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Association of dietary acid load and plant-based diet index with sleep, stress, anxiety and depression in diabetic women

Elnaz Daneshzad[1], Seyed-Ali Keshavarz[2], Mostafa Qorbani[3,4], Bagher Larijani[5], Nick Bellissimo[6] and Leila Azadbakht[1,7]*

[1]*Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran*
[2]*Department of Clinical Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran*
[3]*Non-communicable Diseases Research Center, Alborz University of Medical Sciences, Karaj, Iran*
[4]*Chronic Diseases Research Center, Endocrinology and Metabolism Population Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran*
[5]*Endocrinology and Metabolism Research Center, Endocrinology and Metabolism Clinical Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran*
[6]*School of Nutrition, Ryerson University, Toronto, Canada*
[7]*Diabetes Research Center, Endocrinology and Metabolism Clinical Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran*

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Abstract

Diabetes is a common chronic disease with various complications. The present study was conducted to determine the association of plant-based diet index (PDI) and dietary acid load (DAL) with sleep status as well as mental health in type 2 diabetic women. In this cross-sectional study, a validated FFQ was used to assess dietary intakes of 230 diabetic patients. We created a whole PDI, healthful PDI (hPDI) and unhealthful PDI (uPDI). DAL was calculated based on potential renal acid load and net endogenous acid production method. The Pittsburgh Sleep Quality Index and twenty-one-item Depression, Anxiety and Stress Scale were used to assess sleep and mental health disorders, respectively. Participants in the top group of uPDI had greater risk of poor sleep (OR 6·47, 95 % CI 2·75, 15·24). However, patients who were in the top group of hPDI had a lower risk of sleep problems (OR 0·28, 95 % CI 0·13, 0·62). Participants in the top group of uPDI had greater risk of depression, anxiety and stress (OR 9·35, 95 % CI 3·96, 22·07; OR 4·74, 95 % CI 2·28, 9·85; OR 4·24, 95 % CI 2·14, 8·38, respectively). In conclusion, participants with higher DAL scores and patients who adhered to animal-based diets rather than plant-based diets were more likely to be poor sleepers and have mental health disorders.

Key words: Dietary acid load: Plant-based diet index: Sleep: Depression: Diabetic patients: Women

Sleep disturbances and psychological disorders including stress, anxiety, aggression and depression are common complications in diabetic patients. Diabetic patients have poor sleep quality, with poorer sleep efficiency and sleep disorders compared with non-diabetics[1–3]. Moreover, anxiety and depression are more prevalent in diabetic patients than individuals with normal glucose tolerance[4]. Approximately one-third of type 2 diabetic patients have sub-threshold depression[5] and over 40 % present with minor or major depression with anxiety disorders[6].

Diet is an important and modifiable environmental factor, which can affect glycaemic control as well as psychological disorders and sleep disturbances. For example, low glycaemic index foods which contain high dietary fibre are associated with lower blood glucose[7]. Moreover, Zn, Mg and B-vitamins, which are abundant in vegetables, are associated with decreased risk of depression[8,9]. Based on previous studies, these micronutrients can also lead to an improved sleep quality[10,11]. Today, according to interaction and combination of various macro- and micronutrients in a whole diet, epidemiological studies are conducted to determine the association of dietary patterns and dietary quality indices and various diseases. Protective dietary patterns with the content of nuts, fruits and vegetables are associated with

Abbreviations: DAL, dietary acid load; hPDI, healthful plant-based diet index; NEAP, net endogenous acid production; PA, physical activity; PDI, plant-based diet index; PRAL, potential renal acid load; uPDI, unhealthful PDI.

* **Corresponding author:** Leila Azadbakht, fax + 98/218/8984 861, email azadbakhtleila@gmail.com

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reduced risk of depression[12]. Plant-based diet index (PDI) and dietary acid load (DAL) are two indices to assess whole diet quality. As nutrients which present in vegetable and fruits have indicated good effects on sleep and psychological status, the present study hypothesised that whether a whole plant diet has a reduced association with sleep disturbances and psychological disorders. Based on previous studies in diabetic patients, DAL was positively associated with type 2 diabetes risk[13] and the metabolic syndrome[14]. Also, women with higher DAL scores had increased risk of gestational diabetes mellitus[15]. Furthermore, metabolic acidosis leads to reduced insulin secretion and induces insulin resistance[15].

Therefore, the aim of this cross-sectional study was to determine the association of a PDI and DAL with sleep status, anxiety, stress and depression in type 2 diabetic women.

Methods

This cross-sectional study was carried out in 230 type 2 diabetic women who were referred to diabetes research or health centres in Tehran, Iran. The sample size was determined based on the mean of psychological distress score in patients with lowest (15·98 (SD 9·72)) and highest (12·38 (SD 9·95)) adherence to the PDI, respectively: α 0·05 and β 0·2 (power 80 %). Therefore, in the present study, the sample size was determined about 115 individuals in each group[16]. Participants were randomly selected and provided informed written consent. Only women with type 2 diabetes without other medical complications were included in the present study. Women who had other chronic diseases such as thyroid problems, cancers, CVD and kidney disease were excluded. In addition, individuals who reported a total energy intake of <3347·2 and >17 572·8 kJ were excluded. The present study was approved by the ethical committee of Tehran University of Medical Sciences (96-03-161-36923).

Assessment of anthropometric measures

Body weight was measured in minimal clothing using a calibrated digital scale (SECA 803). Height was measured while participants were in standing position using an unstretched tape measure to the nearest to 0·1 mm. BMI was calculated as weight divided by height squared (kg/m^2). Waist circumference was measured using an unstretched tape measure to the nearest to 0·1 cm at the narrowest cite of the waist in light clothing.

Assessment of dietary intake

A 168-item semi-quantitative FFQ, which was validated and reliable for the Iranian population, was used to determine past year dietary intakes[17]. All participants filled the amount and frequency of consumption of each food item on a daily, weekly or monthly basis during the past year. The reported portion sizes of consumed foods converted to g/d. Nutritionist IV software (version 7.0; N-Squared Computing) which was adapted for Iranian foods was used for nutrients analysis.

Plant-based diet indices

We created a whole PDI, healthful PDI (hPDI) and unhealthful PDI (uPDI) as reported in previous studies[18,19]. Briefly, eighteen food groups are created and classified into three main categories: animal foods, and healthy and unhealthy plant foods. Healthy food groups included fruits, vegetables, whole grains, legumes, vegetable oils, nuts, tea and coffee, whereas less healthy food groups included sugar-sweetened beverages, refined grains, fruit juices, potatoes, sweets and desserts. Animal food groups included dairy products, eggs, animal fats, fish and seafood, poultry and red meat, and miscellaneous animal-based foods. Food grouping details are shown in online Supplementary Table S1. These eighteen food groups were ranked into quintiles and given scores between 1 and 10. For creating PDI, the highest decile of a food group received a score of 10 and the lowest decile received a score of 1.

Participants in the highest decile of animal food groups received a score of 1 and to the lowest decile received a score of 10. For hPDI, healthy plant food groups received a positive score, whereas scores were reversed for unhealthy plant food groups and animal food groups. For uPDI, a score of 1 was given to the lowest decile of less healthy plant food groups and 10 for the highest decile, whereas reverse scores were attributed to healthy plant and animal food groups (online Supplementary Table S1)[19]. Finally, all eighteen food group scores were summed (range 18–180) to attain the indices score, which indicates that a higher intake of all three indices reflected lower animal food intake. Finally, these three indices were categorised into two groups by median-split to assess their association with dependent measures.

