The Association of Food Insecurity and Cardiometabolic Risk Factors May Be Independent of Body Mass Index

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Abstract

Background: Investigations on food insecurity have shown that food insecurity is negatively associated with health. We examined the association of food insecurity, cardiometabolic risk factors, and dietary patterns in women.

Methods: The cross-sectional study was performed on 190 females referred to primary health care centers in Shiraz, Iran. Food insecurity was assessed by Household Food Insecurity Access Scale. Cardiometabolic risk factors including anthropometric characteristics, blood pressure, and serum glucose and lipids were measured. Diet was assessed with a semi-quantitative food frequency questionnaire.

Results: Cardiometabolic risk factors increased across food insecurity levels (P<0.001 to 0.009). Two healthy and 1 unhealthy dietary patterns were extracted. Food insecure participants consumed less meats, dairy, fruit, and vegetables but more processed meats (P<0.001). Intake of fat, cholesterol, and sodium increased and that of fiber, vitamins A and C, folic acid, potassium, and calcium decreased along with increasing food insecurity. Food secure individuals had better eating habits than food insecure participants. Cardiometabolic risk factors except triglycerides had inverse associations with healthy and positive associations with unhealthy dietary patterns (P<0.05). The associations between food insecurity and cardiometabolic risk factors were independent of age, sex, education level, and body mass index (BMI).

Conclusions: Overall, food insecurity was associated with increased cardiometabolic risk and less healthier dietary patterns. The association between food insecurity and cardiometabolic risk was independent of demographic factors and BMI, suggesting that other factors such as diet and eating habits may have contributed to the exacerbated cardiometabolic risk factors in food insecure individuals.

Introduction

Food insecurity is a public nutrition concern which treats every country in the world including high-income countries such as the USA [1]. According to recent statistics, 10.5% of the US households in 2019 [2] and 20.8% of a representative sample from the UK in 2016 were food insecure [3]. Also, 19% [4] to 35% [5] of the US university students were proved to be food insecure.

Investigations have consistently shown that food insecurity is negatively associated with poor health status [6]. Food insecure individuals have higher rates of hypertension, diabetes, coronary heart disease, stroke, depression, cancer, and asthma [7, 8] and are more likely to have a premature death [9]. A large retrospective cohort study showed that people with severe food insecurity die approximately 9 years earlier than their food secure counterparts [9]. On the other hand, morbidities which come along food insecurity impose medical costs to the household and in turn exacerbate food insecurity [10].

Cardiovascular mortality is an important cause of death in food insecure population, with a hazard ratio of 1.75 for cardiovascular mortality compared to the hazard ratio of 1.45 for all-cause mortality [11]. A number of investigations have indicated the association between cardiovascular disease risk and food insecurity (reviewed by Miguel et al.) [12]. However, none, except one of these studies has examined a wide range of cardiometabolic risk factors [13]. Moreover, only few of these studies have shed small light on the relationship between food insecurity and diet [14–16]. For instance, Mendy et al. reported that in Mississippi adults, food insecurity was inversely associated with consumption of fruit and vegetables [14]. Also, Leung et al. reported that food insecurity had an inverse association with diet quality scored by Alternate Healthy Eating Index in women but not men [15]. However, the literature is lacking information on the difference in dietary patterns between food security and insecurity. Also, it is not known how the change in dietary pattern during food insecurity relates to alterations in cardiometabolic risk factors. In this study, we studied, in a cross-sectional design, the relationship between food insecurity, dietary patterns, and cardiometabolic risk factors in a number of apparently healthy Iranian women. Studying dietary patterns help to have foods and nutrients and their interaction in a complex and this help to investigate the effect of the whole diet without bias caused by single nutrients [17].

Methods
Study design. This was a cross-sectional study conducted in spring and summer 2016 in Shiraz. A sample size of 190 was determined using a prevalence rate of 16.1% for food insecurity as reported by previous investigations [18], a confidence interval of 95%, and 5% margin of error. The sampling continued until the sample size was completed.

Subjects. Participants were selected from attendees of primary health care centers located in all 9 municipal districts of Shiraz. Sampling was performed by multi-stage stratified cluster method from health care centers and through convenience sampling from attendees of each center. Inclusion criteria were as follows: apparently healthy females aged 20 to 55 years without medical conditions, such as hypertension, diabetes mellitus, renal or hepatic disorders, thyroid abnormalities, cancer, anorexia nervosa, pregnancy, and lactation. They were also needed not to be on special diets, such as weight loss or vegetarian diets. Exclusion criteria were cases without blood sampling and food frequency questionnaire (FFQ) forms with less than 80% filled items. All the participants gave their written informed consent. The project was approved by the Research Deputy of Shiraz University of Medical Sciences (project number: 93-7271).

Food insecurity. Food insecurity was assessed by Household Food Insecurity Access Scale (HFIAS) which is a tool for determining food insecurity in developing countries [19]. The questionnaire contains 9 items and has been translated and validated for use in Iranian community [20]. The HFIAS scale scores the food insecurity from 0 to 27 and categorizes it into 4 levels of food secure (0–1), and mild (2–8), moderate (9–14), and severe (15–27) food insecure conditions.

Anthropometric measurements. Weight was measured with minimal clothing using a digital scale (Glamor BS-801, Hitachi, China). Height was estimated without shoes with a tape fixed on a wall. Waist circumference was measured at the middle of the distance between the lowest rib and the iliac crest by using a non-stretchable tape. Body mass index (BMI) was calculated by dividing weight in kilograms by the square of height in meters.

