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Association of Dietary Approaches to Stop Hypertension (DASH) diet with self-reported sleep-disordered breathing (SDB): a cross-sectional study from China

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Abstract

Adherence to the Dietary Approaches to Stop Hypertension (DASH) diet has been associated with sleep quality. However, its relationship with sleep-disordered breathing (SDB) remains unknown. This study aimed to explore the association between the DASH diet and SDB using data from a community-based survey among adults in Suzhou, Eastern China. We conducted a cross-sectional analysis of the Suzhou Food Consumption and Health Survey in 2018–2020. Dietary intake was measured by a validated FFQ. The association between the DASH diet and SDB was estimated by multivariable logistic regression analysis. In addition, subgroup analysis and sensitivity analysis were performed to reinforce our findings. A total of 3939 participants were included in the final analysis. Participants in the upper quintile of the DASH score consumed more fruits, vegetables, nuts and legumes, whole grains, and dairy products, and less Na, red/processed meats, and sweetened beverages. The OR for the highest compared with the lowest quintile of the DASH score was 0·68 (95 % CI 0·52, 0·88; $P_{\text{for trend}} = 0{\cdot}004$) for SDB after multivariable adjustment. Of the eight DASH components, vegetables, nuts and legumes, and dairy products were inversely associated with SDB. The associations were similar in subgroups by age, sex, BMI, smoking, alcohol drinking, hypertension, diabetes and hyperlipidaemia. Adherence to the DASH diet was independently associated with decreased odds of self-reported SDB. Our novel results expand previous findings on diet and sleep and suggest the possibility of improving SDB by enhancing diet quality.

Key words: **DASH diet: Sleep-disordered breathing: Sleep quality: China**

Sleep-disordered breathing (SDB) is characterised by recurrent apnoea and hypopnea events during sleep[1]. An increasing amount of literature suggested that SDB was associated with adverse health outcomes, including hypertension[2], diabetes[3], CVD[4], stroke[5] and increased all-cause mortality[6]. Globally, approximately one billion adults aged between 30 and 69 years suffer from obstructive sleep apnoea, the most common type of SDB[7]. SDB has imposed a considerable health hazard and economic burden on populations worldwide[7], and its prevalence is still increasing[8].

Previous studies have reported that sleep restriction can increase food intake and total energy expenditure[9]. Likewise, a clinical trial suggested that sleeping for short hours can change the type of food intake[10] and increase snack intake[11]. Insomnia was associated with higher intakes of total energy, *trans*-fat, and Na and a lower intake of vegetables[12]. At the same time, a literature review summarised that higher intakes of vegetables, fruits, fish, dairy products and nuts had benefits for sleep improvement[13]. These results suggested a potential bidirectional relation between diet and sleep. In recent years, there is a growing body of research examining the relationship between complete dietary patterns, such as the Mediterranean diet, with sleep disorders and insomnia[14,15]. Nevertheless, research on other sleep-related dietary patterns is still at the preliminary stage[16].

Dietary Approaches to Stop Hypertension (DASH) are thought to be the best example of how the nutrition-intensive diet model can prevent chronic diseases[17]. Since the establishment of the DASH dietary pattern, trials have shown that the DASH diet can reduce the risk of CVD[18], obesity, metabolic and other diseases, in addition to hypertension[19]. Several studies have recently reported an association between the DASH diet

Abbreviations: DASH, Dietary Approaches to Stop Hypertension; SDB, sleep-disordered breathing.

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and sleep quality[20–22]. To our knowledge, however, there have been no studies exploring the association between the DASH diet and SDB. Thus, this study aimed to examine the association between the DASH diet and SDB in community-dwelling adults in Suzhou, Eastern China.

