality sleep has been linked to cardiovascular disease [3], type 2 diabetes [4], and metabolic disturbances [5], and is also associated with risk-taking behaviors, accidents, and elevated mortality. Reports suggest that roughly one-third of adults in developed countries experience sleep problems at some point in life [6], yet data on the impact of sleep disorders in developing populations remain scarce [7]. In Iran, sleep disturbances are common, particularly in older adults, representing a significant public health challenge [1].

Several factors may influence sleep duration and quality, including hormonal fluctuations, metabolic abnormalities, environmental exposures, body weight, and inflammatory processes [8]. Lifestyle behaviors, particularly diet, have been increasingly recognized as important determinants of sleep health [9]. Among dietary patterns, the Dietary Approaches to Stop Hypertension (DASH) diet has attracted attention for its potential to influence sleep. The DASH diet is well-known for preventing metabolic syndrome, type 2 diabetes, stroke, and cardiovascular disease [10, 11], and

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is characterized by high intakes of whole grains, fruits, vegetables, legumes, nuts, and low-fat dairy, alongside limited consumption of red or processed meats, sweets, and sugar-sweetened beverages [12].

Although several studies have explored the relationship between the DASH diet and sleep, most evidence comes from Western populations [13] or focuses on specific sleep domains, such as sleep disturbances [14]. For instance, a large study of nearly 8,000 Chinese adults reported that adherence to healthy dietary patterns, including DASH, was associated with better sleep quality [15]. However, genetic, lifestyle, and physical activity differences limit the generalizability of these findings to the Iranian population. Research within Iran is limited, often targeting select groups such as adolescents or women with specific health conditions, rather than the general adult population [16, 17]. For example, among 350 breastfeeding Iranian mothers, higher DASH adherence was linked to shorter sleep latency, fewer sleep disturbances, and better sleep efficiency [18], whereas in adolescent girls, no significant association was found between DASH diet and insomnia [19]. Similarly, a study of 337 Iranian employees reported that a higher DASH score correlated with reduced odds of short sleep duration but not with poor sleep quality [20].

Sex and hormonal status may further modify these associations. Hormones including estrogen, progesterone, and testosterone are key regulators of sleep. In women, menopause-related fluctuations in estrogen and progesterone are associated with increased sleep disturbances [21, 22], while in men, gradual declines in testosterone during andropause may affect sleep patterns, though this relationship is less well-defined [21, 23].

Given the inconsistent findings from prior studies, the current research aimed to examine the associations between adherence to the sleep quality and DASH diet, biomarkers of inflammation and sleep duration, and oxidative stress in a representative sample of Iranian adults.

Materials and Methods

Participants and study design

This cross-sectional study was performed in 2021 in Isfahan, a major city in central Iran, involving a moderately representative sample of adults. A total of 600 men and women aged 20–65 were selected from 20 schools using a multistage cluster random sampling technique. The detailed study protocol has been previously described [24]. To capture adults from different socioeconomic backgrounds, all school staff—including teachers, administrative personnel, assistants, and support workers—were invited to participate.

Individuals were excluded if they had any of the following: (1) a history of chronic disease, (2) pregnancy or breastfeeding, or (3) were following a calorie-restricted or calorie-increased diet for weight modification. Among those invited, 543 agreed to participate, resulting in a response rate of 90.5%. Additional exclusions were applied for participants who (1) reported daily energy intakes outside 800–4200 kcal ($n = 3$), (2) left more than 70 items unanswered on the food frequency questionnaire ($n = 4$), or (3) refused to provide a blood sample ($n = 1$). After applying these criteria, 535 participants remained for the final analysis. The study protocol adhered to the Helsinki Declaration, with all participants providing written informed consent, and ethical approval was granted by the Ethics Committee of Isfahan University of Medical Sciences.

Dietary assessment

Habitual dietary intake was assessed using a validated, semi-quantitative 168-item Willett-format food frequency questionnaire (FFQ) [25]. In prior validation involving 132 middle-aged Iranians, the FFQ showed acceptable correlations with 24-hour dietary recalls, including energy ($r = 0.55$), protein ($r = 0.65$), fat ($r = 0.59$), and fiber ($r = 0.67$) [25]. A trained dietitian instructed participants on how to complete the FFQ, recording both the frequency and portion size of each food item consumed over the previous year. These intakes were then converted into grams per day based on standard portion sizes [26], and total nutrient and energy intakes were calculated using Nutritionist IV software.

DASH score calculation

Adherence to the DASH diet was evaluated using eight components: five “encouraged” food groups—fruits, vegetables, whole grains, nuts and legumes, and low-fat dairy—and three “limited” groups—sodium, sugar-sweetened beverages (SSBs), and red or processed meats [27]. Intakes were first adjusted for total energy using the residual method. For each component, participants were divided into quintiles based on energy-adjusted intake. The highest quintile of beneficial foods received a score of 5, while the lowest quintile of foods to limit also received a score of 5. All other quintiles were scored from

1 to 5 accordingly, either directly or inversely. Summing the eight component scores yielded an overall DASH adherence score ranging from 8 (lowest adherence) to 40 (highest adherence).

Sleep assessment

Sleep quality and duration were measured with the Pittsburgh Sleep Quality Index (PSQI), a validated instrument widely used in research [28]. The Persian version has been validated in Iranian adults, showing high sensitivity (93.6%) and acceptable specificity (72.2%) [29]. The PSQI evaluates seven domains: overall sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction. Each domain is scored 0–3, with higher scores indicating greater impairment. Summing these domains produces a global score ranging from 0 to 21, with higher scores reflecting worse sleep quality. Participants were classified as having good (0–3), intermediate (4–5), or poor sleep quality (≥6) [28]. Sleep duration was captured from the fourth PSQI item, "How many hours do you sleep at night?" Less than six hours per night was defined as short sleep, in line with prior meta-analytic evidence linking <6 hours of sleep to higher risk of mortality, diabetes, cardiovascular disease, and obesity [30]. A sensitivity analysis was also performed using <7 hours as the cutoff to test the robustness of the results.