Blood pressure. Blood pressure was measured after 5 minutes rest with the use of a standing mercury sphygmomanometer (Alpk2, Japan). Participants were seated quietly for 5 minutes and blood pressure was measured twice with at least 5 min interval in between. The mean of two measurements was considered as the participant’s blood pressure.

Biochemical measurements. Blood was taken after 12-h fasting. Serum was separated immediately and serum samples were stored in -70 ºC for later analysis. Glucose, triglycerides, total cholesterol, low-density lipoprotein (LDL) cholesterol, and high-density lipoprotein (HDL) cholesterol were quantified in serum samples by commercially available kits (Pars-Azmun, Tehran, Iran) and an auto-analyzer (BT 1500, Biotecnica Instruments, Italy). Metabolic syndrome score was calculated according to the criteria described for Iranian adults by Iranian National Committee of Obesity [21].

Dietary assessment. Expert dietitians performed dietary assessments using a validated semi-quantitative FFQ [22]. The FFQ consisted of a list of foods with serving sizes commonly consumed by Iranians. Participants were asked to report the frequency of food items consumed in the stated serving sizes during the previous year on a daily, weekly, or monthly basis. Consumed foods were then converted to grams and their nutrient composition was determined by modified Nutritionist IV version 3.5.2 with a nutrient database based on the US Department of Agriculture (USDA) food composition tables modified for Iranian foods. Dietary patterns were identified using the factor analysis method [23]. Food items of FFQ were divided into 14 groups and the dietary patterns were extracted by principal component factor analysis with varimax rotation on the 14 food groups. Components with eigenvalues > 1 were retained. In the scree plot, three major dietary patterns were located before a clear inflection. The Bartlett factor of dietary patterns was used for the statistical analysis. A higher Bartlett score indicated a higher adherence.

Eating habits were determined by questioning about the frequency of main meals and snacks as well as fried and fast foods, techniques of cooking including that used for cooking rice, and the habit of consuming tea with meals. The last two items were used as a determinant of healthfulness of eating habits in Iran.

Statistical analysis. Data were analyzed by SPSS version 19 (SPSS Inc., Chicago, IL, USA). Normality of data was examined with Kolmogorov-Smirnov test and abnormally distributed data were log-transformed before being used in the analysis. Missing values were replaced using multiple imputation model based on the available data [24]. Missing-at-random
assumption was used to generate 10 sets of imputed data, the pooled of which was used in the analysis. Household characteristics between food insecurity levels were compared with chi-square (for categorical variables) or one-way analysis of variance (ANOVA) (for quantitative variables). Cardiometabolic risk factors between levels of food insecurity were compared by ANOVA. ANOVA test was used to examine the association of cardiometabolic risk factors with scores of dietary patterns categorized in tertiles. Linear regression analysis was performed to examine the association of food insecurity with cardiometabolic risk factors and dietary patterns with age, marital status, and educational level (model 1). In model 2, BMI was added to the covariates for blood pressure and biochemical biomarkers. Statistical analysis was set at P < 0.05.

Results

The flow diagram of the study enrolment is presented in Fig. 1. A total of 316 females accepted to participate in the study but 126 were excluded after checking inclusion/exclusion criteria and thus 190 females aged 20–55 years were included. They had an average age of 35.2 ± 8.2 years, were mostly married (83.2%), housewife (72.6%), and educated lower than university levels (72.1%). According to the classification described in the Methods, 81 females (42.6%) were food secure, 77 (40.5%) were mild food insecure, 30 (15.8%) were moderately food insecure, and 2 (1.1%) were severely food insecure. Due to low number of individuals in the severely food insecure level, participants in moderate and severe food insecure levels were combined in the moderate/severe food insecure level.

Characteristics of the households in different food insecurity levels are presented in Table 1. There were significant differences between food insecurity levels in family head education, income, and family food expense (P < 0.001). Participants in different food insecurity levels did not differ in age and marital status but the educational level was significantly higher in women of food secure families (P < 0.001).
|                          | Secure (n = 81) | Mild insecure (n = 77) | Moderate/severe insecure (n = 32) | p³  |
|--------------------------|----------------|------------------------|----------------------------------|-----|
| Household size, n (%)    |                |                        |                                  |     |
| 1–2                      | 17 (21.0)      | 14 (18.2)              | 5 (15.6)                         | 0.330|
| 3–4                      | 54 (66.7)      | 52 (67.5)              | 18 (56.3)                        |     |
| > 4                      | 10 (12.3)      | 11 (14.3)              | 9 (28.1)                         |     |
| Family head education, n (%) |                |                        |                                  |     |
| School                   | 46 (56.8)      | 63 (81.8)              | 32 (100)                         | < 0.001|
| College                  | 35 (43.2)      | 14 (18.2)              | 0                                |     |
| Family income, rials/month | 15281 ± 7048  | 9870 ± 4915            | 6875 ± 3045                      | < 0.001|
| Family income per capita, rials/month | 5540 ± 4710 | 3064 ± 1762           | 1884 ± 900                      | < 0.001|
| Family food expense, rials/month | 3574 ± 1419 | 2695 ± 1474           | 2117 ± 1363                      | < 0.001|
| Food expense per capita, rials/month | 1266 ± 811 | 818 ± 492              | 578 ± 365                        | < 0.001|
| Participant's age        | 34.9 ± 8.5     | 35.6 ± 8.5             | 35.2 ± 6.7                       | 0.845|
| Marital status           | 12 (14.8)      | 11 (14.3)              | 9 (28.1)                         | 0.173|
| Single                   | 69 (85.2)      | 66 (85.7)              | 23 (71.9)                        |     |
| Married                  |                |                        |                                  |     |
| Participant's education  |                |                        |                                  |     |
| School                   | 38 (46.9)      | 68 (88.3)              | 32 (100)                         | < 0.001|
| College                  | 43 (53.1)      | 9 (11.7)               | 0                                |     |

1 Scores of food security levels are as follows: food secure (0–1), mild food-insecure (2–8), moderate/severe food-insecure (9–27). 2 Data are expressed as n (%) or means ± SD. ³ P value was determined by one-way analysis of variance for quantitative parameters and by chi-square for categorical variables.