Methods

Study population

The Suzhou Food Consumption and Health Survey is a cross-sectional study conducted from August 2018 to September 2020. A multi-stage random sampling method was used to recruit potential participants. The methodology and survey process has been described elsewhere[23]. A total of 5058 adults participated in the survey and had FFQ data. Of these, we excluded the participants under the age of 18 years (n 249) and those with implausible dietary data (energy intake < 800 or > 6000 kcal for males, energy intake < 600 or > 4000 kcal for females) (n 459). In addition, participants with BMI < 14 kg/m^2 or BMI > 45 kg/m^2 (n 21) and abnormal sleep information (individuals with missing sleep data or sleep duration < 2 h/d or > 12 h/d) (n 390) were also removed. The final study population thus included 3939 participants (1869 males and 2070 females). The study protocol was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Institutional Review Board of the Suzhou Center for Disease Control and Prevention. Informed written consent was obtained from each participant.

Dietary intake assessment and calculation of Dietary Approaches to Stop Hypertension score

Dietary intake was assessed with the use of a FFQ derived from the China National Nutrition Surveys. It has been validated with weighted food records[24,25]. Spearman's correlation coefficients between food intakes from the weighed food records and the FFQ ranged from 0·08 for nuts to 0·76 for rice and rice products among a nationally representative sample of 23 198 participants aged 15–75 years[25]. For each of the seventy-four items, participants were asked if they had eaten the food in the past 12 months and, if so, how often they had eaten it on average. FFQ provides four frequency responses of 'daily', 'weekly', 'monthly' and 'yearly', asking for the corresponding consumption times and amount of consumption per time. Separate questions were asked about all the types of spices, such as oil and salt, those households used in cooking each month, and how much they ate. Total dietary energy intake and nutrients intake were calculated according to the Chinese Food Composition Table[26].

DASH score was calculated using the method reported by Fung *et al.*[27]. The score was based on eight major ingredients including fruits, vegetables, nuts and legumes, dairy products, whole grains, Na, sweet beverages, and red/processed meats. Due to the low consumption of low-fat dairy products in the Chinese population, we replaced this ingredient with regular dairy products[28]. For each ingredient, participants were classified based on the quintile categories of their intake. For fruits, vegetables, nuts and legumes, dairy products, and whole grains, scores of 1, 2, 3, 4 and 5 were assigned to those in the lowest quintiles, 2nd, 3rd, 4th and the highest quintiles, respectively. In contrast, for Na, sweet beverages and red/processed meats, the opposite scoring system was applied. Each person's DASH score was calculated by adding up the scores for each of the eight components, which range from 8 to 40 points.

Definition of sleep-disordered breathing

SDB symptoms were obtained using apnoea symptom score, a subscale in the Multivariate Apnea Prediction Index (MAPI), which asked subjects if they have had at least 3 d of sleep in the past month with the following symptoms: loud snoring, breathing holding/pauses and snorting/gasping. Any of which present was assessed as SDB, as defined in our published article[23].

Covariates

Age, sex, education, marital status, smoking, alcohol drinking and sleep duration were obtained using standard questionnaires administered by trained staff. A smoker was defined as a person who had averaged at least one cigarette a day in the previous 30 d. Drinkers were defined as those who had consumed alcohol on average more than once a month in the past year[23]. Insomnia was defined as having one or more of the following symptoms at least 3 d per week in the last 30 d: difficulty falling asleep, waking up too early and not being able to fall asleep again, waking up twice or more during the night, or taking sleeping pills at least 1 d in the last 30 d[23]. Physical activity was assessed by asking subjects about the times they usually had domestic, occupational, transport and leisure activities at different intensities (low, moderate and vigorous) per week over the past year. BMI was calculated as weight divided by the square of height (kg/m^2).

Information on diabetes, hyperlipidaemia, stroke (ischaemic, haemorrhagic and other types) or other chronic diseases (CHD, chronic obstructive pulmonary disease, asthma, bone and joint disease, neck or waist disease, chronic digestive system disease, chronic urinary system disease, and malignant tumours) was obtained by questioning the participants whether they had been diagnosed by a qualified physician at a township or higher hospital. Hypertension was defined as blood pressure ≥ 140/90 mmHg, hospital diagnosis or antihypertensive medication use[23,29].