Other measurements

Anthropometric measurements were conducted with participants standing barefoot and wearing minimal clothing. Body composition—including weight, fat mass, muscle mass, fat-free mass, and body fat percentage—was measured using a bioelectrical impedance analyzer (Tanita MC-780 MA, Tokyo, Japan). Height was recorded to the nearest 0.1 cm with a wall-mounted tape, and BMI was subsequently calculated. Information on age, sex, marital status, educational level, smoking habits, socioeconomic status, late-evening tea or coffee intake, and antidepressant use was collected via self-administered questionnaires.

Obstructive sleep apnea (OSA) risk was screened using the STOP-Bang questionnaire [31], consisting of eight yes/no items: snoring, daytime fatigue, observed apnea, hypertension, BMI >35 kg/m², age >50, neck circumference >40 cm, and male sex [31, 32]. Participants with a score ≥5 were considered at risk of OSA. Physical activity was assessed using the validated International Physical Activity Questionnaire (IPAQ) [33].

Fasting blood samples were collected to assess markers of inflammation, oxidative stress, and antioxidant status. Levels of malondialdehyde (MDA), superoxide dismutase (SOD), and glutathione peroxidase (GPX) were measured using commercial ELISA kits (Kiazist Co, Hamedan, Iran), while C-reactive protein (CRP) was quantified using a latex-enhanced turbidimetric assay (Delta.DP).

Statistical analysis

Participants were divided into tertiles according to their DASH scores: T1 (9–21), T2 (22–26), and T3 (27–37). Continuous variables were compared across tertiles using analysis of variance (ANOVA) and reported as mean ± SD or SE, while categorical variables were compared using the chi-square test and expressed as percentages. Energy-adjusted dietary intakes across DASH tertiles were analyzed using ANCOVA, controlling for age, sex, and total energy intake.

To investigate the relationship between DASH adherence and poor sleep quality (PSQI ≥6 vs. <6) or short sleep duration (<6 vs. ≥6 hours/night), binary logistic regression models were fitted, and linear trends across tertiles were evaluated. Sensitivity analyses were performed with a <7-hour cutoff to assess short sleep. In regression models, the first tertile of DASH was used as the reference, while for linear trend analysis, DASH scores were treated as ordinal variables. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated.

Three models were used sequentially. Model 1 adjusted for age, sex, and energy intake. Model 2 further included marital status, education, smoking, physical activity, socioeconomic status, obstructive sleep apnea, antidepressant use, and late-evening tea or coffee consumption. Model 3 additionally controlled for BMI. Analyses stratified by sex were also conducted. Linear regression was applied to examine potential associations between DASH adherence and biomarkers of inflammation and oxidative stress, adjusting for age, sex, and BMI. Additionally, ANOVA was used to compare oxidative stress and inflammatory biomarkers across categories of sleep quality (good, moderate, poor) and sleep duration (<6, 6–8, >8 hours). All analyses were conducted using SPSS version 26 (IBM, Chicago, IL), with a two-sided $p<0.05$ considered statistically significant.

Mediation analyses were performed to determine whether CRP, MDA, SOD, or GPX mediated the associations between DASH adherence and poor sleep quality or short sleep duration. The "paramed" module in STATA version 17 was used to estimate direct, indirect, and total effects. DASH score, sleep outcomes, and mediators were treated as continuous variables. For effect estimation, the median values of the first (19) and third (29) tertiles of DASH were compared. Potential confounders included age, sex, energy intake, marital status, education, smoking, physical activity, socioeconomic status, obstructive sleep apnea, antidepressant use, and late-evening tea or coffee consumption. BMI was not included as a confounder in mediation analyses because it may lie on the causal pathway.

Results and Discussion

Among the 535 participants, the mean age was 42.58 ± 11.14 years, and mean BMI was 26.91 ± 4.41 kg/m². The cohort consisted of 54% men (n=289) and 46% women (n=246). **Table 1** presents general characteristics across energy-adjusted DASH tertiles. Participants in the highest tertile (T3) were older (p<0.001), had lower weight (p=0.03) and height (p=0.01), were more physically active (p=0.03), and were less likely to consume tea or coffee after 8:00 PM (p=0.02). No other characteristics differed significantly across tertiles.

Table 1. General cardiometabolic and characteristics factors of participants across tertiles of DASH [1]

