

A population-based cohort study on the association of dietary patterns with sleep duration: A Joint modeling by mental health status

Somaye Hosseini

Isfahan University of Medical Sciences

Reyhaneh Rikhtehgaran Rikhtehgaran

Isfahan University of Technology

Noushin Mohammadifard

Isfahan University of Medical Sciences

Hamidreza Roohafza

Isfahan University of Medical Sciences

Masoumeh Sadeghi

Isfahan University of Medical Sciences

Marjan Mansourian (✉ jmansourian@gmail.com)

Isfahan University of Medical Sciences <https://orcid.org/0000-0002-7217-0282>

Nizal Sarrafzadegan

Isfahan University of Medical Sciences

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Introduction

Sleep is one of the basic needs of humans. One third of every person's life is spent in sleep. Inadequate sleep is pervasive in today's modern society. Sleep duration is an important concept in epidemiological studies and is associated with numerous health outcomes (1). The amount and quality of sleep have an enormous impact on daily life. Disordered sleep affects work, concentration, and ability to interact with others (2). Recent research has consistently demonstrated that sleep duration can have important effects on health(1). Observational studies have found that reduced sleep is associated with an increased risk for mortality(3,4).

There are still large uncertainties regarding the association between diet, the intake of nutrients, and sleep both in duration and in quality(2). Dietary patterns which focus on a combination of several foods can provide synergic effects rather than the effects described for individual nutrients or foods(5) . Several studies have identified associations between sleep factors such as sleep duration, quality and disorders, and nutrition quality, dietary patterns and some foods intake(6–9). Adversely some other studies surveyed effect of some foods or dietary patterns on sleep factors(2,10,11) .

Previous studies in Iran demonstrated that more than one fifth of samples suspected of having mental disorders(12). Mental health status is considered to be a major factor associated with sleep habits(13). On the other hand, data from adult populations have indicated that better-quality diet is associated with better mental health outcomes(14).

The studies that investigated the food consumption effect on sleep duration not considered the mental health status (MHS). Relationship between nutrition and depressive disorders has become of increasing interest in recent years(14–17), epidemiological evidence suggests a role for diet quality in the common mental disorders depression and anxiety(18) and there is some evidence that MHS is related by sleep duration(13). Also recent data have highlighted the importance of the contribution of modifiable lifestyle behaviors such as physical inactivity, smoking, and other lifestyle factors to the development of common mental disorders(19). The purpose of this study is to identify the association of most frequent dietary patterns and daily sleep hours of adult population using a joint modelling approach to control mental health status, This is the first study that considered the mental health status effect in association assessment of dietary patterns and sleep duration and used the extensive set of confounders to model adjusting such as: BMI, lipid, sugar, hypertension, smoking and physical activity.

Methods

Study population

This longitudinal study was conducted on 1383 subject with complete information who participated in the Isfahan Cohort Study (ICS). The ICS is a population-based, longitudinal study on adults aged 35 years old or more recruited from urban and rural areas of three districts in central of Iran from January to September 2001. Participants were selected by multistage random sampling to reflect age, sex and urban/rural distribution of the community. Laboratory measurements, physical examinations, and interviews were conducted at baseline and repeated in those without any CVD events in 2007 and 2013. Among them, 1383 participants with complete information on dietary intake, covariates, and outcomes were included in the current study. The protocol used in the 2007 and 2013 survey was similar to what was used in 2001. Study design, details of subjects' recruitment and data collection methods have been described previously(20) . The study was approved by the Ethics Committee of Isfahan Cardiovascular Research Center (ICRC), a WHO collaborating center. Having obtained an informed written consent, the participants underwent physical examination, laboratory measurements, and interview.

Assessment of covariates

Trained interviewers were completed standardized questionnaires on life-style components (nutrition, smoking, and physical activity), socio-economics variables and demographic properties. We used factor analysis (with only one extracted factor to obtain factor score) to quantify socioeconomic status and divided the participants into tertiles according to their score. Education level, occupation type, and income were used as inputs of the factor analysis. Also the number of people aged under 18 and over 65 and the number of those aged 18 to 65 at home were added so as to consider the population that is economically dependent in the active age group. We categorized education level as illiterate, primary school, guidance school, high school, associate or bachelor degree, and master's degree or higher. The occupation type was classified using the following categories: "upper white-collar employees", "lower white-collar employees", "manual workers", "self-employed persons", "unemployed", "retired", and "housewife" groups. Income was categorized into five following groups, <5 million RIALs (Iranian currency unit), 5-9 million RIALs, 9-15 million RIALs, 15-20 million RIALs and >20 million RIALs. Individuals in the lowest tertile of the score were classified as a low SES; individuals in the second tertile were labeled as a medium SES, whereas those in the highest tertile were classified as a high SES.