Assessment of dietary acid load

DAL was calculated based on potential renal acid load (PRAL)[20,21] and net endogenous acid production (NEAP) method[22].

$$\begin{aligned}\text{PRAL (mEq/d)} = {} & (\text{protein (g/d)} \times 0{\cdot}49) \\ & + (\text{P (mg/d)} \times 0{\cdot}037) \\ & - (\text{K (mg/d)} \times 0{\cdot}021) \\ & - (\text{Ca (mg/d)} \times 0{\cdot}013) \\ & - (\text{Mg (mg/d)} \times 0{\cdot}026).\end{aligned}$$

$$\text{Estimated NEAP (mEq/d)} = (54{\cdot}5 \times \text{protein intake (g/d)}/\text{K intake (mEq/d)}) - 10{\cdot}2.$$

Assessment of sleep

The Pittsburgh Sleep Quality Index is a self-report sleep instrument which has been validated in several studies[23–25]. This questionnaire measures the quality and pattern of sleep over the past month and consists of nine items, differentiating from poor to good on a 0–3 scale (0, not in the past month; 1, less than once per week; 2, once or twice per week and 3, three or more times per week). These items explain sleep latency, duration and efficiency, use of sleep medication, sleep disturbances and daytime dysfunction. Pittsburgh Sleep Quality Index scores are between 0 and 21. A score of 5 and above indicates poor sleep quality.

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Assessment of stress, anxiety and depression

The twenty-one-item Depression, Anxiety and Stress Scale is a self-reported questionnaire which contains twenty-one items to assess the severity of negative emotional states and symptoms of depression, anxiety and stress in the last week. These subscales include seven questions with a rating scale between 0 (never) and 3 (always). For depression, total score between 0 and 9 is considered normal, whereas scores above 9 indicate increasing severity of depression. For anxiety, a total score between 0 and 7 is normal, whereas scores above 7 indicate an increase for stress, a total score of 0–14 is normal, and greater is determined as having stress. The validity and reliability of twenty-one-item Depression, Anxiety and Stress Scale have been investigated in Iran[26,27].

Assessment of other variables

Socio-demographic information including age, education level and occupation, income, smoking habits, medical history and current medication and supplement use were assessed by the questionnaire. Physical activity (PA) levels were recorded over 7 d and expressed as metabolic equivalent h/week[28]. Blood pressure was measured in duplicate using a sphygmomanometer, and the mean of both measured was used as the participants blood pressure. Biochemical markers including fasting blood sugar, 2-h postprandial blood sugar, Hb A1C, total cholesterol, HDL-cholesterol, LDL-cholesterol and TAG were obtained from the participants' medical files.

Statistical analysis

Participant characteristics were compared by ANOVA or χ^2 tests and reported as the mean values and standard deviations or percentages. Dietary intakes were reported by median-split for PDI and DAL, adjusted for energy intake using ANCOVA. Also, energy-adjusted dietary intakes in poor and good sleepers and healthy participants or participants with mental health disorders were reported using ANCOVA. The association of sleep and mental health status by media-split for PDI and DAL was determined using the χ^2 test. Moreover, having a mental health disorder and poor sleep in diabetic patients was presented in different models using binary logistic regression. In model 1, adjustment was performed for age, BMI, PA, socio-economic status, supplements consumption, vitamin D and energy intake. Further statistical control was performed in model 2 for medications, lipid profile, blood pressure, sleep duration at night and nap time. Finally, linear regression as a continuous statistical method was used to present the association between DAL score and the score of PDI with mental health disorders and having poor sleep through the fully adjusted model. SPSS version 16 was used to analyse the data. $P < 0{\cdot}05$ was considered statistically significant.

Results

Table 1 shows the general participant characteristics. Mean age was 59·9 years. There was a significant association between both weight and BMI with uPDI ($P < 0{\cdot}05$). A significant difference was observed in nap time and sleep duration at night and PRAL as well as uPDI ($P < 0{\cdot}05$). There was a significant difference for SES across groups of the PDI, hPDI, uPDI and PRAL scores. Participants did not report consuming alcohol or smoking.

Consumption of carbohydrate, Na, organ meats, processed meats, high-fat dairy products, starchy vegetables and refined grains was greater in the top uPDI group. Consumption of carbohydrate, fibre, K, Fe, Mg, Cu, P, Mn, vitamins A, K, E, C, B_6, and folate was lower in the top PRAL group. Table 2 presents energy-adjusted dietary intakes among PDI, NEAP and PRAL.

Energy-adjusted dietary intakes among good and poor sleepers and patients with and without mental health disorders are described in Table 3. Protein, fibre, K, Fe, Ca, Mg, P, Zn, Cu, Mn, folate, vitamins B_2, B_3, B_6, A and C intake and low-fat dairy products, vegetables and fruits consumption in poor sleepers and patients with mental health disorders were lower than participants without these problems ($P < 0{\cdot}05$). Starchy vegetables, refined grains and high-fat dairy consumption were greater in participants with mental health disorders and poor sleepers ($P < 0{\cdot}05$).

According to the χ^2 test, there was a significant association between sleep status and hPDI and uPDI ($P < 0{\cdot}0001$). There was also a significant association between sleep status and NEAP and PRAL ($P < 0{\cdot}0001$). Table 4 shows the OR and 95 % CI for having mental health disorders and poor sleep in crude model and adjusted models across DAL scores and PDI groups. Participants in the top group of uPDI, NEAP and PRAL scores were more likely to be poor sleepers in crude and adjusted models. Participants in the top group of hPDI had a 72 % decreased risk of poor sleep. Participants in the top group of hPDI had 74 and 76 % decreased risk of anxiety and stress, respectively. Participants in the top group of uPDI had more than nine, four and four times increased risk of depression, anxiety and stress, respectively. Table 5 presents the association between DAL score and the score of PDI with mental health disorders and having poor sleep using linear regression as a continuous statistical method.

Discussion

This cross-sectional study revealed that higher DAL scores and adherence to uPDI were associated with poor sleep. Also, greater adherence to uPDI increased the risk of depression, anxiety and stress. Participants in the top group of the hPDI had decreased risk of poor sleep, depression, anxiety and stress. To the best of our knowledge, this is the first study that has assessed the association between DAL and PDI and psychological disorders and sleep status in diabetic patients.

It was reported in a prospective cohort study that DAL was associated with the development of type 2 diabetes[13] and gestational diabetes mellitus[15]. Also, some vegetarian diets are associated with a reduction in the incidence of diabetes[29]. However, there is no study that has assessed the association between DAL and PDI with diabetes complications. PDI emphasise greater intakes of whole grains, fruits, vegetables, nuts, vegetable oils, nuts and legumes and lower consumption of animal fats, fish, meat and animal-based foods (online Supplementary Table S1).

Table 1. Participant characteristics by median-split plant-based indices and dietary acid load
(Mean values and standard deviations)