Characteristic	Tertile 1 (n=165)	Tertile 2 (n=207)	Tertile 3 (n=163)	P-value
DASH score range	9–21	22–26	27–37	
Sex - Male (%)	57.6	49.8	55.8	0.28
Sex - Female (%)	42.4	50.2	44.2	
Age (years)	38.08 ± 9.03	42.60 ± 10.79	47.10 ± 11.14	<0.001
Weight (kg)	78.00 ± 14.80	74.07 ± 13.83	75.55 ± 14.91	0.03
Height (cm)	169.32 ± 8.87	166.89 ± 8.73	166.94 ± 7.69	0.01
BMI (kg/m²)	27.16 ± 4.32	26.59 ± 4.30	27.06 ± 4.65	0.41
Muscle mass (kg)	52.40 ± 10.12	49.99 ± 9.90	50.95 ± 9.50	0.06
Fat-free mass (kg)	55.17 ± 10.62	52.64 ± 10.39	53.65 ± 9.97	0.07
Fat percent (%)	28.87 ± 8.20	28.66 ± 7.46	28.64 ± 6.95	0.95
Fat mass (kg)	22.84 ± 8.47	21.46 ± 7.33	21.90 ± 8.33	0.25
Physical activity - Inactive (%)	57.0	63.9	46.9	0.03
Physical activity - Minimally active (%)	35.2	29.8	43.2	
Physical activity - Active (%)	7.9	6.3	9.9	
Education - Higher than diploma (%)	90.9	87.9	88.1	
Education - Diploma or lower (%)	9.1	12.1	11.9	0.61
Marital status - Single (%)	15.9	14.6	19.3	0.35
Marital status - Married (%)	82.9	84.9	78.3	
Marital status - Divorced or widow (%)	1.2	0.5	2.5	
Smoking status - Ex-smoker (%)	2.0	3.7	3.5	
Smoking status - Nonsmoker (%)	94.6	93.1	93.6	0.92
Smoking status - Current smoker (%)	3.4	3.2	2.8	
Socio-economic status - Moderate (%)	31.6	33.6	30.4	
Socio-economic status - High (%)	33.3	38.9	35.9	
Socio-economic status - Low (%)	35.0	27.5	33.7	0.74
OSA - Borderline (%)	26.0	27.1	31.8	
OSA - Yes (%)	6.7	4.0	5.7	
OSA - No (%)	67.3	68.8	62.4	0.59
Antidepressant drug - Yes (%)	5.6	7.0	3.1	
Antidepressant drug - No (%)	94.4	93.0	96.9	0.27
Drinking tea and coffee after 8:00 PM - No (%)	33.3	44.7	48.1	
Drinking tea and coffee after 8:00 PM - Yes (%)	66.7	55.3	51.9	0.02
Superoxide dismutase (Unit)	1.16 ± 0.04	1.13 ± 0.03	1.08 ± 0.49	0.34

Malondialdehyde (nmol/mL)	167.74 ± 7.13	176.49 ± 6.32	162.50 ± 7.41	0.34
Glutathione peroxidase (mU/mL)	1.99 ± 0.24	1.93 ± 0.31	2.01 ± 0.28	0.98
C-reactive protein (mg/L)	3.24 ± 0.26	3.17 ± 0.20	3.15 ± 0.13	0.96

1. [1]Continuous variables are presented as mean ± SD, while categorical variables are expressed as percentages.
2. [2]P-values were derived from one-way ANOVA for continuous variables and χ^2 tests for categorical variables.
3. Abbreviations: BMI, Body Mass Index; OSA, Obstructive Sleep Apnea; DASH, Dietary Approaches to Stop Hypertension.

Table 2 summarizes dietary intakes according to tertiles of DASH diet adherence. Participants in the highest DASH tertile (T3) consumed significantly higher amounts of carbohydrates, fruits, vegetables, whole grains, low-fat dairy, nuts and legumes, total fiber, plant protein, and calcium compared with those in the lowest tertile (T1). In contrast, Intakes of red and processed meats, total fat, monounsaturated fatty acids (MUFA), saturated fatty acids (SFA), polyunsaturated fatty acids (PUFA), cholesterol, sugar-sweetened beverages (SSBs) and sodium, were lower in T3 than T1 (all P-values <0.05). No additional significant differences in dietary intake were observed across the DASH tertiles.

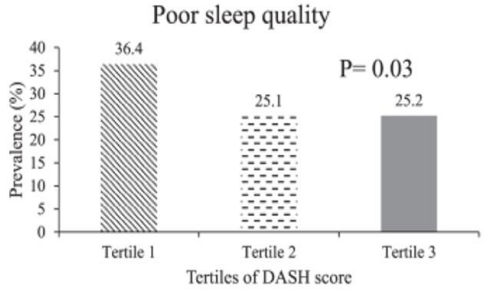
Table 2. Dietary intake (energy, macro- and micronutrients, and food groups) across tertiles of DASH adherence[1]

	Tertile 1 (Lowest adherence) (n = 165) DASH score: 9–21	**Tertile 2 (Moderate adherence) (n = 207) DASH score: 22–26**	**Tertile 3 (Highest adherence) (n = 163) DASH score: 27–37**	**P-value***
Nutrients				
Energy (kcal)	2350.43 ± 53.81	2136.50 ± 46.69	2362.87 ± 54.00	0.01
Total protein (g/day)	79.88 ± 1.34	80.86 ± 1.17	81.08 ± 1.35	0.80
Animal protein (g/day)	47.70 ± 1.52	45.82 ± 1.33	44.81 ± 1.53	0.41
Plant protein (g/day)	32.17 ± 0.61	35.04 ± 0.54	36.27 ± 0.62	< 0.001
Carbohydrate (g/day)	330.96 ± 3.86	345.03 ± 3.37	356.77 ± 3.88	< 0.001
Fat (g/day)	73.54 ± 1.43	68.12 ± 1.24	64.22 ± 1.43	< 0.001
Cholesterol (mg/day)	288.24 ± 9.38	280.89 ± 8.18	256.89 ± 9.42	0.05
Saturated fatty acids (g/day)	24.45 ± 0.62	21.87 ± 0.54	20.72 ± 0.62	< 0.001
Monounsaturated fatty acids (g/day)	24.03 ± 0.53	21.31 ± 0.46	20.11 ± 0.53	< 0.001
Polyunsaturated fatty acids (g/day)	16.62 ± 0.59	16.67 ± 0.51	14.91 ± 0.59	0.05
Calcium (mg/day)	820.33 ± 29.13	909.20 ± 25.42	1036.12 ± 29.25	< 0.001
Vitamin E (mg/day)	6.59 ± 0.25	6.83 ± 0.22	7.17 ± 0.25	0.27
Total dietary fiber (g/day)	16.61 ± 0.44	21.11 ± 0.38	25.75 ± 0.44	< 0.001
Food groups				
Whole grains (g/day)	26.16 ± 3.91	48.57 ± 3.42	66.06 ± 3.93	< 0.001
Vegetables (g/day)	241.19 ± 17.26	333.68 ± 15.07	460.69 ± 17.34	< 0.001
Fruits (g/day)	408.28 ± 23.99	554.27 ± 20.93	697.84 ± 24.09	< 0.001
Red and processed meat (g/day)	86.43 ± 3.41	67.59 ± 2.98	47.90 ± 3.43	< 0.001
Low-fat dairy (g/day)	197.98 ± 19.71	238.94 ± 17.20	333.92 ± 19.79	< 0.001
Nuts and legumes (g/day)	37.51 ± 2.95	52.23 ± 2.57	66.55 ± 2.96	< 0.001
Sodium (mg/day)	4683.73 ± 197.54	3595.13 ± 172.39	3081.93 ± 198.35	< 0.001
Sugar-sweetened beverages (g/day)	69.60 ± 6.63	34.27 ± 5.78	9.19 ± 6.65	< 0.001

