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Irregular daily energy intake and diet quality in Iranian adults

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Abstract

The present cross-sectional study aimed to assess the association of daily irregularity in energy intake and diet quality among apparently healthy adults in Iran. The research was conducted on 850 adult men and women (age range: 20–59 years) who attended health care centres in Tehran. Dietary intake was assessed by three, 24-h dietary recalls. Diet quality was assessed using the Dietary Approaches to Stop Hypertension (DASH) diet score and Healthy Eating Index-2015 (HEI-2015). An irregularity score of daily energy intake was calculated based on the deviation from the 3-d mean energy intake, with a higher score indicating more fluctuations in daily energy intake. Multiple linear regression analysis was used to assess the association of irregularity score of daily energy intake with food group intakes and DASH diet score and HEI-2015, controlling for age, sex, BMI, physical activity, education level and occupation status. The range of irregularity score was 0·55–133·3 (22·4 (SD 19·0)). Higher irregularity score of daily energy intake was significantly associated with a lower consumption of fruit, vegetables, legumes, low-fat dairy products and poultry, higher consumption of soft drinks, processed meat and nuts, and lower overall DASH diet score and HEI-2015. Overall, our findings showed that more day-to-day variations in energy intake may be correlated with a lower diet quality. More research is needed to confirm the associations observed in the present study and to clarify potential mechanisms explaining these associations.

Key words: Chrononutrition: Dietary Approaches to Stop Hypertension diet: Diet quality: Energy intake: Irregularity

The effects of diet quality on human health have been of interest for a long time. There is evidence that higher diet quality may be associated with better quality of life in children and adolescents[1] and adults[2]. There is also convincing evidence that greater adherence to healthy or unhealthy dietary patterns is associated with the risk of cardiometabolic disease and mortality[3]. According to current evidence, about 11 million deaths in 2017 were attributable to dietary factors[4]. Therefore, clarifying determinants of healthy eating may help develop more useful recommendations to improve the quality of eating habits.

Chronobiology is a field of biology that examines periodic variations in living organisms[5]. Chronobiology assesses time-dependent variations in biological functions considering three aspects of time including clock time (defined as time of day), frequency (defined as events per time span) and regularity (defined as events at specific time). Similarly, chrononutrition is a field of nutrition science that assesses circadian-related changes in dietary habits including change in meal timing, change in distribution of energy intake throughout the day or changes in eating frequency (the number of eating occasions throughout the day)[6].

Several investigations have assessed the association of different aspects of chrononutrition on quality of the diet. Results from cross-sectional studies suggest that higher eating frequency during the day may be associated with higher diet quality and lower energy intake[7–11]. Meal timing has been thought to be associated with diet quality[12]. Epidemiological studies have indicated that more frequent eating occasions during the evening hours, defined as later temporal eating pattern, may be associated with lower diet quality[13,14] and higher energy intake[15–17].

The 2017 American Heart Association scientific statement[18] reported that irregular eating habits and day-to-day inconsistencies in the timing and frequency of meals have increased during the past decades[19]. The report suggested that irregular eating styles such as irregular meal timing and frequency and breakfast skipping are associated with lower diet quality and unfavourable cardiometabolic profile and highlighted the need for focus on

Abbreviations: DASH, Dietary Approaches to Stop Hypertension; HEI, Healthy Eating Index; MET, metabolic equivalent.

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the timing and frequency of meals and snacks to achieve healthier lifestyle and improved risk factor management[18].

These findings indicated that irregular patterns of dietary intake including irregular meal frequency or timing may be associated with a lower diet quality. However, another aspect of irregularity including day-to-day variation in dietary intake has been poorly investigated. A recent cross-sectional evaluation indicated that more day-to-day variation in energy intake was associated with a higher likelihood of adiposity[20]. A cohort study suggested that more fluctuations in daily energy intake during the week may be associated with a higher risk of the metabolic syndrome[21]. However, the association of irregularity in daily energy intake with the diet quality has not been investigated. Therefore, the aim of this cross-sectional study was to evaluate the potential association of irregularity in daily energy intake with diet quality and intake of different healthy and unhealthy food groups.

Materials and methods

Study participants

The present study was a cross-sectional study in Tehran from 2018 to 2019. Participants were apparently healthy men and women, aged 20–59 years who attended the local health care centres during the study period and had willingness to take part in the study. The present study was performed by using data from a cross-sectional study designed to investigate the association of diet quality and adiposity. The following formula was used for sample size calculation: $n = (pqz^2)/E^2$[22,23]. Considering the prevalence of overweight and obesity in Tehranian adults (65 %)[24], an error coefficient of $d = 0{\cdot}04$ and at α level of 0·05, the sample size of 546 people was obtained. With design effect of 1·5 and in order to compensate for the potential exclusion of participants due to under- and over-reporting of total energy intake, or attrition due to other reasons, the final sample size of 850 participants was selected for inclusion.

A two-stage cluster sampling was used to recruit participants from health care centres. First, we classified health centres into five districts of the city including North, South, East, West and centre. Next, a list of all health centres existed in each district was provided. Then, we randomly chose eight health centres from each district (forty health centres). Finally, to obtain the number of subjects in each health centre, we divided the total number of sample size (850) by the number of health centres[40].

