*British Journal of Nutrition* (2023), 129, 1443–1450 doi:10.1017/S0007114521005079


# Association of nightly fasting duration, meal timing and frequency with the metabolic syndrome among Iranian adults

Sheida Zeraattalab-Motlagh[1], Azadeh Lesani[1], Nasim Janbozorgi[1], Kurosh Djafarian[2], Maryam Majdi[1] and Sakineh Shab-Bidar[1]*

[1]*Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences (TUMS), Tehran, Iran*

[2]*Department of Clinical Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences (TUMS), Tehran, Iran*

*(Submitted 4 August 2021 – Final revision received 6 December 2021 – Accepted 14 December 2021 – First published online 12 April 2022)*

## Abstract

Accumulative evidence indicates that meal timing is associated with cardiometabolic risks by deteriorating circadian rhythms. However, evidence is unclear. This cross-sectional study aimed to investigate the relation between nightly fasting duration, meal timing and frequency and metabolic syndrome (MetS) among Iranian adults. Eight hundred fifty adults were recruited in this study. Dietary data were collected by 24-h dietary recalls. Time-related eating patterns were determined as nightly fasting duration, occasions of eating, time and energy proportion of first and last meal and meal frequency on a day. The MetS was recognised on the basis of the National Cholesterol Education Program Adult Treatment Panel III criteria. A binary logistic regression was applied to examine the relation between meal timing and MetS. A significant inverse relation between habitual nightly fasting duration with MetS (OR = 0·74, 95 % CI 0·55, 0·99, $P$ = 0·04) and 'increased TAG' (OR = 0·73, 95 % CI 0·55, 0·98, $P$ = 0·03) was found after confounder adjustment. Also, habitual first and last meal energy had no significant connection with MetS. However, the odds of 'increased fasting blood glucose' were lower in subjects who consumed ≥25% of habitual energy intake in the last meal (OR = 0·60, 95 % CI 0·42, 0·85, $P$ = 0·005). Having longer nightly fasting duration may be useful for decreasing the risk of both MetS and 'elevated TAG'. These findings introduce a new insight that time-related eating patterns, instead of nightly fasting duration alone, might be related to cardiometabolic risks in Iranian adults.

**Key words: Circadian rhythms: The MetS: Meal timing: Eating pattern: Frequency**

The metabolic syndrome (MetS) is specified by clustering of cardiometabolic events, such as hyperglycaemia/insulin resistance, abdominal obesity and dyslipidaemia[1,2]. Globally, the prevalence of the MetS is indicated between 14 and 32 % in men and women, and this trend will be increasing with expanded life expectancy[3]. Estimations indicated that one-third of Iranians over the age of 20 years suffered from the MetS between 2000 and 2016[4], which is much greater than the incidence in other countries like Japan (5·3 %)[5] and the USA (22·9 %)[6]. Also, individuals with the MetS are at twice the risk of developing cardiovascular events during the coming 5–10 years than those without. Moreover, the MetS confers a five times increase in the incidence of type 2 diabetes[1,7]. Furthermore, a growing body of evidence indicated fasting and eating patterns (involving nightly fasting duration, meal timing and frequency) affect cardiometabolic health[8,9].

Human metabolism is highly regulated by internal body clocks (circadian rhythms), which are nearly 24 h long[10]. Hence, proper functioning of internal body clocks is important for keeping metabolic health[11]. Consuming meals irregularly, defined as consuming food in different amounts during the day and at different times from one day to another, could affect the circadian rhythms, which is unfavourably linked with cardiometabolic disease risk, such as the MetS or type 2 diabetes[12].

In addition, numerous studies demonstrated that meal timing[13–15] and nightly fasting duration (24 h minus mealtime interval between the first and last meal for each day)[16] significantly affect weight gain and obesity. Also, higher meal frequency is positively linked with improving body composition, including increased fat-free mass, as well as decreased fat mass and body fat percentage, which is suggested to be related to cardiometabolic health[17]. Marinac *et al.* in a study of 2212 women in the USA indicated that a longer nightly fasting

**Abbreviations** BP, blood pressure; FBG, fasting blood glucose; MetS, metabolic syndrome; WC, waist circumference.

* **Corresponding author:** Sakineh Shab-Bidar, email s_shabbidar@tums.ac.ir

duration was related to lower HbA1c and cardiometabolic factors[18]. However, a study in 1054 non-shift workers in Japan showed that there was no consistent connection between nightly fasting duration and the MetS[19]. A study in 116 US women, aged 20–64 years, showed that earlier meal timing and more frequent eating could lead to lower cardiometabolic events. Additionally, adverse effects were seen in individuals with longer nightly fasting duration[16]. Another study in 14 279 Korean adults showed an inverse association between eating frequency and the MetS components in men subjects only[20]. Due to cultural differences related to time-related eating patterns and a great incidence of the MetS in Iran and a limited number of inconclusive studies, we sought to explore the relationship between nightly fasting duration, meal timing and frequency with the MetS in Iranian adults.

## Methods

### Design and study population

Subjects for this cross-sectional study were adults selected from health houses in Tehran, Iran. Eight hundred fifty adults aged 20–59 years were selected by the two-stage cluster sampling method, from five districts of the Tehran province, including North, South, West and East, and the urban core. The subjects were randomly chosen from five districts (forty health houses), and then the number of subjects in each centre was obtained in the following manner: total sample size (850)/the number of health houses (40). Eligible criteria was 20–59 years, willing to participate, with no specific health issues, living in Tehran and be a member of health houses. Those who had cancer, chronic kidney and liver disease, rheumatoid arthritis, Parkinson's and any other chronic health issues, and pregnant or lactating people and those with under- or over-reporting food intake (< 191·20 KJ/d or > 1003·82 KJ/d) were excluded[21,22]. Finally, 850 participants (266 men and 584 women) were added to the analysis.