Smoking status was categorized as current smoker for those who smoked at least one cigarette per day at the time of the study and non-smoker.

Physical activity (PA) data, expressed as metabolic equivalent hours per week (MET_h/wk.), were obtained through the Iranian version of the International Physical Activity Questionnaire

(IPAQ), it's reliability and validity have been confirmed in several studies(21–23) . It included questions on household, leisure time, transportation and occupational items. The total physical activity score was obtained by summing up questions in all items.

Trained physicians conducted medical interviews and physical examinations. Blood pressure and anthropometric measurements were taken according to standard protocols. Fasting blood samples were taken and serum lipid profiles along with plasma glucose levels were quantified.

Dietary assessment

A simplified food frequency questionnaire (SFFQ) consisting of 48 food items was used for dietary assessment by trained interviewers in a face-to-face manner(24,25) . The validity and reproducibility of SFFQ were examined in literature(24) .

The FFQ and the procedures used for completing and calculating dietary intake were repeated in the same way in all phases. Participants reported the frequency consumption of each food item during the previous year regarding daily, weekly and monthly consumption. All frequencies were converted to weekly consumption and 'zero' was used in cases of 'never' or 'rare' food consumption. Categorization of food items were done in certain food groups (Table1) based on similarity of nutrients(25) . Thus, we came up with 21 groups.

The validation study confirmed reasonably relative validity and reproducibility of SFFQ. The SFFQ was validated by comparing one 24-h dietary recall and two-day dietary record in 264 adults. Spearman correlation coefficient between examined and reference methods ranged from 0.105(P Z 0.378) to 0.48 (P < 0.001) and intra-class correlation for reproducibility of FFQ was between 0.47 and 0.69 (P < 0.001) in different food groups (24).

Table 1 Food grouping used in the dietary pattern analyses.

Food groups	Food items
Whole dairy product	Whole fat milk, whole fat yogurt
Fast foods	Sausages, hamburger, pizza
Animal fat	Ghee, butter, tallow
Organ meats	Liver, lung
Fruits and vegetables	Fresh fruits, fruit juices, dried fruits, raw vegetables, cooked vegetables, dried vegetables
Sweets	Pastry, biscuits, cookies, chocolates, jam
Red meat	Beef, lamb
Chicken	Chicken
Fish	Fish
Hydrogenated oil	Hydrogenated oil
Liquid oil	Liquid oil
Olive oil	Olive oil
Bread	All kind of bread
Rice	Rice
Pickles	Pickle and salty cucumber
Beans	Beans
Egg	Egg
Nuts	Almonds, pistachios, hazelnuts, roasted seeds, walnuts

Canned foods	All kind of canned food
Carbonated beverages	All kind of carbonated beverages
Fried foods	All kind of foods fried in oil

Outcomes

Sleep duration is main response in this study but we used MHS as second response to control its association by first response and dietary patterns.

In ICS study, self-reported duration of sleep was assessed by how many hours a person sleeps during the day and night, because the daily sleep may affect the night sleep and vice versa, so we use the total of these two components as sleep duration.

MHS was measured by a self-administered 12-item GHQ, that consists of 12 items, each assessing the severity of a mental problem over the past few weeks using a 4-point scale (from 0 to 3). The score was used to generate a total score ranging from 0 to 36, with higher scores indicating worse condition. Mental health status determined by GHQ-12 score, that less than 15 is normal, between 15 and 20 is suggestive of distress and a total score more than 20 suggests severe psychological distress(26,27).

Statistical analysis

Lack of data on energy intake in the current study caused to use BMI as a surrogate measure to obtain energy-adjusted intakes of food groups for each study year (28,29). Using the residual method of Willett [26], all dietary intakes of food groups were adjusted for BMI. Then we applied principal component factor analysis (PCA) to identify major dietary patterns based on the BMI-adjusted food groups. PCA was performed separately for each study phase, and the factors were rotated by an orthogonal transformation. We focused on the interpretability of the factors, eigenvalues more than 1.5 and the Scree test to determine whether a factor should be retained.