Ethical approval

The sample collection was facilitated by the coordination of the Health Bureau of the Municipality of Tehran and the cooperation of the health care centres of Tehran. The ethical committee of the Tehran University of Medical Sciences approved the study protocol and informed consent form (Ethic Number: IR.TUMS.VCR.REC.1397.157). All patients received written information regarding the background and procedures of the study and gave written informed consent prior to entering the study.

Data collection

During the first visit, participant's characteristics were obtained by using pre-specified data extraction forms. Subjects completed a questionnaire designed to assess the participants' demographics including age (years), sex, BMI, educational level (illiterate, under diploma = uncompleted primary or secondary education, diploma = completed secondary education, educated = bachelor's degree or higher), marital status (married or other (not married or divorced)), occupation (employed, retired, housekeeper or unemployed) and smoking status (never smoked, former smoker and current smoker).

Dietary assessment

Dietary intakes of participants were assessed by using three 24-h dietary recalls. Trained dietitians completed the first 24-h dietary recall by face-to-face interview at the first visit at each health centre. The other two 24-h dietary recalls were completed at random days including one weekend, by telephone interviews. All 24-h dietary recall interviews were carried out by trained dietitians. For dietary analysis, daily intakes of all food items obtained from 24-h dietary recalls were computed and then were converted into grams by using household measures[25]. The 3-d dietary intakes were summed and then averaged over the 3 d. Dietary intakes were expressed as food groups including total grains, fruit, vegetables, green leafy vegetables, red/yellow vegetables, legumes, nuts, red meat, processed meat, poultry, fish, low- and high-fat dairy products, eggs, soft drinks, salty snacks, and solid and liquid oils. Liquid oil includes vegetable oils that were liquid in room temperature. Solid oil includes animal fat and hydrogenated vegetable oils that were solid in room temperature. Dietary intakes were adjusted for energy intake by using the residual method[26].

Physical examinations

Weight was measured using a digital adult scale (Seca model 808, measurement accuracy ±100 g)[27]. Participant's height was measured unshod using a wall stadiometer with a precision of 1 cm (Seca)[27]. The BMI was calculated as weight in kg divided by the square of height in metres. Waist circumference was measured with a tape measure to the nearest 0·1 cm between the iliac crest and the lowest rib during exhalation. Hip circumference was recorded at maximal point, over light clothing, using a non-stretch tape measure and without exerting any pressure on body surface.

Systolic and diastolic blood pressure were measured with a standard mercury sphygmomanometer by a trained physician, on the right arm, while sitting after a resting period of 15 min. The second measurement was performed 1–2 min later. The mean of the two measurements was calculated. Physical activity was assessed by using the International Physical Activity Questionnaire[28], and data were expressed as metabolic equivalent min/week (MET-min/week)[29]. Accordingly, International Physical Activity Questionnaire scores were categorised as 'low physical activity' (point score <600 MET-min/week), 'moderate physical activity' (point score between 600 and 3000 MET-min/week) and 'high physical activity' (point score >3000 MET-min/week).

Calculating score of irregularity in daily energy intake

To evaluate day-to-day variations in total daily energy intake for each participants, a newly developed irregularity score, introduced by Pot *et al.*[20], was calculated. First, the absolute difference of the individual daily energy intake from the 3-d mean energy intake was divided by the 3-d mean energy intake. Then, these values were multiplied by 100 and then averaged over the 3 d. This score served as a proxy of irregularity in daily energy intake. Accordingly, a low score indicates smaller day-to-day variation in daily energy intake and more regular daily energy intake, and a high score indicates larger day-to-day variation in daily energy intake.

Diet quality

The overall quality of the diet was evaluated by using the Dietary Approaches to Stop Hypertension (DASH) score and Healthy Eating Index-2015 (HEI-2015)[30]. The DASH diet score was calculated according to the recommendations of Fung *et al.*[31]. The score includes eight components in the DASH diet. All eight components were categorised into quintiles, in which for fruits, vegetables, nuts, legumes and low-fat dairy products; one point was assigned to the lowest intake (quintile first), and five points were assigned to the highest intake (quintile fifth). An inverse scoring was used for red and processed meat, sugar-sweetened beverages and Na. The scores of eight components were added together to calculate the overall DASH diet score. Due to lack of consumption of whole grains in the Iranian diet, we did not include whole grains when calculating the DASH diet score and considered nuts and legumes as two different components. The minimum and maximum scores possible are, respectively, 5 and 40, with higher score indicating higher adherence to the DASH dietary pattern and better diet quality.

The HEI-2015 score measures the degree of adherence to the 2015–2020 US Dietary Guidelines for Americans and ranges from 0 to 100 points[30]. Healthy components that received points for higher consumption included total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy products, total protein, seafood and plant proteins, and ratio of unsaturated fat: saturated fat. Unhealthy components that received points for lower consumption included refined grains, saturated fat, Na and added sugar. We did not include wholegrain intake in the score due to lack of consumption of whole grains in the Iranian diet, and therefore, the minimum and maximum scores possible are, respectively, 0 and 90 (compared with 0 and 100 in the traditional HEI-2015), with higher score indicating higher adherence to 2015–2020 US Dietary Guidelines for Americans and better diet quality.