The study protocol was confirmed by the Medical Ethics Committee of the Tehran University of Medical Sciences, Tehran, Iran (Ethic number: IR.TUMS.MEDICINE.REC.1399.797). The written informed agreement was acquired by all individuals who involved in this study.

### Demographic data

Participant's age, sex (men/women), education (illiterate, under diploma, diploma and educated) and occupation (employed, housekeeper, retired and unemployed) status, marital status (single/married/divorced), smoking status (non-smoker/smoker), having CVD (yes/no), menopause (yes/no) and diabetes (yes/no) were completed using a standard questionnaire.

### Physical activity

Physical activity was evaluated by applying the International Physical Activity Questionnaire[23]. Individuals were categorised into three groups, comprising very low (< 600 metabolic equivalent-min/week), low (600–3000 metabolic equivalent-m/week) and moderate and high (> 3000 metabolic equivalent-min/week), assessed on the basis of metabolic equivalents[24].

### Anthropometric measures and blood pressure

Before the assessment, all the anthropometric instruments were calibrated. Weight was assessed with an accuracy of 0·1 kg and minimal clothing without shoes, applying a digital scale (Seca 808). Height was assessed with a precision of 0·1 cm, in the stand-up state, unshod, applying a stadiometer (Seca 206). BMI was assessed as weight (kg)/height$^2$ (m$^2$). Waist circumference (WC) was assessed in the middle of lower rib and iliac crest, with light clothing, applying a tape meter (Seca 201)[25]. All the anthropometric measures were carried out two times and the average of them was reported.

Blood pressure (BP) was measured twice, applying a digital sphygmomanometer (BC 08, Beurer), in a sitting position after 10–15 min of rest. The average of its measurement was recorded.

### Laboratory investigation

All subjects were given 10 ml of fasting blood between 07.00 and 10.00 hours. Accordingly, acid-washed test tubes (with no anticoagulants) were used for collecting blood samples. Then, after clot formation by storing the blood samples for 30 min at room temperature, samples of blood were centrifuged for about 20 min. For future testing, we stored serums at −80°C. The enzymatic (glucose oxidase) colorimetric approach applying a commercial kit (Pars Azmun) was adopted for measuring fasting blood glucose (FBG). In addition, cholesterol oxidase phenol aminoantipyrine and glycerol-3 phosphate oxidase phenol aminoantipyrine enzymatic approaches were applied to assess serum total cholesterol and HDL-cholesterol, and TAG, respectively.

### Dietary assessment

Dietary data were collected by a trained dietitian using three non-consecutive days (two weekdays and one weekend day) 24-h dietary recalls. The initial 24-h recall is collected via interviews, and another two recalls are documented by using the telephone during this study. Food and food groups were also extracted from these questionnaires[26]. Then, an individual's nutrients intake was analysed by Nutritionist IV software.

### Meal timing

Frequency of eating was evaluated as the eating occasions number reported each day, explained as food or beverage consumption of 1 kcal or more (to remove water drinking and yet recognise all other time-related eating patterns) at a single point in time[27]. First and last meal eating times (time and energy proportion) reported each day, explained as consuming 25 kcal or more[28,29]. Nightly fasting duration was calculated as 24 h minus mealtime interval between the first and last meal for each day[18,28], the average nightly fasting duration across 3 d was computed and the first eating occasion defined as eating occurred from 05.00 hour, since no eating was recorded from 12.00 to 05.00 hours. The first meal was described as the first eating occasion after waking and the last meal was described as the last eating occasion prior to sleep[30]. Late night eating was regarded as eating after 21.00 hour. We classified individuals into non-late night eaters if they ate less than 25 % of total energy intake > 21.00 hour and late night eaters if they ate at least 25 % of their total energy intake > 21.00 hour, according to the night eating syndrome definition[31]. Early morning eating was regarded as eating from 05.00 to 09.00 hours. By applying the estimated value of the top quartile for a percentage of energy intake in the morning (25 %), we classified individuals as non-early morning eaters if they ate less than 25 % of their total energy intake from 05.00 to 09.00 hours and early morning eaters if they ate at least 25 % of their total energy content intake from 05.00 to 09.00 hours[20].

### Definition of the metabolic syndrome

On the basis of National Cholesterol Education Program Adult Treatment Panel III criteria[32], without considering WC[33], the MetS was diagnosed in individuals who had at least three of the following medical conditions: (1) WC ( ≥ 99·5 cm in men and ≥ 94·25 cm in women); (2) decreased HDL-cholesterol (< 40 mg/dl in men and < 50 mg/dl in women); (3) increased BP (systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg); (4) high levels of TAG (≥ 150 mg/dl) and (5) increased FBG (≥ 100 mg/dl)[1].

### Statistical analysis

Data on daily time-related eating patterns are provided as the averages from three dietary recalls for each participant. Generally, for all applicable variables, the averages are referred to as 'habitual'. Moreover, each of the time-related eating patterns (time and energy proportion of first and last meal, meal frequency and nightly fasting duration) was treated in a separate model. Therefore, for each meal time variable, we considered the following confounders: age, energy intake, marital status, smoking, education, occupation, BMI (not including abdominal obesity) and physical activity. Moreover, in the model of energy intake throughout each time interval, the habitual early/late first meal (with the 09.00 hour cut-off and only for the habitual first meal), habitual early/late last meal (with the 21.00 hour cut-off and only for the habitual last meal) and habitual eating occasions were additionally confounder adjusted.

