Diabetes & Metabolic Syndrome: Clinical Research & Reviews 13 (2019) 322–331

Contents lists available at ScienceDirect

Diabetes & Metabolic Syndrome: Clinical Research & Reviews

journal homepage: www.elsevier.com/locate/dsx

Original Article

# Relations of major dietary patterns and metabolically unhealthy overweight/obesity phenotypes among Iranian women

Atieh Mirzababaei [a], Seyedeh Forough Sajjadi [a], Nasim Ghodoosi [a], Sara Pooyan [a], Hana Arghavani [a], Mir Saeed Yekaninejad [b], Khadijeh Mirzaei [a, *]

[a] Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences (TUMS), Tehran, Iran
[b] Department of Epidemiology and Biostatistics, School of Public Health, Tehran University of Medical Sciences (TUMS), Tehran, Iran

ARTICLE INFO

*Article history:*
Received 19 August 2018
Accepted 11 September 2018

*Keywords:*
Metabolic healthy
Metabolic unhealthy
Dietary pattern
Karelis criteria
Obesity and overweight

ABSTRACT

*Objective:* No studies have examined the contribution of major dietary patterns to MUH phenotypes in obese and overweight people based on Karelis criteria. This study was conducted to evaluate the association of major dietary patterns with MUHOW/O and MHOW/O phenotypes.

*Methods:* This cross-sectional study was conducted on 290 overweight and obese women aged 18–50 (BMI≥25 kg/m$^2$). Anthropometric measurements were assessed in all participants. The MH phenotype was defined according to the Karelis criteria. Major dietary patterns were determined using factor analysis of 21 foods groups using a valid and reliable FFQ containing 147 items. Participants' body composition was assessed by BIA. Serum HDL, LDL, TG, insulin, and hs-CRP levels were quantified by ELISA.

*Results:* By the use of factor analysis, 3 major dietary patterns were extracted: healthy dietary pattern (HDP), western dietary pattern (WDP) and unhealthy dietary pattern (UNHDP). Binary logistic analysis showed that participants in the in the upper category of WDP had greater odds of MUH phenotype (OR = 2.33, 95%CI = 1.11–4.91, P = 0.02), after confounder factor control. Individuals with high adherence to the UNHDP score had high odds of MUH phenotype (OR = 1.75, 95%CI = 0.98–3.10, P = 0.05), after adjustment for BMI, age, and total EI, compared to those with low adherence. A positive relation was observed between WDP and levels of hs-CRP, HOMA-IR (OR = 1.94, 95%CI = 0.91–4.10, P = 0.05 and OR = 2.53, 95%CI = 1.26–5.11, P = 0.009) as well as a positive association between UHDP and plasma level of LDL (OR = 1.90, 95%CI = 1.04–3.47, P = 0.03), but an inverse association between HDP and hs-CRP level (OR = 0.56, 95%CI = 0.29–0.92, P = 0.03).

*Conclusions:* The present evidence indicates various significant associations among major dietary patterns and MUHOW/O phenotypes.



## 1. Introduction

The prevalence of obesity is increasing in most parts of the world, and the International Obesity Task Force (IOF) estimates that at least 1.1 billion adults are overweight worldwide, including 312 million who are obese [1]. Obesity often clusters with risk factors of cardiovascular disease (CVDs) and type 2 diabetes (T2D) that comprise metabolic syndrome (MetS), including insulin resistance (IR), hypertension, dyslipidemia, and low levels of high density lipoprotein-cholesterol (HDL-C) [2].

Intriguingly, obesity is not synonymous with metabolic disease, as people who are overweight or obese do not always have metabolic dysfunction, especially cardio-metabolic dysfunction [3]. These populations have been termed as having metabolically healthy obesity (MHO) [4]. MHO describes [5] the absence of any overt cardio-metabolic disease, along with a favorable metabolic profile and inflammation profile, characterized by high levels of insulin sensitivity, a lower proportion of visceral fat, less liver fat, low prevalence of hypertension and components in an individual with a body mass index (BMI) ≥30 kg/m$^2$. The diagnostic criteria

* Corresponding author. Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences (TUMS), Tehran, Iran.
*E-mail addresses:* ati_babaee@yahoo.com (A. Mirzababaei), frq.sajadi@gmail.com (S.F. Sajjadi), nasim_ghodoosi@yahoo.com (N. Ghodoosi), sara_pooyan@yahoo.com (S. Pooyan), hana.arghavani@yahoo.com (H. Arghavani), yekaninejad@yahoo.com (M.S. Yekaninejad), mina_mirzaei101@yahoo.com (K. Mirzaei).

https://doi.org/10.1016/j.dsx.2018.09.012
1871-4021/

**List of abbreviations**

| | |
|---|---|
| ***ATPIII*** | Adult Treatment Panel |
| ***BMI*** | Body mass index |
| ***BIA*** | Bioelectrical impedance analysis |
| **BP** | blood pressure |
| ***BF %*** | body fat percentage |
| ***CVDs*** | cardiovascular diseases |
| ***CHOD-PAP*** | cholesterol oxidase Phenol 4-Aminoantipyrine Peroxidase |
| ***ELISA*** | enzyme-linked immunosorbent assay |
| ***FBS*** | Fasting Blood Glucose |
| ***EI*** | energy intake |
| ***FFQ*** | food frequency questionnaire |
| ***FPG*** | fasting plasma glucose |
| ***FBS*** | fasting blood sugar |
| ***FFM*** | Fat Free Mass |
| ***FM*** | Fat Mass |
| ***GOD-PAP*** | Glucose Oxidase Phenol 4-Aminoantipyrine Peroxidase |
| ***GPO-PAP*** | Glycerol-3-phosphate oxidase Phenol 4-Aminoantipyrine Peroxidase |
| ***hs-CRP*** | Serum hyper sensitive C-reactive protein |
| ***HDP*** | healthy dietary pattern |
| ***HOMA-IR*** | Homeostatic model assessment insulin resistance |
| ***HDL-C*** | High density lipoprotein cholesterol |
| ***IR*** | insulin resistance |
| ***IOF*** | International Obesity Task Force |
| ***IDF*** | International Diabetes Federation |
| ***IPAQ*** | International Physical Activity Questionnaire |
| ***IL6*** | interlukin6 |
| ***KMO*** | Kaiser-Meyer-Olkin |
| ***LDL*** | Low density lipoprotein cholesterol |
| ***MetS*** | metabolic syndrome |
| ***MH*** | Metabolically healthy |
| ***MUH*** | Metabolically unhealthy |
| ***MHO*** | Metabolically healthy obesity |
| ***MUHO*** | Metabolically unhealthy obesity |
| ***NC*** | Neck circumference |
| ***NAFLD*** | Non-alcoholic fatty liver disease |
| ***OR*** | odds ratio |
| ***PA*** | physical activity |
| ***PCA*** | Principal component analysis |
| ***PCO*** | Polycystic Ovary Syndrome |
| ***T2D*** | type 2 diabetes |
| ***TBW*** | Total Body Water |
| ***Total-Chol*** | Total cholesterol |
| ***TG*** | Triglyceride |
| ***TNF α*** | Tumor necrosis factor alpha |
| ***TUMS*** | Tehran University of Medical Sciences |
| ***UNHDP*** | unhealthy dietary pattern |
| ***USDA*** | United States Department of Agriculture |
| ***WC*** | waist circumference |
| ***WHR*** | waist to hip ratio |
| ***WDP*** | western dietary pattern |