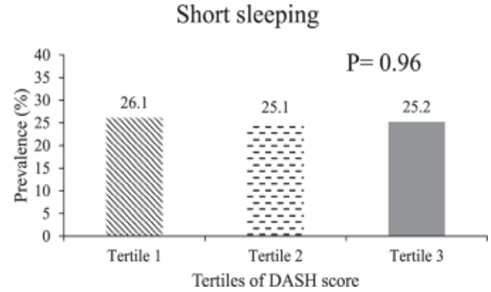
1. [1]Values are reported as Mean ± SE. Energy intake was adjusted for sex and age, whereas all other variables were adjusted for sex, age, and energy intake.
2. [2]P-values were calculated using ANCOVA to adjust for energy intake.
3. Abbreviations: PUFA, Polyunsaturated fatty acids; MUFA, Monounsaturated fatty acids; SFA, Saturated fatty acids.

Out of all participants, 136 were identified with poor sleep quality (PSQI ≥6) and 153 were classified as short sleepers (<6 hours of sleep per night). **Figure 1** presents the distribution of poor sleep quality and short sleep

duration across tertiles of DASH adherence. The prevalence of poor sleep quality decreased across DASH tertiles, with 36.4% in T1, 25.1% in T2, and 25.2% in T3 (p = 0.03). However, the proportion of participants with short sleep did not show significant differences between tertiles (p = 0.96).



a)



b)

Figure 1. Distribution of poor sleep quality and short sleep duration across DASH diet adherence levels (tertiles)

The fully adjusted odds ratios for both poor sleep quality and short sleep duration by DASH diet adherence tertiles are shown in **Table 3**. Without adjustments, people with medium or high DASH diet adherence had about 41% lower chances of reporting poor sleep quality than those with low adherence (middle vs. low tertile: OR = 0.59, 95% CI: 0.38–0.92; high vs. low tertile: OR = 0.59, 95% CI: 0.37–0.95). Once potential confounding factors were accounted for, the protective effect grew stronger (middle vs. low: OR = 0.47, 95% CI: 0.24–0.93; high vs. low: OR = 0.43, 95% CI: 0.20–0.92). There was also a clear trend: every step up in DASH adherence tertile lowered the risk of poor sleep quality by 24% in the unadjusted analysis (OR = 0.76, 95% CI: 0.60–0.97) and by 36% after adjustments (OR = 0.64, 95% CI: 0.44–0.94).

Regarding short sleep duration, the unadjusted results suggested a possible benefit only in the highest adherence group, but it was not statistically significant. After controlling for confounders, however, strong protection emerged in the top tertile (high vs. low: OR = 0.43, 95% CI: 0.20–0.92). Moreover, moving up one tertile in DASH adherence was linked to a 34% decrease in the likelihood of short sleep duration (OR = 0.66, 95% CI: 0.45–0.96).

Table 3. Fully adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for poor sleep quality and short sleep duration by DASH diet score tertiles[1]

Outcome	Sex	Model	Tertile 1 (Lowest DASH adherence, n=165)	Tertile 2 (Middle, n=207)	Tertile 3 (Highest DASH adherence, n=163)	P for trend
Poor sleep quality						
	Men (n=289)	Cases/participants	26/95	25/103	19/91	
		Crude	1.00 (Reference)	0.85 (0.45–1.61)	0.70 (0.36–1.38)	0.30
		Model 1	1.00 (Reference)	0.85 (0.43–1.68)	0.68 (0.32–1.44)	0.32
		Model 2	1.00 (Reference)	0.47 (0.18–1.23)	0.72 (0.26–2.00)	0.45
		Model 3	1.00 (Reference)	0.47 (0.18–1.23)	0.69 (0.24–1.98)	0.40
	Women (n=246)	Cases/participants	34/70	27/104	22/72	
		Crude	1.00 (Reference)	0.37 (0.20–0.71)	0.47 (0.24–0.93)	0.03
		Model 1	1.00 (Reference)	0.37 (0.19–0.70)	0.45 (0.22–0.90)	0.02
		Model 2	1.00 (Reference)	0.42 (0.14–1.23)	0.17 (0.05–0.63)	0.01
		Model 3	1.00 (Reference)	0.39 (0.13–1.15)	0.14 (0.04–0.56)	0.01