General characteristics of subjects in accordance with sex were evaluated by independent sample *t* test and $\chi^2$ test for continuous and categorical variables, respectively. Binary logistic regression was conducted to obtain OR and 95 % CI for the MetS and its elements in accordance with habitual mealtime eating, frequency and nightly fasting duration. We determined confounders from the previous study[20], without considering nightly fasting duration because last and first meal energy intake might be affected by the time of the last and first meal. Therefore, instead of adjusting for nightly fasting duration, we adjusted for early/late first meal (with the 09.00 hour cut-off) for the first meal analyses and for early/late last meal (with the 21.00 hour cut-off) for the last meal analyses to obtain more accurate results. Moreover, these confounders identified a correlation with the MetS and its components[34–40].

We performed binary logistic regression in adjusted models for age, energy intake, marital status, smoking, education, occupation, BMI (not including abdominal obesity) and physical activity. Besides, in the model of energy intake throughout each time interval, the habitual early/late first meal (with the 09.00 hour cut-off and only for the habitual first meal), habitual early/late last meal (with the 21.00 hour cut-off and only for the habitual last meal) and habitual eating occasions were additionally adjusted. Habitual meal frequency was classified into two groups based on a median split (< 4 *v.* ≥ 4 times/d). Habitual nightly fasting duration was also classified into two groups based on the median split (< 11·25 *v.* ≥ 11·25 h). In this analysis, habitual eating occasions < 4 times/d, habitual nightly fasting duration < 11·25 h, habitual first meal and last meal energy < 25 % of total energy, habitual early first meal eating from 05.00 to 09.00 hours and habitual early last meal eating from 17.00 to 21.00 hours were considered as the reference groups. A *P*-value < 0·05 was considered statistical significance. We applied SPSS version 26 (IBM) for all analyses.

## Results

The general characteristics of the study population, containing habitual meal timing, frequency and nightly fasting duration, are indicated in Table 1. The average and standard deviation age was 44·2 (SD 9·87) years in men and 44·5 (SD 11·0) years in women. The women were more likely to be employed (51·4% *v.* 48·6%) and be married (65·6% *v.* 34·4%) and were less likely to be a smoker (25·0% *v.* 75·0%) and have high WC (90·5 (SD 12·3) *v.* 95·3 (SD 12·0) cm) than men. Moreover, the women were more likely to have CVD (85·1% *v.* 14·9%) and the MetS (76·1% *v.* 23·9%) than men. Women consumed a higher total energy intake than men (*P* < 0·001). Moreover, the average habitual eating occasions per day were 4·13 (SD 0·81) and were greater in women than in men (*P* = 0·001). The mean habitual energy intake of first and last meals was 19·3 (SD 10·0) % and 23·3 (SD 11·5) %, respectively, and was greater in women than in men (all *P* < 0·001). The average habitual nightly fasting duration was 11·2 (SD 0·57) h and was greater in men compared with women, although this result was not significant. Of 850 participants, 310 individuals met our criteria for diagnosing the MetS (36·5%).

The results of binary logistic regression indicating the OR and 95% CI for the MetS based on habitual nightly fasting duration, meal timing and frequency are indicated in Table 2. We found that longer habitual fasting duration was associated with lower prevalence of both the MetS (adjusted OR = 0·74, 95 % CI 0·55, 0·99, *P* = 0·04) and 'increased TAG' (adjusted OR = 0·73, 95 % CI 0·55, 0·98, *P* = 0·03). However, no consistent relations between the habitual eating occasions and habitual meal timing and the MetS and its elements were found after adjusting for age, energy intake, marital status, smoking, education, occupation, BMI (not including abdominal obesity) and physical activity (all *P* > 0·05). Re-analysing data by sex demonstrated that the longer habitual nightly fasting duration was associated with lower prevalence of both the MetS (adjusted OR = 0·50, 95 % CI 0·28, 0·88, *P* = 0·02) and 'increased BP' only in men (adjusted OR = 0·43, 95 % CI 0·22, 0·87, *P* = 0·02) (online Supplementary Table S1).

British Journal of Nutrition

**Table 1.** General characteristics of the study population (Mean values and standard deviations; numbers and percentages)