Distribution of cardiometabolic risk factors in different food insecurity levels is shown in Table 2. Weight, BMI, waist circumference, systolic and diastolic blood pressure, serum fasting glucose, triglycerides, total cholesterol, and LDL cholesterol increased while HDL cholesterol decreased across food insecurity levels (P < 0.001 to 0.009).
Table 2
Cardiometabolic risk factors and iron status markers in different food security levels¹,²

|                        | Secure (n = 81) | Mild insecure (n = 77) | Moderate/severe insecure (n = 32) | p³   |
|------------------------|----------------|------------------------|----------------------------------|------|
| Height (cm)            | 160.9 ± 6.3    | 159.4 ± 5.3            | 158.5 ± 4.9                      | 0.077|
| Weight (kg)            | 65.3 ± 10.4    | 71.1 ± 12.1            | 83.1 ± 13.4                      | < 0.001|
| Body mass index (kg/m²)| 25.2 ± 3.9     | 28.1 ± 5.1             | 33.1 ± 5.4                       | < 0.001|
| Waist circumference (cm)| 85.0 ± 10.4  | 87.5 ± 11.9            | 97.5 ± 12.0                      | < 0.001|
| Waist/hip ratio        | 0.86 ± 0.06    | 0.87 ± 0.06            | 0.90 ± 0.06                      | 0.009|
| Systolic blood pressure (mmHg)| 111.9 ± 11.6 | 116.4 ± 13.0          | 125.9 ± 14.0                     | < 0.001|
| Diastolic blood pressure (mmHg)| 84.0 ± 9.5  | 88.5 ± 10.1            | 93.7 ± 11.3                      | < 0.001|
| Fasting blood glucose (mg/dL)| 82.5 ± 12.0 | 87.7 ± 13.8            | 95.6 ± 21.8                      | 0.001|
| Triglycerides (mg/dL)  | 133.2 ± 53.2   | 137.9 ± 48.9           | 179.3 ± 48.9                     | < 0.001|
| Total cholesterol (mg/dL)| 174.3 ± 28.5 | 184.8 ± 39.6           | 230.6 ± 43.5                     | < 0.001|
| LDL cholesterol (mg/dL)| 113.2 ± 22.8   | 120.4 ± 35.7           | 160.6 ± 37.9                     | < 0.001|
| HDL cholesterol (mg/dL)| 47.2 ± 7.6     | 44.5 ± 8.1             | 39.2 ± 7.0                       | < 0.001|
| Metabolic syndrome score| 1.85 ± 0.83   | 2.41 ± 1.20            | 3.48 ± 0.95                      | < 0.001|

¹ Scores of food security are as follows: food secure (0–1), mild food-insecure (2–8), moderate/severe food-insecure (9–27).
² Data are presented as means ± SD.
³ P values were determined by one-way analysis of variance.

Three major dietary patterns were detected in our study participants (Table 3). The first pattern contained mainly fruits, red meat, nuts, legumes, and non-starchy vegetables and little amounts of processed meats. We called it healthy pattern 1. The second pattern composed mainly from fish, chicken, low-fat dairy, and non-starchy vegetables but was low in processed meats, grains, and sugary foods. This was called healthy pattern 2. The third pattern contained potato, high-fat dairy, sugar-containing products, egg, processed meats, and grains. This pattern was called unhealthy pattern. Processed meats were especially low in healthy dietary patterns and grains were low in the healthy dietary pattern 2.
Table 3
Food groups and their factor loadings in the three extracted dietary patterns.

| Food groups          | Healthy dietary pattern 1 | Healthy dietary pattern 2 | Unhealthy pattern |
|----------------------|---------------------------|---------------------------|-------------------|
| Fruits               | 0.833                     | 0.112                     | -0.223            |
| Red meat             | 0.704                     | 0.286                     |                   |
| Nuts                 | 0.612                     |                           |                   |
| Legumes              | 0.537                     | -0.130                    |                   |
| Processed meats      | -0.464                    | -0.358                    | 0.436             |
| Fish                 |                           | 0.821                     |                   |
| Chicken              | -0.156                    | 0.760                     | 0.142             |
| Low-fat dairy        |                           | 0.588                     | -0.158            |
| Non-starchy vegetables | 0.405                     | 0.497                     |                   |
| Grains               |                           | -0.447                    | 0.433             |
| Potato               | -0.128                    | -0.114                    | 0.571             |
| High-fat dairy       | 0.108                     | 0.113                     | 0.557             |
| Sugary products      |                           | -0.266                    | 0.533             |
| Egg                  | -0.152                    |                           | 0.446             |