Statistical analyses

To compare the demographic characteristics of study participants across the DASH score quintiles and self-reported SDB, we applied the Kruskal–Wallis tests for continuous variables and the χ^2 test for categorical variables. To examine the association between the DASH dietary pattern and SDB, we used multivariable logistic regression in several models: (1) model 1 was adjusted for age (continuous) and sex; model 2 was adjusted as model 1 plus marital status (married or others), education (junior high school and below, senior high school, or university), physical activity (low: no moderate or vigorous activity; moderate: < 4 h/week moderate or < 2 h/week vigorous activity; high: ≥ 4 h/week moderate or ≥ 2 h/week vigorous activity)[30],

BMI (< 24 kg/m^2 and ≥ 24 kg/m^2), smoking (yes or no), alcohol drinking (yes or no); model 3 was adjusted as model 2 plus energy intake (continuous), hypertension (yes or no), diabetes (yes or no), hyperlipidaemia (yes or no), insomnia (yes or no) and sleep duration (< 7 h/d, 7–9 h/d and > 9 h/d); model 4 was further adjusted for vitamin D intake (continuous).

In addition, interaction and stratified analysis were conducted by age group (18–45 years, 45–60 years and ≥ 60 years), sex, BMI, smoking, alcohol drinking hypertension, diabetes and hyperlipidaemia. Sensitivity analyses were performed to determine the robustness of the primary findings. We restricted the risk association analyses to those participants without hypertension, diabetes, hyperlipidaemia, stroke and other chronic diseases.

SAS statistical software (version 9.4; SAS Institute, Inc.) and R (V.4.1.3, www. r-project.org) were used for statistical analyses. All tests were two-sided, and a *P*-value < 0·05 was considered statistically significant.

Results

Of the 3939 participants, 2070 (52·6 %) participants were females, with a median age of 48 years (IQR 35–60) and mean BMI of 23·9 kg/m^2 (SD 3·4), 968 individuals (24·6 %) had self-reported SDB. The baseline characteristics of the participants across the quintiles of the DASH score are shown in Table 1. Compared with the participants with lower DASH score quintiles, those with higher quintiles were more likely to be younger, female, more educated, non-smokers, non-drinkers, and with lower BMI and prevalence of hypertension ($P < 0·001$). As expected, achieving a higher DASH score was associated with lower intakes of Na, red/processed meats and sweetened beverages, but higher intakes of energy intake, vitamin D, potassium, fruits, vegetables, nuts and legumes, whole grains and dairy products ($P < 0·001$).

As shown in Table 2, those with SDB were more likely to be older, male, married, smokers, drinkers, less educated, have less physical activity, and have higher BMI and hypertension, diabetes, hyperlipidaemia, insomnia, and irrational sleep duration. Of note, those participants with self-reported SDB generally had a lower DASH score ($P < 0·001$).

A higher DASH score was significantly associated with decreased odds of SDB in the basic model adjusted for age and sex, and the model with further adjustment for BMI, education, marital status, physical activity, smoking, alcohol drinking, and in the model 3 with additional adjustment for energy intake, hypertension, diabetes, hyperlipidaemia, insomnia, and sleep duration. The inverse association remained significant in the fully adjusted model with additional adjustment for vitamin D intake. The multivariable-adjusted OR for SDB was 0·68 (95 % CI 0·52, 0·88, $P_{for\ trend} = 0·004$) for those in the highest quintile of the DASH score compared with the lowest quintile (Table 3).

The associations between the DASH score and SDB were similar in subgroups stratified by age group, sex, BMI, smoking, alcohol drinking, hypertension, diabetes and hyperlipidaemia (all $P_{for\ interaction} > 0·05$, Fig. 1). Moreover, a multivariable logistic regression analysis of the eight components of the DASH diet showed that vegetables, nuts and legumes, and dairy products were negatively associated with SDB (Table S1). In sensitivity analyses, the association with SDB remained significant when the study population was restricted to 2038 participants without hypertension, diabetes, hyperlipidaemia, stroke and other chronic diseases (multivariable-adjusted OR = 0·96; 95 % CI 0·93, 1·00; $P < 0·05$).