| | Total (*n* 850) | | Men (*n* 266) | | Women (*n* 584) | | |
|---|---|---|---|---|---|---|---|
| Variables | *n* | % | *n* | % | *n* | % | *P** |
| Age (years) | | | | | | | |
| Mean | 44·7 | | 45·2 | | 44·5 | | 0·34 |
| SD | 10·6 | | 9·87 | | 11·0 | | |
| BMI (kg/m²) | | | | | | | |
| Mean | 27·7 | | 27·6 | | 27·8 | | 0·57 |
| SD | 4·69 | | 4·14 | | 4·92 | | |
| WC (cm) | | | | | | | |
| Mean | 92·0 | | 95·3 | | 90·5 | | < 0·001 |
| SD | 12·4 | | 12·0 | | 12·3 | | |
| Educated | 292 | 34·4 | 101 | 34·6 | 191 | 65·4 | 0·05 |
| Employed | 220 | 25·9 | 107 | 48·6 | 113 | 51·4 | <0·001 |
| Married | 688 | 80·9 | 237 | 34·4 | 451 | 65·6 | 0·01 |
| Smoker | 44 | 5·2 | 33 | 75·0 | 11 | 25·0 | <0·001 |
| Physical activity | | | | | | | 0·17 |
| Low | 539 | 63·4 | 162 | 30·1 | 377 | 69·9 | |
| Moderate | 311 | 36·6 | 104 | 33·4 | 207 | 66·6 | |
| | Mean | SD | Mean | SD | Mean | SD | |
| SBP (mmHg) | 119 | 22·3 | 121 | 22·6 | 118 | 22·1 | 0·16 |
| DBP (mmHg) | 78·3 | 13·8 | 79·0 | 14·2 | 87·0 | 13·7 | 0·30 |
| HDL (mg/dl) | 49·8 | 10·2 | 49·2 | 10·0 | 50·1 | 10·2 | 0·24 |
| TAG (mg/dl) | 145 | 79·4 | 140 | 76·8 | 144 | 80·5 | 0·47 |
| FBG (ng/ml) | 108 | 42·7 | 110 | 57·9 | 107 | 33·5 | 0·28 |
| Total energy intake (kcal/d) | 2407 | 883 | 2629 | 887 | 2306 | 864 | <0·001 |
| Habitual eating occasions (times/d) | 4·13 | 0·81 | 3·40 | 0·88 | 4·20 | 0·78 | 0·001 |
| Habitual nightly fasting duration (h) | 11·2 | 0·57 | 11·3 | 0·52 | 11·2 | 0·59 | 0·53 |
| Habitual first meal eating (h:min) | 8:05 | 0:44 | 8:08 | 0:44 | 8:04 | 0:44 | 0·28 |
| Habitual first meal energy (% of total energy) | 19·3 | 10·0 | 16·0 | 8·09 | 20·7 | 10·4 | <0·001 |
| Habitual last meal eating (h:min) | 20:42 | 0:34 | 20:44 | 0:34 | 20:42 | 0:34 | 0·28 |
| Habitual last meal energy (% of total energy) | 23·3 | 11·5 | 20·5 | 9·73 | 24·5 | 12·0 | <0·001 |
| | *n* | % | *n* | % | *n* | % | |
| CVD | | | | | | | 0·007 |
| Yes | 47 | 5·5 | 7 | 14·9 | 40 | 85·1 | |
| No | 803 | 94·5 | 259 | 32·3 | 544 | 67·7 | |
| Diabetes | | | | | | | 0·14 |
| Yes | 72 | 8·5 | 27 | 37·5 | 45 | 62·5 | |
| No | 777 | 91·4 | 238 | 30·6 | 539 | 69·4 | |
| Menopause status | | | | | | | 0·16 |
| Yes | 355 | 41·8 | – | | 251 | 100 | |
| No | 495 | 58·2 | – | | 333 | 100 | |
| MetS | | | | | | | <0·001 |
| Yes | 310 | 36·5 | 74 | 23·9 | 236 | 76·1 | |
| No | 540 | 63·5 | 192 | 35·6 | 348 | 64·4 | |

DBP, diastolic blood pressure; FBG, fasting blood glucose; MetS, metabolic syndrome; SBP, systolic blood pressure WC, waist circumference.
* Calculated by $\chi^2$ and independent sample *t* test for qualitative and quantitative variables, respectively, and *P*-value < 0·05 indicates significant level.

The results of binary logistic regression indicating the OR and 95 % CIs for the MetS based on habitual energy intake in the first and last meal are shown in Table 3. No consistent relations between habitual first and last meal energy intake and the MetS and its components were found after controlling for age, energy intake, marital status, smoking, education, occupation, BMI (except for abdominal obesity), early/late habitual first meal (with the 09.00 hour cut-off and only for the habitual first meal), early/late habitual last meal (with the 21.00 hour cut-off and only for the habitual last meal), habitual eating occasions and physical activity (all $P > 0·05$). However, the odds of 'increased FBG' were lower in subjects who consumed ≥ 25% of habitual energy intake in the last meal (adjusted OR = 0·60, 95 % CI 0·42, 0·85, $P = 0·005$). Re-analysing data by sex did not modify our findings. However, women who consumed ≥ 25% of habitual energy intake in the last meal had lower odds of 'increased FBG' (adjusted OR = 0·56, 95 % CI 0·36, 0·86, $P = 0·009$) (online Supplementary Table S2).

## Discussion

In this cross-sectional study of 850 Iranian adults, longer habitual nightly fasting duration was related to lower prevalence of both the MetS and 'elevated TAG', but this association was not significant for other mealtime eating, that is, habitual meal timing and frequency were not related to the MetS and its components (including abdominal obesity, decreased HDL-cholesterol and increased BP, TAG and FBG). Furthermore, men with a longer habitual nightly fasting duration (≥ 11·25 h) indicated a lower chance of both the MetS and having high BP. Moreover, no significant association was seen between habitual first and last


https://doi.org/10.1017/S0007114521005079 Published online by Cambridge University Press