		PDI			hPDI			uPDI			NEAP			PRAL		
	Total	1†	2†		1†	2†		1†	2†		1†	2†		1†	2†	
Variables	Mean (SD)	Mean (SD)	Mean (SD)	*P**	Mean (SD)	Mean (SD)	*P**	Mean (SD)	Mean (SD)	*P**	Mean (SD)	Mean (SD)	*P**	Mean (SD)	Mean (SD)	*P**
Number	230	106	124		114	116		111	119		115	115		117	113	
Age (years)	59·9	60·8	59·1	0·146	59·9	59·8	0·933	59·0	60·7	0·177	59·2	60·5	0·303	58·7	61·1	0·053
	(9·2)	(8·7)	(9·5)		(10·2)	(8·1)		(7·9)	(10·2)		(9·4)	(8·9)		(9·8)	(8·3)	
Weight (kg)	73·42	74·03	72·59	0·467	73·71	73·13	0·715	75·41	71·56	0·013	73·84	73·00	0·588	73·20	73·64	0·78
	(11·83)	(12·19)	(11·54)		(12·70)	(10·95)		(12·37)	(11·04)		(12·29)	(11·39)		(11·52)	(12·19)	
BMI (kg/m^2)	29·3	29·7	28·9	0·19	29·6	28·9	0·221	29·9	28·7	0·048	29·3	29·3	0·988	29·1	29·5	0·445
	(4·5)	(4·4)	(4·6)		(4·8)	(4·2)		(4·5)	(4·4)		(4·8)	(4·2)		(4·4)	(4·5)	
WC (cm)	95·28	96·46	94·28	0·094	95·91	94·66	0·334	96·23	94·40	0·159	93·98	96·58	0·045	94·18	96·42	0·085
	(9·83)	(9·68)	(9·89)		(10·40)	(9·24)		(10·74)	(8·86)		(9·61)	(9·92)		(9·46)	(10·12)	
SBP (mmHg)	121·13	122·54	119·91	0·088	121·75	120·51	0·422	122·07	120·25	0·237	119·73	122·52	0·07	119·91	122·38	0·108
	(11·65)	(10·87)	(12·19)		(11·46)	(11·85)		(11·04)	(12·17)		(11·03)	(12·12)		(11·48)	(11·79)	
DBP (mmHg)	77·00	77·45	76·61	0·37	77·10	76·89	0·823	77·65	76·38	0·173	76·34	77·65	0·162	76·41	77·61	0·198
	(7·06)	(7·17)	(6·97)		(7·49)	(6·64)		(6·02)	(7·89)		(6·79)	(7·29)		(6·75)	(7·35)	
TC (mmol/l)	4·14	4·11	4·17	0·656	4·21	4·07	0·342	4·20	4·08	0·408	4·12	4·16	0·777	4·11	4·17	0·708
	(1·05)	(1·01)	(1·08)		(0·98)	(1·11)		(1·05)	(1·04)		(1·08)	(1·02)		(1·14)	(1·02)	
HDL (mmol/l)	1·18	1·16	1·20	0·378	1·19	1·18	0·808	1·19	1·18	0·811	1·18	1·18	0·918	1·17	1·19	0·599
	(0·26)	(0·21)	(0·30)		(0·27)	(0·24)		(0·24)	(0·28)		(0·23)	(0·29)		(0·22)	(0·29)	
LDL (mmol/l)	2·52	2·53	2·51	0·889	2·59	2·46	0·232	2·54	2·51	0·791	2·45	2·59	0·21	2·49	2·56	0·532
	(0·84)	(0·81)	(0·88)		(0·83)	(0·86)		(0·85)	(0·84)		(0·84)	(0·85)		(0·87)	(0·82)	
TAG (mmol/l)	1·81	1·77	1·84	0·492	1·81	1·81	0·969	1·85	1·77	0·455	1·80	1·82	0·874	1·78	1·84	0·623
	(0·86)	(0·70)	(0·97)		(0·78)	(0·94)		(0·91)	(0·81)		(0·92)	(0·80)		(0·90)	(0·82)	
Nap (min/d)	29·53	26·70	31·95	0·283	26·15	32·86	0·169	34·56	24·84	0·046	32·15	26·92	0·283	31·85	27·14	0·334
	(36·93)	(35·72)	(37·91)		(33·98)	(39·49)		(39·36)	(34·01)		(41·92)	(31·13)		(39·32)	(34·29)	
How long does it take to	40·53	42·78	38·61	0·478	43·07	38·04	0·391	34·24	46·40	0·037	36·60	44·46	0·179	32·15	49·21	0·003
sleep at night (min)	(4·43)	(47·12)	(41·94)		(38·33)	(49·61)		(48·21)	(39·73)		(37·72)	(49·98)		(36·09)	(50·23)	
How much sleep at	6·51	6·27	6·47	0·321	6·30	6·46	0·448	6·62	6·15	0·017	6·55	6·21	0·093	6·69	6·06	0·001
night (h)	(2·79)	(1·64)	(1·37)		(1·60)	(1·39)		(1·39)	(1·56)		(1·26)	(1·69)		(1·32)	(1·61)	
Years of having diabetes	6·58	6·50	6·65	0·716	6·34	6·82	0·256	6·71	6·46	0·553	6·75	6·42	0·431	6·70	6·46	0·567
	(0·20)	(3·23)	(3·13)		(3·19)	(3·15)		(3·33)	(3·17)		(3·08)	(3·26)		(3·16)	(3·19)	

Table 1. (*Continued*)

		PDI			hPDI			uPDI			NEAP			PRAL		
	Total	1†	2†		1†	2†		1†	2†		1†	2†		1†	2†	
Variables	Mean (SD)	Mean (SD)	Mean (SD)	*P**	Mean (SD)	Mean (SD)	*P**	Mean (SD)	Mean (SD)	*P**	Mean (SD)	Mean (SD)	*P**	Mean (SD)	Mean (SD)	*P**
Years of post-menopause	10·81 (0·58)	11·22 (8·58)	10·46 (9·12)	0·52	10·25 (8·33)	11·35 (9·37)	0·349	9·96 (8·78)	11·60 (8·91)	0·164	10·61 (9·48)	11·01 (8·24)	0·733	10·07 (9·29)	11·58 (8·37)	0·198
PA (metabolic equivalent ·h/week)	30·11 (5·31)	30·12 (5·94)	30·10 (4·74)	0·978	29·57 (5·81)	30·64 (4·74)	0·127	30·76 (5·51)	29·51 (5·07)	0·075	30·13 (4·26)	30·10 (5·94)	0·961	30·76 (4·92)	29·44 (5·63)	0·058
SES *n* (%)																
Poor	(31·70)	42 (57·5)	31 (42·5)	0·043	49 (67·1)	24 (32·9)	<0·0001	23 (31·5)	50 (68·5)	<0·0001	29 (39·7)	44 (60·3)	0·104	23 (31·5)	50 (68·5)	<0·0001
Moderate	87 (37·80)	38 (43·7)	49 (56·3)		42 (48·3)	45 (51·7)		40 (46·0)	47 (54·0)		48 (55·2)	39 (44·8)		50 (57·5)	37 (42·5)	
Rich	70 (30·50)	26 (37·1)	44 (62·9)		23 (32·9)	47 (67·1)		48 (68·8)	22 (31·4)		38 (54·3)	32 (45·7)		44 (62·9)	26 (37·1)	
Supplement consumption (*n* (%))																
Yes	59 (25·70)	26 (44·1)	33 (55·9)	0·718	26 (44·1)	33 (33·9)	0·327	28 (47·5)	31 (52·5)	0·886	34 (57·6)	25 (42·4)	0·174	33 (55·9)	26 (44·1)	0·367
No	171 (74·30)	80 (46·8)	91 (53·2)		88 (51·5)	83 (48·5)		83 (48·5)	88 (51·5)		81 (47·4)	90 (52·6)		84 (49·1)	87 (50·9)	
Medications (*n* (%))																
BGR	48 (20·9)	25 (52·1)	23 (47·9)	0·594	33 (68·8)	15 (31·2)	0·001	24 (50)	24 (50)	0·076	26 (54·2)	22 (45·8)	0·021	23 (47·9)	25 (52·1)	0·188
BGR + BPR	25 (10·9)	12 (48)	13 (52)		7 (28)	18 (72)		18 (72)	7 (28)		6 (24)	19 (76)		8 (32)	17 (68)	
BGR + BLR	73 (31·7)	35 (47·9)	38 (52·1)		41 (56·2)	32 (43·8)		32 (43·8)	41 (56·2)		34 (46·6)	39 (53·4)		41 (56·2)	32 (43·8)	
All	84 (36·5)	34 (40·5)	50 (59·5)		33 (39·3)	51 (60·7)		37 (44)	47 (56)		49 (58·3)	35 (41·7)		45 (53·6)	39 (46·4)	

PDI, Plant-based diet index; hPDI, healthy PDI; uPDI, unhealthy PDI; NEAP, net endogenous acid production; PRAL, potential renal acid load; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; PA, physical activity; SES; socio-economic status; BGR, blood glucose reducers; BPR, blood pressure reducers; BLR, blood lipids reducers.

* Calculated by the χ^2 and *t* tests for qualitative and quantitative variables, respectively.

† 1: lower than median, 2: higher than median.