for MHO are controversial, therefore the prevalence of MHO is difficult to quantify, and varies according to the definition used [6]. The prevalence of MHO has been reported as being 10%–25% [7]. However, factors such as race, age, physical activity (PA) have effects on the prevalence of MHO [8]. The underlying mechanisms which cause the MHO phenotype among obese people are multiple and complex. This phenotype is the result of complex interactions between genetic, environmental, and behavioral factors [9]. The absence of genetic traits associated with fat distribution, reduced visceral fat mass and ectopic fat accumulation in liver, muscle, and pancreatic beta cells, and low systemic inflammation all contribute to MHO [10]. Metabolically unhealthy obesity (MUHO), in contrast to the MHO group, displays the typical obesity-related metabolic disturbances of IR, hypertriglyceridemia and possibly elevated risk of developing T2D and CVDs, which could be due to higher fat mass as well as higher visceral fat and liver fat content [11].

Although diet is a modifiable risk factor, controversy remains surrounding the relation between diet and obesity, particularly regarding the role of fat intake [12]. Due to the possibility of many undiscovered compounds in foods, the enormity of interactions among nutrients and foods, and the collinearity among food and nutrient intakes, using a multivariate approach like dietary patterns has the potential to resolve concerns about confounding factors and interactions of foods and nutrients [13]. Furthermore, a dietary pattern approach reflects individuals' dietary behaviors and therefore can provide more detailed information about the nutritional etiology of chronic disease [14]. Several studies have reported the associations of major dietary patterns with obesity and central adiposity [15,16].

However, no study is currently available evaluating major dietary patterns in metabolic healthy (MH)/metabolic unhealthy (MUH) individual based on Karelis criteria. It was therefore decided to test whether differences in major dietary patterns in MUHOW/O and MHOW/O phenotypes can lead to differences in metabolic status.

## 2. Methods and materials

### 2.1. Participants

This cross-sectional study was conducted among a representative sample of Tehrani overweight/obese females aged 18–50, selected by a multistage cluster random sampling method. Registered patients in the health center were enrolled in the study, according to inclusion and exclusion criteria. Individuals were included if they met following criteria: age 18–50 years; no current weight loss program; no use of weight loss supplements. Participants with a history of T2D, CVDs, polycystic ovary syndrome (PCO), stroke, non-alcoholic fatty liver disease (NAFLD), inflammatory disease, hypertension, cancer, thyroid diseases, or who were currently pregnant were excluded because of possible changes in diet. Women were also excluded who did not respond to more than 70 food items in the food frequency questionnaire (FFQ), or who reported a total daily energy intake (EI) outside the range of 800–4200 kcal (3344–17556 kJ), as well as those taking medication that could affect plasma lipoproteins (Atorvastatin, Cholestyramine, etc.), blood pressure (Captopril, etc.) and carbohydrate metabolism (Metformin, etc.). After these exclusions, 290 women remained in the current analysis. Each participant was informed completely regarding the study protocol and provided a written and informed consent form before taking part in the study. The study protocol was approved by the ethics committee of Tehran University of Medical Sciences (TUMS) with the following identification IR.TUMS.VCR.REC.1395.1234.

### 2.2. Measurement of biochemical parameters

All samples were collected, after 10–12 h fast, at the Nutrition and Biochemistry laboratory of School of Nutritional Sciences and Dietetics, TUMS. Blood samples, collected in tubes containing 0.1% EDTA, were taken in a sitting position according to standard protocol. To collect serums, serum samples were centrifuged for 10 min at 3000 rpm, aliquoted into 1 ml tubes and stored at −70 °C until analysis. Samples were analyzed by using an Auto-analyzer BT 1500 (Selectra 2; Vital Scientific, Spankeren, Netherlands). Fasting plasma glucose (FPG) was measured on the day of blood collection by Glucose Oxidase Phenol 4-Aminoantipyrine Peroxidase (GOD/PAP) method. Serum triglycerides (TG) concentrations were assayed with triacylglycerol kits (Pars Azmoon Inc, Tehran, Iran) by using enzymatic colorimetric tests with Glycerol-3-phosphate oxidase Phenol 4-Aminoantipyrine Peroxidase (GPO-PAP). Total cholesterol (total-chol) levels were measured by the cholesterol oxidase Phenol 4-Aminoantipyrine Peroxidase (CHOD-PAP), and low-density lipoprotein (LDL) and HDL was measured by the direct method and immunoinhibition. Serum hyper sensitive C-reactive protein (hs-CRP) was measured by an immunoturbidimetric assay. All kits were from Pars Azmoon (Pars Azmoon Inc. Tehran, Iran). Serum insulin concentrations were analyzed through the enzyme-linked immunosorbent assay (ELISA) method (Human insulin ELISA kit, DRG Pharmaceuticals, GmbH, USA), and the minimum detectable concentration was 1.76 mlU/ml, Intra CV was 2.19% and Inter CV was 4.4%.

### 2.3. Assessment of anthropometric measures

Weight was measured with digital scales and recorded to the nearest 100 g while the subjects were minimally clothed and not wearing shoes. Height was measured using a tape measure while the subjects were standing, were not wearing shoes and had shoulders in a normal position. BMI was calculated by dividing the weight (kg) by the square of the height (cm). Neck circumference (NC) was measured below the laryngeal prominence and perpendicular to the long axis of the neck [17], and the minimal circumference was recorded to the nearest 0.1 cm. To reduce error, all measurements were taken by the same technician.

### 2.4. Assessment of other variables

Data on PA were obtained using participants' oral responses to an interview-based International Physical Activity Questionnaire (IPAQ) and expressed as metabolic equivalent h/wk (MET-h/wk) [31]. This questionnaire included questions in 5 activity domains: job-related physical activity; transportation physical activity; activities for housework and house maintenance; recreation, sport and leisure-time physical activity; and time spent sitting. Participants were asked to think about all the vigorous and moderate activities they had engaged in during the last 7 days, considering times spent for these activities. The PA of the participants was classified as follows: low <600 (MET-h/wk), moderate = 600–3500 (MET-h/wk) and severe >3500 (MET-h/wk) [18]. A demographic questionnaire (information on age, marital status and family history of obesity) was collected by researchers.

### 2.5. Assessment of blood pressure

For blood pressure (BP) measurements, participants were first asked to rest for 15 min. Then, a trained physician measured BP using a standardized sphygmomanometer (Omron, Germany, European).