**Table 2.** The metabolic syndrome based on habitual* nightly fasting duration, meal timing and frequency (Odds ratios and 95 % confidence intervals)†

| | MetS | | Abdominal obesity | | Increased blood pressure | | Decreased HDL-cholesterol | | Increased TAG | | Increased FBG | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variables | Odds ratio | 95 % CI | Odds ratio | 95 % CI | Odds ratio | 95 % CI | Odds ratio | 95 % CI | Odds ratio | 95 % CI | Odds ratio | 95 % CI |
| Habitual eating occasions (times/d)‡ | | | | | | | | | | | | |
| < 4 (*n* 463) | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | |
| ≥ 4 (*n* 387) | 0·91 | 0·66, 1·23 | 0·88 | 0·62, 1·25 | 0·82 | 0·54, 1·26 | 1·00 | 0·74, 1·35 | 0·82 | 0·60, 1·10 | 0·97 | 0·72, 1·32 |
| Habitual nightly fasting duration (h)‡ | | | | | | | | | | | | |
| < 11·25 (*n* 416) | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | |
| ≥ 11·25 (*n* 434) | 0·74 | 0·55, 0·99§ | 0·86 | 0·62, 1·20 | 0·87 | 0·59, 1·29 | 0·99 | 0·75, 1·31 | 0·73 | 0·55, 0·98§ | 0·85 | 0·64, 1·12 |
| Habitual first meal eating‡ | | | | | | | | | | | | |
| < 09.00 (*n* 733) | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | |
| > 09.00 (*n* 117) | 0·93 | 0·61, 1·42 | 1·19 | 0·71, 2·01 | 0·89 | 0·50, 1·59 | 1·27 | 0·86, 1·90 | 0·70 | 0·45, 1·07 | 1·06 | 0·70, 1·59 |
| Habitual last meal eating‡ | | | | | | | | | | | | |
| < 21.00 (*n* 547) | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | |
| > 21.00 (*n* 303) | 1·15 | 0·85, 1·55 | 1·26 | 0·86, 1·83 | 1·36 | 0·91, 2·03 | 1·14 | 0·85, 1·52 | 1·13 | 0·84, 1·51 | 0·84 | 0·63, 1·13 |

FBG, fasting blood glucose; MetS, metabolic syndrome.
* This means that the exposure was averaged over all recalls.
† Calculated by logistic regression.
‡ Adjusted for age, energy intake, marital status, smoking, education, occupation, BMI (except for abdominal obesity) and physical activity.
§ *P*-value < 0·05 indicates significant level.

meal energy and the MetS. However, individuals who consumed ≥ 25 % of habitual energy intake in the last meal had a lower prevalence of 'increased FBG'. This effect was seen in the stratified analyses to be driven by women.

Our findings were in line with previous studies in rodent models[8] and US adults[41,42], in which they indicated that more prolonged nightly fasting duration had preventive impacts towards cardiometabolic events. The findings from observational studies in Asian adults have shown results conflicting with those carried out in the USA, where Asian adults are quite under-represented[19,20]. Ueda *et al.*, in a survey of 1054 Japanese non-shift employees, indicated no consistent connection between nightly fasting duration and the MetS[19]. However, a more prolonged nightly fasting duration (16 h compared with 10–12 h) might have adverse effects on cardiometabolic events in the Korean NHANES (average age: 41 years)[20].

This discrepancy with previous studies might be due to different study populations, in which overnight fasting-related metabolic events may differ across racial and ethnic groups. Another reason for this discrepancy among studies might be due to differences in nightly fasting duration classification and definition. For example, our study defined nightly fasting duration based on the duration between the first and last meal, whereas another study defined nightly fasting duration based on the duration between breakfast and dinner[19]. Moreover, we classified habitual nightly fasting duration into two groups based on the median split (< 11·25 *v.* ≥ 11·25 h), whereas other studies classified nightly fasting duration into four groups (≤ 9, 10, 11 or ≥ 12 h)[19] and five groups (< 8, 8–10, 10–12, 12–16 or ≥ 16 h)[20].

In this study, habitual longer nightly fasting duration was related to lower prevalence of both the MetS and 'increased BP' in men. We could not totally explain why these significant relations were seen in men but not in women. However, men had lower habitual energy intake in the last meal than women, which might be related to other lifestyle behaviours, including low employment rate and marriage. These differences, together with endocrine factors, might impact cardiometabolic events[43]. In line with our findings, Sutton *et al.* indicated that 5 weeks early time-restricted feeding (6 h feeding period compared with 12 h feeding period) could significantly lower systolic blood pressure and diastolic blood pressure in men[42], which might be explained by reducing insulin level and promoting natriuresis through altering salt intake to early time as Na excretion is up-regulated by internal body clock[44].

We also indicated no significant relationships between habitual eating occasions and the MetS and its components. This was contrary to previous studies, which demonstrated that higher eating occasions were linked with a lower incidence of metabolic abnormalities among Korean men[20]. The findings of cross-sectional studies demonstrated that more eating occasions were related to a lower chance of having 'increased BP', obesity and abdominal obesity in US and European adults[45,46]. However, Murakami and Livingstone reported apposite findings in which a greater eating frequency was related to greater BMI and WC[47]. These discrepancies among findings might be due to methodological differences. For instance, our study and several studies assessed dietary intakes by the 24-h dietary recall[20,45], while some other studies assessed by 168-item dietary questionnaire[46] or 7-d dietary record[47]. In addition, the subjects in these studies were from different geographical areas.

