Dietary Energy Density Is Inversely Associated with the Diet Quality Indices among Iranian Young Adults

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Summary Dietary energy density (DED) might be associated with the quality of the consumed diet. Therefore, this study was conducted to report the relationship between dietary energy density and diet quality index in Iranian youths. In this cross-sectional study we enrolled 410 female young adults in Isfahan-Iran who were selected according to the stratified random sampling method from among students of Isfahan University of Medical Sciences. A validated semi quantitative food frequency questionnaire was used to assess the usual dietary intakes. Dietary energy density was calculated as each individual’s reported daily energy intake (kcal/d) into total weight of foods (excluding beverages) consumed (g/d). Diet quality was assessed by healthy eating index (HEI), nutrient adequacy ratio (NAR), and mean adequacy ratio (MAR). For calculating the NAR the ratio of daily individual intakes to standard recommended amounts for the subject’s sex and age category was used. MAR was calculated as the sum of NARs divided by the number of nutrients (n=10). Mean dietary energy density was 1.5±0.2 kcal/g and mean HEI was 57.5±16.0. Those in the highest quartile of DED had the lowest value for HEI, MAR, and NAR of zinc, calcium, vitamin C, vitamin B12 and vitamin B2 (p<0.05). Those in the highest quartile of DED had the highest prevalence of calcium, zinc, vitamin B2, vitamin B12, and vitamin C deficiency (p<0.05). Dietary energy density was inversely associated with the diet quality indices among Iranian young women adults.

Key Words healthy eating index, dietary energy density, mean adequacy ratio, diet quality, nutrient adequacy ratio

Total energy intake is one of the most important issues in the field of the relationship between dietary intake and the prevalence of the chronic diseases such as overweight and obesity (1). However, recently the amount of energy in a given weight of food named as dietary energy density is considered as a determinant of non-communicable diseases (2–6). There are some cross-sectional and prospective reports regarding the association between dietary energy density and obesity, metabolic syndrome and type 2 diabetes (7–12). A clinical trial also confirmed that reduced dietary energy density had resulted in significant weight loss (13). Preliminary findings suggest that consuming a diet lower in ED may aid with weight loss maintenance (14).

Energy density of the diets could also be associated with the healthy or unhealthy characteristic of the diets. Energy-dense diets have been reported to contain higher amounts of fat, refined grains and added sugars, but lower amounts of fruits and vegetables, whole-grains and dietary fiber. High dietary energy density is associated with unhealthy food choices (15). The main characteristic of energy-dense diets is higher amounts of saturated and trans fats and a higher glycemic load (15). According to a previous report, consumption of a low-energy-dense diet had been associated with higher intakes of micronutrient-rich foods, lower intakes of total dietary fat and higher intakes of different vitamins (16). A recent study among Swedish children and adolescents revealed that energy density had advantages over other whole-diet analysis methods and could be an index of diet quality (17). There are different studies that show the relationship between the diet quality indices and the risk of chronic diseases (18–20). It seems that high quality diet consumption is associated with lower risk of obesity and overweight (18, 19).

However, low energy-dense diets in different countries might have specific characteristics. Therefore, it is necessary to conduct separate studies in different regions and countries to determine the definition of low energy dense diet according to the dietary behavior of that region. According to our knowledge, there are few studies regarding the relationship between dietary energy density and the diet quality indices in Iran. Therefore, the aim of the present study is reporting the association between energy density and diet quality among Iranian young female adults.

SUBJECTS AND METHODS

Subjects. The sample of the present study was recruited based on the representative sample of young fe-
males adults in Isfahan, Iran aged 18–28 y. They were selected by the multistage cluster random sampling method from among the students of Isfahan University of Medical Sciences. First, we considered all the schools of the Isfahan University of Medical Sciences, then some departments were randomly chosen and some students chosen from each department, randomly.

Finally, after omitting the under and over reporters of energy intake 410 students were enrolled for the statistical analysis for the present study. Written informed consent was obtained from each participant. The study was approved by the research council and ethical committee of the School of Health, Isfahan University of Medical Sciences.