### 2.6. The HOMA-IR calculation

IR was calculated by the homeostatic model assessment (HOMA) according to the following equation: HOMA-IR = [fasting plasma glucose (mmol/l) × fasting plasma insulin (mIU/l)]/22.5 [19].

### 2.7. Definition of metabolic health and its components

Karelis criteria were used, since they examine both inflammatory profiles and insulin-sensitization to other indicators. The MH was defined as the presence of four or more of the following five components, according to Karelis criteria: TG ≤ 1.7 mmol/l, HDL ≥1.3 mmol/l and no treatment, LDL ≤2.6 mmol/l and no treatment, hs-CRP≤ 3.0 mg/l, and HOMA-IR ≤2.7 [4].

### 2.8. Complete body composition analysis

Body composition was assessed through multi-frequency bioelectrical impedance analyzer (BIA): InBody 770 Scanner (Inbody Co., Seoul, Korea). This electrical impedance analyzer calculates the resistance of body tissues to the flow of an electrical signal sent through both hands and feet. The amount and proportion of body fat percentage (BF %), fat free mass (FFM) and fat mass (FM), waist circumference (WC) and waist-to-hip ratio (WHR) is measured as the current flows more efficiently through certain parts of the body. Participants were asked not to exercise vigorously, carry any electric devices, consume excessive fluid or food; the measurements were performed in the morning in a fasting condition, with participants urinating just before the body composition analysis to get a more accurate result. According to the manufacturer's instructions, after shoes, coats, and sweaters had been removed, subjects were required to stand on the balance scale in bare feet and hold the handles of the machine. The measurements took approximately 20 s, and the output was printed.

### 2.9. Assessment of dietary intake

Usual dietary intake was assessed using a validated 147-item semi-quantitative FFQ. A trained dietitian administered all the questionnaires. The FFQ consisted of a list of foods with standard serving sizes commonly consumed by Iranians. Participants were asked to report their frequency of consumption of a given serving 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. The reported frequency for each food item was then converted into a daily intake. Portion sizes of consumed foods were converted to grams by using household measures [20]. Total EI was calculated by summing up EIs from all foods. To determine the nutrient compositions of Iranian foods, an Iranian food composition table was used [21] in conjunction with United States Department of Agriculture (USDA) food composition data [22]. A previous validation study of this FFQ among 132 randomly chosen participants (not included in this study) revealed correlations between dietary intakes assessed by similar FFQs, and multiple-day 24-h food recalls completed during the year ($P < 0.05$) [23]. To identify major dietary patterns, 147 food items were first categorized into 21 predefined food groups. This classification was based on the similarity of their nutrients and according to previous studies [24].

### 2.10. Statistical analyses

Normality distribution was tested by applying Kolmogorov-Smirnov's test; data that was not normally distributed and could not be transformed appropriately for normal distribution were

used for z-scores. Data on quantitative characteristics were reported as the mean ± SD and data on qualitative characteristics were expressed as a percentage. To identify major dietary patterns based on the 21 food groups, principal component analysis (PCA) we used. The Scree plot is a plot of the eigenvalues >1.5 of derived factors. To achieve a simple matrix with a better ability to interpret and derive dominant dietary patterns, varimax rotation was used. The number of meaningful components retained from the total number of extracted patterns depended mainly on the assessment of scree plots and the components' interpretability. According to previous studies, and because of the nature of the data and correlations, values with a load factor greater than 0.3 were considered to determine the items of each food pattern. Factor loadings are correlation coefficients between food groups and dietary patterns; a positive loading in a factor indicates a direct association with the factor, whereas a negative loading indicates that the food is inversely associated with the factor. The dietary patterns were labeled on the basis of the researchers' interpretation of the data, as well as on prior literature. Participants were categorized by the median of healthy, unhealthy, and western dietary pattern scores, which were converted into low first quartile and other groups. Independent *t*-test was performed to evaluate significant differences in general characteristics (e.g. age, anthropometry, and physical activity) across categories of dietary pattern scores and metabolic phenotypes; the distribution of qualitative variables across quintiles was evaluated by using chi-square tests. To determine the associations of major dietary patterns (independent variable) with the MUH (dependent variable) and metabolic components (dependent variable), logistic binary regression was used in crude model and adjusted models. Confounding factors were determined from a best-fit model and the change in −2 log likelihood ratio test. Adjustments were made for age, PA, BMI and total EI. In all multivariate models, the low adherence of dietary patterns score was considered as a reference. SPSS software was used (version 23; SPSS Inc, Chicago IL) for all statistical analyses.