Finally, we identified three factors for each study phase and labeled dietary patterns based on the data interpretation and literature. Also we considered the food groups in each factor in three phases. For each participant, a factor score for each identified pattern in each phase was computed by summing up the intakes of food groups weighted by their factor loadings, obtained based on the PCA analysis. A high factor score for a particular pattern means greater adherence to that dietary pattern and vice versa. We assessed the dose-response effects of dietary patterns score because of longitudinal structure of study and repeated measurements of dietary patterns score.

In this study we used MHS, dietary pattern factors, socio-demographic factors and some other variables as independent variables in sleep duration (SD) modelling, but there are studies

confirmed the relation between mental health status, dietary patterns and some of confounders(15,16) and it caused to multicollinearity so we used Bahrami Samani and Ganjali multivariate mixed model with random effects (30) for joint modeling of sleep duration (count) and mental health status (ordinal) using parametric models (Negative binomial and logit), respectively according to the equations 1 and 2:

$$P(Y_{MHS_{it}} \leq y_{MTH_{it}}) = \text{logit}(\theta_{y_{MHS_{it}}} + \alpha_1 X'_{it} + \beta_1 N_{it}) \quad \text{Equation 1}$$

$$\log(\mu_{it}) = \beta_0 + \alpha_2 X'_{it} + \beta_2 N_{it} + \gamma * MHS_{it} \quad \text{Equation 2}$$

$$SD_{it} \sim \text{NegativeBinomial}(q_{it}, r)$$

$$q_{it} = \frac{r}{r + \mu_{it}} \quad i=1, 2, \dots, 1383 \quad t=1,2$$

Where $\theta_{y_{MHS_{it}}}$ s are cut points, X_{it} is the matrix of covariates containing: age, sex, socioeconomic status (SES), smoking status, physical activity, BMI, diastolic blood pressure (DBP), systolic blood pressure (SBP), fasting blood sugar (FBS), high-density lipoprotein (HDL), Low-density lipoprotein (LDL) and triglyceride (TG). N_{it} is the nutrition patterns and γ association parameter of MHS and SD.

Descriptive statistics for demographic and health related characteristics were summarized using mean \pm standard deviation and range for continuous data whereas, for categorical data using frequencies and percentage. Adjusted odds ratio (OR) and regression coefficients (95% confidence intervals [CI]) are used to present dietary patterns effects. Student-t or Manne-Whitney U (if the normality assumption was not held) tests were performed to evaluate significant differences in quantitative variables across follow up times. The association of categorical variables and follow up times was assessed by applying chi-square tests.

Free software Open Bugs 3.2.3 was used for data analysis and estimation of unknown parameters.

Results

The mean age at 2017 was 53.5 ± 9.2 . 51.4% were women and 48.6% were men. General characteristics of participants in both phases of the study are presented in Table 2. All of dietary patterns had no significant difference in two follow up times (p-value=0.78, 0.96, 0.96 respectively). MHS also had no difference in first and second follow (p-value=0.58). But the mean of sleep duration in second follow was strongly more than sleep duration in first follow (P-value<0.001).

Table 2 General characteristics of study population and comparison for subjects mental health status in second and third phases of Isfahan cohort study

	Sample (n=1383)		p-value
	First follow up	Second follow up	
Married	90.9	87.6	0.07
SES			0.001
Low	52.3	58.5	
Moderate	40	31.4	
High	6.9	10.1	
Smoker	12.3	11.5	0.51
BMI(kg/m ²)	27.74±4.43	27.76±4.65	0.055
Physical activity (METS)	14.58±9.23	12.81±9.86	<0.001
Dbp	78.29±10.45	82.87±12.51	<0.001
Sbp	124.45±18.58	128.67±17.69	<0.001
Fbs	101.87±39.34	106.81±38.24	<0.001
HDL	50.22±58.92	44.58±2168	0.001
LDL	127.55±30.41	111.57±27.86	0.001
Tg	171.84±116.2	155.30±85.04	<0.001
Iranian diet	10.64±4.65	6.08±3.54	0.78
Western diet	7.32±7.82	10.28±4.32	0.96
Healthy diet	10.92±5.32	6.12±3.67	0.96
MHS			0.58
Normal	85.3	84.0	
Distress	10.5	10.1	
Sever distress	4.3	5.9	
Sleep duration (h)	7.17±1.77	7.56±2.39	<0.001

Quantitative variables were expressed as mean ± s.d. and qualitative variables were expressed as percent.

SES, socioeconomic status; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; FBS, Fasting blood sugar; HDL, High-density lipoprotein; Low-density lipoprotein; TG, Triglyceride.