The association of cardiometabolic risk factors with tertiles of the dietary patterns is shown in Table 4. Weight, BMI, waist circumference, systolic and diastolic blood pressure, total cholesterol and LDL cholesterol had inverse association with healthy pattern 1. Similarly, these risk factors as well as fasting glucose had inverse relationship with healthy pattern 2. HDL cholesterol was only associated with the first dietary pattern. Among these risk factors, only weight, BMI, systolic and diastolic blood pressure, and HDL cholesterol had association with unhealthy pattern. Except HDL, other risk factors had positive association with this pattern. Triglycerides had no association with dietary patterns.
In regression analysis, all of the examined risk factors had significant association with food insecurity in unadjusted model and after adjustments for age, marital status, and educational level (model 1) (Table 5). Addition of BMI to the covariates did not affect the associations except for blood pressure, particularly diastolic blood pressure which demonstrated a decreased β and increased P value (P = 0.051 for diastolic blood pressure). Both healthy dietary patterns had inverse association with food insecurity in unadjusted model (β = -0.422 and -0.435, P < 0.001), model 1 (adjustment for age, marital status, and educational level) (β = -0.475 and -0.341, P < 0.001), and model 2 (addition of BMI among the confounders) (β = -0.473 and -0.253, P ≤ 0.003). Unhealthy pattern did not show a relationship unless when BMI was added to the confounders (model 2) which demonstrated a trend for an inverse relationship (β = -0.177, P = 0.053) (Table 5).

### Table 4

| Cardiometabolic risk factors across tertiles of the three major dietary patterns<sup>1,2</sup> |
|---------------------------------------------------------------|
| **Healthy Pattern 1** | **Healthy Pattern 2** | **Unhealthy Pattern** |
| **Tertile 1** | **Tertile 2** | **Tertile 3** | **p<sup>3</sup>** | **Tertile 1** | **Tertile 2** | **Tertile 3** | **P** | **Tertile 1** | **Tertile 2** | **Tertile 3** | **P** |
| Food insecurity score | 7.0 ± 5.1 | 3.1 ± 3.8 | 1.8 ± 2.7 | < 0.001 | 6.0 ± 4.8 | 4.5 ± 4.5 | 1.3 ± 2.7 | < 0.001 | 3.4 ± 4.3 | 3.0 ± 3.7 | 5.4 ± 5.2 | 0.007 |
| Weight (kg) | 76.5 ± 14.3 | 67.0 ± 12.3 | 68.5 ± 10.8 | < 0.001 | 74.8 ± 14.6 | 71.9 ± 13.0 | 65.3 ± 9.7 | < 0.001 | 67.8 ± 10.2 | 68.4 ± 11.8 | 75.7 ± 15.5 | 0.001 |
| BMI (kg/m<sup>2</sup>) | 30.4 ± 5.9 | 26.1 ± 5.0 | 26.6 ± 4.3 | < 0.001 | 29.6 ± 5.9 | 28.0 ± 5.6 | 25.5 ± 3.9 | < 0.001 | 26.5 ± 4.1 | 26.6 ± 5.0 | 30.0 ± 6.3 | < 0.001 |
| WC (cm) | 89.4 ± 13.1 | 85.0 ± 11.8 | 90.0 ± 10.7 | 0.038 | 92.2 ± 12.6 | 87.9 ± 12.1 | 84.3 ± 10.3 | < 0.001 | 88.0 ± 10.1 | 87.2 ± 12.1 | 89.2 ± 13.8 | 0.652 |
| SBP (mmHg) | 121.8 ± 13.4 | 115.7 ± 12.3 | 111.1 ± 12.6 | < 0.001 | 119.5 ± 13.9 | 115.8 ± 13.6 | 113.4 ± 12.4 | 0.042 | 113.0 ± 12.1 | 113.5 ± 12.0 | 122.3 ± 14.4 | < 0.001 |
| DBP (mmHg) | 90.6 ± 11.5 | 86.5 ± 10.3 | 85.5 ± 9.3 | 0.017 | 90.0 ± 10.8 | 89.6 ± 10.4 | 83.0 ± 9.3 | < 0.001 | 86.8 ± 9.8 | 84.6 ± 9.0 | 91.3 ± 11.9 | 0.002 |
| FBG (mg/dL) | 90.7 ± 16.8 | 87.0 ± 15.5 | 83.9 ± 14.0 | 0.085 | 92.4 ± 17.9 | 86.5 ± 14.3 | 80.9 ± 11.1 | 0.001 | 84.3 ± 16.8 | 87.0 ± 14.2 | 89.7 ± 15.1 | 0.192 |
| TG (mg/dL) | 144.1 ± 57.8 | 137.1 ± 54.1 | 149.3 ± 48.5 | 0.479 | 148.9 ± 55.3 | 148.9 ± 56.7 | 131.2 ± 44.9 | 0.160 | 140.9 ± 59.1 | 141.2 ± 46.9 | 148.4 ± 52.8 | 0.716 |
| Total-C (mg/dL) | 201.3 ± 49.9 | 181.8 ± 36.9 | 185.3 ± 35.6 | 0.042 | 199.7 ± 45.6 | 191.4 ± 44.7 | 172.6 ± 23.8 | 0.003 | 189.1 ± 46.7 | 181.5 ± 31.8 | 195.0 ± 42.5 | 0.215 |
| LDL-C (mg/dL) | 139.4 ± 43.5 | 119.6 ± 34.4 | 117.7 ± 25.8 | 0.003 | 134.9 ± 41.6 | 122.0 ± 37.0 | 115.5 ± 21.4 | 0.016 | 125.4 ± 37.6 | 118.4 ± 30.1 | 130.0 ± 38.0 | 0.265 |
| HDL-C (mg/dL) | 40.0 ± 8.0 | ± 45.4 | ± 7.8 | 47.7 | 0.001 | 43.9 ± 9.1 | 44.8 ± 8.3 | 45.4 ± 6.9 | 0.620 | 45.9 ± 7.9 | 45.8 ± 8.5 | 42.3 ± 7.9 | 0.033 |
| MetS score | 2.78 ± 1.31 | 2.24 ± 1.02 | 2.22 ± 1.13 | 0.028 | 2.77 ± 1.26 | 2.42 ± 1.14 | 1.90 ± 0.90 | 0.001 | 2.30 ± 1.09 | 2.13 ± 1.00 | 2.74 ± 1.32 | 0.026 |