Statistical analysis

The irregularity score of daily energy intake was categorised into tertiles, and then characteristics of the study participants were reported across tertiles of the score. Demographic characteristics of participants across tertiles of the score were compared using χ^2 for categorical variables and ANOVA for continuous variables. Total and meal-specific energy intake and intake of macronutrients and food groups were expressed as means and standard deviations and compared by using ANOVA. Multiple linear regression analysis was used to investigate the association of DASH diet score, HEI-2015 and intake of different food groups (g/d) with irregularity score (treated as a continuous variable) controlling for age, sex, BMI, physical activity, smoking status, educational level and occupation as covariates. Potential covariates included in the model were selected based on the literature search and their hypothetical relation with independent (irregularity score) and dependent (food group intakes) variables. All analyses were carried out by using SPSS software (SPSS Inc., version 22), and $P < 0{\cdot}05$ was defined significant.

Results

Characteristics of the participants

This cross-sectional study included 850 adults, including 584 women and 266 men aged 20–59 years, with a mean age of 44·7 (SD 10·8) years and a mean BMI of 27·9 (SD 5·6) kg/m^2. The irregularity score ranged from 0·55 to 133·3 (22·4 (SD 19·0)). The mean irregularity score of participants was 21·4 (SD 1·0) in men and 22·8 (SD 0·8) in women ($P = 0{\cdot}3$). The DASH diet score and the HEI-2015 ranged from 12 to 37 (24·0 (SD 3·8)) and 24 to 79 (54·0 (SD 9·0)), respectively.

Characteristics of participants across tertile of irregularity score of daily energy intake are presented in Table 1. Participants in the third tertile of irregularity score were at younger age and had lower levels of leisure-time physical activity. The educational level was higher in participants whose values of irregularity score were higher (Table 1).

Energy intake

Table 2 shows the values of total and meal-specific energy intake across tertiles of irregularity score. Participants in the top tertile of irregularity score consumed less daily energy intake. The absolute intake of carbohydrates and proteins and the proportion of daily energy intake obtained from carbohydrates and proteins did not differ significantly across tertiles. However, there was a significant decrease in fat intake along with the increase in irregularity score ($P = 0{\cdot}008$).

Intakes of food groups and diet quality

The intake of different food groups across tertiles of irregularity score of daily energy intake is presented in Table 3. There was a significant decrease in the consumption of fruit, vegetables, legumes, poultry, liquid oil and DASH diet score and HEI-2015 along with increase in the score of irregularity in daily energy intake. In contrast, participants in the third tertile of irregularity score consumed more processed meat, soft drinks and nuts.

The association of irregularity score with the intake of different foods and food groups and DASH diet score and HEI-2015

Table 1. Descriptive characteristics of participants across tertile of irregularity score of daily energy intake
(Mean values and standard deviations; percentages)

Daily irregularity score...	T1 (0·55–12·34), *n* 282		T2 (12·35–23·82), *n* 284		T3 (23·88–133·33), *n* 284		$P_{for\ trend}$*
	Mean	SD	Mean	SD	Mean	SD	
Age (years)	46·1	10·5	44·5	10·4	43·7	11·2	0·026
Sex (% female)	69·5		65·7		70·7		0·41
Socio-economic status (% no job)	3·2		2·5		3·5		0·76
Smoking status (% current)	5·3		6·7		3·5		0·23
Physical activity level (% low)	48·9		69·3		72·1		<0·001
Educational status (% diploma and educated)	61		62·6		71·7		0·04
BMI (kg/m^2)	27·9	4·8	28·1	6·7	27·5	5·1	0·97
Waist circumference (cm)	92·7	12·6	92·2	12·8	91·4	12·0	0·48
Hip circumference (cm)	104·3	11·4	103·7	10·7	104·1	10·7	0·60
Systolic blood pressure (mmHg)	121·7	26·1	118·6	19·0	118·8	21·3	0·25
Diastolic blood pressure (mmHg)	79·0	14·9	78·1	12·2	77·9	14·4	0·15

* Obtained from ANOVA for continuous variables or χ^2 test for categorical variables. *P* value is considered significant at <0·05.

Table 2. Dietary intake of energy and macronutrients across tertile of irregularity score of daily energy intake
(Mean values and standard deviations)

Daily irregularity score...	T1 (0·55–12·34), *n* 282		T2 (12·35–23·82), *n* 284		T3 (23·88–133·33), *n* 284		$P_{for\ trend}$*
	Mean	SD	Mean	SD	Mean	SD	
Total energy intake (kcal/d)†	1724·1	319·3	1724·3	339·4	1579·4	448·9	<0·001
Energy intake during mealtime slots							
Breakfast (kcal/d)†	420·8	122·4	451·0	154·9	401·6	172·1	0·001
Breakfast (% energy per d)	24·6	6·4	26·3	7·2	25·3	8·9	0·03
Lunch (kcal/d)†	569·3	170·9	537·0	152·5	501·2	204·5	<0·001
Lunch (% energy per d)	33·1	7·9	31·4	8·0	31·3	9·8	0·03
Dinner (kcal/d)†	504·4	183·8	514·3	177·0	500·3	220·6	0·68
Dinner (% energy per d)	29·2	9·0	29·8	7·8	31·2	10·6	0·04
Carbohydrate intake (g/d)	251·3	5·2	245·5	5·2	251·4	5·2	0·65
Carbohydrate intake (% of energy per d)	59·8	1·2	58·5	1·2	59·4	1·2	0·74
Fat intake (g/d)	60·9	1·6	53·9	1·6	56·8	1·6	0·008
Fat intake (% energy per d)	31·7	0·6	29·2	0·6	30·1	0·6	0·008
Protein intake (g/d)	57·6	0·7	58·4	0·7	57·7	0·7	0·73
Protein intake (% energy per d)	13·8	0·2	14·0	0·2	13·9	0·2	0·65