## 3. Results

After data analysis using the PCA method and based on data related to food intake, the suitability of the data collected for PCA analysis was examined by studying a review of the Anti-Image table, the results of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy test, and Bartlett's Test of Sphericity. Then, according to the Scree Plot chart review, three major dietary patterns were identified (Fig. 1). Three major dietary patterns were determined: the healthy dietary pattern (HDP), with high intake of vegetables, fruits, legume and nuts, starchy vegetables, low-fat dairy, meat, and olives; the western dietary pattern (WDP), associated with a higher intake of fast food, high-energy drinks and beverages, snacks, mayonnaise, sweets, cereals, and condiments; and the unhealthy dietary pattern (UNHDP), with higher intake of solid oil, high-fat dairy, red meat, liver, brain and kidney, tea and coffee, and a lower consumption of liquid oil. In order to identify the dietary patterns, factors were selected which had a load factor greater than 0.3 and were discarded if the load factor was lower than 0.3. The factor-loading matrices for these dietary patterns are shown in Table 1. The HDP, the WDP and the UNHDP, explained 13.33%, 11.90% and 7.80% of total variance, respectively. Some food groups have positive and some have negative load factors. A positive load factor means it is positively associated with a dietary pattern and a negative load factor means an inverse relationship with that food pattern. A total of 290 subjects, including 79 MHOW/O (27.3%) and 211 MUHOW/O individuals (72.7%), were included in this study. It was found that 5.2% met 5/5 criteria, 22.1% met 4/5 criteria, 27.9% met 3/5 criteria; 28.6% met 2/5 criteria, 12.4% met 1/5 criteria and 3.8% met 0/5 criteria. The percentage of MH participants in the following BMI categories: 25–30 (kg/m$^2$), 30–35 (kg/m$^2$) and >35 (kg/m$^2$) was 77.2%, 20.3% and 2.5%, respectively. The clinical and anthropometric characteristics of the study population according to MH and MUH status are shown in Table 2. In comparison with MHOW/O participants, MUHOW/O subjects had 3.77 fold higher serum levels of hs-CRP. MH subjects showed more favorable lipid profiles, specifically mean serum TG, total-chol and LDL, ($P < 0.05$). Mean serum insulin in the MH phenotype was about ¼ of those suffering from MUH ($P < 0.0001$). Also, MUH subjects had 1.49 fold higher HOMA-IR levels, compared to MH subjects ($P < 0.001$). However, there was no significant difference in PA among the two groups ($P > 0.05$). It should be noted, though, that 73.7% of MUHOW/O participants had low level PA (≤600 MET min/week) and only 30% had high-level PA (>3500 MET min/week). Furthermore, as far as body composition is concerned, these results demonstrated that there was a statistically significant difference, even after controlling for confounder factors, in terms of BMI ($P < 0.0001$), WC ($P < 0.0001$), WHR ($P < 0.0001$), NC ($P < 0.0001$), BF% ($P = 0.004$), body fat mass (BFM) ($P < 0.0001$), FFM ($P = 0.005$), between the two groups. In particular, MUHOW/O subjects had 1.04, 1.14 and 1.05 fold higher BF%, BFM and FFM in comparison with MH participants, respectively. Characteristics of the study participants across adherence categories of the dietary patterns scores are shown in Table 3. After controlling for confounder factors, those with the highest adherence of the HDP had significantly lower serum hs-CRP ($P = 0.03$), compared with participants with low adherence. Conversely, in comparison with participants with the lowest adherence, those with the highest adherence to the WDP had significantly higher FBS ($P = 0.06$), NC ($P = 0.009$), and lower serum level HDL ($P = 0.05$), as well as having significantly higher MUH prevalence ($P = 0.03$). Also, participants with the highest adherence to the UNHDP had significantly higher weight compared to those with low adherence ($P = 0.02$). Dietary intakes of the study participants across adherence categories of the dietary pattern scores are shown in Table 4. Those with the highest adherence to the HDP had significantly lower intakes of energy, fat, carbohydrate and cholesterol ($P < 0.0001$), and significantly higher intakes of vitamin B-6, B-2, B9, magnesium, calcium, copper and fiber ($P < 0.0001$), whereas those in the highest categorical of the WDP had statistically significant higher intakes of energy, fat, trans fatty acid and cholesterol, and statistically significant lower intakes of vitamin B-6, B-9, magnesium and fiber. Also, participants with the highest intake of the UNHDP had statistically significantly higher intakes of energy, fat, saturated fatty acid, trans fatty acid and cholesterol ($P < 0.0001$), after adjustment for confounder factors. No significant overall associations were seen between the HDP score and the MUH ($P > 0.05$). Odds ratio (OR) for the MUH phenotype across adherence categories of UNHDP and WDP scores in the crude and adjusted models are presented in Table 5. In the crude model, participants with the highest adherence to the UNHDP were marginally positively associated with greater odds of MUH, and the WDP score had greater odds of this phenotype (OR: 1.58, 95%CI = 0.93–2.69, $P = 0.08$ and OR = 1.86, 95% CI = 1.04–3.32, $P = 0.03$) than those with the lowest adherence, respectively. Also, after controlling for BMI, subjects with the highest adherence of UNHDP had 79% higher likely odds for MUH phenotype, compared to those with the lowest adherence (OR = 1.79,95%CI = 1.02–3.13, $P = 0.04$). Even after additional control for age and total EI, the positive association of the UNHDP score with higher odds for the MUH phenotype remained significant (OR = 1.75,95%CI = 0.98–3.10,$P = 0.05$). However, after adjustment for BMI, total EI, age, and PA, the positive association of the UNHDP with MUH disappeared (OR = 1.34, 95%CI = 0.69–2.57, $P = 0.37$), but individuals with the highest adherence to the WDP had 2.33

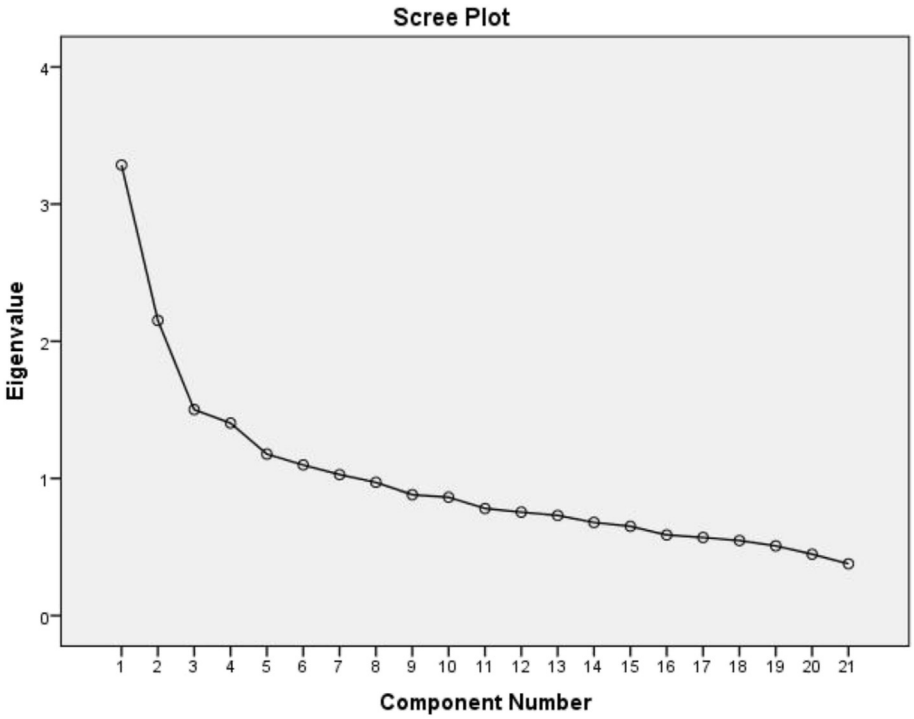


**Fig. 1.** Scree plot chart for extracting major dietary patterns from principal component analysis.

**Table 1**
Factor-loading matrix for major dietary patterns.[a]

| Dietary Patterns | | | |
|---|---|---|---|
| Food Groups | Healthy | Western | Unhealthy |
| Vegetables | 0.74 | – | – |
| Fruits | 0.58 | – | – |
| Legume and nuts | 0.57 | – | – |
| Starchy vegetables | 0.56 | – | – |
| Low fat dairy | 0.56 | – | – |
| Withe meat | 0.52 | – | – |
| Olive | 0.40 | – | – |
| Condiment | – | 0.34 | – |
| Salt | – | – | – |
| Fast food | – | 0.68 | – |
| High-energy drinks and beverages | – | 0.64 | – |
| Snacks | – | 0.63 | – |
| Mayonnaise | – | 0.57 | – |
| Sweets | – | 0.52 | – |
| Cereals | – | 0.36 | – |
| Liquid oil | – | – | −0.54 |
| Solid oil | – | – | 0.60 |
| High fat dairy | – | – | 0.41 |
| Red meat | – | – | 0.36 |
| Tea and coffee | – | – | 0.32 |
| Liver, brain and kidney | – | – | 0.40 |
| Percentage of variance Explained (%) | 13.33% | 11.90% | 7.80% |

[a] Values are factor loadings of dietary patterns measured by factor analysis (n=265). Factor loadings below <0.30 were excluded for simplicity. † Eigenvalues>1.5, (KMO) index: 0.71.

fold greater odds for the MUH phenotype, compared to those with the lowest adherence (OR = 2.33, 95%CI = 1.11 = 4.91, P = 0.02). Associations between dietary patterns and metabolic status, based on the Karelis criteria, are shown in Table 6. In the full model, participants with the highest adherence to the HDP score had 46% reduced odds of serum level of hs-CRP (OR = 0.56, 95% CI = 0.29–0.92, P = 0.03), whereas those with the highest adherence to the UNHDP had greater odds of serum level of LDL (OR = 1.90, 95%CI = 1.04–1.65, P = 0.03). Also, higher adherence to the WDP led to 1.94 fold and 2.53 fold increased serum levels of hs-CRP and HOMA-IR (95%CI = 0.91–4.10, P = 0.05 and 95% CI = 1.26–5.11, P = 0.009) respectively.