<sup>1</sup> Healthy dietary pattern 1 included mainly fruits, red meat, nuts, legumes, and non-starchy vegetables. Healthy dietary pattern 2 included mainly fish, chicken, low-fat dairy, and non-starchy vegetables. Unhealthy dietary pattern included potato, high fat dairy, sugar-containing products, egg, processed meats, and refined grains. <sup>2</sup> Data are means ± SD. <sup>3</sup> P values were obtained by one-way ANOVA. Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; MetS, metabolic syndrome; SBP, systolic blood pressure; TG, triglycerides; WC, waist circumference.
### Table 5
Regression analysis assessing the association between levels of food insecurity and cardiometabolic risk factors as well as major dietary patterns

| Cardiometabolic risk factors                  | Unadjusted model | Model 1\(^2\) | Model 2\(^3\) |
|----------------------------------------------|------------------|----------------|----------------|
| Weight (kg)                                  | 0.513 \(< 0.001\)| 0.480 \(< 0.001\)| 0.512 \(< 0.001\)|
| Body mass index (kg/m\(^2\))                 | 0.555 \(< 0.001\)| 0.512 \(< 0.001\)|
| Waist circumference (cm)                     | 0.384 \(< 0.001\)| 0.369 \(< 0.001\)|
| Waist/hip ratio                              | 0.230 0.002      | 0.245 0.003    |
| Systolic blood pressure (mmHg)               | 0.389 \(< 0.001\)| 0.407 \(< 0.001\)| 0.223 0.010 |
| Diastolic blood pressure (mmHg)              | 0.379 \(< 0.001\)| 0.337 \(< 0.001\)| 0.173 0.051 |
| Fasting blood glucose (mg/dL)                | 0.313 \(< 0.001\)| 0.300 0.001      | 0.322 0.001 |
| Triglycerides (mg/dL)                        | 0.305 \(< 0.001\)| 0.271 0.003      | 0.284 0.006 |
| Total cholesterol (mg/dL)                    | 0.471 \(< 0.001\)| 0.422 \(< 0.001\)| 0.325 \(< 0.001\)|
| LDL cholesterol (mg/dL)                      | 0.444 \(< 0.001\)| 0.451 \(< 0.001\)| 0.384 \(< 0.001\)|
| HDL cholesterol (mg/dL)                      | -0.369 \(< 0.001\)| -0.450 \(< 0.001\)| -0.408 \(< 0.001\)|
| Metabolic syndrome score                     | 0.537 \(< 0.001\)| 0.540 \(< 0.001\)| 0.377 \(< 0.001\)|
| Dietary patterns                              |                  |                |                |
| Healthy dietary pattern 1                    | -0.422 \(< 0.001\)| -0.475 \(< 0.001\)| -0.473 \(< 0.001\)|
| Healthy dietary pattern 2                    | -0.435 \(< 0.001\)| -0.341 \(< 0.001\)| -0.253 0.003 |
| Unhealthy dietary pattern                    | 0.054 0.462      | -0.050 0.538   | -0.177 0.053   |

1 The associations were examined by linear regression, except for metabolic syndrome, for which ordinal regression was used. 2 Model 1 was adjusted for age, marital status, and educational level. 3 Model 2 was additionally adjusted for BMI.

Assessment of dietary intakes revealed that consumption of red meat, poultry, fish, dairy, fruits, and non-starchy vegetables decreased whereas processed meats increased as food insecurity increased (P \(\leq 0.001\)) (Table 6). Consumption of potato also showed an increasing trend (P = 0.056). Grains, legumes, eggs, potato, nuts, and sugar-containing products did not show a significant association.
Table 6
Consumption of food groups (g/day) in different food insecurity levels$^{1,2}$

|                  | Secure (n = 81) | Mild insecure (n = 77) | Moderate/severe insecure (n = 32) | P value$^3$ |
|------------------|----------------|------------------------|-----------------------------------|-------------|
| Grains           | 391.7 ± 175.5  | 426.6 ± 128.4          | 433.0 ± 134.1                     | 0.259       |
| Legumes          | 40.0 ± 27.7    | 35.2 ± 31.2            | 34.6 ± 26.3                       | 0.511       |
| Red meat         | 21.9 ± 20.8    | 13.0 ± 12.3            | 6.4 ± 7.5                         | < 0.001     |
| Poultry          | 5.6 ± 7.6      | 3.0 ± 3.7              | 1.7 ± 2.9                         | 0.001       |
| Fish             | 14.5 ± 18.8    | 2.9 ± 3.3              | 0.93 ± 1.9                        | < 0.001     |
| Processed meats  | 12.8 ± 19.6    | 36.8 ± 36.2            | 60.0 ± 43.2                       | < 0.001     |
| Eggs             | 27.2 ± 16.2    | 26.1 ± 13.5            | 30.4 ± 16.0                       | 0.392       |
| Dairy            | 294.8 ± 180.3  | 193.6 ± 115.0          | 169.1 ± 98.2                      | < 0.001     |
| Fruits           | 440.0 ± 222.4  | 268.2 ± 226.3          | 119.2 ± 115.0                     | < 0.001     |
| Non-starchy vegetables | 404.8 ± 158.6  | 316.3 ± 141.2          | 294.6 ± 87.1                      | < 0.001     |
| Potato           | 30.8 ± 23.9    | 36.8 ± 19.6            | 41.8 ± 21.7                       | 0.056       |
| Nuts             | 7.4 ± 9.9      | 5.3 ± 9.6              | 3.8 ± 6.2                         | 0.134       |
| Sugary foods$^4$ | 116.0 ± 168.0  | 140.2 ± 87.7           | 166.0 ± 75.6                      | 0.170       |

$^1$ Scores of food security are as follows: food secure (0–1), mild food-insecure (2–8), moderate/severe food-insecure (9–27).