The prevalence of distress and sever distress in 2007 were 9.5% and 4.3%, and in 2013 were 10% and 4.5% of the study population respectively (p-value =0.87). Mean sleep duration were 7.17 and 7.56 hours respectively (p-value < 0.001). Mean sleep duration of participants in both phases of the study across MHS are presented in Table 3. The persons with normal and distressed mental health had better sleep duration in second follow (p-value=0.001 and 0.009 respectively), but sever distressed persons had no significant difference in sleep duration (p-value=0.933) in first and second follow. Among MHS, normal persons had better sleep duration

than other (p-value=0.015) in first follow but in second follow no significant difference was observed (p-value=0.16).

Table 3 Mean sleep duration of subjects across MHS in each study year

		Sleep duration		
		First follow	Second follow	p-value
MHS	Normal	7.23±1.69	7.59±2.29	0.001
	Distress	6.71±2.15	7.62±3.10	0.009
	Sever distress	7.02±2.36	6.98±2.36	0.933
	p-value	0.015	0.16	

Three major dietary patterns were identified that explained 21.57% and 20.21% of the total variance in two phases of the study, respectively. The Healthy diet was characterized by high intake of fruits and vegetables, olive oil, nuts, low diary product, chicken and fish. The Iranian diet contained high intakes of Iranian traditional product, such as dairy products, animal fat, red meat, pickles, bean, bread and hydrogenated oil. Nut and organ meat fell in this pattern in 2013. The Western diet was greatly loaded with frequent consumption of fried foods, rice, sweat, carbonated beverages. Also, fast foods and rice fell in the Western pattern in 2013 (Table 4).

Table 4 Factor-loading matrix for the major factors (diet patterns) identified by using food consumption data from the food-frequency questionnaire used in the Isfahan Cohort Study

Food groups	2007			2013		
	Dietary patterns			Dietary patterns		
	Iranian	Western	Healthy	Iranian	Western	Healthy
Whole dairy product	0.557	-	-	0.394	-	-
Fast foods	-	0.253	-	-	0.356	-
Animal fat	0.470	-	-	0.331	0.233	-
Organ meats	-	-	-	-	0.281	-
Fruits and vegetables	0.227	0.255	0.519	-	0.341	0.397
Sweets	-	0.362	-	-	0.348	-
Red meat	0.379	-	-	0.392	-	-0.261
Chicken	-	-	0.287	-	-	-
Fish	-	-	0.237	0.222	-	-
Hydrogenated oil	0.214	-	-0.222	-	-	-
Liquid oil	-	-	-	-	0.263	-
Olive oil	-	-	0.419	-	-	0.405
Bread	0.211	-	-	-	-	-
Rice	-	0.368	-	-	0.222	-0.287
Pickles	0.332	0.294	-	0.202	0.389	-
Beans	0.244	0.250	-	-	0.258	-
Egg	-	0.305	-	-	0.350	-
Nuts	-	-	0.368	0.278	-	0.417
Canned foods	-	0.244	-	-	-	-
Carbonated beverages	-	0.303	-	-	0.365	-
Fried foods	-	0.423	-	-	0.460	-

Table 5 compares the results of joint analysis for the effect estimation of dietary patterns on two responses. After controlling for age, sex, marriage, SES, physical activity, DBP, SBP, FBS, HDL, LDL and Tg, among dietary patterns only Western diet had meaningful effect on sleep hours (OR=1.08 and 95% CI: 1.02–1.12), the higher scores (high intake) of the Western diet during the 5 year follow-up was associated with greater sleep duration. The other patterns were not associated by sleep duration. MHS was adversely related by Iranian diet (OR=0.18 and 95% CI: 0.5–0.24), so the high intake of Iranian diet was related by better MHS. Also the parameter of sleep duration and MHS association was negatively meaningful; it means the persons with better MHS have more sleep hours in day. The western and healthy diets were not related by MHS.

Table 5 The estimated effects of dietary patterns associated with sleep duration and mental health status using joint analysis

Sub-model	Parameter	β (SE)
Sleep duration	Iranian diet	-0.017(0.03)
	Western diet	0.075*(0.04)
	Healthy diet	-0.049(0.21)
Mental health status	Iranian diet	-1.73*(1.05)
	Western diet	0.72(0.59)
	Healthy diet	0.48(0.58)
Association Parameter	Association	-0.097*(0.02)

Controlled by age, sex, marriage, SES, BMI, physical activity, DBP, SBP, FBS, HDL, LDL and Tg