Table 2. Dietary intakes by median-split plant-based diet indices (PDI) and dietary acid load
(Mean values with their standard errors)

		PDI			hPDI			uPDI			NEAP			PRAL		
	Total (*n* 230)	1†	2†		1†	2†		1†	2†		1†	2†		1†	2†	
Variables	Mean (SE)	Mean (SE)	Mean (SE)	*P**	Mean (SE)	Mean (SE)	*P**	Mean (SE)	Mean (SE)	*P**	Mean (SE)	Mean (SE)	*P**	Mean (SE)	Mean (SE)	*P**
Energy (kJ/d)	9601·44 (136·90)	9772·90 (194·51)	9454·91 (191·71)	0·248	9393·66 (168·69)	9805·66 (214·01)	0·133	9815·78 (218·61)	9401·53 (167·48)	0·131	9354·50 (187·31)	9848·42 (197·90)	0·071	9897·41 (205·05)	9296·01 (176·89)	0·028
CHO (g/d)	330·69 (4·64)	321·51 (4·79)	338·55 (4·43)	0·010	337·96 (4·65)	323·55 (4·61)	0·029	314·46 (4·52)	345·84 (4·36)	<0·0001	345·44 (4·47)	315·95 (4·47)	<0·0001	344·54 (4·46)	316·35 (4·54)	<0·0001
Protein (g/d)	70·81 (1·15)	70·18 (0·97)	71·35 (0·90)	0·378	67·01 (0·87)	74·55 (0·86)	<0·0001	77·02 (0·76)	65·01 (0·73)	<0·0001	68·35 (0·91)	73·26 (0·91)	<0·0001	70·52 (0·93)	71·10 (0·94)	0·664
Fat (g/d)	84·93 (2·44)	88·74 (2·08)	81·68 (1·92)	0·014	81·89 (2·01)	87·93 (2·01)	0·035	90·76 (1·99)	79·50 (1·92)	<0·0001	80·07 (1·98)	89·79 (1·98)	0·001	79·84 (1·95)	90·21 (1·99)	<0·0001
Cholesterol (mg/d)	171·86 (4·27)	192·67 (5·90)	154·07 (5·46)	<0·0001	193·85 (5·62)	150·24 (5·57)	<0·0001	173·47 (6·06)	170·35 (5·85)	0·712	163·84 (5·91)	179·88 (5·91)	0·057	162·92 (5·86)	181·12 (5·96)	0·031
SFA (mg/d)	20·45 (0·44)	22·33 (0·41)	18·84 (0·38)	<0·0001	22·01 (0·40)	18·92 (0·40)	<0·0001	20·43 (0·43)	20·47 (0·42)	0·946	19·90 (0·42)	21·01 (0·42)	0·070	19·41 (0·41)	21·52 (0·42)	<0·0001
MUFA (mg/d)	29·39 (1·09)	30·16 (1·04)	28·74 (0·96)	0·316	26·35 (0·96)	32·39 (0·95)	<0·0001	33·35 (0·95)	25·71 (0·92)	<0·0001	27·41 (0·98)	31·38 (0·98)	0·005	27·56 (0·98)	31·29 (0·99)	0·009
PUFA (mg/d)	19·15 (0·57)	19·70 (0·63)	18·69 (0·58)	0·240	18·33 (0·60)	19·96 (0·60)	0·058	20·01 (0·61)	18·36 (0·59)	0·056	17·58 (0·59)	20·72 (0·59)	<0·0001	17·35 (0·58)	21·03 (0·59)	<0·0001
Fibre (g/d)	20·84 (0·43)	19·35 (0·44)	22·12 (0·41)	<0·0001	18·07 (0·36)	23·57 (0·36)	<0·0001	23·49 (0·38)	18·38 (0·37)	<0·0001	22·26 (0·42)	19·43 (0·42)	<0·0001	23·03 (0·39)	18·58 (0·39)	<0·0001
Na (mg/d)	3546·13 (93·74)	3743·34 (127·36)	3377·55 (117·73)	0·036	3769·25 (122·37)	3326·86 (121·30)	0·011	3279·88 (123·39)	3794·48 (119·15)	0·003	3388·55 (122·83)	3703·72 (122·83)	0·072	3225·27 (119·09)	3878·35 (121·20)	<0·0001
K (mg/d)	3595·77 (69·03)	3401·85 (72·10)	3761·55 (66·65)	<0·0001	3298·01 (66·01)	3888·41 (65·44)	<0·0001	3950·77 (64·81)	3264·65 (62·58)	<0·0001	4022·86 (59·15)	3168·69 (59·15)	<0·0001	4071·84 (54·90)	3102·86 (55·88)	<0·0001
Fe (mg/d)	17·44 (0·24)	16·71 (0·25)	18·06 (0·23)	<0·0001	16·54 (0·23)	18·32 (0·23)	<0·0001	18·49 (0·23)	16·46 (0·22)	<0·0001	18·54 (0·22)	16·34 (0·22)	<0·0001	18·77 (0·21)	16·06 (0·21)	<0·0001
Ca (mg/d)	837·49 (16·87)	832·84 (22·09)	841·48 (20·42)	0·775	786·32 (20·79)	887·79 (20·60)	0·001	942·33 (19·34)	739·70 (18·68)	<0·0001	838·47 (21·26)	836·52 (21·26)	0·948	861·82 (20·98)	812·30 (21·36)	0·101
Mg (mg/d)	326·75 (8·29)	307·01 (7·87)	343·63 (7·27)	0·001	282·61 (6·61)	370·13 (6·55)	<0·0001	374·52 (6·55)	282·19 (6·33)	<0·0001	338·33 (7·69)	315·17 (7·69)	0·035	349·59 (7·40)	303·10 (7·53)	<0·0001
P (mg/d)	1110·55 (21·26)	1095·24 (19·19)	1123·63 (17·74)	0·279	1049·26 (17·67)	1170·77 (17·51)	<0·0001	1217·85 (16·02)	1010·46 (15·47)	<0·0001	1127·92 (18·44)	1093·18 (18·44)	0·186	1136·65 (18·21)	1083·52 (18·54)	0·043
Zn (mg/d)	7·41 (0·15)	7·25 (0·15)	7·55 (0·14)	0·152	6·86 (0·13)	7·96 (0·13)	<0·0001	8·32 (0·12)	6·57 (0·12)	<0·0001	7·33 (0·14)	7·50 (0·14)	0·408	7·55 (0·14)	7·28 (0·14)	0·198
Vitamin A (RAE/d)	1146·58 (41·47)	1060·27 (59·84)	1220·36 (55·32)	0·051	997·18 (56·56)	1293·40 (56·07)	<0·0001	1364·55 (55·52)	943·26 (53·61)	<0·0001	1343·64 (55·05)	949·52 (55·05)	<0·0001	1393·01 (52·78)	891·43 (53·71)	<0·0001
Vitamin D (µg/d)	1·18 (0·05)	1·38 (0·07)	1·01 (0·07)	0·001	1·23 (0·07)	1·13 (0·07)	0·324	1·34 (0·07)	1·03 (0·07)	0·004	1·15 (0·07)	1·21 (0·07)	0·566	1·16 (0·07)	1·21 (0·07)	0·665
Vitamin K (mg/d)	187·12 (6·83)	162·90 (9·88)	207·82 (9·13)	0·001	155·02 (9·29)	218·66 (9·21)	<0·0001	216·24 (9·53)	159·95 (9·20)	<0·0001	222·63 (9·15)	151·61 (9·15)	<0·0001	232·56 (8·66)	140·06 (8·82)	<0·0001
Vitamin E (mg/d)	3·76 (0·08)	3·57 (0·12)	3·93 (0·11)	0·028	3·64 (0·11)	3·88 (0·11)	0·149	3·95 (0·12)	3·59 (0·11)	0·031	4·14 (0·11)	3·39 (0·11)	<0·0001	4·20 (0·11)	3·32 (0·11)	<0·0001
Vitamin C (mg/d)	129·60 (3·05)	119·70 (4·27)	138·06 (3·94)	0·002	114·90 (3·98)	144·05 (3·94)	<0·0001	145·94 (3·99)	114·36 (3·85)	<0·0001	150·67 (3·70)	108·53 (3·70)	<0·0001	154·94 (3·41)	103·36 (3·47)	<0·0001
Vitamin B_1 (mg/d)	1·89 (0·02)	1·83 (0·02)	1·94 (0·02)	0·001	1·86 (0·02)	1·92 (0·02)	0·095	1·88 (0·02)	1·90 (0·02)	0·484	1·92 (0·02)	1·86 (0·02)	0·132	1·93 (0·02)	1·85 (0·02)	0·014