$^2$ Data are presented as means ± SD.

$^3$ P value was determined by one-way analysis of variance.

$^4$ Sugary foods included sugar-sweetened beverages, cakes, biscuits, cookies, confections, candies, ice cream, etc.

Among nutrients, carbohydrates (P = 0.016), fiber (P < 0.001), vitamin A (P < 0.001), vitamin C (P < 0.001), folic acid (P < 0.001), potassium (P < 0.001), calcium (P < 0.001), and magnesium (P < 0.001) decreased while fat (P < 0.001) and sodium (P < 0.001) increased as food security decreased (Table 7). Energy, protein, cholesterol, vitamin B$_{12}$, iron, and zinc did not show significant association.
Table 7
Daily nutrient intakes in different food security levels\(^1,2\)

|                       | Secure (n = 81) | Mild insecure (n = 77) | Moderate/severe insecure (n = 32) | P value\(^3\) |
|-----------------------|----------------|-----------------------|----------------------------------|---------------|
| Energy (kcal)         | 2197 ± 537     | 2156 ± 540            | 2231 ± 488                       | 0.799         |
| Carbohydrate (g)      | 348.9 ± 93.2   | 316.8 ± 80.3          | 299.0 ± 54.6                     | 0.016         |
| Protein (g)           | 65.4 ± 16.3    | 61.1 ± 13.9           | 63.3 ± 15.7                      | 0.298         |
| Fat (g)               | 60.0 ± 20.2    | 71.6 ± 33.7           | 86.9 ± 34.8                      | \(< 0.001\)   |
| Cholesterol (g)       | 199.5 ± 78.8   | 200.2 ± 83.6          | 240.0 ± 99.1                     | 0.077         |
| Fiber (g)             | 27.0 ± 8.9     | 20.2 ± 7.9            | 16.9 ± 5.1                       | \(< 0.001\)   |
| Vitamin A (µg RE)     | 707.4 ± 405.9  | 516.6 ± 300.3         | 418.5 ± 276.0                    | \(< 0.001\)   |
| Vitamin C (mg)        | 319.6 ± 149.5  | 196.8 ± 123.2         | 149.7 ± 90.7                     | \(< 0.001\)   |
| Folic acid (µg)       | 328.9 ± 117.8  | 239.8 ± 95.9          | 221.5 ± 84.6                     | \(< 0.001\)   |
| Vitamin B\(_{12}\) (µg)| 5.1 ± 4.8     | 3.9 ± 3.5             | 5.5 ± 6.5                        | 0.213         |
| Sodium (mg)           | 747 ± 343      | 1162 ± 742            | 1411 ± 843                       | \(< 0.001\)   |
| Potassium (mg)        | 4148 ± 1391    | 3054 ± 1130           | 2735 ± 809                       | \(< 0.001\)   |
| Calcium (mg)          | 745.7 ± 269.6  | 582.5 ± 172.5         | 575.0 ± 190.0                    | \(< 0.001\)   |
| Magnesium (mg)        | 278.9 ± 75.3   | 224.2 ± 62.4          | 212.5 ± 53.5                     | \(< 0.001\)   |
| Iron (mg)             | 15.1 ± 4.2     | 14.3 ± 3.6            | 14.3 ± 3.1                       | 0.476         |
| Zinc (mg)             | 6.9 ± 1.8      | 6.3 ± 1.9             | 6.8 ± 1.9                        | 0.176         |

\(^1\) Scores of food security are as follows: food secure (0–1), mild food-insecure (2–8), moderate/severe food-insecure (9–27). \(^2\) Data are presented as means ± SD. \(^3\) P value was determined by one-way analysis of variance.

Frequency of main meals and snacks (P < 0.05) decreased along with decreasing food security levels but the association for dinner was not significant (Table 8). On the contrary, the frequency of fast and fired foods increased as food security decreased (P ≤ 0.001). Food secure participants used boiling as the main technique of cooking while frying was the main method of cooking among food insecure participants (P = 0.001). Although in each category of food insecurity, more women were straining rice than doing it as a pilaf, 96.9% of women in moderate/severe food insecurity level strained rice while 63.0% and 71.4% of women in food secure and mild insecure levels strained it, respectively (P = 0.001). Compared to food secure families more women in food insecure category drunk tea with meals (56.2% vs. 25.9%) (P = 0.001).
### Table 8
Eating habits in different food security levels\(^1,2\)