Discussion

Principal findings

In this study, we observed that adherence to the DASH dietary pattern was associated with reduced odds of SDB. The association between DASH score and SDB appeared to be independent of potential confounding factors and was similar across subgroups stratified by age, sex, BMI, smoking, alcohol drinking, hypertension, diabetes and hyperlipidaemia. The association persisted when restricting the participants to those without chronic diseases. Inverse associations with SDB were also observed for the DASH components vegetables, nuts and legumes, and dairy products.

The Dietary Approaches to Stop Hypertension diet and sleep-disordered breathing

Our study found an inverse association between the DASH score and SDB. Similar results were reported by Liang *et al.*[22], who observed the DASH diet score was inversely related to sleep-related daytime dysfunction among middle-aged and older individuals. A study from Southern Iran showed that mothers and their infants with higher DASH scores had fewer sleep disorders than those with lower DASH scores[31]. Besides, the inverse association between the DASH diet and insomnia has been found in adolescent girls aged 12 to 18 years[21,32]. It seems that adherence to the DASH diet is associated wither better sleep quality in different populations, as reported in our study. In the final model, we furthermore adjusted for vitamin D intake levels, and the results were essentially not affected. Besides the DASH score, similar associations have been reported for other diet quality indices including the Mediterranean diet pattern[14,15,33] and the Dietary Inflammation Index (DII) with sleep problems[34].

The DASH diet supports a higher intake of foods considered healthy, including fruits, vegetables, nuts and legumes, whole grains, and dairy products, and lower consumption of red meat, carbohydrates, and fizzy drink, which have been shown to improve sleep[13,33,35]. A randomised clinical trial showed that men with a Na-restricted diet could improve symptoms of SDB[36]. Reid *et al.* showed that lower whole-grain intake was associated with increased consumption of red meat and moderate to severe SDB[37]. Of the eight components of the DASH diet in our study, vegetables, nuts and legumes, and dairy products were inversely associated with SDB, but other components were not associated. Therefore, the inverse association with SDB was mainly driven by vegetables, nuts and legumes, and dairy products in our study population.

Table 1. Descriptive characteristics of the study participants by quintiles of DASH score (*n* 3939)