Table 2. *(Continued)*

		PDI			hPDI			uPDI			NEAP			PRAL		
	Total (*n* 230)	1†	2†		1†	2†		1†	2†		1†	2†		1†	2†	
Variables	Mean (SE)	Mean (SE)	Mean (SE)	*P**	Mean (SE)	Mean (SE)	*P**	Mean (SE)	Mean (SE)	*P**	Mean (SE)	Mean (SE)	*P**	Mean (SE)	Mean (SE)	*P**
Vitamin B_2 (mg/d)	1·35 (0·02)	1·36 (0·03)	1·34 (0·03)	0·620	1·27 (0·03)	1·42 (0·03)	0·002	1·52 (0·02)	1·18 (0·02)	<0·0001	1·33 (0·03)	1·36 (0·03)	0·467	1·37 (0·03)	1·32 (0·03)	0·303
Vitamin B_3 (mg/d)	22·29 (0·42)	21·45 (0·31)	23·02 (0·29)	<0·0001	21·09 (0·29)	23·48 (0·28)	<0·0001	23·10 (0·30)	21·54 (0·29)	<0·0001	22·09 (0·31)	22·50 (0·31)	0·355	22·53 (0·30)	22·05 (0·31)	0·283
Vitamin B_6 (mg/d)	1·40 (0·02)	1·33 (0·03)	1·47 (0·02)	0·001	1·30 (0·03)	1·51 (0·02)	<0·0001	1·52 (0·03)	1·29 (0·02)	<0·0001	1·53 (0·02)	1·28 (0·02)	<0·0001	1·54 (0·02)	1·26 (0·02)	<0·0001
Vitamin B_{12} (mg/d)	2·58 (0·06)	2·78 (0·10)	2·41 (0·09)	0·007	2·70 (0·09)	2·46 (0·09)	0·084	2·85 (0·09)	2·33 (0·09)	<0·0001	2·50 (0·09)	2·66 (0·09)	0·236	2·52 (0·09)	2·64 (0·09)	0·384
Folate (μg/d)	325·98 (8·24)	295·37 (10·05)	352·16 (9·29)	<0·0001	275·06 (8·87)	376·03 (8·79)	<0·0001	378·80 (8·96)	276·72 (8·66)	<0·0001	349·50 (9·78)	302·47 (9·78)	0·001	368·24 (9·13)	282·23 (9·29)	<0·0001
Red meat (g/d)	20·42 (0·71)	22·02 (1·05)	19·05 (0·97)	0·039	21·83 (1·01)	19·03 (1·01)	0·051	21·42 (1·03)	19·48 (0·99)	0·179	20·44 (1·01)	20·40 (1·01)	0·975	20·43 (1·01)	20·41 (1·03)	0·990
Organ meat (g/d)	1·29 (0·16)	1·83 (0·24)	0·82 (0·22)	0·003	2·07 (0·23)	0·52 (0·23)	<0·0001	0·60 (0·23)	1·93 (0·23)	<0·0001	1·18 (0·24)	1·40 (0·24)	0·525	0·93 (0·23)	1·66 (0·24)	0·034
Processed meat (g/d)	3·57 (0·57)	5·02 (0·84)	2·33 (0·78)	0·020	6·17 (0·79)	1·01 (0·78)	<0·0001	2·36 (0·83)	4·69 (0·80)	0·046	2·44 (0·81)	4·69 (0·81)	0·053	1·79 (0·80)	5·41 (0·81)	0·002
Fish (g/d)	6·89 (0·51)	7·06 (0·75)	6·74 (0·70)	0·759	6·26 (0·73)	7·51 (0·72)	0·227	9·24 (0·71)	4·70 (0·68)	<0·0001	6·98 (0·73)	6·80 (0·73)	0·868	7·58 (0·72)	6·18 (0·73)	0·176
Poultry (g/d)	14·50 (0·58)	15·01 (0·85)	14·07 (0·79)	0·422	14·90 (0·82)	14·11 (0·81)	0·499	16·94 (0·80)	12·22 (0·77)	<0·0001	12·43 (0·80)	16·58 (0·80)	<0·0001	13·47 (0·81)	15·57 (0·82)	0·073
Eggs (g/d)	18·37 (0·73)	20·51 (1·06)	16·55 (0·98)	0·007	20·31 (1·03)	16·47 (1·02)	0·009	19·02 (1·05)	17·77 (1·02)	0·395	17·67 (1·04)	19·07 (1·04)	0·344	17·89 (1·03)	18·87 (1·05)	0·512
Whole grains (g/d)	52·23 (3·63)	42·14 (5·27)	60·85 (4·87)	0·010	34·60 (4·90)	69·55 (4·85)	<0·0001	66·86 (5·06)	38·58 (4·88)	<0·0001	50·86 (5·15)	53·60 (5·15)	0·708	51·62 (5·11)	52·86 (5·20)	0·865
Refined grains (g/d)	362·08 (9·96)	366·13 (14·64)	358·62 (13·54)	0·707	412·35 (13·34)	312·67 (13·22)	<0·0001	299·50 (13·12)	420·45 (12·67)	<0·0001	360·15 (14·09)	465·01 (14·09)	0·847	351·35 (13·96)	373·18 (14·20)	0·277
Low-fat dairy products (g/d)	169·46 (9·69)	159·06 (14·23)	178·35 (13·15)	0·321	135·59 (13·40)	202·75 (13·28)	<0·0001	232·07 (12·71)	111·07 (12·27)	<0·0001	176·08 (13·71)	162·85 (13·71)	0·497	185·63 (13·54)	152·72 (13·78)	0·092
High-fat dairy products (g/d)	116·84 (8·79)	162·45 (12·16)	77·85 (11·24)	<0·0001	170·50 (11·34)	64·10 (11·24)	<0·0001	84·85 (12·21)	146·68 (11·79)	<0·0001	97·91 (12·22)	135·77 (12·22)	0·030	84·44 (11·88)	150·39 (12·09)	<0·0001
Vegetables (g/d)	430·07 (12·60)	383·36 (18·14)	470·01 (16·76)	0·001	368·28 (17·02)	490·80 (16·87)	<0·0001	501·16 (17·01)	363·76 (16·41)	<0·0001	490·80 (16·99)	369·34 (16·99)	<0·0001	520·02 (15·64)	336·93 (15·92)	<0·0001
Starchy vegetables (g/d)	82·53 (3·77)	80·59 (5·40)	84·19 (4·99)	0·626	101·06 (4·92)	64·33 (4·88)	<0·0001	58·50 (4·80)	104·96 (4·64)	<0·0001	101·48 (4·89)	63·59 (4·89)	<0·0001	90·76 (5·11)	74·01 (5·20)	0·023
Fruit (g/d)	270·78 (7·50)	241·81 (10·23)	295·53 (9·45)	<0·0001	233·62 (9·58)	307·28 (9·50)	<0·0001	307·89 (9·74)	236·15 (9·41)	<0·0001	302·96 (9·70)	238·59 (9·70)	<0·0001	314·37 (9·21)	225·63 (9·37)	<0·0001
Fruit juice (g/d)	2·58 (0·33)	1·78 (0·48)	3·27 (0·45)	0·027	2·60 (0·47)	2·59 (0·47)	0·957	2·84 (0·48)	2·34 (0·46)	0·463	2·91 (0·47)	2·25 (0·47)	0·328	3·16 (0·46)	1·98 (0·47)	0·081
Tea and coffee (g/d)	608·97 (21·88)	498·86 (30·34)	703·09 (28·04)	<0·0001	572·61 (30·62)	644·70 (30·36)	0·097	616·49 (31·22)	601·94 (30·15)	0·738	644·10 (30·53)	573·83 (30·53)	0·106	654·79 (30·19)	561·52 (30·73)	0·032

hPDI, healthy PDI; uPDI, unhealthy PDI; NEAP, net endogenous acid production; PRAL, potential renal acid load; CHO, carbohydrate; RAE, retinol activity equivalents.
* Calculated by *t* test for energy intake and multivariate ANCOVA for other variables. All the variables, except energy, adjusted for energy intake.
† 1: lower than median, 2: higher than median.

