Associations between adherence to MIND diet and metabolic syndrome and general and abdominal obesity: a cross-sectional study

Saba Mohammadpour, Parivash Ghorbaninejad, Nasim Janbozorgi and Sakineh Shab-Bidar*

Abstract

Background: There is a lack of studies examining the association between Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) and metabolic syndrome (MetS) and obesity. Thus, this study aimed to investigate the association of adherence to the MIND diet with MetS and general and abdominal obesity.

Methods: This cross-sectional study was performed on 836 Iranian adults, 18–75 years old. A 167-item food frequency questionnaire (FFQ) was used to assess dietary intakes of participants. Anthropometric measurements, blood pressure, fasting blood glucose and lipid profile of each participant were recorded. The guidelines of the National Cholesterol Education Program Adult Treatment Panel III (ATP III) was used to define MetS.

Results: Mean age of study participants was 47.7 ± 10.7 years. The prevalence of MetS was 36.1% and mean body mass index (BMI) and waist circumference (WC) was 27.7 ± 4.69 kg/m² and 92.0 ± 12.4 cm respectively. Those who were in the third tertile of the MIND diet score compared to the first tertile had 12% lower odds of having the MetS (ORs: 0.88; 95% CI 0.62–1.24) but the association was not significant (P = 0.77). There was a significant inverse association between the MIND diet score and odds of reduced high-density lipoprotein cholesterol (HDL-C) (ORs: 0.59; 95% CI 0.41–0.85; P = 0.008) and general obesity (ORs: 1.19; 0.80–1.78; 95% CI 0.80–1.78; P = 0.02) in crude model and after controlling for confounders.

Conclusions: We found that the MIND diet score is inversely associated with odds of reduced HDL and general obesity in Iranian adults.

Keywords: MIND diet, Metabolic syndrome, General obesity, Central obesity, Cross-sectional
but the findings were inconsistent [6–8]. In some studies, adherence to the DASH diet was inversely associated with odds of MetS and some of its components including elevated blood pressure, serum HDL-C, serum triglyceride (TG) and high waist circumference (WC), and body mass index (BMI) in Iranian population [6, 8], but this association was not observed in European patients [7]. Also, some components of the MD have been related to a lower prevalence of MetS criteria and insulin resistance [9]. In addition, a cross-sectional study demonstrated no association between MD and MetS in patients with T2D [10].

Recently, Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) was identified as a new dietary pattern, which is a combination of Mediterranean-DASH diets [11]. That has been shown to be effective in brain health and many studies have shown the association of the MIND diet and neurological diseases [12, 13]. The MIND diet emphasizes 10 components, that are brain-healthy foods including green leafy vegetables, other vegetables, berries, nuts, beans, whole grains, fish, poultry, olive oil, and wine; and 5 brain-unhealthy foods including cheese, butter or margarine, fast foods or fried foods, red meat and pastries or sweets [13].

Therefore, unlike the DASH and MD diets, it emphasizes on consumption of green leafy vegetables and berries, not other types of vegetables and fruits, and a separate category for cakes and pastries. Also includes fast foods, fried foods, butter and margarine that they had not been included in the DASH or MD diet [13].

There are limited studies on the relationship between the MIND diet and obesity. Aminianfar et al. [14] found no significant association between adherence to the MIND diet and general and central obesity in a sample of Iranian adults live in Isfahan. However, the relationship between the MIND diet and MetS has not been assessed. Due to the continuous increase in MetS prevalence during the last few decades and an increasing rate of obesity, we aimed to investigate the relationship between adherence to the MIND diet and MetS and obesity in Iranian adults.

**Materials and methods**

**Study design and participants**

This cross-sectional study was performed on 850 Iranian adults (20–59 years old) who referred to Health centers in five regions of Tehran: North, South, East, West, and Central. After the random selection of Health centers, an identical number of subjects were randomly chosen from each center. Individuals who had at least one incomplete variable were excluded and finally, 836 adults remained.

Inclusion criteria were being 18–75 years old and to be inclined to cooperate in the present study and exclusion criteria were having the kidney, liver, and lung diseases and other conditions that had negative effects on the cardiovascular or respiratory system health, or infectious and active inflammatory diseases, pregnancy, lactation, routine supplement or drug use, like weight loss, hormonal, sedative drugs, thermogenic supplements such as caffeine and green tea, conjugated linoleic acid (CLA), etc. The study protocols were approved by the ethical committee of Tehran University of Medical Sciences and in accordance with the Declaration of Helsinki. After informing subjects in detail about the study aims, written informed consent was obtained from all of them.

**Demographic data**

Data on age, sex, education level, marital status, smoking, occupation, and the number of diseases was collected by demographic questionnaire.

**Physical activity**

A validated International Physical Activity Questionnaire (IPAQ) was used to assess subjects’ physical activity levels. Recorded amounts were presented based on Metabolic Equivalents (METs) and categorized into three classes (very low: < 600, low: 600–3000, and moderate and high > 3000 MET-min/week) [15].

**Anthropometric and blood pressure assessment**

Weight was measured with light clothing and without shoes using a digital scale (808Seca, Germany) to the nearest of 0.1 kg and the height was estimated while standing and keeping the shoulders and hips against the wall without shoes, using a stadiometer (Seca, Germany) with an accuracy of 0.1 cm. Body mass index (BMI) was calculated as weight divided by squared height and presented as kg/m². Waist circumference (WC) was measured between the lower rib and iliac crest, using a tape meter, according to standard guidelines. Waist to hip ratio (WHR) was calculated as waist circumference (cm) divided by hip circumference (cm).

After enough rest (at least 10–15 min), blood pressure was obtained by a digital barometer (BC 08, Beurer, Germany) in sitting position, and the mean of two measurements reported for each person.

**Biochemical assessments**

First, a 10 mL venous blood sample was obtained from each subject after 7–10 h of fasting, then centrifuged for 20 min. Fasting blood glucose (FBG) was measured using a commercial kit (Pars Azmoon, Tehran) by enzymatic colorimetric assay (glucose oxidase). High-density lipoprotein (HDL-C) was assessed by the cholesterol oxidase phenol-amino-pyrine method, and triglyceride (TG) was measured by the enzymatic
method of glycerol-3-phosphate oxidase phenol-amino-
pyrene with automatic apparatus (Selecta E, Vitalab, Netherland).