* Obtained from ANOVA. *P* value is considered significant at <0·05.
† To convert kcal to kJ, multiply by 4·184.

is presented in Table 4. In the analysis where the irregularity score of daily energy intake was treated as a continuous variable, there was an inverse association between irregularity score and the intake of total grains, fruit, vegetables, green leafy vegetables, legumes, poultry, low-fat dairy products, liquid oil, DASH diet score and HEI-2015, after controlling for age, sex, physical activity, smoking status, educational level, occupation and BMI. There was also significant positive association between irregularity score of daily energy intake and the intake of processed meat, soft drinks and nuts.

There was substantial difference in physical activity levels across tertiles of irregularity score. We therefore performed a subgroup analysis to assess the potential effect modification by physical activity. The subgroup analysis indicated that there was an inverse association between irregularity score and DASH diet score (β-coefficient: −0·04, 95 % CI −0·06, −0·03; $P < 0·001$) and HEI-2015 (β-coefficient: −0·11, 95 % CI −0·15, −0·07; $P < 0·001$) in individuals with low physical activity level ((<600 MET)/h per week, *n* 539). However, the associations became non-significant in participants with moderate physical activity ((600–3000 MET)/h per week, *n* 310), DASH diet score (β-coefficient: −0·02, 95 % CI −0·04, 0·00; $P = 0·07$) and HEI-2015 (β-coefficient: −0·03, 95 % CI −0·08, 0·02; $P = 0·30$).

Discussion

The present cross-sectional study investigated the association of irregularity in daily energy intake with diet quality and food group intake. The results showed that larger day-to-day variation in energy intake, as represented by higher irregularity score of daily energy intake, was associated with a lower DASH diet score and HEI-2015. A higher irregularity score was also accompanied by lower intake of healthy food groups such as fruit, vegetables, legumes, low-fat dairy products and poultry, as well as higher intake of soft drinks and processed meat. The subgroup analysis

Table 3. Energy-adjusted dietary intake of food groups across tertile of irregularity score of daily energy intake
(Mean values and standard deviations)

Daily irregularity score...	T1 (0·55–12·34), *n* 282		T2 (12·35–23·82), *n* 284		T3 (23·88–133·33), *n* 284		
	Mean	SD	Mean	SD	Mean	SD	$P_{\text{for trend}}$*
Healthy Eating Index-2015 (score)	55·4	9·4	54·4	9·1	52·1	8·4	<0·001
DASH diet score (units)	24·6	3·6	24·3	3·8	23·2	3·8	<0·001
Total grains (g/d)	298·7	4·8	301·6	4·8	294·4	4·9	0·59
Fruits (g/d)	111·8	4·2	112·9	4·1	97·5	4·2	0·02
Vegetables (g/d)	144·1	4·4	143·9	4·4	131·3	4·4	0·07
Green leafy vegetables (g/d)	65·9	2·7	66·9	2·7	57·7	2·7	0·03
Nuts (g/d)	3·6	0·6	4·4	0·6	6·7	0·6	<0·001
Red/yellow vegetables (g/d)	43·5	2·1	45·5	2·1	46·5	2·1	0·59
Legumes (g/d)	31·1	1·5	29·6	1·5	24·2	1·7	0·005
Red meat (g/d)	7·6	0·7	9·4	0·7	7·5	0·7	0·13
Processed meat (g/d)	5·3	1·0	5·1	1·0	11·1	1·0	<0·001
Fish (g/d)	3·8	0·7	3·3	0·7	3·6	0·7	0·89
Poultry (g/d)	32·3	1·7	34·8	1·7	28·0	1·7	0·08
Low-fat dairy products (g/d)	123·7	5·5	123·4	5·4	108·7	5·5	0·09
High-fat dairy products (g/d)	15·1	1·9	15·3	1·9	17·7	1·9	0·57
Eggs (g/d)	23·0	1·3	24·1	1·3	23·1	1·3	0·79
Soft drinks (g/d)	17·8	2·6	23·6	2·5	31·4	2·6	0·001
Liquid oil (g/d)	17·5	0·4	16·9	0·4	15·6	0·4	0·006
Solid oil (g/d)	2·8	0·3	3·4	0·3	3·4	0·3	0·25
Salty snacks (g/d)	8·5	0·8	8·2	0·8	9·4	0·8	0·56

DASH, Dietary Approaches to Stop Hypertension.
* Obtained from ANOVA. *P* value is considered significant at <0·05.