## 4. Discussion

This is the first investigation in which major dietary patterns identified by factor analysis have been associated directly with MUH/MH phenotypes based on Karelis criteria. It was observed that the UHDP and WDP were associated with higher odds of the MUH phenotype in overweight and obese women, whereas no

**Table 2**
Characteristics metabolic feature MH and MUH subjects.

| | MHOW/O | MUHOW/O | 0.95 CI of the difference | P value | P value* |
|---|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | | | |
| | (n = 79) | (n = 211) | | | |
| Quantitative variables Demography [a] | | | | | |
| Age (years) | 36.26 ± 8.29 | 36.22 ± 8.45 | −2.1 to −2.23 | 0.96 | 0.94 |
| Height (cm) | 161.50 ± 5.20 | 160.75 ± 12.41 | −1.29 to 2.79 | 0.47 | 0.66 |
| Weight (kg) | 74.96 ± 8.38 | 79.44 ± 12.10 | −7.83 to-1.55 | 0.003 | 0.001 |
| Body Composition | | | | | |
| BMI(kg/m2) | 28.65 ± 2.81 | 30.64 ± 3.56 | −2.68 to −1.10 | <0.001 | <0.001 |
| Fat percentage % | 39.51 ± 4.82 | 41.46 ± 5.18 | −3.36 to −0.53 | 0.007 | 0.004 |
| BFM (Kg) | 29.76 ± 5.96 | 34.03 ± 7.34 | −6.27 to −2.27 | 0.001 | <0.001 |
| FFM (Kg) | 44.84 ± 4.68 | 47.10 ± 5.75 | −3.67 to −0.83 | 0.002 | 0.005 |
| TBW (L) | 32.93 ± 3.43 | 34.58 ± 4.08 | −2.68 to −0.60 | 0.002 | 0.005 |
| VFL | 14.04 ± 8.89 | 16.80 ± 14.92 | −5.08 to −0.42 | 0.02 | 0.13 |
| BMR | 1338.67 ± 101.40 | 1444.23 ± 773.78 | −222.30 to −122.13 | 0.07 | 0.28 |
| FFMI | 17.26 ± 1.21 | 18.75 ± 9.88 | −2.98 to 0.1 | 0.05 | 0.25 |
| FMI | 11.65 ± 2.62 | 13.06 ± 2.78 | −2.18 to −0.63 | <0.001 | <0.001 |
| NC (cm) | 35.18 ± 2.13 | 37.36 ± 2.35 | −2.94 to −1.42 | <0.001 | <0.001 |
| WC (cm) | 93.38 ± 7.01 | 99.61 ± 9.29 | −8.7 to −3.7 | <0.001 | <0.001 |
| WHR | 0.91 ± 0.04 | 0.93 ± 0.05 | −0.04 to 0.01 | <0.001 | <0.001 |
| Blood Parameters | | | | | |
| FBS(mmol/L) | 86.51 ± 15.05 | 88.75 ± 9.79 | −5.8 to 1.37 | 0.22 | 0.03 |
| TG (mmol/L) | 82.41 ± 27.25 | 131.69 ± 70.65 | −65.30 to −15.01 | <0.001 | <0.001 |
| Insulin (mIU/mL) | 11.88 ± 3.67 | 17.01 ± 6.26 | −6.75 to −3.50 | <0.001 | <0.001 |
| LDL-C (mmol/L) | 88.64 ± 25.52 | 99.54 ± 26.93 | −17.97 to −4.18 | 0.002 | 0.001 |
| HDL-C (mmol/L) | 52.63 ± 9.60 | 45.24 ± 10.55 | 4.81 to 9.96 | <0.001 | <0.001 |
| Total- chol (mmo/l) | 173.00 ± 34.93 | 190.00 ± 39.10 | −26.41 to −7.59 | <0.001 | 0.001 |
| HOMA | 2.44 ± 0.97 | 3.65 ± 1.56 | −1.58 to −0.84 | <0.001 | <0.001 |
| Blood pressure | | | | | |
| Systolic (mmHg) | 92.48 ± 38.35 | 96.99 ± 38.74 | −14.77 to 5.74 | 0.38 | 0.15 |
| Diastolic (mmHg) | 62.48 ± 26.07 | 68.28 ± 27.53 | −12.85 to 1.26 | 0.10 | <0.001 |
| Inflammatory Cytokine | | | | | |
| hs-CRP (mg/L) | 1.38 ± 1.15 | 5.21 ± 4.92 | −4.93 to 2.72 | <0.001 | <0.001 |
| Qualitative variables [b] | | | | | |
| Education | | | | | |
| Bachelor | 29 (24.2) | 91 (75.8) | 0.22–0.24 | 0.33 | 0.77 |
| Master | 35 (29.7) | 83 (70.3) | | | |
| Martial | | | | | |
| Married | 47 (25) | 141 (75) | 0.28–0.30 | 0.20 | 0.37 |
| Single | 17 (34.0) | 33 (66) | | | |
| Family history of obesity | | | | | |
| Yes | 48 (25.4) | 141 (76.4) | | 0.33 | 0.87 |
| No | 14 (32.6) | 29 (67.4) | | | |
| Physical activity [c] | | | | | |
| Low | 35 (26.3) | 98 (73.7) | 0.44–0.46 | 0.96 | 0.90 |
| Moderate | 27 (27.0) | 73 (73.0) | | | |
| High | 7 (70.0) | 3 (30.0) | | | |

BMI: body mass index; BFM: body fat mass; FM: fat free mass; TBW: total body water; VFL: visceral fat level; BMR: basal metabolic rate; FMI; fat mass index; FFMI: fat free mass index; WHR: waist to hip ratio; WC: waist circumference; NC; neck circumference; FBS: fasting blood sugar; TG: triglyceride; Total-Chol: total cholesterol; HDL-C: high density lipoprotein cholesterol; LDL-C: low density lipoprotein cholesterol; HOMA; homeostatic model assessment; hs-CRP: high-sensitivity C-reactive protein; MHOW: metabolic healthy overweight/obesity; MUHOW/O: metabolic unhealthy overweight/obesity.
*After adjustment for age, BMI, total Energy intake and physical activity.
**Put out the collinear variable from the GLM as confounders.
[a] Mean ±SD.
[b] n (%).
[c] Physical activity of the participants was classified to low <600 MET-h/wk., moderate =600-3500 MET-h/wk. and sever >3500 MET-h/wk. levels.

significant association was found between the HDP with lower odds of this phenotype.