	Quintiles of DASH score										
	Q1 (*n* 788)		Q2 (*n* 787)		Q3 (*n* 788)		Q4 (*n* 788)		Q5 (*n* 788)		
Characteristic	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*P*
Age (years)											
Median	52		50		47		45		45		<0·001
p25, p75	37, 63		35, 60		35, 60		34, 57		34, 59		
Male (%)	475	60·3	386	49·1	371	47·1	325	41·2	312	39·6	<0·001
Education (%)											<0·001
Junior high school and below	228	28·9	170	21·7	150	19·1	117	14·8	92	11·7	
Senior high school	322	40·9	323	41·1	335	42·7	318	40·4	325	41·3	
University	238	30·2	292	37·2	300	38·2	353	44·8	370	47·0	
Married (%)	708	90·0	706	89·7	722	91·6	701	89·1	711	90·2	0·532
Smoking (%)	239	30·3	185	23·5	150	19·0	106	13·5	101	12·8	<0·001
Alcohol drinking (%)	323	41·0	284	36·1	276	35·0	234	29·7	200	25·4	<0·001
BMI (%)											<0·001
< 24 kg/m^2	381	48·3	398	50·5	419	53·2	456	57·9	426	54·1	
≥ 24 kg/m^2	407	51·7	389	49·4	369	46·8	332	42·1	333	42·2	
Hypertension (%)	281	35·7	230	29·2	222	28·2	170	21·6	189	24·0	<0·001
Diabetes (%)	57	7·2	34	4·3	48	6·1	45	5·7	51	6·5	0·163
Hyperlipidaemia (%)	83	10·5	81	10·3	65	8·3	60	7·6	67	8·5	0·167
Physical activity (%)											
Low	508	64·5	499	63·4	489	62·0	490	62·1	485	61·6	0·495
Moderate	194	24·6	222	28·2	226	28·7	217	27·5	229	29·1	
High	86	10·9	66	8·4	73	9·3	81	10·3	74	9·4	
	Median	p25, p75	Median	p25, p75	Median	p25, p75	Median	p25, p75	Median	p25, p75	
Vitamin D (mg/d)	3·2	1·7, 5·5	3·2	1·7, 5·7	3·1	1·9, 5·4	3·5	1·8, 6·8	3·6	2·0, 6·3	<0·001
Potassium (mg/d)	1292·4	923·8, 1965·3	1517·4	1106·7, 2355·4	1753·0	1260·7, 2561·0	2034·9	1495·8, 3132·0	2541·7	1847·3, 4090·9	<0·001
Components of DASH score											
Fruits (g/d)	35·1	15·8, 71·0	58·9	29·3, 105·7	87·8	48·0, 146·8	111·6	66·7, 193·5	164·9	103·1, 260·5	<0·001
Vegetables (g/d)	111·5	71·4, 172·0	154·1	95·7, 254·8	188·1	113·5, 306·5	253·0	152·3, 379·4	347·5	232·9, 532·8	<0·001
Nuts and legumes (g/d)	23·4	13·4, 40·2	36·6	20·9, 60·0	48·8	28·6, 82·9	67·1	39·2, 113·8	102·9	57·6, 169·6	<0·001
Whole grains (g/d)	0	0, 0	0	0, 0·4	0	0, 3·3	1·7	0, 7·1	5·7	0, 14·3	<0·001
Dairy products (g/d)	0	0, 28·0	20·8	0, 85·7	57·1	2·5, 123·8	88·1	29·6, 200·0	175·4	85·7, 250·0	<0·001
Na (mg/d)	4898·3	3555·3, 6772·2	4414·5	3027·6, 5904·4	3839·8	2746·7, 5517·9	3693·9	2702·7, 5002·9	3273·7	2303·7, 4341·6	<0·001
Red and processed meats (g/d)	55·1	28·4, 96·8	44·7	22·6, 80·5	48·3	25·7, 79·4	50·0	24·3, 83·7	45·7	24·8, 85·7	<0·001
Sweetened beverages (g/d)	0·48	0, 26·7	0	0, 23·0	0	0, 16·7	0	0, 17·6	0	0, 6·7	<0·001
Energy intake (kcal)	1492·6	1106·9, 2141·6	1501·0	1142·9, 2165·6	1613·8	1185·7, 2314·6	1693·0	1245·4, 2528·8	1935·8	1436·9, 2760·0	<0·001
DASH score	18	17, 19	21	21, 22	24	23, 24	26	26, 27	29	28, 31	<0·001

DASH, Dietary Approaches to Stop Hypertension; Q, quintile.
Data are presented as median (p25, p75) for continuous measures and *n* (%) for categorical measures. *P* values were determined by χ^2 tests for categorical and Kruskal–Wallis tests for continuous variables.

Table 2. Descriptive characteristics of the study participants stratified by sleep-disordered breathing (*n* 3939)