Short sleep duration						
	Men (n=289)	Cases/participants	24/95	28/103	23/91	
		Crude	1.00 (Reference)	1.10 (0.59–2.08)	1.00 (0.52–1.94)	0.99
		Model 1	1.00 (Reference)	1.20 (0.61–2.39)	0.95 (0.45–1.98)	0.86
		Model 2	1.00 (Reference)	1.07 (0.42–2.72)	0.99 (0.37–2.64)	0.98
		Model 3	1.00 (Reference)	1.05 (0.41–2.67)	0.88 (0.32–2.41)	0.81
	Women (n=246)	Cases/participants	19/70	24/104	18/72	
		Crude	1.00 (Reference)	0.81 (0.40–1.62)	0.90 (0.42–1.89)	0.77
		Model 1	1.00 (Reference)	0.77 (0.38–1.55)	0.75 (0.35–1.63)	0.47
		Model 2	1.00 (Reference)	0.46 (0.15–1.41)	0.11 (0.03–0.50)	0.01
		Model 3	1.00 (Reference)	0.47 (0.15–1.47)	0.12 (0.03–0.55)	0.01

1. [1]Every reported figure consists of odds ratios together with their corresponding 95% confidence intervals. In Model 1, adjustments were made for age and daily energy intake; Model 2 further included adjustments for marital status, level of education, smoking behavior, physical activity levels, socioeconomic position, diagnosis of obstructive sleep apnea, use of antidepressants, and intake of tea or coffee after 8:00 PM; Model 3 added an extra adjustment for body mass index.
2. [2]The trend P-value was determined by entering the DASH score tertiles into the model as a continuous variable instead of discrete categories.
3. [3]Abbreviation: DASH, Dietary Approaches to Stop Hypertension; Ref, reference.

A sensitivity analysis was conducted defining short sleepers as those sleeping less than 7 hours per night. In this analysis, 70.1% of the study participants (n = 375) qualified as short sleepers, and the prevalence of short sleep did not vary meaningfully between the DASH score tertiles (p = 0.79).

Table 4 illustrates the odds ratios from multivariable regression for experiencing poor sleep quality or short sleep duration according to DASH score tertiles, with separate results for each sex. Statistically meaningful links between DASH scores and both poor sleep quality and short sleep duration emerged exclusively in women, not in men. Among women, the unadjusted analysis revealed decreased odds of poor sleep quality (OR tertile 3 versus tertile 1 = 0.47; 95% CI: 0.24–0.93), and this protective effect grew much more pronounced after full covariate adjustment (OR tertile 3 versus tertile 1 = 0.14; 95% CI: 0.04–0.56). Likewise, greater adherence to the DASH diet was linked to substantially lower odds of short sleep duration in women once all adjustments were applied (OR tertile 3 versus tertile 1 = 0.12; 95% CI: 0.03–0.55).

Table 4. Odds ratios (with multivariable adjustment) and corresponding 95% confidence intervals for inadequate sleep quality and reduced sleep duration, categorized by tertiles of Dietary Approaches to Stop Hypertension (DASH) diet scores, presented separately for women and men[1]

Outcome	Sex	T1 (n=165)	T2 (n=207)	T3 (n=163)	P-trend
Poor sleep quality	Men (n=289)				
Cases/participants (n)	26/95	25/103	19/91		
Crude	1.00 (Ref.)	0.85 (0.45, 1.61)	0.70 (0.36, 1.38)	0.30	
Model 1	1.00 (Ref.)	0.85 (0.43, 1.68)	0.68 (0.32, 1.44)	0.32	
Model 2	1.00 (Ref.)	0.47 (0.18, 1.23)	0.72 (0.26, 2.00)	0.45	
Model 3	1.00 (Ref.)	0.47 (0.18, 1.23)	0.69 (0.24, 1.98)	0.40	
	Women (n=246)				
Cases/participants (n)	34/70	27/104	22/72		
Crude	1.00 (Ref.)	0.37 (0.20, 0.71)	0.47 (0.24, 0.93)	0.03	
Model 1	1.00 (Ref.)	0.37 (0.19, 0.70)	0.45 (0.22, 0.90)	0.02	
Model 2	1.00 (Ref.)	0.42 (0.14, 1.23)	0.17 (0.05, 0.63)	0.01	
Model 3	1.00 (Ref.)	0.39 (0.13, 1.15)	0.14 (0.04, 0.56)	0.01	

Short sleeping	Men (n=289)			
Cases/participants (n)	24/95	28/103	23/91	
Crude	1.00 (Ref.)	1.10 (0.59, 2.08)	1.00 (0.52, 1.94)	0.99
Model 1	1.00 (Ref.)	1.20 (0.61, 2.39)	0.95 (0.45, 1.98)	0.86
Model 2	1.00 (Ref.)	1.07 (0.42, 2.72)	0.99 (0.37, 2.64)	0.98
Model 3	1.00 (Ref.)	1.05 (0.41, 2.67)	0.88 (0.32, 2.41)	0.81
	Women (n=246)			
Cases/participants (n)	19/70	24/104	18/72	
Crude	1.00 (Ref.)	0.81 (0.40, 1.62)	0.90 (0.42, 1.89)	0.77
Model 1	1.00 (Ref.)	0.77 (0.38, 1.55)	0.75 (0.35, 1.63)	0.47
Model 2	1.00 (Ref.)	0.46 (0.15, 1.41)	0.11 (0.03, 0.50)	0.01
Model 3	1.00 (Ref.)	0.47 (0.15, 1.47)	0.12 (0.03, 0.55)	0.01

Table 5 outlines the links between particular aspects of sleep quality and DASH score tertiles. Individuals with moderate DASH diet adherence, relative to those with the lowest adherence, showed approximately 60% lower odds of experiencing "delay in falling asleep" before adjustments (OR tertile 2 versus tertile 1 = 0.40; 95% CI: 0.21–0.76) and 61% lower odds after multivariable adjustment (OR tertile 2 versus tertile 1 = 0.39; 95% CI: 0.15–0.98). Furthermore, those in the highest DASH adherence group had a markedly reduced chance of reporting "sleep disorders" compared to the lowest group, both in unadjusted analyses (OR tertile 3 versus tertile 1 = 0.41; 95% CI: 0.19–0.85) and after complete adjustment (OR tertile 3 versus tertile 1 = 0.26; 95% CI: 0.08–0.84).