The prevalence of MHO has been reported to be 10%–30% worldwide [25]. The prevalence of MHO has been reported by different criteria, such as the Adult Treatment Panel (ATPIII), Kaleris, Wildman, the International Diabetes Federation (IDF) and HOMA criteria [26]. In fact, many variables, including FBS, TG, HDL, LDL, HOMA-IR, hs-CRP and WC, have been used to identify MH. In the current study, the percentage of MHOW/O phenotype was 27.0% according to the Kaleris criteria. Moreover, a high percentage of this phenotype was observed in overweight individuals. Another important point is that the prevalence of the MUHO phenotype was 2.32-fold as large as the MHO phenotype.

In the present study, the MH phenotype had significantly lower GOT, GPT, insulin, HOMA, TG, LDL, hs-CRP and total-chol, compared to the MUH group. Interestingly, no differences between the MH and MUH phenotypes were noted for age, weight and PA. These findings are in line with other studies reporting that MH individuals had lower BMI, FBS, TG and higher HDL concentrations, and reduced HOMA-IR, in comparison with MUH participants [27]. The study also demonstrated that significant differences were seen regarding WC, BMI, BF%, FM, and BFM between the two groups. Therefore, it seems that the MUH phenotype can increase inflammation, and in this way can lead to atherosclerosis. Accumulating FM is associated with IR, which in turn is an underlying cause of MetS. A large volume of studies have shown elevated levels of

**Table 3**
Characteristics of the study participants across adherence categories of dietary patterns score.

| | Healthy | | | Unhealthy | | | Western | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low adherence | High adherence | P value* | Low adherence | High adherence | P value* | Low adherence | High adherence | P value* |
| | Mean ± SD | Mean ± SD | | Mean ± SD | Mean ± SD | | Mean ± SD | Mean ± SD | |
| **Demography** | | | | | | | | | |
| Age (years) | 35.95 ± 8.80 | 36.42 ± 8.36 | 0.10 | 36.17 ± 8.93 | 36.36 ± 8.07 | 0.03 | 38.18 ± 7.94 | 35.62 ± 8.60 | 0.24 |
| Height (cm) | 158.78 ± 17.31 | 161.86 ± 5.73 | 0.31 | 160.13 ± 14.58 | 161.55 ± 5.67 | 0.87 | 161.13 ± 5.47 | 160.74 ± 12.43 | 0.70 |
| Weight (kg) | 73.86 ± 10.80 | 80.12 ± 10.72 | 0.04 | 77.82 ± 11.66 | 78.25 ± 10.60 | 0.02 | 76.78 ± 9.26 | 78.45 ± 11.67 | 0.21 |
| **Body Composition** | | | | | | | | | |
| BMI(kg/m$^2$) | 29.20 ± 3.21 | 30.56 ± 3.54 | 0.28 | 30.22 ± 3.32 | 30.01 ± 3.66 | 0.67 | 29.62 ± 3.12 | 30.28 ± 3.6 | 0.62 |
| Fat percentage % | 40.87 ± 5.08 | 40.96 ± 5.30 | 0.56 | 41.00 ± 5.02 | 40.86 ± 5.47 | 0.93 | 40.79 ± 5.41 | 41.42 ± 4.56 | 0.42 |
| Fat Mass (kg) | 31.58 ± 6.72 | 33.39 ± 7.37 | 0.62 | 32.73 ± 6.85 | 33.04 ± 7.46 | 0.92 | 32.56 ± 6.26 | 32.98 ± 7.50 | 0.82 |
| FFM(kg) | 44.76 ± 3.82 | 47.14 ± 5.69 | 0.02 | 46.41 ± 5.40 | 46.52 ± 5.28 | 0.61 | 45.68 ± 5.35 | 46.70 ± 5.32 | 0.60 |
| VFL | 17.69 ± 24.21 | 15.44 ± 3.31 | 0.22 | 15.17 ± 3.10 | 17.07 ± 18.72 | 0.30 | 15.41 ± 2.91 | 16.27 ± 14.86 | 0.78 |
| BMR | 13336.89 ± 82.7 | 1448.53 ± 79.6 | 0.07 | 1455.38 ± 93.0 | 1375.02 ± 11.40 | 0.43 | 1356.84 ± 11.58 | 1435.06 ± 76.32 | 0.32 |
| WC(cm) | 95.93 ± 7.79 | 98.68 ± 9.44 | 0.18 | 97.55 ± 8.54 | 98.29 ± 9.7 | 0.83 | 97.35 ± 8.15 | 98.07 ± 9.40 | 0.94 |
| WHR | 0.92 ± 0.04 | 0.93 ± 0.05 | 0.25 | 0.92 ± 0.04 | 0.93 ± 0.05 | 0.39 | 0.93 ± 0.05 | 0.92 ± 0.05 | 0.47 |
| NC(cm) | 36.58 ± 2.56 | 36.84 ± 2.49 | 0.58 | 36.62 ± 2.21 | 36.93 ± 2.82 | 0.76 | 35.54 ± 1.98 | 37.09 ± 2.53 | 0.009 |
| FFMI | 17.45 ± 1.26 | 18.76 ± 10.21 | 0.14 | 18.96 ± 11.93 | 17.78 ± 1.49 | 0.24 | 20.06 ± 17.93 | 17.89 ± 1.42 | 0.14 |
| FMI | 12.34 ± 2.34 | 12.84 ± 2.86 | 0.99 | 12.74 ± 2.77 | 12.65 ± 2.90 | 0.69 | 12.76 ± 2.73 | 12.68 ± 2.87 | 0.70 |
| **Blood Parameters** | | | | | | | | | |
| FBS(mmol/L) | 88.95 ± 10.90 | 87.82 ± 11.91 | 0.46 | 88.56 ± 13.97 | 87.84 ± 8.54 | 0.97 | 87.56 ± 8.57 | 88.41 ± 12.42 | 0.06 |
| TG (mmol/L) | 109.35 ± 53.74 | 122.51 ± 72.10 | 0.33 | 116.89 ± 74.88 | 119.40 ± 57.66 | 0.87 | 119.46 ± 73.12 | 117.71 ± 64.68 | 0.91 |
| T-chol (mmol/L) | 191.13 ± 46.26 | 181.70 ± 34.74 | 0.77 | 183.32 ± 39.39 | 186.35 ± 38.92 | 0.26 | 190.08 ± 45.03 | 183.09 ± 36.90 | 0.86 |
| HDL-C (mg/dL) | 48.78 ± 10.99 | 46.65 ± 10.56 | 0.95 | 47.42 ± 10.61 | 47.29 ± 10.89 | 0.95 | 49.98 ± 12.46 | 46.49 ± 9.97 | 0.05 |
| LDL-C (mg/dL) | 100.44 ± 33.68 | 93.90 ± 22.81 | 0.86 | 94.61 ± 26.26 | 97.55 ± 27.80 | 0.22 | 99.94 ± 32.13 | 94.79 ± 25.06 | 0.61 |
| HOMA-IR | 3.23 ± 1.31 | 3.33 ± 1.65 | 0.11 | 3.20 ± 1.27 | 3.39 ± 1.77 | 0.24 | 3.01 ± 1.37 | 3.39 ± 1.59 | 0.14 |
| Insulin (IU/mL) | 15.45 ± 4.97 | 15.57 ± 6.61 | 0.17 | 15.18 ± 4.99 | 15.93 ± 7.28 | 0.17 | 14.39 ± 5.75 | 15.89 ± 6.28 | 0.20 |
| **Inflammation** | | | | | | | | | |
| hs-CRP (mg/l) | 4.15 ± 4.84 | 4.14 ± 4.50 | 0.03 | 3.95 ± 4.36 | 4.35 ± 4.84 | 0.22 | 3.45 ± 4.33 | 4.38 ± 4.68 | 0.32 |
| **Blood pressure** | | | | | | | | | |
| Systolic (mmHg) | 83.59 ± 45.77 | 101.65 ± 33.19 | 0.71 | 99.11 ± 35.28 | 91.80 ± 41.95 | 0.95 | 88.50 ± 43.44 | 97.86 ± 36.94 | 0.84 |
| Diastolic (mmHg) | 59.08 ± 32.69 | 70.23 ± 23.27 | 0.10 | 36.62 ± 2.21 | 36.93 ± 2.82 | 0.83 | 60.96 ± 30.34 | 68.27 ± 26.02 | 0.38 |