**Dietary assessment**

Usual dietary intake was estimated using a valid and reli-
able 168-item Food Frequency Questionnaire (FFQ) [16] which included a list of groceries and a standard size of each food item and was administered by skilled dietitians via face-to-face interviews. Participants were asked to report the frequency of consumption of each item on a daily, weekly, monthly, and annual basis.

Converting of consumed food portion sizes to grams was done by household measures [17] and calculated using a modified version of NUTRITIONIST IV software for Iranian foods (version 7.0; N-Squared Computing, Salem, OR, USA).

**Calculation of MIND diet score**

We used dietary intakes obtained from FFQ to calcu-
late the MIND diet score. This diet score was included 15 food items which were classified to brain-healthy and unhealthy food groups. The first food group con-
tained 10 items such as green leafy vegetables, other vege-
tables, nuts, berries, beans, whole grains, fish, poultry, olive oil, and wine [18]. However, wine consumption was excluded. This beverage is consumed generally low in Muslim countries and prohibited in Islam, so the information on its consumption among Iranian is limited. Red meats, butter and stick margarine, cheese, pastries and sweets, and fast/fried food, are also considered as an unhealthy food group. To estimate the MIND diet score, we categorized participants based on tertile groups of the above-mentioned components’ intakes to minimize mis-
classification. Participants in the first, second, and third tertiles of brain-healthy food groups’ intake were given a score of 0, 0.5, and 1, respectively. Moreover, in brain-
unhealthy food groups, we advocated scores of 1, 0.5, and 0 to individuals of the lowest, middle, and the highest tertiles, in order. Finally, the total MIND diet score was obtained by summing up the scores of these food items and ranged from 0 to 13 [19].

**Obesity and MetS definition**

General obesity was defined as BMI ≥ 30 kg/m². Further, WC ≥ 102 cm for men and ≥ 88 cm for women, were considered as central obesity risk factors [20].

The presence of at least 3 of the following criteria was considered as MetS: (1) abdominal obesity (WC ≥ 102 cm for men and ≥ 88 cm for women); (2) low concentrations of HDL-C (< 50 mg/dL for women and < 40 mg/dL for men); (3) high serum TG levels (≥ 150 mg/dL); (4) abnormal homeostasis of glucose (FBS > 100 mg/dL); and (5) elevated blood pressure (systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg) [21].

**Data analysis**

All statistical analyses were done using the Statistical Package for the Social Sciences (SPSS version 25; SPSS Inc.). We considered P < 0.05 as the significance level. The normality test was performed by the Kolmogorov–Smirnov test and also the Q–Q plot. We analyzed the study participants’ characteristics according to the MIND diet score tertiles, using one-way analysis of variance (ANOVA) and χ² tests for continuous and categorical variables, respectively. Data are shown as the mean ± SD for continuous variables and percent (%) for categorical ones. Analysis of covariance (ANCOVA) was conducted to compare variables across the tertiles of the MIND diet score after controlling for confounders such as age, gen-
der, marital status, physical activity, educations status, occupation, smoking, energy intake, and BMI. Odds ratio and 95% confidence intervals were obtained using logis-
tic regression to determine the relationship of the MIND diet score with obesity and MetS. The risk was reported in crude and 3 adjusted models. In this analysis, the first tertile of exposure was considered as the reference category.

**Results**

Mean age of study participants was 47.7 ± 10.7 years and 584 of them were female. MetS was prevalent among 36.1% (307) of study participants and mean BMI and WC in the whole study population was 27.7 ± 4.69 kg/m² and 92.0 ± 12.4 cm, respectively. Demographic characteris-
tics and anthropometric measures of participants across tertiles of the MIND diet score are shown in Table 1. There were no significant statistical differences in mean WC, BMI, SBP, and DBP and distribution of sex, smoking, education, occupation, metabolic disorders, marital status, and physical activity across tertiles of the MIND diet score. There were statistical differences in the distribution of general obesity (P = 0.01) and reduced serum HDL-C (P = 0.002).

Dietary intakes of macronutrients and components of MIND diet score across tertiles of the MIND diet score are indicated in Table 2. Participants in the highest tertile of the MIND diet score had greater intakes of green leafy vegetables, other vegetables, berries, beans, fish, poultry, and olive oil, and lower intakes of fast fried foods and pastries and sweets compared with those in the lowest tertile.

The multivariate-adjusted means for TG, SBP, DBP, FBS, HDL-C, WC, and BMI according to the tertiles of the MIND diet score are shown in Table 3. In the crude
Table 1  General characteristics of the participants in the study based on tertiles (T) of MIND diet score