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Table 3. Dietary intakes among poor and good sleepers and healthy participants or participants with mental disorders
(Mean values with their standard errors)

	Total (*n* 230)		Good sleepers (*n* 66)		Poor sleepers (*n* 164)			Non-depressed (*n* 162)		Depressed (*n* 68)			Without anxiety (*n* 153)		With anxiety (*n* 77)			Without stress (*n* 129)		With stress (*n* 101)		
Variables	Mean	SE	Mean	SE	Mean	SE	*P**	Mean	SE	Mean	SE	*P**	Mean	SE	Mean	SE	*P**	Mean	SE	Mean	SE	*P**
Energy (kJ/d)	9601·44	2076·68	9801·43	2267·76	9521·11	1996·31	0·356	9699·76	2128·06	9367·97	1944·01	0·270	9542·03	2141·24	9719·43	1950·24	0·542	9805·62	2271·70	9340·78	1774·22	0·092
CHO (g/d)	330·7	4·64	324·8	6·15	333·1	3·89	0·257	327	3·90	339·6	6·04	0·082	321·8	3·91	348·4	5·52	<0·0001	329·4	4·41	332·4	4·99	0·656
Protein (g/d)	70·81	1·15	75·40	1·18	68·96	0·75	<0·0001	72·92	0·74	65·78	1·15	<0·0001	72·78	0·78	66·90	1·09	<0·0001	73·82	0·83	66·97	0·94	<0·0001
Fat (g/d)	84·93	2·44	87·27	2·66	83·99	1·69	0·301	86·25	1·69	81·80	2·62	0·156	88·82	1·69	77·21	2·39	<0·0001	85·01	1·91	84·84	2·16	0·954
Cholesterol (mg/d)	171·86	4·27	160·4	7·80	176·5	4·94	0·084	171	5·01	173·9	7·74	0·758	165	5·09	185·6	7·18	0·020	170·6	5·62	173·5	6·36	0·728
SFA (mg/d)	20·45	0·44	18·84	0·55	21·09	0·34	0·001	20·18	0·35	21·09	0·55	0·168	20·18	0·37	20·97	0·52	0·217	19·63	0·39	21·49	0·44	0·002
MUFA (mg/d)	29·39	1·09	32·53	1·29	28·13	0·82	0·005	30·60	0·83	26·52	1·28	0·008	31·61	0·82	24·99	1·17	<0·0001	30·31	0·94	28·23	1·06	0·146
PUFA (mg/d)	19·15	0·57	18·79	0·80	19·30	0·50	0·594	19·15	0·51	19·17	0·79	0·982	19·90	0·52	17·68	0·73	0·015	18·70	0·57	19·74	0·64	0·231
Fibre (g/d)	20·84	0·43	24·32	0·52	19·48	0·33	<0·0001	22·01	0·34	18·07	0·53	<0·0001	22·25	0·35	18·05	0·49	<0·0001	22·60	0·38	18·61	0·43	<0·0001
Na (mg/d)	3546·1	93·74	2870	154·04	3818	97·64	<0·0001	3330	100·54	4062	155·36	<0·0001	3447	106·30	3742	149·88	0·110	3204	111·61	3983	126·23	<0·0001
K (mg/d)	3595·8	69·03	4040	87·30	3417	55·34	<0·0001	3758	56·61	3209	87·48	<0·0001	3736	59·54	3317	83·95	<0·0001	3861	61·92	3257	70·03	<0·0001
Fe (mg/d)	17·44	0·24	19·02	0·30	16·80	0·19	<0·0001	17·97	0·19	16·17	0·30	<0·0001	17·84	0·21	16·64	0·29	0·001	18·30	0·21	16·34	0·24	<0·0001
Ca (mg/d)	837·50	16·87	910·8	27·40	808·0	17·36	0·002	876·1	17·23	745·6	26·62	<0·0001	858·9	18·20	795	25·67	0·044	902	18·99	755·2	21·48	<0·0001
Mg (mg/d)	326·75	8·29	381·2	9·29	304·8	5·88	<0·0001	345·5	6·11	282·1	9·44	<0·0001	348·3	6·23	283·9	8·79	<0·0001	352·7	6·85	293·6	7·75	<0·0001
P (mg/d)	1110·55	21·26	1192	23·52	1078	14·90	<0·0001	1145	14·97	1028	23·13	<0·0001	1142	15·59	1049	21·98	0·001	1162	16·68	1045	18·87	<0·0001
Zn (mg/d)	7·41	0·15	8·17	0·18	7·11	0·11	<0·0001	7·71	0·11	6·72	0·18	<0·0001	7·69	0·12	6·87	0·17	<0·0001	7·83	0·13	6·88	0·15	<0·0001
Cu (mg/d)	1·70	0·04	1·92	0·04	1·62	0·02	<0·0001	1·77	0·02	1·54	0·04	<0·0001	1·79	0·02	1·54	0·04	<0·0001	1·79	0·03	1·60	0·03	<0·0001
Mn (mg/d)	4·18	0·09	4·61	0·12	4·01	0·07	<0·0001	4·33	0·08	3·83	0·12	0·001	4·34	0·08	3·87	0·11	0·001	4·37	0·09	3·94	0·10	0·002
Se (mg/d)	0·03	0·001	0·027	0·002	0·033	0·001	0·022	0·029	0·001	0·037	0·002	0·003	0·03	0·001	0·03	0·002	0·143	0·029	0·002	0·035	0·002	0·008
Cr (mg/d)	0·005	0·0002	0·006	<0·0001	0·005	<0·0001	0·012	0·005	<0·0001	0·006	<0·0001	0·077	0·005	<0·0001	0·005	<0·0001	0·521	0·005	<0·0001	0·005	<0·0001	0·666
Vitamin A (RAE/d)	1146·6	41·47	1449	72·67	1025	46·06	<0·0001	1255	46·95	888·1	72·55	<0·0001	1212	49·60	1016	69·94	0·023	1293	52·79	959·8	59·70	<0·0001
Vitamin D (μg/d)	1·18	0·05	1·15	0·10	1·19	0·06	0·743	1·19	0·06	1·15	0·09	0·700	1·15	0·06	1·23	0·09	0·478	1·21	0·07	1·15	0·08	0·575
Vitamin K (mg/d)	187·12	6·83	226·0	12·45	171·5	7·89	<0·0001	204·1	7·91	146·7	12·22	<0·0001	195·2	8·36	171·1	11·79	0·096	215·9	8·72	150·3	9·86	<0·0001
Vitamin E (mg/d)	3·76	0·08	4·11	0·15	3·62	0·09	0·009	3·81	0·10	3·65	0·15	0·383	3·78	0·10	3·73	0·14	0·792	3·98	0·11	3·48	0·12	0·003
Vitamin C (mg/d)	129·61	3·05	152·0	5·24	120·6	3·32	<0·0001	136·8	3·41	112·4	5·27	<0·0001	135·5	3·56	117·9	5·02	0·005	145·3	3·63	109·6	4·11	<0·0001
Vitamin B_1 (mg/d)	1·89	0·02	1·93	0·03	1·87	0·02	0·173	1·90	0·02	1·87	0·03	0·407	1·88	0·02	1·91	0·02	0·320	1·92	0·02	1·85	0·02	0·070
Vitamin B_2 (mg/d)	1·35	0·02	1·47	0·04	1·30	0·02	0·001	1·41	0·02	1·19	0·04	<0·0001	1·40	0·02	1·24	0·03	0·001	1·45	0·02	1·22	0·03	<0·0001
Vitamin B_3 (mg/d)	22·29	0·42	23·63	0·39	21·76	0·25	<0·0001	22·68	0·25	21·39	0·39	0·007	22·87	0·26	21·16	0·36	<0·0001	22·74	0·29	21·73	0·32	0·022
Vitamin B_6 (mg/d)	1·40	0·02	1·57	0·03	1·34	0·02	<0·0001	1·47	0·02	1·25	0·03	<0·0001	1·46	0·02	1·29	0·03	<0·0001	1·49	0·02	1·29	0·03	<0·0001
Vitamin B_{12} (mg/d)	2·58	0·06	2·58	0·12	2·58	0·08	0·975	2·62	0·08	2·48	0·12	0·354	2·56	0·08	2·62	0·11	0·655	2·64	0·09	2·50	0·10	0·305
Folate (μg/d)	325·99	8·24	3·85	12·37	3·02	7·84	<0·0001	347·2	8·02	275·5	12·39	<0·0001	346·3	8·35	285·7	11·77	<0·0001	361	8·79	281·3	9·94	<0·0001
Red meat (g/d)	20·42	0·72	20·77	1·34	20·28	0·85	0·758	20·19	0·85	20·96	1·32	0·628	20·78	0·88	19·70	1·24	0·479	21·57	0·95	18·94	1·08	0·070
Organ meat (g/d)	1·29	0·57	0·94	0·31	1·42	0·20	0·203	0·97	0·20	2·04	0·30	0·004	1·11	0·20	1·64	0·29	0·139	0·91	0·22	1·77	0·25	0·013
Processed meat (g/d)	3·57	0·57	1·31	1·07	4·48	0·67	0·013	2·97	0·68	5·01	1·06	0·109	3·18	0·71	4·33	1·01	0·350	2·79	0·77	4·56	0·87	0·133
Fish (g/d)	6·89	0·51	7·86	0·95	6·50	0·60	0·234	7·62	0·60	5·15	0·93	0·029	7·43	0·62	5·83	0·88	0·142	7·68	0·68	5·88	0·77	0·083
Poultry (g/d)	14·50	0·58	15·70	1·08	14·02	0·68	0·191	15·39	0·68	12·39	1·05	0·018	14·67	0·71	14·16	1·01	0·678	14·72	0·77	14·22	0·87	0·668
Eggs (g/d)	18·37	0·73	17·77	1·37	18·62	0·87	0·606	18·84	0·87	17·27	1·35	0·334	17·77	0·89	19·57	1·26	0·248	19·33	0·98	17·16	1·10	0·145
Whole grains (g/d)	52·23	3·63	58·50	6·76	49·70	4·29	0·274	59·44	4·23	35·04	6·55	0·002	61·14	4·33	34·52	6·11	<0·0001	55·84	4·84	47·62	5·48	0·264
Refined grains (g/d)	362·08	9·96	325·6	18·34	376·8	11·62	0·019	339·2	11·51	416·5	17·78	<0·0001	330·1	11·61	425·6	16·37	<0·0001	339·9	13·11	390·4	14·82	0·012
Low-fat dairy products (g/d)	169·46	9·69	232·2	17·39	144·2	11·02	<0·0001	195	11·10	108·8	17·16	<0·0001	195·2	11·48	118·3	16·19	<0·0001	214	12·16	112·6	13·75	<0·0001
High-fat dairy products (g/d)	116·84	8·79	37·73	15·04	148·7	9·53	<0·0001	92·47	9·94	174·9	15·37	<0·0001	90·96	10·25	168·3	14·46	<0·0001	75·54	10·90	169·6	12·33	<0·0001
Vegetables (g/d)	430·07	12·60	526·5	22·34	391·3	14·16	<0·0001	460	14·60	358·8	22·56	<0·0001	457·7	15·15	375·2	21·36	0·002	488·9	15·85	355	17·92	<0·0001
Starchy vegetables (g/d)	82·53	3·77	65·05	6·71	89·57	4·25	0·002	76·01	4·30	98·09	6·64	0·006	74·83	4·41	97·85	6·21	0·003	72·28	4·80	95·64	5·43	0·002
Fruit (g/d)	270·78	7·50	313·8	12·94	253·5	8·20	<0·0001	287·3	8·29	231·3	12·81	<0·0001	286·2	8·59	240·2	12·12	0·002	306·2	8·90	2·25	10·07	<0·0001
Fruit juice (g/d)	2·58	0·33	3·29	0·62	2·30	0·39	0·183	2·74	0·39	2·22	0·61	0·481	2·72	0·41	2·32	0·57	0·575	2·99	0·44	2·06	0·50	0·169
Tea and coffee (g/d)	608·97	21·88	553·5	40·21	631·3	25·49	0·104	596·7	25·76	638·2	39·80	0·383	589·4	26·44	647·9	37·28	0·202	588·8	28·90	634·7	32·69	0·296