Assessment of dietary intake. For evaluating the dietary intake, a 168-item semi quantitative food frequency questionnaire was used. The FFQ consisted of a list of foods with a standard serving size. Participants were asked to report their frequency and amount of intake of each food item during the previous year on a daily (e.g. bread), weekly (e.g. rice, meat) or monthly (e.g. fish) basis. Portion sizes of consumed foods were converted to grams using household measures (21). Nutritionist III software (Version 7.0; N-Squared Computing, Salem, OR) was used for nutrient analysis of the diets. The database of this software was modified for Iranian foods. Finally, we converted all the items to a daily intake. Validity and reliability of the FFQ was reported previously which showed good results in this regard (22–24).

The population in which this FFQ has been examined was adults (older than 18). Therefore, we had also the age range of 18–28 in this population, which was the age range of the present study. Studies regarding the determination of the validity and reliability of FFQs are expensive. Therefore, there may be no cost benefit in repeating these kinds of studies in similar populations. Furthermore, a previously published paper among this population showed a significant relationship between dietary diversity score and obesity and abdominal adiposity. Therefore, we came to the conclusion that this FFQ had suitable validity and reliability. Total energy intake was calculated by summing up energy intakes from all foods. We had excluded the under reporters and over reporters of energy intake. According to our previous studies in Iran (22–24) we considered those with energy intake lower than 800 kcal per day as under reporters and those with energy intake higher than 4,200 kcal per day as over reporters.

Assessment of anthropometric measures. Weight was measured in minimally clothed subjects by digital scales. Height was measured by using a tape measure while the subjects were standing in a normal position. Body mass index (BMI) was calculated as weight (in kg) divided by height (in m²). The narrowest level was considered for measuring the waist circumference (WC) and the maximum level over light clothing was used for measuring hip circumference, both of them by using an unscratched tape, without any pressure to body surface; measurements were recorded to the nearest 0.1 cm (25).

Assessment of other variables. Socio-demographic and physical status information was obtained with questionnaires. A metabolic equivalent hour per week was considered as the unit for expression of physical activity level (MET·h/week) (26).

Definition of terms. Obesity was defined as BMI ≥ 30 kg/m² (27) and overweight was considered as BMI 25 < 30 kg/m² (25). Waist circumference more than 88 cm, was considered as abdominal obesity (28).

Dietary diversity score. Dietary diversity score was calculated according to the method of Kant et al. (29, 30). Five food groups based on the food groups introduced by the USDA Food Guide Pyramid (bread-grains, vegetables, fruits, meats and dairy) was considered (31). The main groups mentioned were divided into 23 subgroups. These subgroups show the dietary diversity across the groups of the Food Guide Pyramid (31). Seven subgroups were considered for bread-grain group (refined bread, biscuits, macaroni, whole bread, corn flakes, rice, refined flour). We divided fruits into 2 subgroups (fruit and fruit juice, berries and citrus). Vegetable was divided in to 7 subgroups (vegetables, potato, tomato, other starchy vegetables, legumes, yellow vegetables, green vegetables). Four subgroups were considered for meat (red meat, poultry, fish, eggs) and for dairy we considered 3 subgroups (milk, yogurt, cheese). Consuming at least one-half serving on one day according to the Food Pyramid quantity criteria defined are as a consumer of each group. Each of the 5 broad food categories receive a maximum diversity score of 2 out of the 10 possible score points. Total score was the sum of the scores of the five main groups. The maximum and minimum scores of total dietary diversity were between 0 and 10. The same method was used for calculating each food group diversity score, so the maximum and minimum scores of food group diversity were 0–2 within each of the food groups. Consuming at least one-half serving of any subgroup on one day according to the Food Pyramid quantity criteria was considered. For example in bread-grain group, if a person was the consumer of whole grain and macaroni and biscuits his or her score was calculated as (3 × 7) × 2 = 8.5. Therefore, the diversity score of the bread grain group is 0.85.

Dietary energy density (DED). For calculating this variable each individual’s reported daily energy intake (kcal/d) was divided into total weight of foods (excluding beverages) consumed (g/d) (30). Total weight of foods consumed by subjects was calculated by summing up the weight of foods only (154 out of 168 food items in the FFQ). We did not consider weight of drinks consumed because based on some findings, the effect of dietary energy density on body weight is related to the changes in weight of food intake, not drinks (33).