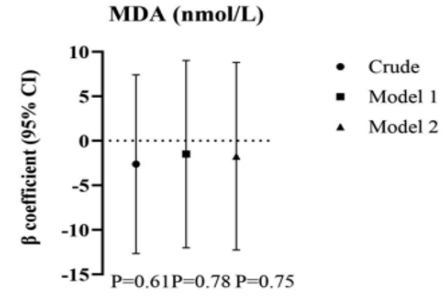
Table 5. Multivariable-adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for separate components of sleep quality according to DASH score tertiles[1]

Sleep Outcome	Tertile	Cases / Participants (n)	Crude OR (95% CI)	Multivariate-Adjusted OR (95% CI)	P for Trend
Person's general description of his/her sleep	T1	23 / 165	1.00 (Reference)	1.00 (Reference)	
	T2	21 / 207	0.70 (0.37–1.31)	0.63 (0.26–1.55)	0.12 (crude) 0.20 (adjusted)
	T3	14 / 163	0.58 (0.29–1.17)	0.50 (0.15–1.63)	
Delay in falling asleep	T1	30 / 165	1.00 (Reference)	1.00 (Reference)	
	T2	17 / 207	0.40 (0.21–0.76)	0.39 (0.15–0.98)	0.35 (crude) 0.05 (adjusted)
	T3	24 / 163	0.77 (0.43–1.40)	0.38 (0.14–1.07)	
Duration of beneficial sleep	T1	68 / 165	1.00 (Reference)	1.00 (Reference)	
	T2	78 / 207	0.86 (0.57–1.31)	0.86 (0.46–1.61)	0.98 (crude) 0.46 (adjusted)
	T3	67 / 163	1.00 (0.64–1.55)	0.77 (0.39–1.54)	
Sleep efficiency	T1	1 / 165	1.00 (Reference)	1.00 (Reference)	
	T2	0 / 207	—	—	—
	T3	1 / 163	—	—	
Sleep disorders	T1	25 / 165	1.00 (Reference)	1.00 (Reference)	
	T2	20 / 207	0.60 (0.32–1.12)	0.15 (0.04–0.55)	0.01 (both crude and adjusted)
	T3	11 / 163	0.41 (0.19–0.85)	0.26 (0.08–0.84)	
Use of sleeping medicine	T1	7 / 165	1.00 (Reference)	1.00 (Reference)	

	T2	6 / 207	0.67 (0.22–2.05)	0.21 (0.03–1.51)	0.56 (crude) 0.23 (adjusted)
	T3	5 / 163	0.74 (0.22–2.30)	0.31 (0.05–2.07)	
Daily functional disorders (due to sleep)	T1	26 / 165	1.00 (Reference)	1.00 (Reference)	
	T2	27 / 207	0.80 (0.45–1.44)	0.93 (0.41–2.13)	0.36 (crude) 0.85 (adjusted)
	T3	20 / 163	0.75 (0.40–1.40)	0.92 (0.34–2.45)	

1. [1]Values are reported as odds ratios (ORs) with 95% confidence intervals (CIs). The multivariable model was adjusted for marital status, education, socio-economic status, age, body mass index (BMI), energy intake, smoking, physical activity, use of antidepressants, and obstructive sleep apnea, as well as consumption of tea and coffee after 8:00 PM.
2. [2]The P-trend was assessed by treating DASH score tertiles as a continuous variable rather than categorical groups.
3. ORs (95% CIs) could not be calculated for a tertile with no cases.
4. Abbreviations: DASH stands for Dietary Approaches to Stop Hypertension; Ref indicates the reference group.

Figure 2 shows the associations between DASH diet tertiles and levels of MDA, SOD, GPX, and CRP. No significant relationships were observed between higher DASH scores and these biomarkers ($p > 0.05$).



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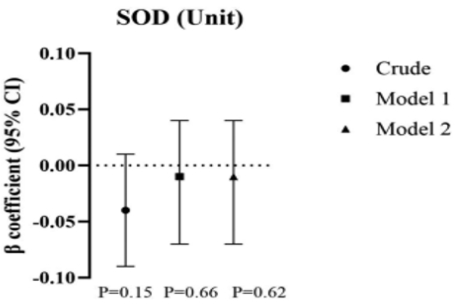

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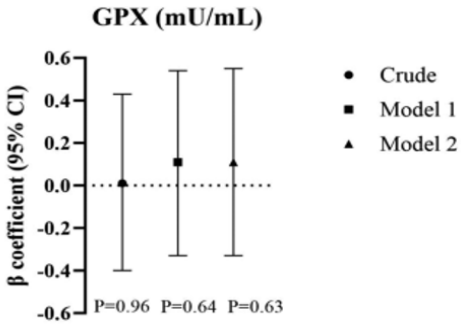