We also did not find any consistent relationship between habitual timing and amount of eating and the MetS. In comparison, our study findings were opposed to other studies, which demonstrated that meal timing was related to obesity, diabetes, cardiometabolic and cardiovascular events[9,20,48]. A review study that analysed data from ten observational studies indicated

https://doi.org/10.1017/S0007114521005079 Published online by Cambridge University Press

British Journal of Nutrition

British Journal of Nutrition



**Table 3.** The metabolic syndrome based on habitual* energy intake in the first and last meal (Odds ratios and 95 % confidence intervals)†

| Variables | MetS | | Abdominal obesity | | Increased blood pressure | | Decreased HDL-cholesterol | | Increased TAG | | Increased FBG | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Odds ratio | 95 % CI | Odds ratio | 95 % CI | Odds ratio | 95 % CI | Odds ratio | 95 % CI | Odds ratio | 95 % CI | Odds ratio | 95 % CI |
| Habitual first meal energy (% of total energy)‡,§ | | | | | | | | | | | | |
| < 25 % (*n* 656) | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | |
| ≥ 25 % (*n* 194) | 0·82 | 0·54, 1·23 | 0·89 | 0·57, 1·40 | 0·98 | 0·56, 1·71 | 1·08 | 0·74, 1·59 | 0·70 | 0·47, 1·04 | 0·71 | 0·48, 1·05 |
| Habitual last meal energy (% of total energy)‡,‖ | | | | | | | | | | | | |
| < 25 % (*n* 546) | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | | 1 (ref.) | |
| ≥ 25 % (*n* 304) | 0·93 | 0·65, 1·35 | 1·21 | 0·80, 1·83 | 1·61 | 0·99, 2·64 | 1·06 | 0·75, 1·50 | 0·82 | 0·58, 1·17 | 0·60 | 0·42, 0·85¶ |

FBG, fasting blood glucose; MetS, metabolic syndrome.
* This means that the exposure was averaged over all recalls.
† Calculated by logistic regression.
‡ Adjusted for age, energy intake, marital status, smoking, education, occupation, BMI (except for abdominal obesity), eating occasions and physical activity.
§ Adjusted for b + habitual early/late first meal (with the 09.00 hour cut-off).
‖ Adjusted for b + habitual early/late last meal (with the 21.00 hour cut-off).
¶ *P*-value < 0·05 indicates significant level.

that late-evening eating was related to higher BMI[49] by disturbing the circadian rhythms[8]. On the other hand, earlier first meal eating can be a protective factor against cardiometabolic events[16]. In addition, the results of two observational studies indicated a positive relation between evening or dinner energy intake and the MetS and obesity risks[50–52]. Reid *et al.* indicated that higher energy intake in the breakfast was linked to higher weight loss than high energy intake during dinner[53].

In this study, we also showed that greater habitual energy intake (≥ 25 % of total energy intake) in the last meal was linked with a lower probability of 'increased FBG', and this relationship was independent of the time of the habitual last meal eating (early/late last meal). However, a study by Jakubowicz *et al.* indicated a greater glucose concentration after higher energy intake in the dinner (700 kcal) than higher energy intake in the breakfast (700 kcal) after 12 weeks of isoenergetic weight loss intervention (1400 kcal) among obese women with the MetS[14]. Other studies indicated that glucose tolerance and insulin sensitivity decline during the day with insulin sensitivity reaching the lowest level in the evening[54–56]. These relations might explain why evening or night eating is related to weight gain or obesity[57]. Nevertheless, it is plausible that we underestimated the relation between habitual timing and amount of eating and cardiometabolic risks due to our dietary data collection that was based on three non-consecutive days, as the last meal of the previous day influences the first meal of the following day. Moreover, most of our participants were healthy adults, while other studies were conducted in high-risk populations (such as adults with the MetS and/or obesity)[14,54].

The strengths of our study include that our study sample size was sufficient, so it was possible to analyse data for both men and women separately. Adjusting for confounders was further strength of our study. Moreover, dietary data collection was based on three non-consecutive days. Hence, we could better capture within-person variation for all of the time-related eating patterns except for nightly fasting duration, as the last meal of the previous day influences the first meal of the following day. Also, several limitations should be outlined. The cross-section design of this study wards off any indication of causality among habitual meal timing and frequency and overnight fasting and the MetS. We used 24-h dietary recall for collecting individual's dietary data, so recall bias is plausible. Finally, our participants did not have habitual nightly fasting duration ≥ 16 h that did not allow analysis data for a longer duration. Previous studies indicated the beneficial effects of longer nightly fasting duration (16 *v.* 10–12 h) on cardiometabolic events in the Korean NHANCE adults (average age: 41 years)[16].

## Conclusion

In summary, having longer nightly fasting duration may be useful for decreasing the risk of both the MetS and 'elevated TAG'. However, no significant association was seen between habitual meal timing and frequency and the MetS. Also, habitual first and last meal energy had no significant connection with the MetS. However, individuals who consumed ≥ 25 % of habitual energy intake in the last meal had a lower prevalence of 'increased FBG'. Considering the limitations of our study, further studies using dietary data on consecutive days with a longer duration are needed to explore the relationship between habitual meal timing and frequency and nightly fasting duration with the MetS.

## Acknowledgements

We thank all participants of the study for their cooperation.

S. S. B. and K. D. contributed to the conceptual framework of the study. A. L., N. J. and M. M. collected the data. S. Z. M. performed the statistical analysis. S. Z. M. wrote the first draft of the manuscript. K. D. and S. S. B. critically revised the first draft. All of the authors are responsible for the final manuscript.

There are no competing interests to declare.