Healthy eating index (HEI). HEI was calculated according to the method of Kennedy et al. (34). In this method, HEI contains 10 different components. The first five components are the amount of five groups of grains, vegetables, fruits, milk and meat groups as expressed in servings/d. Intakes at or above recom-
Table 1. Socio-demographic characteristics of the Isfahanian young women adults among different quartiles of dietary energy density.

| Variables                  | Quartiles of dietary energy density |  |  |  |  |
|----------------------------|-------------------------------------|---|---|---|---|
| n                          | 114                                 | 167 | 57 | 72 | — |
| Age (y)                    | 23.2±1.8 ^1                        | 20.7±1.6 | 20.5±1.4 | 19.1±1.2 | 0.04 |
| Body mass index (kg/m^2)   | 24.0±4.1                            | 24.9±4.2 | 26.1±4.6 | 27.8±5.0 | 0.03 |
| Weight (kg)                | 60.5±7.1                            | 63.8±8.3 | 66.8±9.0 | 73.9±10.1 | 0.01 |
| Height (m)                 | 1.59±0.3                            | 1.60±0.3 | 1.60±0.4 | 1.63±0.4 | 0.08 |
| Waist circumference (cm)   | 83.1±10.1                           | 85.3±10.5 | 87.7±11.1 | 89.0±11.3 | 0.04 |
| Physical activity (MET.h/w)| 13.1±8.9                            | 12.5±8.3 | 11.8±7.9 | 11.1±7.6 | 0.03 |
| Overweight and obesity (%) | 8.1                                 | 14.2    | 24.0    | 30.2    | 0.01 |
| Abdominal adiposity (%) ^2 | 3.1                                 | 7.8     | 11.2    | 17.9    | 0.02 |
| Socioeconomic status (%)   | 0.89                                |        |        |        |  |
| Weak                       | 20                                  | 19      | 20      | 20      | — |
| Moderate                   | 62                                  | 61      | 60      | 60      | — |
| Strong                     | 18                                  | 20      | 20      | 20      | — |
| Systolic blood pressure (mmHg) | 101±13                  | 103±11  | 105±10  | 103±10  | 0.15 |
| Diastolic blood pressure (mmHg) | 72±9                                  | 74±10   | 73±10   | 72±11   | 0.41 |

1^p-values are resulted from multivariate analysis of variance in quantitative variables and from Fisher’s exact and χ^2 tests regarding the qualitative variables.

2Values are mean±SD, otherwise it is indicated.

3Defined as BMI more than 25 kg/m^2.

4Defined as waist circumference more than 88 cm.

Recommended amounts were awarded a food score of 10 points (35). Those who consumed no servings of a food group received a score of 0. Between 0 and 10, the scores were calculated proportionately. Component numbers 6 and 7 show the score of the percent consumed of total fat and saturated fatty acids, respectively. Components 8 and 9 show the score of cholesterol intake and dietary variety. A full score of 10 points was awarded for diets with <30% energy from fat, <10% energy from saturated fat and <300 mg cholesterol. The number 10 is related to sodium. A full score of 10 was awarded to those not adding table salt according to the food habit questionnaire.

Mean adequacy ratio (MAR) and nutrient adequacy ratios (NAR). For calculating the MAR the ratio of daily individual intakes to standard recommended amounts for the subject’s sex and age category was used. The standard recommended amounts were based on RDA (Recommended Dietary Allowances) and DRI (Dietary Reference Intake) (36). The MAR for ten nutrients including vitamin D, vitamin B12, vitamin B6, vitamin A, vitamin B2, niacin, vitamin C, calcium, iron, zinc was estimated according to the mentioned formula. MAR was calculated as the sum of NARs divided by the number of nutrients (n=10) (37).

Prevalence of nutrient deficiency. NAR was used for estimating the nutrient deficiency. NAR lower than 1 was considered as deficiency.

Statistical methods. Statistical Package for Social Science (SPSS Inc., Chicago, IL, Version 16.0) was used for all statistical analyses. For comparing the mean of diet quality indices such as HEI, MAR and NAR of ten nutrients as well as the general characteristics among different quartiles of dietary energy density multivariate analysis of variance (MANOVA) was used. χ^2 test was used for comparing the qualitative variables and also percentage of population who have nutrient deficiency among different quartiles of dietary energy density.

RESULTS

General characteristics of the participants across quartiles of DED are shown in Table 1. Compared to those in the lowest quartile, women in the highest quartile of DED had higher BMI and waist circumference, were less physically active, more likely to be overweight or obese, and had higher prevalence of abdominal adiposity.