CHO, carbohydrate.
* Calculated by *t* test for energy intake and multivariate ANCOVA for other variables. All the variables, except energy, adjusted for energy intake.

Table 4. Mental disorders and having poor sleep by median-split dietary acid load and plant-based diet indices (PDI)
(Odds ratios and 95 % confidence intervals)

	PDI				hPDI				uPDI				NEAP				PRAL			
	1‡	2‡ (*n* 124)			1‡	2‡ (*n* 116)			1‡	2‡ (*n* 119)			1‡	2‡ (*n* 115)			1‡	2‡ (*n* 113)		
Variables	(*n* 106)	OR	95 % CI	*P**	(*n* 114)	OR	95 % CI	*P*†	(*n* 111)	OR	95 % CI	*P*†	(*n* 115)	OR	95 % CI	P_{trend}	(*n* 117)	OR	95 % CI	*P*
Poor sleep (*n* 164)																				
Crude model	1	0·74	0·41, 1·32	0·318	1	0·29	0·15, 0·54	<0·0001	1	5·27	2·76, 10·06	<0·0001	1	2·87	1·57, 5·26	0·001	1	5·04	2·62, 9·17	<0·0001
Model 1§	1	0·92	0·49, 1·74	0·813	1	0·33	0·17, 0·64	0·001	1	5·93	2·88, 12·22	<0·0001	1	2·94	1·53, 5·65	0·001	1	4·35	2·18, 8·68	<0·0001
Model 2‖	1	1·13	0·54, 2·38	0·730	1	0·28	0·13, 0·62	0·001	1	6·47	2·75, 15·24	<0·0001	1	2·81	1·34, 5·90	0·006	1	3·74	1·73, 8·11	0·001
Depression (*n* 68)																				
Crude model	1	0·67	0·38, 1·19	0·178	1	0·21	0·11, 0·40	<0·0001	1	7·33	3·64, 14·75	<0·0001	1	1·39	0·79, 2·47	0·249	1	2·47	1·37, 4·44	0·003
Model 1§	1	0·76	0·40, 1·45	0·421	1	0·26	0·13, 0·51	<0·0001	1	7·90	3·60, 17·32	<0·0001	1	1·14	0·61, 2·12	0·670	1	1·82	0·95, 3·46	0·067
Model 2‖	1	0·76	0·39, 1·48	0·426	1	0·21	0·10, 0·43	<0·0001	1	9·35	3·96, 22·07	<0·0001	1	1·15	0·60, 2·21	0·668	1	1·88	0·95, 3·73	0·069
Anxiety (*n* 77)																				
Crude model	1	0·75	0·43, 1·31	0·325	1	0·30	0·16, 0·53	<0·0001	1	4·18	2·28, 7·64	<0·0001	1	1·54	0·88, 2·67	0·125	1	2·43	1·38, 4·28	0·002
Model 1§	1	0·95	0·52, 1·73	0·877	1	0·32	0·17, 0·59	<0·0001	1	4·19	2·15, 8·13	<0·0001	1	1·26	0·70, 2·25	0·438	1	2·16	1·18, 3·97	0·012
Model 2‖	1	0·93	0·49, 1·78	0·841	1	0·26	0·13, 0·51	<0·0001	1	4·74	2·28, 9·85	<0·0001	1	1·27	0·67, 2·38	0·454	1	2·62	1·35, 5·07	0·004
Stress (*n* 101)																				
Crude model	1	0·72	0·43, 1·23	0·236	1	0·31	0·18, 0·54	<0·0001	1	4·70	2·67, 8·28	<0·0001	1	2·11	1·24, 3·60	0·006	1	3·29	1·90, 5·67	<0·0001
Model 1§	1	0·79	0·44, 1·43	0·450	1	0·37	0·21, 0·66	0·001	1	4·06	2·20, 7·50	<0·0001	1	1·94	1·10, 3·42	0·022	1	2·58	1·44, 4·60	0·001
Model 2‖	1	0·74	0·39, 1·39	0·354	1	0·24	0·12, 0·48	<0·0001	1	4·24	2·14, 8·38	<0·0001	1	2·13	1·13, 4·01	0·018	1	2·59	1·36, 4·94	0·004