|                          | MIND diet score | P-value |
|--------------------------|-----------------|---------|
|                          | T1 (< 6) (n = 294) | T2 (6.5–7.5) (n = 278) | T3 (8<) (n = 264) |
|                          | Mean ± SD       | Mean ± SD       | Mean ± SD       |
| Age (year)               | 43.6 ± 10.7     | 45.9 ± 10.6     | 44.7 ± 10.7     | 0.03 |
| Weight (kg)              | 72.3 ± 12.7     | 74.1 ± 14.4     | 74.3 ± 13.4     | 0.16 |
| BMI (kg/m²)              | 27.2 ± 4.22     | 28.1 ± 5.06     | 27.9 ± 4.69     | 0.09 |
| WC (cm)                  | 91.7 ± 11.8     | 93.0 ± 12.7     | 91.7 ± 12.4     | 0.34 |
| Systolic blood pressure (mmHg) | 119.8 ± 19.1   | 119.7 ± 24.4   | 119.3 ± 23.1   | 0.95 |
| Diastolic blood pressure (mmHg) | 78.4 ± 11.9    | 77.9 ± 14.7    | 78.3 ± 14.8    | 0.79 |
| Sex, n (%)               |                 |                 |                 | 0.37 |
| Male                     | 83 (31.8)       | 93 (35.6)       | 85 (32.6)       |     |
| Female                   | 211 (36.7)      | 185 (32.2)      | 179 (31.1)      |     |
| Smoking, n (%)           |                 |                 |                 | 0.09 |
| Not smoking              | 278 (36.6)      | 248 (32.7)      | 233 (30.7)      |     |
| Quit smoking             | 6 (18.2)        | 13 (39.4)       | 14 (42.4)       |     |
| Smoking                  | 10 (22.7)       | 17 (38.6)       | 17 (38.6)       |     |
| Education, n (%)         |                 |                 |                 | 0.43 |
| Illiterate               | 23 (31.9)       | 28 (38.9)       | 21 (29.2)       |     |
| Under diploma            | 75 (33.8)       | 71 (32.0)       | 76 (34.2)       |     |
| Diploma                  | 102 (39.8)      | 75 (29.3)       | 79 (30.9)       |     |
| Educated                 | 94 (32.9)       | 104 (36.4)      | 88 (30.8)       |     |
| Occupation, n(%)         |                 |                 |                 | 0.89 |
| Employee                 | 74 (34.3)       | 77 (35.6)       | 65 (30.1)       |     |
| Housekeeper              | 172 (36.4)      | 148 (31.4)      | 152 (32.2)      |     |
| Retired                  | 40 (32.5)       | 43 (35.0)       | 40 (32.5)       |     |
| Unemployed               | 8 (32.0)        | 10 (40.0)       | 7 (28.0)        |     |
| Metabolic disorders, n (%)|                 |                 |                 | 0.36 |
| Yes                      | 184 (33.4)      | 187 (33.9)      | 180 (32.7)      |     |
| No                       | 108 (38.3)      | 90 (31.9)       | 84 (29.8)       |     |
| Marital status, n (%)    |                 |                 |                 | 0.87 |
| Single                   | 35 (39.3)       | 28 (31.5)       | 26 (29.2)       |     |
| Married                  | 236 (34.9)      | 224 (33.1)      | 217 (32.1)      |     |
| Divorced                 | 23 (32.9)       | 26 (37.1)       | 21 (30.0)       |     |
| Physical activity, n (%) |                 |                 |                 | 0.23 |
| Low                      | 177 (33.3)      | 175 (33.0)      | 179 (33.7)      |     |
| Moderate                 | 117 (38.5)      | 102 (33.6)      | 85 (28.0)       |     |
| High                     | 0 (0)           | 1 (100)         | 0 (0)           |     |
| General obesity          | 69 (29.1)       | 95 (40.1)       | 73 (30.8)       | 0.01 |
| Components of metabolic syndrome |         |                 |                 |     |
| Abdominal adiposity      | 137 (33.5)      | 148 (36.2)      | 124 (30.3)      | 0.21 |
| Elevated blood pressure  | 103 (35.5)      | 100 (34.5)      | 87 (30.0)       | 0.73 |
| High serum TG            | 112 (35.4)      | 102 (32.3)      | 102 (32.3)      | 0.88 |
| Reduced serum HDL-C      | 148 (41.9)      | 106 (30.0)      | 99 (28.0)       | 0.002 |
| Abnormal glucose homeostasis | 138 (36.1)    | 117 (30.6)      | 127 (33.2)      | 0.32 |

Values are based on mean ± standard deviation or reported percentage
One-way ANOVA for quantitative data and Chi-2 test for qualitative data have been used
MIND diet score: Mediterranean-DASH Intervention for Neurodegenerative Delay; WC: Waist circumference; BMI: body mass index; mmHg: millimeter of mercury; kg: kilogram; kg/m²: kilogram per meter²
P value less than 0.05 was considered significant
In the crude model, there was no significant difference in terms of other components of MetS and BMI across tertiles of the MIND diet score. After controlling for covariates, these associations remained non-significant.

Multivariate adjusted odds ratios and 95% CIs for MetS and its components across tertiles of the MIND diet score are provided in Table 4. In the crude model, although those who were in the third tertile of the MIND diet score compared to the first tertile were less likely to have MetS (OR = 0.88; 95% CI 0.62–1.24), there was no association between higher MIND diet score and MetS (P = 0.77). After adjusting for covariates, this result remained non-significant. Moreover, we found that adherence to the MIND diet was inversely associated with odds of reduced levels of HDL-C (OR: 0.59, 95% CI 0.42–0.83, P = 0.002) and general obesity (OR: 1.24, 95% CI 0.85–1.82, P = 0.01). When potential confounders were taken into account, such association remained significant for reduced levels of HDL-C (OR: 0.59, 95% CI 0.41–0.85, P = 0.008) and general obesity (OR: 1.19, 95% CI 0.80–1.78, P = 0.02). No significant association was seen between adherence to the MIND diet and abdominal obesity, elevated BP, elevated FBS, and increased serum TG in the crude and fully adjusted model.

### Table 2 Dietary intake of macronutrients and components of MIND diet score according to the tertiles (T) of the MIND diet score