Characteristic	Sleep-disordered breathing				*P*
	No (*n* 2971)		Yes (*n* 968)		
Age (years)					
Median	45		53		<0·001
p25, p75	34, 58		41, 63		
Male (%)	1218	41·0	651	67·3	<0·001
Education (%)					<0·001
Junior high school and below	525	17·7	232	24·0	
Senior high school	1170	39·4	453	46·9	
University	1272	42·9	281	29·1	
Married (%)	2633	88·7	915	94·5	<0·001
Smoking (%)	475	16·0	306	31·6	<0·001
Alcohol drinking (%)	858	28·9	459	47·4	<0·001
BMI (%)					<0·001
<24 kg/m^2	1757	59·1	352	36·3	
≥24 kg/m^2	1214	40·9	616	63·3	
Hypertension (%)	691	23·3	401	41·4	<0·001
Diabetes (%)	157	5·3	78	8·1	0·002
Hyperlipidaemia (%)	222	7·5	134	13·8	<0·001
DASH score	24	21, 27	23	20, 26	<0·001
Energy intake (kcal)					
Median	1581·8		1757·9		<0·001
p25, p75	1181·4, 2338·6		1307·4, 2548·1		
Physical activity (%)					<0·001
Low	1832	61·7	639	66·0	
Moderate	874	29·4	214	22·1	
High	265	8·9	115	11·9	
Vitamin D (mg/d)					
Median	3·2		3·5		0·228
p25, p75	1·8, 5·9		1·9, 6·2		
Insomnia (%)	737	24·8	400	41·3	<0·001
Sleep duration (%)					<0·001
<7 h/d	348	12·4	251	22·1	
7–9 h/d	2310	82·2	817	71·8	
>9 h/d	144	5·1	69	6·1	

DASH, Dietary Approaches to Stop Hypertension; Q, quintile.
Data are presented as median (p25, p75) for continuous measures and *n* (%) for categorical measures. *P* values were determined by χ^2 tests for categorical and Kruskal–Wallis tests for continuous variables.

Table 3. Adjusted OR (95 % CI) for the association between DASH score and sleep-disordered breathing (*n* 3939)

	Q1	Q2		Q3		Q4		Q5		$P_{for\ trend}$
		OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI	
Case/*n*	255/788	202/787		197/788		158/788		156/788		
Model 1	1	0·83	0·66, 1·04	0·83	0·66, 1·04	0·68	0·53, 0·86	0·66	0·52, 0·84	<0·001
Model 2	1	0·83	0·66, 1·05	0·83	0·66, 1·06	0·73	0·57, 0·94	0·72	0·57, 0·94	0·008
Model 3	1	0·83	0·66, 1·06	0·85	0·67, 1·09	0·73	0·57, 0·94	0·68	0·52, 0·88	0·002
Model 4	1	0·81	0·64, 1·04	0·84	0·66, 1·08	0·73	0·56, 0·95	0·68	0·52, 0·88	0·004

DASH, Dietary Approaches to Stop Hypertension; Q, quintile.
Model 1: adjusted for age and sex.
Model 2: further adjusted for BMI, education, physical activity, marital status, smoking and alcohol drinking.
Model 3: additionally adjusted for energy intake, hypertension, diabetes, hyperlipidaemia, insomnia and sleep duration.
Model 4: additionally adjusted for vitamin D intake.

Possible mechanisms

Although the exact mechanism is unclear, we hypothesised several potential explanations for the observed association. Reimund proposed a theory that sleep itself contained an antioxidant defence systems, meaning that excess free radicals can be reduced during sleep by a decreased rate of formation of free radicals and increased efficiency of endogenous antioxidant process[38]. Patients with SDB have increased oxidative stress in the body due to repeated ischaemia-reperfusion[39] and meanwhile underutilisation of the antioxidant function. In addition, inflammation is considered relevant to the pathogenesis of obstructive sleep apnoea[40]. Fruits, vegetables, legumes and whole grains rich in the DASH diet have been shown with antioxidative[41] and anti-inflammatory effects[42,43]. Moreover, the tryptophan–hydroxytryptamine–melatonin system may be involved in the association between the DASH diet and SDB[44]. Vegetables and fruits, whole grains, legumes, and dairy