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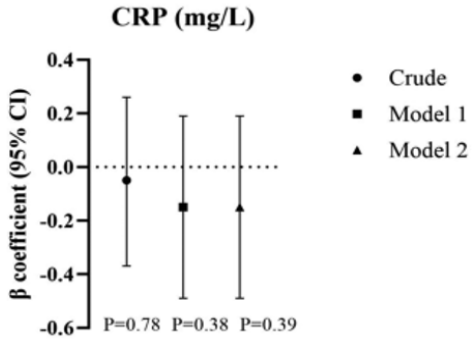

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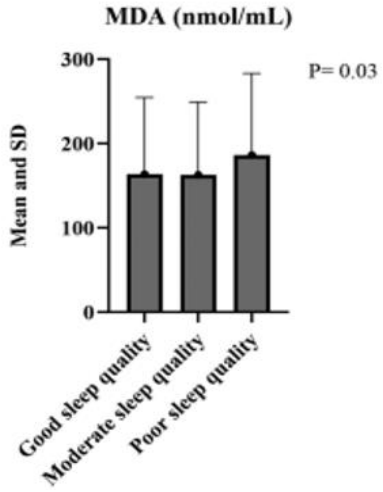
Figure 2. Linear relationships between each increase in DASH diet tertiles and the levels of CRP, GPX, SOD, and MDA are presented.

In **Figures 3 and 4** show CRP, GPX, SOD, and MDA levels across three categories of sleep quality and sleep duration. As illustrated in **Figure 3**, MDA levels differed significantly among participants with varying sleep quality: those with good sleep quality had 163.35 ± 90.97 nmol/mL, moderate sleep quality had 162.51 ± 86.55 nmol/mL, and poor sleep quality had 186.00 ± 96.95 nmol/mL ($p = 0.03$). No significant differences were observed for CRP, GPX, or SOD across sleep quality or sleep duration categories.



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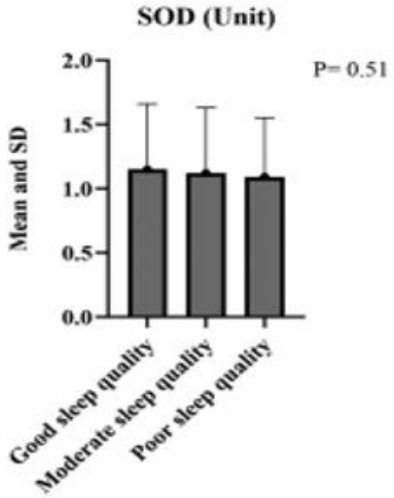

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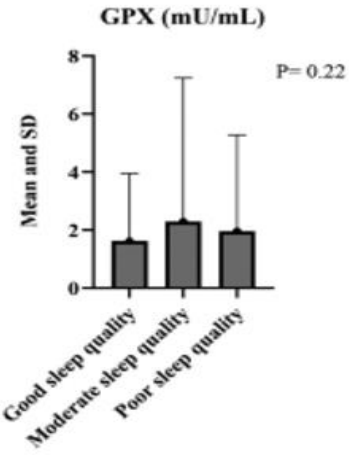

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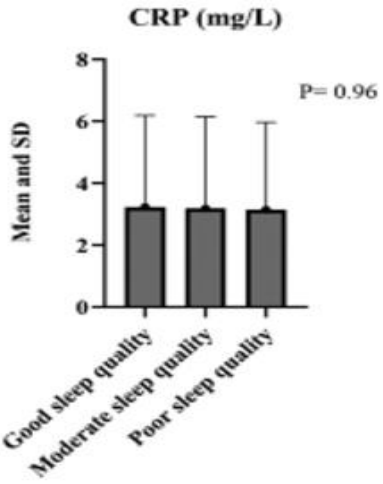

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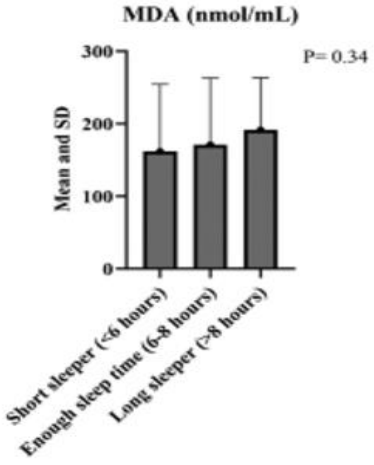
Figure 3. Oxidative stress and inflammatory biomarker levels among participants according to different sleep quality categories



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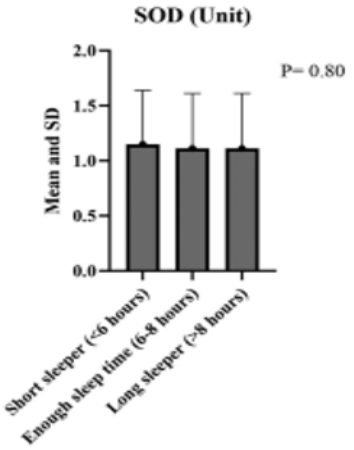

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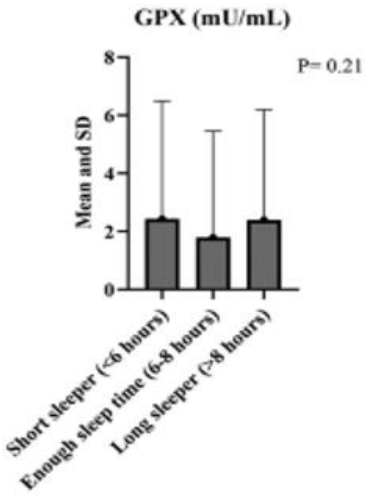

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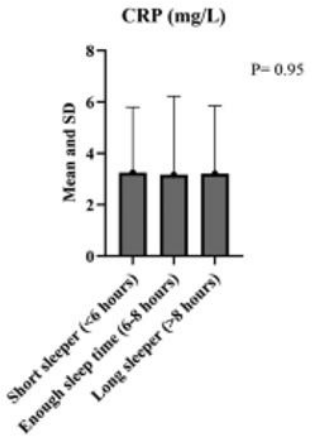

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Figure 4. Oxidative stress and inflammatory biomarker levels across the participants' sleep duration categories.