Table 4. Associations of irregularity score of daily energy intake with diet quality and food group intakes among Iranian adults (*n* 850)
(*β*-Coefficients and 95 % confidence intervals)

	Irregularity score of daily energy intake†		
Food intakes	*β*	95 % CI	*P**
HEI-2015	−0·08	−0·12, −0·05	<0·001
DASH diet score	−0·04	−0·05, −0·02	<0·001
Total grains (g/d)	−0·48	−0·79, −0·18	0·002
Fruits (g/d)	−0·41	−0·68, −0·14	0·04
Vegetables (g/d)	−0·65	−0·93, −0·37	<0·001
Green leafy vegetables (g/d)	−0·36	−0·53, −0·19	<0·001
Red/yellow vegetables (g/d)	−0·04	−0·18, 0·09	0·53
Legumes (g/d)	−0·25	−0·35, −0·15	<0·001
Nuts (g/d)	0·06	0·04, 0·08	<0·001
Red meat (g/d)	−0·04	−0·08, 0·003	0·06
Processed meat (g/d)	0·14	0·07, 0·20	<0·001
Poultry (g/d)	−0·13	−0·24, −0·02	0·02
Fish (g/d)	0·001	−0·04, 0·05	0·96
Low-fat dairy products (g/d)	−0·59	−0·95, −0·24	0·001
High-fat dairy products (g/d)	0·00	−0·007, 0·006	0·12
Eggs (g/d)	−0·02	−0·10, 0·06	0·62
Soft drinks (g/d)	0·21	0·01, 0·38	0·01
Salty snacks (g/d)	0·01	−0·04, 0·06	0·67
Liquid oil (g/d)	−0·06	−0·09, −0·03	<0·001
Solid oil (g/d)	0·00	−0·01, 0·03	0·36

DASH, Dietary Approaches to Stop Hypertension; HEI, Healthy Eating Index.
* *P* value is considered significant at <0·05.
† Results are from multiple linear regression analyses controlling for age, sex, physical activity, smoking status, BMI, educational status and employment status.

suggested a potential effect modification by physical activity. The associations remained significant in the subgroup with low physical activity, but attenuated substantially (for DASH diet score) or became non-significant (for HEI-2015) in participants with moderate physical activity level. To our knowledge, this study is the first try to investigate the association between daily irregularity in energy intake and diet quality in adults.

The association of irregularity in dietary habits with diet quality and cardiometabolic risk factors has been recently taken into consideration. The 2017 American Heart Association scientific statement suggested that irregular eating patterns such as irregular meal frequency and timing and breakfast skipping may be associated with lower diet quality and an unhealthy cardiometabolic profile[18]. The Sister Study cohort among 46 000 women indicated that having a consistent and regular breakfast consumption pattern, defined as eating breakfast every day or never, was associated with better diet quality, higher energy intake and lower risk of developing obesity as compared with those who had irregular breakfast consumption pattern (3–4 d/week)[32]. Another cross-sectional study on young adults indicated that larger fluctuations in the timing of food intake during the week was significantly associated with a higher BMI[33]. The study proposed that greater variation in the timing of food intake during the week may be associated with internal misalignment.

A large cross-sectional study on 14 000 school-aged children in Iran indicated that skipping main meals, an irregular eating style, was associated with low frequency of fruit and vegetable intake[34]. A report from the National Health and Nutrition Examination Survey (1999–2002) indicated that breakfast skipping was associated by higher percentage energy from added sugar, lower micronutrients intake, lower mean adequacy ratio for nutrient intakes and lower diet quality[35]. A cross-sectional study in Korean adults reported that rare breakfast eaters consumed less rice, potatoes, vegetables, fish, milk and dairy products, fibre, Ca and K as compared with breakfast eaters[36]. Another cross-sectional study on young adults in the USA indicated that a high percentage of breakfast skippers did not meet two-thirds of the RDA[37]. Findings from interventional

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studies also confirmed that more regular eating frequency (regular six occasions/d *v.* variable 3–9 meals/d) may favourably affect lipid profile and insulin resistance[38,39].

There was also evidence that irregular distribution of eating occasions during the day may be associated with diet quality. Two cross-sectional investigations indicated that later temporal eating patterns and higher frequency of eating occasions in the evening hours may be associated with a lower diet quality[13,14]. The 2017 American Heart Association scientific statement suggested that late-night eating may be associated with an unfavourable cardiometabolic profile[18].

However, the association between another aspect of irregularity in dietary intake, as reflected by day-to-day variation in energy intake, and diet quality has not been investigated. To our knowledge, only a recent cross-sectional evaluation within a British cohort study suggested that larger day-to-day variation in daily and meal-specific energy intake may be associated with a higher likelihood of general and abdominal adiposity[20]. Another prospective study within that cohort suggested a positive association between larger day-to-day fluctuation in energy intake, as reflected by higher irregularity score, may be associated with a higher odds of the metabolic syndrome and its components[21]. The present study used variability in daily energy intake as a proxy of irregular eating style and indicated that the observed association between daily irregularity in energy intake and adiposity and the metabolic syndrome may be mediated, in part, by diet quality.

Current evidence suggests that there are common temporal fluctuations in dietary intakes during a week. The results suggest that there is an increase in the consumption of energy, fats and added sugar during weekends as compared with weekdays, with the weekends having lower diet quality[40–42]. However, there is no exact theory to explain how more fluctuations in daily energy intake can be associated with lower diet quality. Participants with more irregular energy intake consumed more soft drinks and processed meat and less fruit, vegetables, low-fat dairy products, poultry and legumes. It is likely that they consumed more fast foods and snacks and thus had an unhealthy diet. Although higher eating frequency is associated with better diet quality, higher snack frequency can be associated with a lower diet quality[7,10,11], especially snacks from desserts and sugar-sweetened beverages[43].