hPDI, healthy PDI; uPDI, unhealthy PDI; NEAP, net endogenous acid production; PRAL, potential renal acid load.
* Calculated by logistic regression.
‡ 1: lower than median, 2: higher than median.
§ Model 1: All the variables adjusted for age, BMI, socio-economic status, physical activity, supplement intake, and vitamin D and energy intake.
‖ Model 2: All the variables adjusted further for medications, lipid profile, blood pressure, sleep duration at night and nap time in addition to adjusted variables in model 1.

Table 5. Association between dietary acid load score and the score of plant-based diet indices (PDI) with mental disorders and having poor sleep using linear regression*
(β-Coefficients and P values)

	PDI		hPDI		uPDI		NEAP		PRAL	
	β	P	β	P	β	P	β	P	β	P
PSQI score	−0·197	0·003	−0·360	<0·0001	0·319	<0·0001	0·151	0·022	0·262	<0·0001
Anxiety score	−0·050	0·456	−0·297	<0·0001	0·313	<0·0001	0·082	0·211	0·137	0·041
Stress score	−0·167	0·014	−0·351	<0·0001	0·426	<0·0001	0·193	0·004	0·296	<0·0001
Depression score	−0·126	0·062	−0·299	<0·0001	0·424	<0·0001	0·118	0·076	0·211	0·002

hPDI, healthy PDI; uPDI, unhealthy PDI; NEAP, net endogenous acid production; PRAL, potential renal acid load; PSQI, Pittsburgh Sleep Quality Index.
* Calculated by linear regression. Full-adjusted model: all the variables adjusted for age, BMI, socio-economic status, physical activity, supplement intake, vitamin D and energy intake, medications, lipid profile, blood pressure, sleep duration at night and nap time.

The cumulative and synergic effects of these healthy food groups within dietary patterns can have protective effects on depressive symptoms[30]. A meta-analysis of thirteen studies represented that high intakes of fruits, vegetables, nuts and whole grains were associated with a reduced odds of depression[31]. Another systematic review found that vegetarian diets have an inverse association with depressive symptoms[32]. Moreover, dietary patterns rich in fruits and vegetables, which have a high content of fibre, antioxidants and polyphenols, have been positively associated with mental health outcomes in adolescents[33,34].

One of the biological mechanisms that is involved in reducing mental disorders is a low level of inflammation status[35]. Inflammation can trigger melancholic symptoms through activation of inflammatory pathways in the brain[36]. Low intake of whole grains, fruits and vegetables is associated with increased inflammatory markers[37]. Plant-based diets contain alkali-rich food groups such as whole grains, vegetables and fruits, while containing less of animal products, high-protein, and high-phosphorus foods[38]. Plant-based diets increase bicarbonate and bicarbonate precursors, while animal products increase potential anorganic acid precursors[39]. Hence, vegetarian diets significantly have lower DAL[40]. Even moderate increases in DAL stimulate secretion and activity of glucocorticoids which leads to renal acid excretion[41,42]. On the other hand, glucocorticoids modulate emotion and behaviour through changes in limbic areas of the brain[43,44]. Systematic acid–base balance modifies blood-brain turnover and glutamate turnover in the brain[45]. Glucocorticoids alter the expression and activation of vesicular proteins which are involved in glutamate neurotransmission[46]. Moreover, glutamatergic neurons regulate brain activity and sleep stages[47].

To the best of our knowledge, there is only one publication that has assessed the association between DAL and mental disorders in, which showed that participants with higher PRAL had more hyperactivity and emotional problems[48]. However, this study was conducted in adolescents, and psychological disorders were determined using the Strengths and Difficulties Questionnaire.

The main analysis indicates that higher adherence to hPDI is associated with lower odds of mental disorders in crude and all adjusted models. Also, higher adherence to the hPDI was associated with a 90 % lower odds of sleep disorders. Consistent with the foregoing, a recent review suggests plant-based diets may have the potential to improve overall health status through the effect on improving sleep quality[49]. Cao *et al*. have showed that there was a significant inverse association between isoflavone intakes and sleep duration[50]. Besides lower DAL and related mechanisms in plant-based diets, high amounts of antioxidants, phytochemicals, flavonoids, vitamins and minerals are related to beneficial effects on mental[51] and sleep disorders through suppression of inflammation and reducing oxidative stress[52]. Legumes and beans are high in tryptophan which is a precursor of melatonin and serotonin, which play a role in sleep regulation[53]. Beezhold *et al*. reported that greater adherence to a vegetarian diet and even less animal food intake was associated with better mood[54].

In the present study, outcome measures were adjusted for several confounders such as age, BMI, energy intake and PA. Although we adjusted for several known confounders, there are possible residual effects which can have effect on the outcome variables of interest. Increased body weight and BMI increase the risk of diabetes, insulin resistance and higher blood glucose concentrations. Furthermore, there is an association between obesity, sleep quality and depressive symptoms[55,56]. Moreover, body fatness is associated with both depression and sleep quality[57]. A study in Swiss adolescents showed that higher levels of PA were related to more favourable sleep quality and lower insomnia scores, but participants tend to overestimate their level of PA[58]. However, PA has been shown to have favourable effects on sleep quality[59], by modulating symptoms of anxiety, stress and depression[60]. Totally, PA was not significantly associated with poor sleep and psychological symptoms in the present study.

While this is the first study that has examined the association between DAL and PDI with sleep and psychological status among diabetic patients, there are several limitations. We randomly included diabetic women from different socio-economic status which could be a representative sample of diabetic women in Tehran. However, the relationship is not generalisable to other populations with different sex and health conditions. Moreover, the present study was conducted on a diabetic population from Tehran, and the generalisability of results to the other cities in Iran is uncertain. Due to the observational nature of the present study, cause and effect cannot be established. Furthermore, while adjustment for confounding was performed, there are possible residual effects which may have affected the outcome variables. In addition, laboratory markers of acid–base balance were not collected in the present study. While the limitations of FFQ have been widely reported for dietary assessment in large studies, there is limited validation data for anions. The twenty-one-item Depression, Anxiety and Stress Scale questionnaire is a self-reported scale which may lead to misclassification of participants and is therefore not suitable scale for clinical diagnosis of depression and anxiety.

In conclusion, the present study has shown that there was a positive association between psychological and sleep disorders with DAL, while plant-based diets had a protective effect. Prospective cohorts or intervention studies of vegetarian diets are needed to confirm our findings.

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E. D., B. L. and L. A. designed and L. A. supervised the study. E. D. conducted the study. E. D., M. Q. and L. A. performed the statistical analyses. E. D. prepared a first draft of the manuscript and L. A., S. A. K. and B. A. finalised it. N. B. reviewed and edited the manuscript.

The authors declare that they have no conflicts of interest.

Supplementary material

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114519003179

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