## Supplementary material

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114521005079

## References

1. Alberti KG, Eckel RH, Grundy SM, *et al.* (2009) Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation* **120**, 1640–1645.
2. Huang PL (2009) A comprehensive definition for metabolic syndrome. *Dis Model Mech* **2**, 231–237.
3. Obeidat AA, Ahmad MN, Haddad FH, *et al.* (2015) Alarming high prevalence of metabolic syndrome among Jordanian adults. *Pak J Med Sci* **31**, 1377.
4. Kalan Farmanfarma K, Kaykhaei MA, Adineh HA, *et al.* (2019) Prevalence of metabolic syndrome in Iran: a meta-analysis of 69 studies. *Diabetes Metab Syndr* **13**, 792–799.
5. Urashima M, Wada T, Fukumoto T, *et al.* (2005) Prevalence of metabolic syndrome in a 22 892 Japanese population and its associations with life style. *Jpn Med Assoc J* **48**, 441.
6. Beltrán-Sánchez H, Harhay MO, Harhay MM, *et al.* (2013) Prevalence and trends of metabolic syndrome in the adult US population, 1999–2010. *J Am Coll Cardiol* **62**, 697–703.
7. Virani SS, Alonso A, Benjamin EJ, *et al.* (2020) Heart disease and stroke statistics – 2020 update: a report from the American Heart Association. *Circulation* **141**, e139–e596.
8. Patterson RE & Sears DD (2017) Metabolic effects of intermittent fasting. *Annu Rev Nutr* **37**, 371–393.
9. St-Onge MP, 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.
10. Panda S (2016) Circadian physiology of metabolism. *Science* **354**, 1008–1015.
11. Zimmet P, Alberti KGMM, Stern N, *et al.* (2019) The Circadian Syndrome: is the metabolic syndrome and much more! *J Intern Med* **286**, 181–191.
12. Pot GK, Almoosawi S & Stephen AM (2016) Meal irregularity and cardiometabolic consequences: results from observational and intervention studies. Proc Nutr Soc 75, 475–486.
13. Baron KG, Reid KJ, Kern AS, *et al.* (2011) Role of sleep timing in caloric intake and BMI. *Obesity* **19**, 1374–1381.
14. Jakubowicz D, Barnea M, Wainstein J, *et al.* (2013) High caloric intake at breakfast *v.* dinner differentially influences weight loss of overweight and obese women. *Obesity* **21**, 2504–2512.
15. Bandin C, Scheer F, Luque A, *et al.* (2015) Meal timing affects glucose tolerance, substrate oxidation and circadian-related variables: a randomized, crossover trial. *Int J Obes* **39**, 828–833.
16. Makarem N, Sears DD, St-Onge M-P, *et al.* (2020) Habitual nightly fasting duration, eating timing, and eating frequency are associated with cardiometabolic risk in women. *Nutrients* **12**, 3043.
17. Jon Schoenfeld B, Albert Aragon A & Krieger JW (2015) Effects of meal frequency on weight loss and body composition: a meta-analysis. *Nutr Rev* **73**, 69–82.
18. Marinac CR, Natarajan L, Sears DD, *et al.* (2015) Prolonged nightly fasting and breast cancer risk: findings from NHANES (2009–2010). *Cancer Epidemiol Prev Biomarkers* **24**, 783–789.
19. Ueda M, Inoue Y, Hu H, *et al.* (2021) Nightly fasting duration is not associated with the prevalence of metabolic syndrome among non-shift workers: the Furukawa Nutrition and Health Studymx. *Am J Hum Biol* **33**, e23437.
20. Ha K & Song Y (2019) Associations of meal timing and frequency with obesity and metabolic syndrome among Korean adults. *Nutrients* **11**, 2437.
21. Esmaillzadeh A & Azadbakht L (2008) Major dietary patterns in relation to general obesity and central adiposity among Iranian women. *J Nutr* **138**, 358–363.
22. Fung TT, Hu FB, Pereira MA, *et al.* (2002) Whole-grain intake and the risk of type 2 diabetes: a prospective study in men. *Am J Clin Nutr* **76**, 535–540.
23. Moghaddam MB, Aghdam FB, Jafarabadi MA, *et al.* (2012) The Iranian Version of International Physical Activity Questionnaire (IPAQ) in Iran: content and construct validity, factor structure, internal consistency and stability. *World Appl Sci J* **18**, 1073–1080.
24. Wareham NJ, Jakes RW, Rennie KL, *et al.* (2003) Validity and repeatability of a simple index derived from the short physical activity questionnaire used in the European Prospective Investigation into Cancer and Nutrition (EPIC) study. *Public Health Nutr* **6**, 407–413.
25. Kouchi M (2014) Anthropometric methods for apparel design: Body measurement devices and techniques. In *Anthropometry, apparel sizing and design*, pp. 67–94 [Deepti Gupta and Norsaadah Zakaria, editors]. Elsevier.
26. Subar AF, Kipnis V, Troiano RP, *et al.* (2003) Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study. *Am J Epidemiol* **158**, 1–13.
27. Srour B, Plancoulaine S, Andreeva VA, *et al.* (2018) Circadian nutritional behaviours and cancer risk: new insights from the NutriNet-santé prospective cohort study: disclaimers. *Int J Cancer* **143**, 2369–2379.
28. Marinac CR, Nelson SH, Breen CI, *et al.* (2016) Prolonged nightly fasting and breast cancer prognosis. *JAMA Oncol* **2**, 1049–1055.
29. Marinac CR, Sears DD, Natarajan L, *et al.* (2015) Frequency and circadian timing of eating may influence biomarkers of inflammation and insulin resistance associated with breast cancer risk. *PLOS ONE* **10**, e0136240.
30. Gill S & Panda S (2015) A smartphone app reveals erratic diurnal eating patterns in humans that can be modulated for health benefits. *Cell Metab* **22**, 789–798.
31. Allison KC, Lundgren JD, O'Reardon JP, *et al.* (2010) Proposed diagnostic criteria for night eating syndrome. *Int J Eating Disord* **43**, 241–247.
32. Grundy SM, Cleeman JI, Daniels SR, *et al.* (2005) Diagnosis and management of the metabolic syndrome: an American Heart

Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation* **112**, 2735–2752.