Table 2 shows the means of HEI, MAR and NARs of different nutrients and the amount of macronutrients and fiber across different quartiles of DED. Those in the highest quartile of DED had the lowest value of HEI, MAR, and NAR of zinc, calcium, vitamin C, vitamin B12 and vitamin B2. Those in the highest quartile of DED had the highest intake of fat, either partially hydrogenated vegetable oil or non-hydrogenated vegetable oil.

Table 3 shows the prevalence of nutrient deficiency across different quartiles of DED. Those in the highest quartile of DED had the highest prevalence of calcium, zinc, vitamin B2, vitamin B12, and vitamin C deficiency (p<0.05).
Table 2. Dietary quality indices among the quartiles of dietary energy density of Isfahanian young women adults.

| Variables                        | Quartiles of dietary energy density | $p$  |
|----------------------------------|-------------------------------------|------|
|                                 | First $<1.3$ | Second $1.3–1.6$ | Third $1.6–1.7$ | Fourth $>1.7$ |      |
| HEI$^1$                          | $61.5\pm14.1$ | $58.1\pm16.4$ | $55.7\pm16.2$ | $51.1\pm16.0$ | 0.001 |
| MAR$^2$                          | $1.34\pm6.1$ | $1.29\pm5.7$ | $1.28\pm4.7$ | $1.11\pm4.6$ | 0.04  |
| NARs$^3$ of different nutrients  |                                     |      |                |                |      |
| Zinc                             | $1.1\pm0.4$ | $1.1\pm0.4$ | $1.1\pm0.3$ | $0.9\pm0.3$ | 0.02  |
| Iron                             | $0.7\pm0.3$ | $0.7\pm0.3$ | $0.7\pm0.2$ | $0.7\pm0.2$ | 0.86  |
| Calcium                          | $1.2\pm0.4$ | $1.1\pm0.5$ | $1.1\pm0.5$ | $0.9\pm0.4$ | 0.01  |
| Vitamin C                        | $2.2\pm1.5$ | $2.2\pm1.4$ | $1.8\pm0.8$ | $1.7\pm1.5$ | 0.03  |
| Vitamin D                        | $0.4\pm0.4$ | $0.4\pm0.4$ | $0.3\pm0.3$ | $0.3\pm0.2$ | 0.07  |
| Niacin                           | $1.4\pm0.5$ | $1.5\pm0.7$ | $1.4\pm0.5$ | $1.4\pm0.6$ | 0.39  |
| Vitamin B12                      | $2.0\pm1.5$ | $1.9\pm1.4$ | $2.3\pm2.2$ | $1.4\pm1.1$ | 0.006 |
| Vitamin B2                       | $2.2\pm0.8$ | $2.1\pm0.8$ | $2.0\pm0.7$ | $1.8\pm0.6$ | 0.01  |
| Vitamin B6                       | $1.3\pm0.6$ | $1.3\pm0.6$ | $1.2\pm0.4$ | $1.2\pm0.5$ | 0.57  |
| Vitamin A                        | $1.4\pm1.7$ | $1.4\pm1.5$ | $1.3\pm0.6$ | $1.2\pm0.6$ | 0.88  |
| Macronutrients (g/d)             |                                     |      |                |                |      |
| Carbohydrate                     | $316\pm33$  | $321\pm35$  | $327\pm37$  | $339\pm38$  | 0.04  |
| Fat                              | $69\pm11$   | $72\pm13$   | $75\pm15$   | $83\pm17$   | 0.03  |
| Protein                          | $64\pm14$   | $67\pm15$   | $65\pm14$   | $66\pm13$   | 0.56  |
| Fiber                            | $19\pm8$    | $15\pm6$    | $13\pm6$    | $8\pm3$     | 0.03  |
| Total weight of foods (g/d)      | $1.392\pm143$ | $1.234\pm123$ | $1.183\pm102$ | $1.153\pm101$ | 0.13 |
| Total energy intake (kcal/d)     | $1.783\pm157$ | $1.981\pm166$ | $2.011\pm189$ | $2.131\pm197$ | 0.02 |

$^1$ HEI: healthy eating index.  
$^2$ MAR: mean adequacy ratio.  
$^3$ NAR: nutrient adequacy ratio.