| Component                                | Tertiles of MIND diet score | P value | P for trend | P*  |
|-------------------------------------------|----------------------------|---------|-------------|-----|
|                                           | T1 (< 6) (n = 294)         |         |             |     |
|                                           | T2 (6.5–7.5) (n = 278)     |         |             |     |
|                                           | T3 (8<) (n = 264)          |         |             |     |
| Energy, kcal/day                          | Mean ± SD                  |         |             |     |
|                                           | 2504 ± 1168                | 2688 ± 3040 | 2506 ± 1199 | 0.46 | 0.99 | – |
| Macronutrients                            |                            |         |             |     |
| Carbohydrates, g/day                      | 371 ± 198                  | 415 ± 759 | 366 ± 173 | 0.39 | 0.89 | 0.77 |
| Protein, g/day                            | 85.6 ± 45.2                | 88.9 ± 58.6 | 84.5 ± 38.1 | 0.53 | 0.79 | 0.87 |
| Total fat, g/day                          | 82.5 ± 45.3                | 80.9 ± 49.7 | 83.4 ± 59.1 | 0.84 | 0.83 | 0.40 |
| Components of MIND diet score             |                            |         |             |     |
| Brain healthy foods                       |                            |         |             |     |
| Green leafy vegetables, g/day             | 32.6 ± 26.0                | 54.9 ± 68.5 | 96.2 ± 88.4 | <0.001 | <0.001 | <0.001 |
| Other vegetables, g/day                   | 253 ± 139                  | 380 ± 301 | 533 ± 352 | <0.001 | <0.001 | <0.001 |
| Nuts, g/day                               | 8.25 ± 34.1                | 8.07 ± 23.9 | 12.2 ± 31.6 | 0.19 | 0.11 | 0.19 |
| Berries, g/day                            | 3.80 ± 29.4                | 6.29 ± 23.3 | 14.2 ± 50.8 | 0.002 | 0.001 | 0.002 |
| Beans, g/day                              | 31.5 ± 42.8                | 40.4 ± 40.3 | 50.7 ± 50.7 | <0.001 | <0.001 | <0.001 |
| Whole grains, g/day                       | 1.64 ± 14.1                | 2.55 ± 14.7 | 4.01 ± 13.0 | 0.13 | 0.04 | 0.13 |
| Fish, g/day                               | 7.49 ± 10.5                | 11.6 ± 21.2 | 18.0 ± 29.0 | <0.001 | <0.001 | <0.001 |
| Poultry, g/day                            | 18.0 ± 28.6                | 24.8 ± 33.1 | 37.7 ± 46.5 | <0.001 | <0.001 | <0.001 |
| Olive oil, g/day                          | 0.40 ± 1.36                | 1.51 ± 4.58 | 2.61 ± 4.62 | <0.001 | <0.001 | <0.001 |
| Brain unhealthy foods                     |                            |         |             |     |
| Cheese, g/day                             | 25.0 ± 23.8                | 22.2 ± 30.1 | 20.6 ± 27.0 | 0.15 | 0.05 | 0.13 |
| Red meat and products, g/day              | 43.5 ± 39.3                | 47.5 ± 55.7 | 49.5 ± 91.6 | 0.54 | 0.27 | 0.54 |
| Butter and margarine, g/day               | 7.99 ± 12.7                | 6.66 ± 21.3 | 6.94 ± 22.0 | 0.67 | 0.51 | 0.68 |
| Fast fried foods, g/day                   | 21.1 ± 56.1                | 12.0 ± 22.0 | 10.2 ± 20.1 | 0.001 | 0.001 | 0.001 |
| Pastries and sweets, g/day                | 81.0 ± 89.5                | 67.3 ± 87.4 | 66.8 ± 77.6 | 0.07 | 0.04 | 0.08 |

Values are based on mean ± standard deviation or reported percentage

One-way ANOVA have been used

Green leafy vegetables: cabbage, greens, lettuce, kale, spinach; other vegetables: green/red peppers, potato, peas or lima beans, tomatoes, tomato sauce, eggplant, onion, cucumber, squash, cooked carrots, raw carrots, broccoli, celery, corn, zucchini; berries: strawberries (strawberry, cherries, fresh berries)

Nuts: walnuts, pistachios, hazelnuts, almonds, peanuts; whole grains: dark bread (Iranian); fish: fish and tuna fish; beans: beans, lentils, peas, chick pea, soybeans; poultry: chicken, butter, margarine: butter, margarine, animal fats; cheese: cheese, red meat and products: red meat, hamburger, sausages; fast fried foods: French fries, pizza; pastries and sweets: biscuit, cake, chocolate, ice cream, confections, cocoa, Gaz (an Iranian confectionery made of sugar, nuts and tamarisk), cookies, candy, ice cream

MIND diet score Mediterranean-DASH Intervention for Neurodegenerative Delay

P value less than 0.05 was considered significant

*Adjusted for energy intake
Discussion

In the present study, we found a non-significant inverse association between adherence to the MIND diet and odds of MetS and abdominal obesity. However, our findings showed a negative significant relationship between the MIND diet score and odds of reduced levels of HDL-C and general obesity. Such significant association was also seen even after taking potential confounders into account. To the best of our knowledge, this is the first study that examined the relationship between the MIND diet score with MetS and its components and general and abdominal obesity in Iranian adult population.

Generally, the MIND dietary pattern is a combination of the MD and the DASH diet which differs by assigning separate groups for green leafy vegetables and berries, as well as cakes and pastries. In comparison to the MD and DASH diet, fruit was omitted and fish was not administered regularly, because according to some evidence 2–3 times a week is appropriate for neuroprotective effects [11]. Several studies have assessed the link between dietary pattern and MetS [7, 9]; however, little attention has been paid on the MIND diet. In the current study, we observed a non-significant association between adherence to the MIND diet and the odds of MetS.

Although there are no observational studies that directly assessed the association between adherence to the MIND diet and MetS, several documents have addressed the linkage between the DASH diet and MD and MetS. In agreement with our findings, some studies have shown no significant association between DASH [7] or MD [10] and MetS. Soric et al. [7] in sixty-seven hospitalized schizophrenic patients did not see a significant association between the DASH diet and the prevalence of MetS and its components. In addition, a cross-sectional study on 157 T2D patients, did not show an association between MD and MetS [10]. In contrast, Ghorabi et al. [6] in a sample of 396 Iranian adults, found a significant inverse association between adherence to the DASH diet and odds of MetS, but in line with our study, they found that adherence to DASH diet was inversely associated with reduced levels of HDL-C. Also, a systematic review indicated the beneficial effect of adherence to the MD on the incidence and development of MetS [22].

Another important finding of this study was the inverse significant association between the MIND diet and odds of low serum HDL-C, but no significant association was observed with other components of MetS. In accordance with our finding, Azadbakht et al. [23] in an 8-week randomized trial in 31 patients with T2D suggested the DASH diet could increase HDL-C. In contrast, in the study of Obarzanek et al. [24] DASH diet resulted in lower HDL-C, which can be explained by lower total dietary fat intake.