Human behaviours, including eating habits, are structured during weekdays and depend on time spent at work or school[44]. It seems that participants with less variations in daily energy intake have a more structured and distinct daily programme and, as a results, have a more consistent diet. Irregular changes in daily programmes and structures leading to irregular energy intake can unfavourably affect habitual behaviours such as eating habits[42]. For instance, changes in routine daily programmes such as not working in paid employment or having part-time jobs may exert adverse effects on eating habits[44]. This, at least in part, may explain the positive correlation observed between irregular daily energy intake and poor diet quality.

In addition, it has been reported that weekly fluctuations in meal timing may be associated with chronotype. In a cross-sectional study on young adults, a higher variation in meal timing during the week was observed in evening-type subjects[33]. A review study suggested that evening-type individuals, defined as those who prefer to perform activities in the evening hours and sleep and wake up late or those who have an eveningness preference, are most likely to have unhealthy dietary habits[45]. Therefore, the association between greater day-to-day variations in energy intake and lower diet quality observed in the present study can be attributed to chronotype. However, we did not evaluate the individual's chronotype and thus, more research is needed to investigate the potential association of chronotype with daily irregularity in energy intake.

Our results showed that adults with larger variability in energy intake were at younger age, were less physically active and had higher educational level. It is likely that participants with less variation in energy intake had a healthier lifestyle and accordingly, consumed a more regular, consistent and healthy diet.

There is evidence that some sociodemographic factors including physical activity, educational level and participant's age are important determinants of diet quality[46–48]. In the present study, participants with more irregular daily energy intake were at younger age and had lower levels of physical activity and higher education. It is possible that irregular daily energy intake may be a consequence of the aforementioned sociodemographic characteristics and, therefore, the association observed in the present study may be due to chance. However, in the multiple linear regression analyses, we controlled for age, physical activity, education level and occupation status and, therefore, more research is needed to clarify potential mechanisms behind the observed associations. There is some evidence that more irregular daily and meal-specific energy intake may be associated with a higher risk of adiposity[20] and the metabolic syndrome[21]. The present study suggests that this association may be mediated partly by low diet quality resulting from more irregular daily energy intake.

In the present study, we used the DASH diet score and HEI-2015 to evaluate the overall quality of the diet. The mean of DASH diet score in our study (24·1 (SD 4·2)) was similar with that of a cohort study of Tehranian adults (24·0 (SD 3·8))[49]. The range of HEI in our study was 24–79 which was comparable with a cohort study of Iranian adults (17–88)[50]. The DASH diet score was originally developed to reduce blood pressure in patients with high blood pressure[51]. The HEI-2015 measures the degree of adherence to 2015–2020 US Dietary Guidelines for Americans[18]. Among different dietary metrics developed to evaluate the overall quality of the diet, there is convincing evidence that higher adherence to the DASH dietary pattern and HEI-2015 is associated with a lower risk of all-cause mortality and non-communicable chronic disease[52].

This study has several strengths. To the authors' knowledge, this is the first study to evaluate the association of variability in daily energy intake and diet quality. Previous research showed that irregular eating styles such as irregular meal and snack frequency and irregular distribution of eating occasions during the day may be associated with low diet quality. Here, we considered another aspect of irregularity and indicated that more irregular daily energy intake may be associated with a lower diet quality. We recruited a relatively large number of adults with various socio-economic, education and welfare levels. In addition, we used validated tools and trained dietitians to collect data.

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There are also some important limitations that need to be considered. First and most importantly, this study was a cross-sectional evaluation and, thus, the direction of the associations cannot be determined. It is possible that more day-to-day variation in energy intake may be a consequence of lower diet quality instead of being a determinant of diet quality. In addition, in this study, we used 3-d 24-h dietary recalls, including one weekend, to calculate irregularity score of daily energy intake. The original score was developed by using 5-d 24-h dietary recalls. There are some common temporal variations in daily energy intake during the week and, therefore, 5- or 7-d 24-h dietary recalls may better represent daily variations in energy intake. Finally, due to insufficient data, we were unable to compare the values of whole grains across tertiles of irregularity score of daily energy intake. Finally, the majority of the study populations were female (70 %). This highlights the need for more research to confirm the findings across either sex.

Conclusions

Previous research has indicated that irregular eating styles may be associated with lower diet quality and unhealthy cardiometabolic profile. The present study suggested that more day-to-day variations in energy intake may be associated with lower diet quality as assessed by DASH diet score and HEI-2015, lower consumption of healthy food groups such as fruit, vegetables, legumes and low-fat dairy products, and higher consumption of soft drinks and processed meat. More research is needed to confirm the associations observed in the present study and to clarify the potential theory behind these associations. The research also highlights the need for more research to clarify whether irregular daily energy intake is associated cardiometabolic profile.

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S. S.-B. and K. D. J. conceived and designed the study, A. L. and Z. A. performed data acquisition and completed the questionnaires, A. J. and S. S.-B. performed the analyses and wrote the first draft of the manuscript, S. S.-B. and K. D. J. critically revised the manuscript, K. D. J. received financial support for undertaking this study and all authors read and approved the final manuscript. S. S.-B. in the guarantor.

There are no conflicts of interest.