Table 3. Prevalence of nutrient deficiency among quartiles of dietary energy density.

| Variables               | Quartiles of dietary energy density | $p$   |
|-------------------------|-------------------------------------|-------|
|                        | First $<1.3$ | Second $1.3–1.6$ | Third $1.6–1.7$ | Fourth $>1.7$ |      |
| Zinc deficiency         | $35.1$ | $36.5$ | $38.6$ | $58.3$ | 0.007 |
| Iron deficiency         | $81.6$ | $85.6$ | $84.2$ | $81.9$ | 0.80  |
| Calcium deficiency      | $32.5$ | $37.1$ | $47.4$ | $54.2$ | 0.01  |
| Vitamin C deficiency    | $13.2$ | $16.8$ | $21.1$ | $37.5$ | 0.001 |
| Vitamin D deficiency    | $89.5$ | $90.4$ | $93.0$ | $95.8$ | 0.43  |
| Niacin deficiency       | $20.2$ | $19.8$ | $12.3$ | $30.6$ | 0.07  |
| Vitamin B12 deficiency  | $14.0$ | $12.6$ | $19.3$ | $45.8$ | 0.001 |
| Vitamin B2 deficiency   | $0$    | $1.2$  | $5.3$  | $12.5$ | 0.001 |
| Vitamin B6 deficiency   | $34.2$ | $29.9$ | $36.8$ | $34.7$ | 0.81  |
| Vitamin A deficiency    | $41.2$ | $41.3$ | $35.1$ | $44.4$ | 0.75  |

**DISCUSSION**

The results of the current study, which was conducted on young women adults, indicated that energy-dense diets had low nutrient quality. There are several studies regarding the relationship between DED and dietary quality indices. However, it is recommended to determine such associations separately in each region and country because of different dietary intakes and dietary patterns in each country. Specific dietary habits in Iran such as consuming a high amount of refined carbohydrate, simple sugars and fats make it necessity to conduct separate research in this region. Furthermore, there are few reports from the Middle East and Iran in this regard.

Several studies have suggested that whole foods and different types of foods and total variety of diet are better tools for diet quality assessment rather than quantitative assessment of macro and micronutrients (38). Indeed, using a food-based scoring method may provide more adaptation to short dietary assessment methods which focus on food consumption rather than the detailed measurement of food consumption (39) and because of inclusion measurement of over consumption; it is a better method to assess dietary quality (40).

Our findings regarding the dietary quality and energy density and also energy density and nutrient density are consistent with previous studies. Whereas the less energy-dense diets are nutrient-rich, the more energy-dense diets are nutrient-deficient (15, 16, 41–
In the young women, a high energy-dense-diet was associated with higher carbohydrate and fat and lower fiber consumption than for those consuming a low energy-dense diet. The adherence to a high energy-dense diet was also characterized by lower diet quality indices. These findings may specially explain how the different dietary patterns affect the nutrient needs of youths. It must be taken into account that a low-dense and high quality diet does not necessarily meet all nutrient needs regarding to RDAs. Therefore, we calculated NARs for some key nutrients as compliance with RDA in terms of DED. The adequacy of zinc, calcium, vitamin C, B2 and B12 were significantly lower in the present population. Previous studies also revealed the inverse association between various components of HEI, such as vegetables, fruits, dairy products and DDS, and nutrient adequacy which was shown by several studies (37, 45).

Today, DED has been focused on as an important determinant of chronic disease, specially obesity, weight status and anthropometric measures (7–12). In the present population, we observed an inverse association between DED and anthropometric measures such as DDS and Mediterranean diet score (MDS) was shown by others (37, 43), it is concluded that the inverse association between DED and nutrient adequacy might be derived from lower diet quality in higher DED. On the other hand, decreasing of dietary quality indices across DED quartiles might be the reason for lower means of MARs and NARs. It might be due to the favorable association between various components of HEI, such as vegetables, fruits, dairy products and DDS, and nutrient adequacy which was shown by several studies (37, 45).

In conclusion, our findings suggest that low-energy-dense diets characterized by lower intake of fat and carbohydrate and higher intake of fiber, are associated with higher diet quality indices such as HEI, MARs and NARs for some key nutrients. Furthermore, those in the top versus the bottom quartile of DED had lower risk of being overweight and general or abdominal obesity. However, because of different dietary patterns and habits among Iranians and because of limited studies in this field, our results need to be confirmed by more investigation.

Competing interests
Authors had no competing interest.

Author contributions
LA and AE participated in the collection of data, conception and design, statistical analysis and data interpretation, manuscript drafting and approval of the final manuscript for submission. FH helped in manuscript drafting. LA, FH and AE: no conflicts of interest.

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