In this study, we found a significant decrease in general obesity and a non-significant decrease in abdominal obesity following adherence to the MIND diet score. There is limited evidence in this area. In line with our results, Esposito et al. [25] in a meta-analysis, suggested a beneficial effect of MD on weight regardless of energy intake, and also, they declared that energy restriction

| Table 3 The multivariate adjusted means for metabolic syndrome’s components and BMI according to tertiles (T) of MIND diet score |
|-----------------------------------------------|
| **MIND diet score** | **P-value** | **P<sub>1</sub>** | **P<sub>2</sub>** |
| T1 (< 6) (n = 294) | T2 (6.5–7.5) (n = 278) | T3 (8<) (n = 264) |
| **Mean± SD** |
| TG<sup>†</sup> (mg/dL) | 147 ± 86.8 | 144 ± 77.8 | 144 ± 73.2 | 0.93 | 0.90 | 0.90 |
| HDL<sup>‡</sup> (mg/dL) | 48.9 ± 10.4 | 50.5 ± 10.4 | 50.1 ± 9.71 | 0.13 | 0.20 | 0.20 |
| FBS<sup>§</sup> (mg/dL) | 107 ± 31.5 | 110 ± 61.2 | 106 ± 27.8 | 0.47 | 0.43 | 0.43 |
| SBP<sup>¶</sup> (mmHg) | 119.8 ± 19.1 | 119.7 ± 24.4 | 119.3 ± 23.1 | 0.95 | 0.58 | 0.57 |
| DBP<sup>¶</sup> (mmHg) | 78.4 ± 11.9 | 77.9 ± 14.7 | 78.3 ± 14.8 | 0.79 | 0.58 | 0.58 |
| WC<sup>¶</sup> (cm) | 91.7 ± 11.8 | 93.0 ± 12.7 | 91.7 ± 12.4 | 0.34 | 0.25 | 0.24 |
| BMI (kg/m²) | 27.2 ± 4.22 | 28.1 ± 5.06 | 27.9 ± 4.69 | 0.09 | 0.29 | 0.33 |

Values are based on mean ± standard deviation

One-way ANOVA have been used

MIND diet score: Mediterranean-DASH Intervention for Neurodegenerative Delay; TG: triglyceride; HDL: high density lipoprotein; FBS: fasting blood sugar; SBP: systolic blood pressure; DBP: diastolic blood pressure; WC: waist circumference; BMI: body mass index; mmHg, millimeter of mercury; kg: kilogram; kg/m²: kilogram per meter²

P value less than 0.05 was considered significant

P<sub>1</sub>: adjusted for age, gender, marital status, physical activity, educations status, occupation and smoking

P<sub>2</sub>: additionally, adjusted for energy intake

† Also adjusted for BMI
increased the weight loss caused by a MD. Another meta-analysis showed that adherence to the DASH diet significantly decreases body weight (about—1.42 kg in 8–24 weeks), BMI, and WC, especially along with energy-restricted diets [26]. In contrast, Aminianfar et al. [27] found no significant association between adherence to the MIND diet and odds of general and central obesity in both men and women. However, they did not include olive oil in the score and their sample size was lower.

| Table 4 Odd ratios and 95% CIs for MetS and its components across tertiles of the MIND diet score |
|-----------------------------------|-----------------------------|-----------------------------|-----------------------------|
|                                   | MIND diet score             |                             |                             |
|                                   | T1 (< 6) (n = 294)          | T2 (6.5–7.5) (n = 278)      | T3 (8<) (n = 264)           |
| **OR (CI)***                      |                             |                             |                             |
| MetS                              |                             |                             |                             |
| Crude                             | 0.94 (0.67–1.32)            | 0.88 (0.62–1.24)            | 0.77                        |
| Model 1                           | 0.92 (0.64–1.33)            | 0.83 (0.57–1.21)            | 0.64                        |
| Model 2                           | 0.91 (0.63–1.31)            | 0.83 (0.57–1.20)            | 0.63                        |
| Model 3                           | 0.86 (0.55–1.16)            | 0.80 (0.55–1.16)            | 0.50                        |
| Reduced serum HDL                 |                             |                             |                             |
| Crude                             | 0.60 (0.43–0.84)            | 0.59 (0.42–0.83)            | 0.002                       |
| Model 1                           | 0.62 (0.43–0.89)            | 0.59 (0.41–0.86)            | 0.008                       |
| Model 2                           | 0.62 (0.43–0.90)            | 0.59 (0.41–0.86)            | 0.009                       |
| Model 3                           | 0.62 (0.43–0.89)            | 0.59 (0.41–0.85)            | 0.008                       |
| Elevated BP                       |                             |                             |                             |
| Crude                             | 1.04 (0.74–1.47)            | 0.91 (0.64–1.29)            | 0.73                        |
| Model 1                           | 0.85 (0.57–1.26)            | 0.79 (0.53–1.19)            | 0.51                        |
| Model 2                           | 0.83 (0.56–1.24)            | 0.79 (0.53–1.18)            | 0.49                        |
| Model 3                           | 0.79 (0.53–1.18)            | 0.76 (0.51–1.15)            | 0.37                        |
| Elevated FBS                      |                             |                             |                             |
| Crude                             | 0.82 (0.59–1.14)            | 1.04 (0.75–1.46)            | 0.32                        |
| Model 1                           | 0.80 (0.56–1.13)            | 0.98 (0.69–1.38)            | 0.40                        |
| Model 2                           | 0.80 (0.56–1.13)            | 0.98 (0.69–1.38)            | 0.40                        |
| Model 3                           | 0.79 (0.56–1.12)            | 0.97 (0.68–1.37)            | 0.37                        |
| Increased serum TG                |                             |                             |                             |
| Crude                             | 0.94 (0.67–1.32)            | 1.02 (0.72–1.44)            | 0.88                        |
| Model 1                           | 0.97 (0.69–1.38)            | 1.02 (0.72–1.44)            | 0.97                        |
| Model 2                           | 0.96 (0.68–1.36)            | 1.01 (0.71–1.44)            | 0.95                        |
| Model 3                           | 0.97 (0.68–1.37)            | 1.02 (0.72–1.45)            | 0.96                        |
| Abdominal obesity                 |                             |                             |                             |
| Crude                             | 1.30 (0.93–1.81)            | 1.01 (0.72–1.41)            | 0.21                        |
| Model 1                           | 1.29 (0.88–1.88)            | 0.93 (0.64–1.36)            | 0.22                        |
| Model 2                           | 1.27 (0.87–1.86)            | 0.93 (0.63–1.36)            | 0.25                        |
| Model 3                           | 1.17 (0.78–1.76)            | 0.84 (0.56–1.26)            | 0.29                        |
| General obesity                   |                             |                             |                             |
| Crude                             | 1.69 (1.17–2.44)            | 1.24 (0.85–1.82)            | 0.01                        |
| Model 1                           | 1.71 (1.16–2.52)            | 1.20 (0.80–1.79)            | 0.02                        |
| Model 2                           | 1.69 (1.14–2.49)            | 1.19 (0.80–1.78)            | 0.02                        |