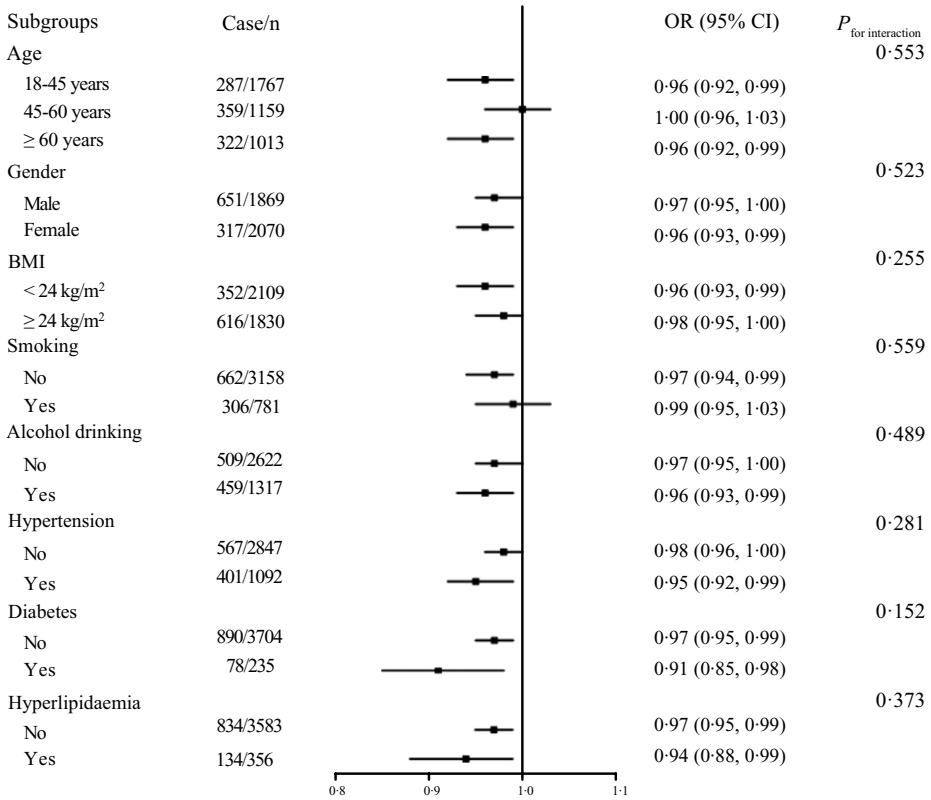

Fig. 1. DASH score in association with sleep-disordered breathing by strata in the study population (*n* 3939). Multivariable model: adjusted for age, sex, BMI, education, physical activity, marital status, smoking, alcohol drinking, energy intake, hypertension, hyperlipidaemia, diabetes, insomnia and sleep duration. DASH, Dietary Approaches to Stop Hypertension; Q, quintile.

products are rich sources of tryptophan, serotonin, and or melatonin[16]. It was reported that melatonin intake had a positive effect on improving oxidative stress and subsequent SDB[45]. Further studies are still warranted to clarify the underlying pathophysiological mechanisms.

Strengths and limitations

To the best of our knowledge, this is the first study to examine the association of the DASH dietary pattern with SDB. In addition, we performed stratification analyses, as well as sensitivity analyses to explore and confirm the robustness of our findings. However, the present study has also some limitations. First, due to the cross-sectional nature, it is impossible to conclude a causal relationship between the DASH score and SDB. Reverse causality (i.e. SDB-caused dietary changes) cannot be precluded. Second, self-report bias may have existed because both diet and SDB information were collected by questionnaires. Third, residual confounding may have existed due to unmeasured or unknown factors, including for example snack intake before sleep, body composition, and medications related to depression or sleep.

Conclusion

The present study provides novel evidence that adherence to the DASH diet is associated with a decreased likelihood of having SDB. Prospective studies are warranted to further confirm these findings.

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S. L. formulated the research questions, analysed the data, interpreted the findings and drafted the manuscript. C. W., S. T., Y. Z. and K. Z. proofread and revised the original manuscript. B. W. and H. Z. designed the study, supervised the work, critically revised the manuscript and approved the final manuscript.

The authors declare no conflicts of interest.

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