|                      | Secure (n = 81) | Mild insecure (n = 77) | Moderate/severe insecure (n = 32) | P value\(^3\) |
|----------------------|----------------|------------------------|-----------------------------------|---------------|
| Breakfast frequency (n/week) | 5.9 ± 2.0 | 5.3 ± 2.1 | 3.4 ± 2.5 | 0.001 |
| Lunch frequency (n/week)     | 6.8 ± 0.7 | 7.0 ± 0.1 | 6.7 ± 0.9 | 0.041 |
| Dinner frequency (n/week)    | 6.1 ± 1.6 | 6.0 ± 1.5 | 5.8 ± 1.4 | 0.645 |
| Meal frequency (n/day)       | 2.7 ± 0.4 | 2.6 ± 0.4 | 2.3 ± 0.5 | < 0.001 |
| Snack frequency (n/day)      | 1.9 ± 1.0 | 1.6 ± 1.1 | 1.2 ± 0.6 | 0.005 |
| Fried foods (n/week)         | 2.8 ± 1.7 | 3.5 ± 1.7 | 4.1 ± 2.1 | 0.001 |
| Fast foods (n/week)          | 1.7 ± 1.4 | 2.8 ± 2.5 | 5.2 ± 3.9 | < 0.001 |
| Main cooking method Boiling | 48 (59.3) | 23 (29.9) | 10 (31.2) | 0.001 |
| Frying                       | 33 (40.7) | 54 (70.1) | 22 (68.8) |               |
| Method of cooking rice Pilaf | 30 (37.0) | 22 (28.6) | 1 (3.1)   | 0.005 |
| Strain                       | 51 (63.0) | 55 (71.4) | 31 (96.9) |               |
| Tea with meals Yes           | 21 (25.9) | 41 (53.3) | 18 (56.2) | 0.001 |
| No                            | 60 (74.1) | 36 (46.7) | 14 (43.8) |               |

\(^1\) Scores of food security are as follows: food secure (0–1), mild food-insecure (2–8), moderate/severe food-insecure (9–27).  
\(^2\) Data are presented as means ± SD.  
\(^3\) P value was determined by one-way analysis of variance or chi-square (for the last 3 items).

### Discussion

Results of this study showed that food insecurity was associated with exacerbated cardiometabolic risk factors. The associations between food insecurity and cardiometabolic risk factors were independent of demographic factors and BMI. Food insecurity had positive association with adherence to an unhealthy dietary pattern while food security was positively associated with adherence to healthy dietary patterns. Both healthy and unhealthy dietary patterns had associations with cardiometabolic risk factors.

### Food insecurity and dietary patterns

There were significant associations between detected dietary patterns and food insecurity. Healthy dietary patterns had an inverse and the unhealthy pattern had a positive association with food insecurity. These results are in accordance with previous findings. For instance, food insecurity has been inversely associated with Mediterranean-like dietary pattern in adolescents of Lebanon [25], university students of Greece [26], and adults of Portugal [27].

In fact, when there is no financial constraint, people are able to design and afford a diverse food plan which is tasty and pleasant [28]. When financial resources are limited, people have to diminish food costs by eliminating expensive food items from the diet, resulting in a less diverse and thus less healthy diet [29]. In such cases, nutrient-dense foods are usually omitted and energy-dense foods are replaced, resulting in turning a healthy diet into an unhealthy regimen.
In addition to financial reasons, socioeconomic characteristics may influence individuals’ food choices. In our study, participants in food insecure families and also the head of food insecure households had significantly lower levels of education in comparison with food secure families. Poor nutritional knowledge about healthy eating in families with low educational level could constitute an additional factor along with budget constraints in the selection of unhealthy foods [30, 31]. In this regard, a cross-sectional study in the UK and Australia showed that higher education was the most important factor associated with healthier dietary behavior in disadvantaged populations [32]. On the other hand, many unhealthy foods are cheap and tasty [33]. Thus, in families with low nutritional information, selection of such foods may be an attempt to satisfy children’s craving for tasty foods. Sugary products and processed meats in the unhealthy dietary pattern of this study are such foods.

**Food insecurity and cardiometabolic risk factors**

Significant associations were found between the degree of food insecurity and all of the examined cardiometabolic risk factors and metabolic syndrome score. Food insecure participants had higher BMI and waist circumference, blood pressure, fasting glucose, triglycerides, and LDL cholesterol, and lower HDL cholesterol. These findings are in agreement with findings of recent meta-analyses indicating a direct relationship of food insecurity with cardiometabolic risk factors, especially excess weight, hypertension, and dyslipidemias [12, 34]. These abnormalities in metabolic and cardiovascular risk markers gradually progress during the lifespan and eventually leads to cardiovascular and other chronic diseases [7]. This results in increased rates of mortality particularly from cardiovascular diseases in food insecure groups [35, 36].

Among cardiometabolic risk factors, BMI had the highest association with food insecurity (OR = 0.555). In agreement, Holben and Taylor reported that among metabolic risk factors, overweight and central obesity had the strongest association with food insecurity in adolescents aged 12 to 18 years in the US [37]. The food insecurity-obesity paradox has been highlighted in previous investigations [38, 39]. In most cases of food insecurity, the amount of food consumption is not affected, but low-calorie nutritious foods are substituted with poor-quality, energy-dense foods that rectify hunger but do not meet nutritional needs of the body [1]. Moreover, insecure households may experience periods of hunger when food and money run out. At such times, to prevent intermittent hunger, families are pushed to choose relatively cheap high-calorie foods that enable them to afford food for more prolonged periods of time [40]. Foods containing sugar, starch, and oil are such foods. In our study, consumption of potato and processed meats increased along with increasing food insecurity while consumption of fruits, non-starchy vegetables, red meat, poultry, fish, and nuts decreased. Furthermore, episodes of food deprivation may create a tendency in individuals to overeat to prolong satiation in periods of food affluence [40]. Studies have shown that both cases of mild and severe food insecurity may increase the likelihood of binge-eating disorder [41]. Anxiety and depression which occurs along with food insecurity [42] may also put individuals at risk of weight gain and obesity [43, 44].