Data are presented as odds ratio (95% CI)

Model 1: adjusted for age, gender, marital status, physical activity, education status, occupation and smoking

Model 2: additionally, adjusted for energy intake

Model 3: further adjustment was made for BMI

*MIND diet score Mediterranean-DASH Intervention for Neurodegenerative Delay, MetS metabolic syndrome, WC waist circumference, FBS fasting blood glucose, TG triglyceride, HDL high-density lipoprotein, SBP systolic blood pressure, DBP diastolic blood pressure

*Obtained by binary logistic regression
The discrepancies between these studies and the results of this study can be explained by different amounts of fiber, potassium, and ca. in DASH, MD, and the MIND diet. In the MIND diet dairy is limited to just cheese and fruits are limited to berries. Studies have shown that dairy products are inversely related to the MetS, body weight, and insulin resistance therefore might have beneficial effects on all metabolic disorder characteristics [28]. Calcium’s beneficial effect on the prevention of fat accumulation can also be due to the expression of the uncoupled protein (UCP2) in the white adipose tissue and help thermogenesis and reduce waist circumference [29]. Additionally, casein and conjugated linoleic acid may also play a role in preventing the accumulation of fat [30]. Lower weight and waist circumference can ultimately contribute to lower blood pressure [31].

Fruits are good sources of fiber, antioxidants, and phytochemicals, which can play an important role in weight control [32], suppressing reactive oxygen species and delaying the progression of systemic oxidative damage [33], regulating inflammatory markers [34], and prevention of insulin resistance and MetS [35]. Fruits and vegetables also have sufficient amounts of potassium. Interventional studies have suggested a protective effect of potassium on blood pressure and hypertension [36]. However, Vendrame et al. [37] in their review suggested that regular intake of berries as part of a healthy diet is a promising strategy to prevent MetS and its complications. Oxidative stress is a common characteristic of MetS [38]. Berries are good sources of polyphenols (including flavonoids), tannins, phenolic acids, and lignans [39]. Ruel et al. administered three different doses (125, 250, and 500 mL/day) of cranberry juice in 30 middle-aged men with abdominal obesity for 4 weeks. They saw a significant decrease in body weight, BMI, waist circumference, total/HDL-C ratio, HDL-C and apolipoprotein B, and a significant increase in plasma total antioxidant capacity after 250 mL and/or 500 mL consumption [40].

The beneficial effects of the MIND diet may have been linked to the use of olive oil as the main source of dietary fats and phenolic compounds. George et al. [41] reported that high polyphenol olive oil can improve total and HDL-C and related parameters of oxidative stress. Tsartsou et al. [42] indicated that the major effect of olive oil high in polyphenols is the increase of HDL-C circulation. Also, some randomized controlled trials showed improvement in endothelial function and insulin sensitivity and secretion by olive oil phenolic compounds and oleic acid [43–45].

Reduction in general obesity in this study may be due to many components of the MIND diet. For example intake of less high-calorie-dense foods in the third tertile of the MIND diet score [46]. Also, this diet contains plant-based and low-glycemic index foods that have high dietary fiber, water content, and low glycemic load [47]. Therefore promotes weight loss [48] and negatively influences MetS features [49] such as regulating blood glucose [50], and lipid profile [49].

Our study had some strengths, to the best of our knowledge, this is the first study to investigate the association between the MIND diet score and MetS and general and abdominal obesity. We adjusted for several known factors that may influence the results also the analysis was conducted on a large sample with a wide age range of adults in a Middle East population. In addition, a validated FFQ which provides accurate and reliable information was used to assess dietary intakes. However, it should be mentioned that this study had some limitations because of the cross-sectional design, and no causal associations can be identified, the residual confounders cannot be removed whilst we have controlled for possible confounding. Further well-designed and long term studies with larger sample sizes are needed to confirm these findings.

Conclusions
In conclusion, significant associations were found between adherence to the MIND diet and odds of reduced levels of HDL-C and general obesity. Given the importance of chronic diseases such as MetS and obesity in health status, further investigations are needed.

Abbreviations
MIND: Mediterranean-DASH Intervention for Neurodegenerative Delay; MetS: Metabolic syndrome; FFQ: Food frequency questionnaire; ATP III: Adult Treatment Panel III; BMI: Body mass index; WC: Waist circumference; OR: Odds ratio; HDL-C: High-density lipoprotein cholesterol; CVDs: Cardiovascular diseases; T2D: Type 2 diabetes; FBS: Fasting blood sugar; NCEP: National Cholesterol Education Program; MD: Mediterranean dietary pattern; DASH: Dietary Approaches to Stop Hypertension; TG: Triglycerides; CLA: Conjugated linoleic acid; IPAQ: Physical Activity Questionnaire; METs: Metabolic Equivalents; WHR: Waist to hip ratio; FBG: Fasting blood glucose; UCP2: Uncoupled protein.

Acknowledgements
The authors thank the subjects who participated in the study.

Authors’ contributions
SM and SSB contributed in conception and design of the study. NJ participated in acquisition of data. SM and SSB contributed to data analysis and data interpretation, SM, PG and SSB participated in manuscript drafting, SSB finalized the manuscript. All authors read and approved the final manuscript.

Funding
This research was not financially supported.

Availability of data and materials
Since the privacy of research participants may be compromised, we cannot make the information publicly available.

Ethics approval and consent to participate
This research was not financially supported. The present study was conducted in accordance with the ethical standards of the Tehran University of Medical
The authors declare that they have no competing interests.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 21 September 2020 Accepted: 11 November 2020
Published online: 18 November 2020