33. Heshmat R, Khashayar P, Meybodi HR, *et al.* (2010) The appropriate waist circumference cut-off for Iranian population. *Acta Med Indones* **42**, 209–215.
34. Al-Daghri NM, Alkharfy KM, Al-Attas OS, *et al.* (2014) Gender-dependent associations between socioeconomic status and metabolic syndrome: a cross-sectional study in the adult Saudi population. *BMC Cardiovasc Disord* **14**, 1–9.
35. Meigs JB, Wilson PWF, Fox CS, *et al.* (2006) Body mass index, metabolic syndrome, and risk of type 2 diabetes or cardiovascular disease. *J Clin Endocrinol Metab* **91**, 2906–2912.
36. Santos AC, Ebrahim S & Barros H (2008) Gender, socio-economic status and metabolic syndrome in middle-aged and old adults. *BMC Public Health* **8**, 1–8.
37. Suastika K, Dwipayana P, Ratna Saraswati IM, *et al.* (2011) Relationship between age and metabolic disorders in the population of Bali. *J Clin Gerontol Geriatr* **2**, 47–52.
38. Taetzsch A, Roberts SB, Bukhari A, *et al.* (2021) Eating timing: associations with Dietary Intake and Metabolic Health. *J Acad Nutr Diet* **121**, 738–748.
39. Yi Y & An J (2020) Sex differences in risk factors for metabolic syndrome in the Korean population. *Int J Environ Res Public Health* **17**, 9513.
40. Zhang WH, Xue P, Yao MY, *et al.* (2013) Prevalence of metabolic syndrome and its relationship with physical activity in suburban Beijing, China. *Ann Nutr Metab* **63**, 298–304.
41. LeCheminant JD, Christenson E, Bailey BW, *et al.* (2013) Restricting night-time eating reduces daily energy intake in healthy young men: a short-term cross-over study. *Br J Nutr* **110**, 2108–2113.
42. Sutton EF, Beyl R, Early KS, *et al.* (2018) Early time-restricted feeding improves insulin sensitivity, blood pressure, and oxidative stress even without weight loss in men with prediabetes. *Cell Metab* **27**, 1212–1221. e1213.
43. Kautzky-Willer A, Harreiter J & Pacini G (2016) Sex and gender differences in risk, pathophysiology and complications of type 2 diabetes mellitus. *Endocr Rev* **37**, 278–316.
44. Johnston JG, Speed JS, Jin C, *et al.* (2016) Loss of endothelin B receptor function impairs sodium excretion in a time-and sex-dependent manner. *Am J Physiology-Renal Physiol* **311**, F991–F998.
45. Ma Y, Bertone ER, Stanek EJ, *et al.* (2003) Association between eating patterns and obesity in a free-living US adult population. *Am J Epidemiol* **158**, 85–92.
46. Holmbäck I, Ericson U, Gullberg B, *et al.* (2010) A high eating frequency is associated with an overall healthy lifestyle in middle-aged men and women and reduced likelihood of general and central obesity in men. *Br J Nutr* **104**, 1065–1073.
47. Murakami K & Livingstone MB (2014) Eating frequency in relation to body mass index and waist circumference in British adults. *Int J Obes* **38**, 1200–1206.
48. Garaulet M & Gómez-Abellán P (2014) Timing of food intake and obesity: a novel association. *Physiol Behav* **134**, 44–50.
49. Fong M, Caterson ID & Madigan CD (2017) Are large dinners associated with excess weight, and does eating a smaller dinner achieve greater weight loss? A systematic review and meta-analysis. *Br J Nutr* **118**, 616–628.
50. Summerbell CD, Moody RC, Shanks J, *et al.* (1996) Relationship between feeding pattern and body mass index in 220 free-living people in four age groups. *Eur J Clin Nutr* **50**, 513–519.
51. Bo S, Musso G, Beccuti G, *et al.* (2014) Consuming more of daily caloric intake at dinner predisposes to obesity. A 6-year population-based prospective cohort study. *PLOS ONE* **9**, e108467.
52. Wang JB, Patterson RE, Ang A, *et al.* (2014) Timing of energy intake during the day is associated with the risk of obesity in adults. J Hum Nutr Diet 27, 255–262.
53. Reid KJ, Baron KG & Zee PC (2014) Meal timing influences daily caloric intake in healthy adults. *Nutr Res* **34**, 930–935.
54. Lee A, Ader M, Bray GA, *et al.* (1992) Diurnal variation in glucose tolerance: cyclic suppression of insulin action and insulin secretion in normal-weight, but not obese, subjects. *Diabetes* **41**, 750–759.
55. Morgan LM, Shi J-W, Hampton SM, *et al.* (2012) Effect of meal timing and glycaemic index on glucose control and insulin secretion in healthy volunteers. *Br J Nutr* **108**, 1286–1291.
56. Van Cauter E, Shapiro ET, Tillil H, *et al.* (1992) Circadian modulation of glucose and insulin responses to meals: relationship to cortisol rhythm. *Am J Physiol-Endocrinol Metab* **262**, E467–E475.
57. Kant A, Schatzkin A & Ballard-Barbash R (1997) Evening eating and subsequent long-term weight change in a national cohort. *Int J Obes* **21**, 407–412.