The obesity itself may predispose individuals to metabolic and cardiovascular diseases [45]. However, in the current study, the addition of BMI among the confounders did not affect the association between food insecurity and cardiometabolic risk factors. This suggests that factors other than overweight may have contributed to the metabolic abnormalities of food insecure participants. Secure individuals had healthier dietary patterns with higher amounts of fruit and vegetables, nuts, legumes, fish, and low-fat dairy and this may have contributed to the lower cardiometabolic risk in this group. On the other hand, lifestyle factors such as eating habits and lifestyle are factors affecting cardiometabolic health. For instance, epidemiologic surveys have shown that food secure individuals have healthier lifestyle, including more physical activity and less smoking habits than food insecure people [15, 46]. In our study, food insecure participants had unhealthier eating habits including skipping breakfast, consumption of fast and fried foods, drinking tea with meals, and the use of frying as the main method of cooking. Factors such as smoking, alcohol consumption, physical activity, and stress can also influence cardiometabolic risk. Therefore, all or some of these factors may speed up cardiometabolic risk in food insecure population.

**Dietary patterns and cardiometabolic risk factors**

The adherence to healthy dietary patterns was associated with reduced cardiometabolic risk. Contrarily, adherence to unhealthy dietary pattern was accompanied with exacerbated risk factors. Such associations between healthy [47–49] and unhealthy [50, 51] dietary patterns and cardiometabolic risk factors and diseases have been highlighted in previous...
investigations. Healthy dietary patterns rely on fruit and vegetables, whole grains, low-fat meats and dairy which provide sufficient quantities of fiber, phytosterols, vitamins (e.g., folic acid, vitamin C, and vitamin A), minerals (e.g., magnesium and potassium), and antioxidants, all of which are necessary to combat against metabolic and cardiovascular diseases. In contrast, unhealthy dietary patterns contain processed meats, salty, and sugary foods. Such diets have high content of fat, saturated fats, cholesterol, sugar, and salt which are all dietary components stimulating cardiovascular risk. It is worth noting that in our study, grains were placed in unhealthy dietary pattern and this may be because the fact that in Iran grains include mainly rice and bread and both of these are refined. In fact, regular rice and bread in Iran are refined and people almost never eat brown rice and very seldom consume whole wheat breads.

**Strengths and limitations**

This study had the advantage of simultaneous assessment of cardiometabolic risk factors along with dietary intakes and eating habits in women with various food insecurity levels, an approach that, to the best of our knowledge, has not been investigated before. Semi-quantitative nature of FFQ allowed us to quantitatively evaluate the amount of foods and nutrients consumed and to properly assess their relationship with food insecurity. However, the contribution of participants’ nutritional knowledge in the selection of foods and lifestyle was not clear. As an important confounder, nutritional literacy can affect dietary pattern and cardiometabolic risk factors and thus could affect the examined relationships. Future studies need to include evaluation of nutritional information and skills of food purchase and preparation in conditions of limited food budget during data collection. Since our participants were women, a comparison could not be performed between men and women but it is likely that due to culturally-imposed gender discrimination, women are influenced more severely than men by food insecurity aftermaths, such as poor diet quality and obesity [38, 52, 53]. Moreover, compared to men, women spend more time at home and so are more likely to satisfy their hunger by high-energy low-nutritious foods, which results in their overweight [54]. We did not assess smoking habits, alcohol consumption, physical activity, and psychologic conditions including depression and stress, all of which are factors with potential to affect diet, eating, and cardiovascular risk. Future studies may need to have these points into consideration.

**Conclusions**

Overall, our study showed that food insecurity was associated with unhealthy dietary pattern, less healthy eating behaviors, lower intakes of meats, dairy, fruit, and vegetables, and higher consumption of processed meat. Food insecure individuals had worse cardiometabolic risk factors and lower metabolic syndrome score. The associations between cardiometabolic risk and food insecurity were independent of demographic factors and BMI, suggesting that other factors such as diet and eating habits may have contributed to the exacerbated cardiometabolic risk factors in food insecure individuals.

**Abbreviations**

ANOVA, one-way analysis of variance; BMI, body mass index; DBP, diastolic blood pressure; FBG, fasting blood glucose; FFQ, food frequency questionnaire; HDL, high-density lipoprotein; HFIAS, household food insecurity access scale; LDL, low-density lipoprotein; MetS, metabolic syndrome; SBP, systolic blood pressure; TG, triglycerides; WC, waist circumference; USDA, US department of agriculture

**Declarations**

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**Ethics approval and consent to participate**
All the participants gave their written informed consent. The project was approved by the Research Deputy of Shiraz University of Medical Sciences (project number: 93-7271).

Consent for publication

Not applicable.

Availability of data and material

Please contact author for data requests.

Competing interests

The authors have no competing interests to declare.

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Authors' contributions

Maral Hashemzadeh, Masoumeh Akhlaghi, and Mohammad Fararouei contributed to the conception and design of the study. Maral Hashemzadeh, Maryam Taymouri, and Reza Barati-Boldaji collected the data, performed statistical analysis, and drafted the manuscript. Masoumeh Akhlaghi and Mohammad Fararouei supervised and participated in the project from the design to data analysis and preparing the manuscript. All the authors approved the final version of the manuscript.

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**Figures**

[Flowchart of the study participants]

- **Excluded (n=126)**
  - Aged < 20 y or > 55 y (n=7)
  - Involved in various morbidities (n=18)
  - Pregnant or lactating (n=21)
  - On special diets (n=5)
  - Without blood sampling (n=34)
  - FFQ < 80% filled items (n=41)

- **Included (n=190)**

**Figure 1**

Flowchart of the study participants