BMI: body mass index; BFM: body fat mass; FM: fat free mass; VFL: visceral fat level; BMR: basal metabolic rate; FMI; fat mass index FFMI; fat free mass index WHR: waist to hip ratio; WC: waist circumference; NC: neck circumference; FBS: fasting blood sugar; TG: triglyceride; Total-Chol: total cholesterol; HDL-C: high density lipoprotein cholesterol; LDL-C: low density lipoprotein cholesterol; HOMA; homeostatic model assessment; hs-CRP: high-sensitivity C-reactive protein; MH: metabolic healthy; MUH: metabolic unhealthy.
* After adjustment for age, BMI, total Energy intake and physical activity.
** Put out the collinear variable from the GLM as confounders.

inflammatory markers in obese subjects. Adipose tissue expresses cytokines such as interleukin-6 (IL-6) and tumor necrosis factor α (TNF α) [28], which stimulate the production of acute-phase proteins, such as hs-CRP, by the liver [28]. Elevated plasma levels of hs-CRP, TNF- a, and IL-6 are associated with the risk of IR and CVDs [29].

Although the MUH phenotype underlies many causes of major chronic diseases and mortality [30,31], no studies have previously assessed the relation of major dietary patterns with this phenotype. To the researchers' knowledge, this is the first investigation to report the association of major dietary patterns with MUH phenotype. Studies that have identified major dietary patterns in developing countries are rare. The current study's western dietary pattern was positively associated with increasing MUH odds before and after controlling for confounder factors. Before adjustment, a high adherence to the WDP had 1.86 fold higher odds for MUH phenotype, compared to low adherence. Also, in the full model (including BMI, age, total EI and PA), compared to low adherence, a high adherence to the WDP increased the odds for MUH phenotype 2.33 fold. The positive association between the WDP and the MUH phenotype could be attributed to the lower amounts of useful foods and nutrients that this pattern contains. In the present study, a positive relationship was observed between the WDP and levels of hs-CRP and HOMA-IR. Higher intakes of fast food, snacks, high-energy drinks and beverages, sweets, refined grains [32], trans fatty acid and cholesterol [33] in this dietary pattern could also explain part of this association. Also, Slattery et al. [34] reported a positive association between the WDP and obesity. Schulz et al. [35] reported that the adoption of a WDP is associated with greater weight gain. Studies reported positive relations between a WDP and concentrations of hs-CRP [36]. In the Health Professional Follow-Up Study, plasma concentrations of hs-CRP were positively related to a WDP in a subgroup of participants. Schulze et al. [37] identified a dietary pattern (high in sugar, sweetened soft drinks, refined grains, diet soft drinks, and processed meat, but low in wine, coffee, cruciferous vegetables, and yellow vegetables) that was strongly related to inflammatory markers in a nested case-control study, even after controlling for confounder factors. Furthermore, in epidemiologic studies, the effect of dietary patterns on inflammatory markers has also been shown in clinical trials [38]. On the other hand, the consumption of high-carbohydrate foods with high glycemic indices increases levels of glucose, HOMA and insulin levels. It also causes: increased carbohydrate oxidation and decreased lipids oxidation; increased expression of enzymes involved in the synthesis of lipids; reductions in the expression of enzymes effective in lipolysis; increased liver glycogen stores; musculo-skeletal disorders due to rapid digestion and intensive insulin response; reductions in satiety; and increases in the synthesis and accumulation of body fat [39]. Statistically significant associations were found between high adherence to the western dietary pattern and increased NC. However, the current analysis showed that, with a higher adherence to the WDP, no statistically significant associations were found with high FM and BF%, after adjusting for confounder factors.

In the present study, the UNHDP was marginally positively associated with greater odds of MUH, before adjustment. When