Mediation analysis performed with "paramed" suggested that raising the DASH score from 19 (median of the lowest tertile) to 29 (highest tertile) was linked to better sleep quality (lower scores) and a modest increase in nightly sleep duration. Nevertheless, these associations did not appear to be mediated by CRP or oxidative stress biomarkers, as all indirect effect P-values were greater than 0.05.

In this study of middle-aged Iranian adults, greater adherence to the DASH diet was associated with a lower risk of poor sleep quality and short sleep duration. These associations were more pronounced in women than in men. Specifically, higher DASH adherence was linked to improvements in two key domains of sleep quality: delayed sleep onset and the presence of sleep disorders. Additionally, participants with better sleep quality exhibited lower MDA levels. While higher DASH adherence was modestly associated with reduced MDA, and lower MDA corresponded with better sleep, mediation analyses indicated that these biomarkers did not explain the relationship between DASH adherence and sleep quality improvements.

Sleep disturbances negatively affect quality of life and social functioning [2, 34] and are associated with increased risks of cardiovascular disease [3], type 2 diabetes [4], and metabolic abnormalities [5]. These findings suggest that promoting the DASH diet, particularly among women, could be an effective strategy to mitigate sleep disturbances.

Previous studies examining the relationship between the DASH diet and sleep outcomes have reported mixed results. A 12-week clinical trial in 66 Iranian women with diabetes found that the DASH diet improved stress and sleep [35]. Similarly, a cross-sectional study involving 350 Iranian breastfeeding mothers reported that greater adherence to DASH was associated with lower sleep disorder scores in both mothers and infants [18]. Among 3,939 Chinese adults, higher DASH adherence was linked to a reduced likelihood of self-reported sleep-disordered breathing [36]. Conversely, a study of 3,941 American adults over 30 years found that higher DASH scores were inversely associated with poor sleep-related daytime dysfunction but not significantly related to sleepiness or disturbances [13]. In 488 Iranian adolescent girls, adherence to the DASH diet showed no significant association with insomnia [19]. Additionally, a study of 6,084 Iranian adults with psychological disorders reported that while the Mediterranean diet improved sleep in those with severe depression, the DASH diet did not yield significant effects [37].

Several mechanisms may explain the link between DASH adherence and sleep outcomes. The diet is rich in antioxidants from fruits, vegetables, and omega-3 fatty acids, which can reduce inflammatory markers implicated in sleep disturbances [38]. By limiting added sugars and increasing fiber intake from whole grains and vegetables, the diet helps stabilize blood glucose and improve insulin sensitivity, reducing circadian rhythm disruptions [39]. Foods such as cherries and nuts, emphasized in DASH, are rich in tryptophan, a precursor for serotonin and melatonin, supporting melatonin synthesis and better sleep regulation [40]. The high-fiber, low-calorie composition also aids in weight management, which can alleviate obstructive sleep apnea

and improve sleep quality [41]. Fiber further benefits gut microbiota composition, which is associated with sleep regulation [42]. Magnesium-rich foods in the DASH diet support neurotransmitter regulation and neural relaxation, enhancing sleep quality [43]. Additionally, increasing potassium intake from fruits and vegetables while reducing sodium helps maintain electrolyte balance, which may contribute to better sleep [44, 45].

In this study, the relationships between DASH adherence, sleep quality, and short sleep duration were not statistically significant in men, despite the relatively large male sample, suggesting potential sex-specific effects. Poor sleep quality was more prevalent among women than men (33.7% vs. 24.2%, $p = 0.01$), whereas short sleep prevalence did not differ significantly by sex (24.8% vs. 26.0%, $p = 0.42$). Higher DASH scores in women (24.2 vs. 23.8) may have contributed to the stronger associations. Hormonal differences, including estrogen and progesterone in women and testosterone in men, may influence sleep patterns, with declines during menopause or andropause potentially exacerbating sleep disturbances [21-23]. Age-related fluctuations in other hormones, such as melatonin and cortisol, may further modulate circadian rhythms and sleep quality in both sexes [46].

A key strength of this study was the inclusion of both men and women, selected via multistage cluster random sampling to achieve a sample somewhat representative of the population and diverse socio-economic backgrounds. However, the cross-sectional design prevents causal inferences and raises the possibility of reverse causation, where poor sleep could influence dietary behaviors and DASH adherence [47, 48]. Residual confounding may also exist despite adjustment for known factors. Dietary intake was assessed via FFQ, which is prone to recall and reporting biases; future studies could supplement with objective measures such as 24-hour recalls. Although efforts were made to ensure representativeness, differences in lifestyle, culture, diet, and genetics may limit generalizability. The sample size was not stratified by sex, restricting analyses of sex-specific associations, and power calculations were based on sleep outcomes rather than oxidative stress or inflammatory biomarkers, possibly explaining non-significant results. Future studies should include additional markers such as total antioxidant capacity (TAC), catalase, and inflammatory markers including IL-6, IL-1β, and TNF-α.

Conclusion

In summary, this study suggests that adherence to the DASH diet is linked to better sleep quality and longer sleep duration, particularly among women. Although reductions in MDA were observed, they did not mediate the associations between DASH adherence and sleep outcomes. Greater adherence to DASH was specifically associated with improvements in delayed sleep onset and sleep disorders. Further prospective research is needed to confirm these findings and clarify the underlying mechanisms.

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Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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