References

1. Wu XY, Zhuang LH, Li W, *et al.* (2019) The influence of diet quality and dietary behavior on health-related quality of life in the general population of children and adolescents: a systematic review and meta-analysis. *Qual Life Res* **28**, 1–27.
2. Milte CM, Thorpe MG, Crawford D, *et al.* (2015) Associations of diet quality with health-related quality of life in older Australian men and women. *Exp Gerontol* **64**, 8–16.
3. Jayedi A, Soltani S, Abdolshahi A, *et al.* (2020) Healthy and unhealthy dietary patterns and the risk of chronic disease: an umbrella review of meta-analyses of prospective cohort studies. *Br J Nutr* **124**, 1133–1144.
4. Afshin A, Sur PJ, Fay KA, *et al.* (2019) Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **393**, 1958–1972.
5. Ekmekcioglu C & Touitou Y (2011) Chronobiological aspects of food intake and metabolism and their relevance on energy balance and weight regulation. *Obes Rev* **12**, 14–25.
6. Johnston JD, Ordovás JM, Scheer FA, *et al.* (2016) Circadian rhythms, metabolism, and chrononutrition in rodents and humans. *Adv Nutr* **7**, 399–406.
7. Leech RM, Livingstone KM, Worsley A, *et al.* (2016) Meal frequency but not snack frequency is associated with micronutrient intakes and overall diet quality in Australian men and women. *J Nutr* **146**, 2027–2034.
8. Lima MTM, Maruyama TC, Custódio IDD, *et al.* (2020) The impact of a higher eating frequency on the diet quality and nutritional status of women with breast cancer undergoing chemotherapy. *Br J Nutr* **123**, 410–418.
9. Murakami K & Livingstone MBE (2016) Associations between meal and snack frequency and diet quality in US adults: National Health and nutrition examination survey 2003–2012. *J Acad Nutr Diet* **116**, 1101–1113.
10. Murakami K & Livingstone MBE (2016) Associations between meal and snack frequency and diet quality and adiposity measures in British adults: findings from the National Diet and Nutrition Survey. *Public Health Nutr* **19**, 1624–1634.
11. Murakami K, Shinozaki N, Livingstone MBE, *et al.* (2020) Meal and snack frequency in relation to diet quality in Japanese adults: a cross-sectional study using different definitions of meals and snacks. *Br J Nutr* **124**, 1219–1228.
12. Leech RM, Worsley A, Timperio A, *et al.* (2015) Understanding meal patterns: definitions, methodology and impact on nutrient intake and diet quality. *Nutr Res Rev* **28**, 1–21.
13. Eicher-Miller HA, Khanna N, Boushey CJ, *et al.* (2016) Temporal dietary patterns derived among the adult participants of the National Health and Nutrition Examination Survey 1999–2004 are associated with diet quality. *J Acad Nutr Diet* **116**, 283–291.
14. Leech RM, Timperio A, Livingstone KM, *et al.* (2017) Temporal eating patterns: associations with nutrient intakes, diet quality, and measures of adiposity. *Am J Clin Nutr* **106**, 1121–1130.
15. Hampl JS, Heaton CL & Taylor CA (2003) Snacking patterns influence energy and nutrient intakes but not body mass index. *J Hum Nutr Diet* **16**, 3–11.
16. Kant AK, Schatzkin A & Ballard-Barbash R (1997) Evening eating and subsequent long-term weight change in a national cohort. *Int J Obes Relat Metab Disord* **21**, 407–412.
17. Reid KJ, Baron KG & Zee PC (2014) Meal timing influences daily caloric intake in healthy adults. *Nutr Res* **34**, 930–935.
18. St-Onge M-P, Ard J, Baskin ML, *et al.* (2017) Meal timing and frequency: implications for cardiovascular disease prevention: a scientific statement from the American Heart Association. *Circulation* **135**, e96–e121.
19. Kant AK & Graubard BI (2015) 40-year trends in meal and snack eating behaviors of American adults. *J Acad Nutr Diet* **115**, 50–63.
20. Pot GK, Hardy R & Stephen AM (2014) Irregular consumption of energy intake in meals is associated with a higher cardiometabolic risk in adults of a British birth cohort. *Int J Obes* **38**, 1518–1524.
21. Pot GK, Hardy R & Stephen AM (2016) Irregularity of energy intake at meals: prospective associations with the metabolic