References
1. Son Le NT, Kunii D, Hung NT, Sakai T, Yamamoto S. The metabolic syndrome: prevalence and risk factors in the urban population of Ho Chi Minh City. Diabetes Res Clin Pract. 2005;67(3):243–50. https://doi.org/10.1016/j.diabres.2004.07.014.
2. Expert Panel on Detection E. Executive summary of the third report of The National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). JAMA. 2001;285(19):2486–97. https://doi.org/10.1001/jama.285.19.2486.
3. Hu F. Obesity epidemiology. Oxford: Oxford University Press; 2008.
4. Kassi E, Pervanidou P, Kaltsas G, Chrousos G. Metabolic syndrome: definitions and controversies. BMC Med. 2011;9:48. https://doi.org/10.1186/1715-7322-9-48.
5. Inoue Y, Qin B, Poti J, Sacks FM, Dong A, Chen L, et al. Mediterranean diet and morbidity and mortality from cardiovascular disease: a meta-analysis of randomized controlled trials. Nutr J. 2019;18(1):1–9.
6. Ghorabi S, Salari-Moghaddam A, Daneshzad E, Sadeghi O, Azadbakht L, Mohtashemi M. Mediterranean diet and metabolic syndrome components in Iranian adults. Diabetes Metab Syndr. 2019;13(3):1699–704. https://doi.org/10.1016/j.dsx.2019.03.039.
7. Soni T, Mavas M, Rumbak J. The effects of the dietary approaches to stop hypertension (DASH) diet on body mass index and body fat mass and percentage in obese Indian patients: a randomized controlled trial. Nutrients. 2019;11(12):2950. https://doi.org/10.3390/nu11122950.
8. Razavi Zade M, Telkabadi MH, Bahmani F, Salehi B, Farshbaf S, Asemi Z. The effects of DASH diet on weight loss and metabolic status in adults with non-alcoholic fatty liver disease: a randomized clinical trial. Liver Int. 2016;36(4):363–71. https://doi.org/10.1111/liv.13290.
9. Alvarez-León E, Henríquez P, Serra-Majem L. Mediterranean diet and metabolic syndrome: a cross-sectional study in the Canary Islands. Public Health Nutr. 2006;9(8a):1089–98. https://doi.org/10.1017/s136898000600241x.
10. Veissi M, Anari R, Arami R, Shahbazi H, Latifi SM. Mediterranean diet and metabolic syndrome prevalence in type 2 diabetes patients in Ahvaz, southwest of Iran. Diabetes Metab Syndr. 2016;10(2 Suppl 1):S26–9. https://doi.org/10.1016/j.dsx.2016.01.015.
11. Morris MC, Tangney CC, Wang Y, Sacks FM, Bennett DA, Apparaval NT. MIND diet associated with reduced incidence of Alzheimer’s disease. Alzheimers Dement. 2015;11(9):1007–14. https://doi.org/10.1016/j.jalz.2015.04.011.
12. Agarwal P, Wang Y, Buchman AS, Holland TM, Bennett DA, Morris MC. MIND diet associated with reduced incidence and delayed progression of Parkinsonism in old age. J Nutr Health Aging. 2018;22(10):1211–5. https://doi.org/10.1007/s12603-018-1094-5.
13. Morris MC, Tangney CC, Wang Y, Sacks FM, Barnes LL, Bennett DA, Apparaval NT. MIND diet slows cognitive decline with aging. Alzheimers Dement. 2015;11(1):1015–22. https://doi.org/10.1016/j.jalz.2015.04.011.
14. Aminianfar A, Hassanzadeh Keshatri A, Esmaillzadeh A, Adibi P. Association between adherence to MIND diet and general and abdominal obesity: a cross-sectional study. Nutr J. 2020;19(1):1–5. https://doi.org/10.1186/s12937-020-00531-1.
15. Wareham NJ, Jakobsen V, Rennie K, Schuit J, Mitchell J, Hennings S, Day NE. 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. 2003;6(4):407–13. https://doi.org/10.1017/s1368946602002439.
16. Mirrman P, Esfahani FH, Mehrabi Y, Hedayati M, Azizi F. Reliability and relative validity of an FFQ for nutrients in the Tehran lipid and glucose study. Public Health Nutr. 2010;13(5):654–62. https://doi.org/10.1017/s136898000991698.
17. Ghafarpour M, Houshiar-Rad A, Kianfar H, Ghaffarpour M. The manual for household measures, cooking yields factors and edible portion of food. Tehran: Nashre Olume Keshavarzy; 1999.
18. Morris MC, Tangney CC, Wang Y, Sacks FM, Bennett DA, Apparaval NT. MIND diet associated with reduced incidence of Alzheimer’s disease. Alzheimers Dement. 2015;11(9):1007–14.
19. Aminianfar A, Keshtri AH, Esmaillzadeh A, Adibi P. Association between adherence to MIND diet and general and abdominal obesity: a cross-sectional study. Nutr J. 2020;19(1):1–9.
20. World Health Organization. Waist circumference and waist–hip ratio: report of a WHO expert consultation. Geneva: World Health Organization; 2008.
21. Expert Panel on Detection. Executive summary of the third report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). JAMA. 2001;285(19):2486.
22. Esposito K, Kastorini CM, Panagiotakos DB, Giugliano D. Mediterranean diet and metabolic syndrome: an updated systematic review. Rev Endocr Metab Disord. 2013;14(3):255–63. https://doi.org/10.1007/s11154-013-9253-9.
23. Azadbakht L, Fard NR, Karimi M, Baghaei MH, Surkan PJ, Rahimi M, Esmaillzadeh A, Willett WC. Effects of the dietary approaches to stop hypertension (DASH) eating plan on cardiovascular risks among type 2 diabetic patients: a randomized crossover clinical trial. Diabetes Care. 2011;34(1):55–7. https://doi.org/10.2337/dc10-0676.
24. Obarzanek E, Sacks FM, Vollmer WM, Bray GA, Miller ER III, Lin PH, Karanja NM, Most-Windhauer MM, Moore TJ, Swain JF, Bales CW, Proschman MA. Effects on blood lipids of a blood pressure-lowering diet: the dietary approaches to stop hypertension (DASH) trial. Am J Clin Nut. 2001;74(1):80–9. https://doi.org/10.1093/ajcn/74.1.80.
25. Esposito K, Kastorini CM, Panagiotakos DB, Giugliano D. Mediterranean diet and weight loss: meta-analysis of randomized controlled trials. Metab Syndr Relat Disord. 2011;9(1):1–12. https://doi.org/10.1089/met.2010.0031.
26. Soltanis S, Shiri R, Chitouzi MJ, Salehi-Abargouei A. The effect of dietary approaches to stop hypertension (DASH) diet on weight and body composition in adults: a systematic review and meta-analysis of randomized controlled clinical trials. Obes Rev. 2016;17(5):442–54. https://doi.org/10.1111/obr.12391.
27. Aminianfar A, Hassanzadeh Keshatri A, Esmaillzadeh A, Adibi P. Association between adherence to MIND diet and general and abdominal obesity: a cross-sectional study. Nutr J. 2020;19(1):11. https://doi.org/10.1186/s12937-020-00531-1.
28. Chen G-C, Szeto IMY, Chen L-H, Lin S-F, Li Y-J, van Heekezen R, Qin L-Q. Dairy products consumption and metabolic syndrome in adults: systematic review and meta-analysis of randomized controlled clinical trials. Obes Rev. 2016;17(5):442–54. https://doi.org/10.1111/obr.12391.
29. Aminianfar A, Hassanzadeh Keshatri A, Esmaillzadeh A, Adibi P. Association between adherence to MIND diet and general and abdominal obesity: a cross-sectional study. Nutr J. 2020;19(1):11. https://doi.org/10.1186/s12937-020-00531-1.
30. Awad AB, Bernardis LL, Fink CS. Failure to demonstrate an effect of dietary fatty acid composition on body weight, body composition and parameters of lipid metabolism in mature rats. J Nutr. 2019;149:1277–82. https://doi.org/10.1093/jn/nxy085.
31. Aminianfar A, Hassanzadeh Keshatri A, Esmaillzadeh A, Adibi P. Association between adherence to MIND diet and general and abdominal obesity: a cross-sectional study. Nutr J. 2020;19(1):1–5. https://doi.org/10.1186/s12937-020-00531-1.
32. Schroder KE. Effects of fruit consumption on body mass index and weight loss in a sample of overweight and obese dieters enrolled in a weight-loss intervention trial. Nutrition. 2010;26(7–8):727–34. https://doi.org/10.1016/j.nut.2009.08.009.
33. Grundy SM. Metabolic syndrome: a multiplex cardiovascular risk factor. J Clin Endocrinol Metab. 2007;92(2):399–404. https://doi.org/10.1210/jc.2006-0513.