Discussion

This longitudinal population-based study examined the long-term relationship between dietary patterns and sleep duration among Iranian population during 6 years of follow-up. Previous

studies in Iran demonstrated that more than one fifth of samples suspected of having mental disorders(12). Mental health status is considered to be a major factor associated with sleep habits, and to date, many cross-sectional epidemiological studies have indicated a close association between the two(31). On the other hand, data from adult populations have indicated that better-quality diet is associated with better mental health outcomes(14). We used a joint modelling approach to control mental health status effect that is an important factor may affect sleep pattern and be affected by dietary patterns. Simultaneous considering of sleep duration and MHS is new aspect of this study. Three major dietary patterns were identified in two phases: Healthy, Iranian and Western dietary patterns. The western diet was positively associated with sleep duration. The Western diet was characterized by high intakes of fried foods, rice, sweat, carbonated beverages, fast foods and rice. This association persisted in a joint modeling of sleep duration and mental health status as a second response to control mental aspect of individuals, the sleep duration and MTS were negatively associated. To controlling the physical aspect of persons, joint model contained BMI, physical activity, smoking and some clinical and biochemical factors.

Most previous studies have focused on sleep effect on food consumption(7–9), but we considered dietary patterns on sleep duration. It is believed that this is the first study to address the association between major Iranian dietary patterns and sleep duration. In similar study in Japan, the subject with sever depressive symptoms were excluded from the study, but in our study we controlled the mental health status. In Japanese study found no association between diet and sleep but healthy dietary pattern was associated with difficulty initiating sleep. Another study showed that insomniacs consumed less protein than normal sleepers(32), since westernized diet is characterized by a high content of proteins (derived from fatty domesticated and processed meats), it confirmed our study. A cross-sectional study in China indicated that the persons with low consume of fat and high consume of carbohydrate in daily energy intake had more sleep hours, Which cannot be justified by the present study information because any of three dietary patterns in our study contains low fat and high carbohydrate intake(10).

As I told above; the current study provides useful information to clarify the longitudinal effect of dietary habits on sleep duration in a longitudinal analysis in the Iranian population who has, until now, not been studied adequately. Rare studies relating sleep to diet were cross-sectional(10,11). Another strengths of this study the extensive set of confounders measured. Data were gathered as part of a large-scale project and thus systematic bias in collection of variables between those who slept less and those who slept more is unlikely.

Several limitations need to be considered in interpreting our results. First, it would have been interesting to have a measure of sleep quality, not just duration, to compare results. Second, the FFQ used in the present study was a short FFQ, which could roughly assess usual dietary habits in the Iranian population. Third, although most of the epidemiological evidence on the association between diet and disease come from quantitative FFQs (33); the FFQ used in this study did not have data on portion sizes; therefore, we could not measure total energy intake in

this study. Using BMI as a surrogate for energy intake might not be clinically valid because some individuals, including those engaged in manual work, will have high energy intakes and low BMI. Therefore, we further adjusted our model for physical activity during statistical analysis(28). Forth principal component analysis requires subjective decisions in determining the number of factors to retain, in choosing the method of rotation of initial factors, and in labeling the dietary patterns(34,35). Finally, dietary measurements were conducted at the same time as the outcome measurements, thus reverse causation bias may have occurred because our study observational cohort design of with repeated measurements so a RCT is needed to identify causality.

Conclusion

We controlled the MHS effect in dietary patterns and sleep duration association. The most Iranian popular were Healthy diet, Iranian traditional diet and Westernized diet. After controlling for MHS, age, sex, marriage, SES, physical activity, DBP, SBP, FBS, HDL, LDL and Tg, among dietary patterns only Western diet had meaningful effect on sleep hours the higher scores of the Western diet during the 5 year follow-up was associated with greater sleep duration. The other patterns were not associated by sleep duration. The Western diet contained fried foods, rice, sweat, carbonated beverages, fast foods and rice.

Availability of data and materials

The dataset used during the study is available from the corresponding author on request.

List of abbreviations

MHS: Mental Health Status

SD: Sleep duration

SES: Socioeconomic Status

DBP: Diastolic Blood Pressure

SBP: Systolic Blood Pressure

FBS: Fasting Blood Sugar

HDL: High-Density Lipoprotein

LDL: Low-Density Lipoprotein

TG: Triglyceride

Author Contributions

NM, MS, HR and NS participated in the study design and data interpretation. SH and MM participated in the statistical analyses, data interpretation and manuscript drafting. RR participated in the statistical analyses and data interpretation. The manuscript was revised by MM and RR. All authors read and approved this final manuscript submitted.

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Conflicts of Interest

The authors declare no conflict of interest.

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