syndrome in adults of the 1946 British Birth Cohort. *Br J Nutr* **115**, 315–323.
22. Payne G & Payne J (2004) *Key Concepts in Social Research*. London: Sage.
23. Sarantakos S (2012) *Social Research*. Basingstoke: Macmillan International Higher Education.
24. Kiadaliri AA, Jafari M, Mahdavi M-RV, *et al.* (2015) The prevalence of adulthood overweight and obesity in Tehran: findings from Urban HEART-2 study. *Med J Islamic Repub Iran* **29**, 178.
25. Ghaffarpour M, Houshiar-Rad A & Kianfar H (1999) The manual for household measures, cooking yields factors and edible
portion of foods. *Tehran: Nashre Olume Keshavarzy* **7**, 213.
26. Willett WC, Howe GR & Kushi LH (1997) Adjustment for total energy intake in epidemiologic studies. *Am J Clin Nutr* **65**, 1220S–1228S.
27. Lohman TG, Roche AF & Martorell R (1988) *Anthropometric Standardization Reference Manual*. Champaign, IL: Human Kinetics Books.
28. Craig CL, Marshall AL, Sjöström M, *et al.* (2003) International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exercise* **35**, 1381–1395.
29. Ainsworth BE, Haskell WL, Herrmann SD, *et al.* (2011) 2011 Compendium of physical activities: a second update of codes and MET values. *Med Sci Sports Exercise* **43**, 1575–1581.
30. Krebs-Smith SM, Pannucci TE, Subar AF, *et al.* (2018) Update of the healthy eating index: HEI-2015. *J Acad Nutr Diet* **118**, 1591–1602.
31. Fung TT, Chiuve SE, McCullough ML, *et al.* (2008) Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. *Arch Intern Med* **168**, 713–720.
32. Guinter MA, Park Y-M, Steck SE, *et al.* (2020) Day-to-day regularity in breakfast consumption is associated with weight status in a prospective cohort of women. *Int J Obes (Lond)* **44**, 186–194.
33. Zerón-Rugerio MF, Hernáez Á, Porras-Loaiza AP, *et al.* (2019) Eating jet lag: a marker of the variability in meal timing and its association with body mass index. *Nutrients* **11**, 2980.
34. Pourrostami K, Heshmat R, Hemati Z, *et al.* (2020) Association of fruit and vegetable intake with meal skipping in children and adolescents: the CASPIAN-V study. *Eat Weight Disord* **25**, 903–910.
35. Deshmukh-Taskar PR, Radcliffe JD, Liu Y, *et al.* (2010) Do breakfast skipping and breakfast type affect energy intake, nutrient intake, nutrient adequacy, and diet quality in young adults? NHANES 1999–2002. *J Am Coll Nutr* **29**, 407–418.
36. Min C, Noh H, Kang Y-S, *et al.* (2011) Skipping breakfast is associated with diet quality and metabolic syndrome risk factors of adults. *Nutr Res Pract* **5**, 455–463.
37. Nicklas TA, Myers L, Reger C, *et al.* (1998) Impact of breakfast consumption on nutritional adequacy of the diets of young adults in Bogalusa, Louisiana: ethnic and gender contrasts. *J Am Diet Assoc* **98**, 1432–1438.
38. Farshchi H, Taylor M & Macdonald I (2004) Regular meal frequency creates more appropriate insulin sensitivity and lipid profiles compared with irregular meal frequency in healthy lean women. *Eur J Clin Nutr* **58**, 1071–1077.
39. Farshchi HR, Taylor MA & Macdonald IA (2005) Beneficial metabolic effects of regular meal frequency on dietary thermogenesis, insulin sensitivity, and fasting lipid profiles in healthy obese women. *Am J Clin Nutr* **81**, 16–24.
40. An R (2016) Weekend-weekday differences in diet among US adults, 2003–2012. *Ann Epidemiol* **26**, 57–65.
41. Monteiro LS, Hassan BK, Estima CCP, *et al.* (2017) Food consumption according to the days of the week–National Food Survey, 2008–2009. *Revista Saude Publica* **51**, 93.
42. Nordman M, Matthiessen J, Biltoft-Jensen A, *et al.* (2020) Weekly variation in diet and physical activity among 4–75-year-old Danes. *Public Health Nutr* **23**, 1350–1361.
43. Barnes TL, French SA, Harnack LJ, *et al.* (2015) Snacking behaviors, diet quality, and body mass index in a community sample of working adults. *J Acad Nutr Diet* **115**, 1117–1123.
44. McCarthy S (2014) Weekly patterns, diet quality and energy balance. *Physiol Behav* **134**, 55–59.
45. Mazri FH, Manaf ZA, Shahar S, *et al.* (2020) The association between chronotype and dietary pattern among adults: a scoping review. *Int J Environ Res Public Health* **17**, 68.
46. de Mello AV, Pereira JL, Leme ACB, *et al.* (2020) Social determinants, lifestyle and diet quality: a population-based study from the 2015 Health Survey of São Paulo, Brazil. *Public Health Nutr* **23**, 1766–1777.
47. Grech A, Rangan A & Allman-Farinelli M (2017) Social determinants and poor diet quality of energy-dense diets of Australian young adults. *Healthcare* **5**, 70.
48. Pestoni G, Krieger J-P, Sych JM, *et al.* (2019) Cultural differences in diet and determinants of diet quality in Switzerland: results from the National Nutrition Survey MenuCH. *Nutrients* **11**, 126.
49. Farhadnejad H, Asghari G, Mirmiran P, *et al.* (2017) Association of Dietary Approach to Stop Hypertension (DASH) diet with 3-year changes in body mass index and risk of obesity in adolescents: Tehran Lipid and Glucose Study. *Iran J Endocrinol Metab* **18**, 325–333.
50. Ghazizadeh H, Yaghooti-Khorasani M, Darroudi S, *et al.* (2020) Evaluation of the association between the healthy eating index and the level of serum and dietary intake of copper and zinc. *Obes Med* **19**, 100277.
51. Sacks FM, Obarzanek E, Windhauser MM, *et al.* (1995) Rationale and design of the Dietary Approaches to Stop Hypertension trial (DASH): a multicenter controlled-feeding study of dietary patterns to lower blood pressure. *Ann Epidemiol* **5**, 108–118.
52. Miller V, Webb P, Micha R, *et al.* (2020) Defining diet quality: a synthesis of dietary quality metrics and their validity for the double burden of malnutrition. *Lancet Planet Health* **4**, e352–e370.