34. Wannamethee SG, Lowe GD, Rumley A, Bruckdorfer KR, Whincup PH. Associations of vitamin C status, fruit and vegetable intakes, and markers of inflammation and hemostasis. Am J Clin Nutr. 2006;83(3):567–74. https://doi.org/10.1093/ajcn.83.3.567 (quiz 726–7).

35. Houston MC. The importance of potassium in managing hypertension. Curr Hypertens Rep. 2011;13(4):309–17. https://doi.org/10.1007/s11906-011-0197-8.

36. Vendrame S, Del Bo C, Ciappellano S, Riso P, Klimis-Zacas D. Berry fruit consumption and metabolic syndrome. Antioxidants. 2016;5(4):34. https://doi.org/10.3390/antiox5040034.

37. Ford ES. Intake and circulating concentrations of antioxidants in metabolic syndrome. Curr Atheroscler Rep. 2006;8(6):448–52. https://doi.org/10.1007/s11883-006-0018-8.

38. Nile SH, Park SW. Edible berries: bioactive components and their effect on human health. Nutrition. 2014;30(2):134–44. https://doi.org/10.1016/j.nut.2013.04.007.

39. Ruel G, Pomerleau S, Couture P, Lemieux S, Lamarche B, Couillard C. Favourable impact of low-calorie cranberry juice consumption on plasma HDL-cholesterol concentrations in men. Br J Nutr. 2006;96(2):357–64. https://doi.org/10.1079/bjn20061814.

40. George ES, Marshall S, Mayr HL, Tatsch-Babet OA, Lassemillante AM, Bramley A, Reddy AJ, Forsyth A, Tierney AC, Thomas CJ, Itsiopoulos C, Marx W. The effect of high-polyphenol extra virgin olive oil on cardiovascular risk factors: a systematic review and meta-analysis. Crit Rev Food Sci Nutr. 2019;59(17):2772–95. https://doi.org/10.1080/10408398.2018.1470491.

41. Tsartou E, Proustos N, Castanas E, Kampa M. Network meta-analysis of metabolic effects of olive-oil in humans shows the importance of olive oil consumption with moderate polyphenol levels as part of the Mediterranean diet. Front Nutr. 2019;6:6–6. https://doi.org/10.3389/fnut.2019.00006.

42. Favourable impact of low-calorie cranberry juice consumption on plasma HDL-cholesterol concentrations in men. Br J Nutr. 2006;96(2):357–64. https://doi.org/10.1079/bjn20061814.

43. de Bock M, Derraik JG, Brennan CM, Biggs JB, Morgan PE, Hodgkinson SC, Hoffman PL, Cutfield WS. Olive (Olea europeae L) leaf polyphenols improve insulin sensitivity in middle-aged overweight men: a randomized, placebo-controlled, crossover trial. PLoS ONE. 2013;8(3):e57622. https://doi.org/10.1371/journal.pone.0057622.

44. Vassiliou EK, Gonzalez A, Garcia C, Tadros JH, Chakraborty G, Toney JH. Oleic acid and peanut oil high in oleic acid reverse the inhibitory effect of insulin production of the inflammatory cytokine TNF-alpha both in vitro and in vivo systems. Lipids Health Dis. 2009;8:25. https://doi.org/10.1186/1479-5868-6-57.

45. Buckland G, Bach A, Serra-Majern L. Obesity and the Mediterranean diet: a systematic review of observational and intervention studies. Obes Rev. 2008;9(6):582–93. https://doi.org/10.1111/j.1467-789X.2008.00503.x.

46. Ludwig DS, Majzoub JA, Al-Zahrani A, Dalal GE, Blanco I, Roberts SB. High glycemic index foods, overeating, and obesity. Pediatrics. 1999;103(3):E26. https://doi.org/10.1542/peds.103.3.e26.

47. Brand-Miller J, Hayne S, Petocz P, Colagiuri S. Low-glycemic index diets in the management of diabetes: a meta-analysis of randomized controlled trials. Diabetes Care. 2003;26(8):2261–7. https://doi.org/10.2337/diacare.26.8.2261.

48. Franz MJ, Bantle JP, Beebe CA, Brunzell JD, Chiasson JL, Garg A, Holzmeister LA, Hoogwerf B, Mayer-Davis E, Mooradian AD, Purnell JQ, Wheeler M. Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications. Diabetes Care. 2002;25(1):148–98. https://doi.org/10.2337/diacare.25.1.148.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.