**Table 4**
Dietary intake of the study participants across adherence categories of the dietary patterns scores.

| | Healthy | | | Unhealthy | | | Western | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low adherence | High adherence | P value* | Low adherence | High adherence | P value* | Low adherence | High adherence | P value* |
| | Mean ± SD | Mean ± SD | | Mean ± SD | Mean ± SD | | Mean ± SD | Mean ± SD | |
| Energy (kcal/d) | 2883.68 ± 701.33 | 2151.03 ± 591.76 | 0.001 | 2370.1246 ± 641.14 | 2668.32 ± 811.42 | <0.001 | 2134.52 ± 674.5 | 2646.12 ± 724.04 | <0.001 |
| Cho | 420.27 ± 112.30 | 300.49 ± 85.75 | 0.002 | 341.34 ± 102.56 | 380.00 ± 126.33 | 0.20 | 309.03 ± 107.35 | 377.71 ± 114.49 | 0.46 |
| Pro | 71.11 ± 20.59 | 101.87 ± 25.13 | <0.001 | 83.52 ± 24.84 | 89.60 ± 29.96 | 0.04 | 79.03 ± 27.15 | 89.04 ± 27.40 | 0.008 |
| Fat | 99.02 ± 31.33 | 79.47 ± 31.02 | <0.001 | 82.59 ± 27.80 | 96.03 ± 35.70 | 0.09 | 72.70 ± 27.92 | 94.79 ± 32.27 | 0.02 |
| S fat | 29.78 ± 11.69 | 24.20 ± 10.09 | <0.001 | 23.82 ± 8.55 | 30.21 ± 12.69 | <0.001 | 0.0006 ± 0.00 | 0.0009 ± 0.00 | 0.22 |
| Trans | 0.0004 ± 0.00 | 0.0012 ± 0.00 | 0.12 | 0.0005 ± 0.00 | 0.0011 ± 0.00 | 0.06 | 21.76 ± 9.50 | 28.74 ± 11.27 | 0.03 |
| Cholesterol | 284.79 ± 98.60 | 204.06 ± 74.23 | 0.003 | 217.86 ± 75.48 | 271.52 ± 113.50 | 0.006 | 218.85 ± 90.30 | 253.10 ± 101.57 | 0.05 |
| B2 | 1.72 ± 0.52 | 2.56 ± 0.62 | <0.001 | 2.10 ± 0.74 | 2.18 ± 0.85 | 0.02 | 1.92 ± 0.66 | 2.22 ± 0.83 | 0.28 |
| B6 | 1.60 ± 0.40 | 2.54 ± 0.62 | <0.001 | 1.99 ± 0.63 | 2.16 ± 0.76 | 0.29 | 2.12 ± 0.69 | 1.95 ± 0.73 | 0.05 |
| B9 | 489.20 ± 128.86 | 686.27 ± 152.66 | <0.001 | 566.08 ± 155.20 | 610.27 ± 185.61 | 0.51 | 599.43 ± 167.31 | 553.94 ± 182.98 | 0.06 |
| B12 | 3.52 ± 1.60 | 4.99 ± 2.47 | 0.07 | 3.91 ± 1.75 | 4.61 ± 2.54 | 0.44 | 3.67 ± 1.62 | 4.45 ± 2.34 | 0.90 |
| C | 111.52 ± 63.28 | 247.17 ± 136.98 | <0.001 | 168.98 ± 129.45 | 190.28 ± 122.87 | 0.88 | 162.98 ± 110.22 | 185.10 ± 131.60 | 0.20 |
| A | ± | ± | | | | | | | |
| D | 1.37 ± 1.03 | 2.36 ± 1.76 | 0.001 | 2.01 ± 1.47 | 1.72 ± 1.57 | 0.01 | 1.81 ± 1.41 | 1.80 ± 1.56 | 0.14 |
| E | 14.37 ± 8.56 | 17.38 ± 8.09 | 0.09 | 17.73 ± 9.89 | 14.02 ± 6.20 | <0.001 | 13.88 ± 6.25 | 16.54 ± 8.97 | 0.50 |
| K | 142.41 ± 91.03 | 275.36 ± 247.28 | <0.001 | 182.03 ± 125.63 | 236.44 ± 247.84 | 0.06 | 237.41 ± 182.60 | 199.76 ± 202.13 | 0.01 |
| Mg | 359.60 ± 114.01 | 536.01 ± 124.48 | 0.001 | 433.77 ± 144.48 | 462.58 ± 151.27 | 0.10 | 454.47 ± 143.10 | 428.99 ± 162.73 | 0.006 |
| Ca | 905.93 ± 305.43 | 1352.40 ± 403.91 | 0.001 | 1127.96 ± 387.81 | 1132.04 ± 454.82 | 0.006 | 1034.75 ± 397.56 | 1161.58 ± 425.74 | 0.11 |
| Copper | 1.57 ± 0.45 | 2.31 ± 0.71 | <0.001 | 1.83 ± 0.60 | 2.05 ± 0.77 | 0.77 | 1.83 ± 0.69 | 1.98 ± 0.70 | <0.001 |
| Mn | 6.19 ± 2.56 | 7.90 ± 2.88 | 0.38 | 6.73 ± 2.65 | 7.37 ± 3.02 | 0.75 | 6.94 ± 3.59 | 7.08 ± 2.57 | 0.04 |
| Se | 107.72 ± 41.23 | 131.77 ± 40.51 | 0.81 | 118.13 ± 42.54 | 121.45 ± 42.63 | 0.009 | 106.75 ± 43.25 | 124.11 ± 41.51 | 0.93 |
| Zinc | 10.68 ± 3.50 | 14.95 ± 3.83 | <0.001 | 12.28 ± 4.00 | 13.37 ± 4.42 | 0.05 | 11.66 ± 4.34 | 13.21 ± 4.14 | 0.01 |
| Fe | 15.23 ± 4.36 | 21.32 ± 5.44 | <0.001 | 17.37 ± 5.35 | 19.21 ± 6.10 | 0.22 | 16.67 ± 5.85 | 18.82 ± 5.69 | 0.002 |
| Na | 4669.92 ± 1336.20 | 3723.84 ± 1325.30 | 0.19 | 4034.67 ± 1284.29 | 4363.69 ± 1544.14 | 0.62 | 3722.24 ± 1263.49 | 4356.61 ± 1424.069 | 0.85 |
| K | 2992.75 ± 877.33 | 5222.85 ± 1321.85 | 0.001 | 3955.42 ± 1473.36 | 4269.35 ± 1668.05 | 0.24 | 3956.44 ± 1706.44 | 4163.36 ± 1534.57 | 0.001 |
| Total Fiber | 35.86 ± 14.36 | 52.23 ± 17.64 | <0.001 | 41.83 ± 15.75 | 46.33 ± 19.87 | 0.38 | 44.30 ± 18.66 | 44.00 ± 17.87 | <0.001 |

*After adjustment for age, BMI, total Energy intake and physical activity.

**Table 5**
Association of adherence of major dietary patterns and odds of MUH phenotype in crude and adjusted models.

| MUH phenotype [a] | Unhealthy Pattern Score | | | Western pattern Score | | |
|---|---|---|---|---|---|---|
| | Low adherence | High adherence | P value | Low adherence | High adherence | P value |
| | OR (95%CI) | OR (95%CI) | | OR (95%CI) | OR (95%CI) | |
| **Model I**[b] | 1 | 1.58 (0.93–2.69) | 0.08 | 1 | 1.86 (1.04–3.32) | 0.03 |
| **Model II**[c] | 1 | 1.79 (1.02–3.13) | 0.04 | 1 | 1.79 (0.98–3.28) | 0.05 |
| **Model III**[d] | 1 | 1.78 (1.01–3.14) | 0.04 | 1 | 1.81 (0.96–3.54) | 0.06 |
| **Model IV**[e] | 1 | 1.75 (0.98–3.10) | 0.05 | 1 | 1.85 (0.97–3.54) | 0.06 |
| **Model V**[f] | 1 | 1.34 (0.69–2.57) | 0.37 | 1 | 2.33 (1.11–4.91) | 0.02 |

MUH: metabolic unhealthy; OR: odds ratio; CI: confidence interval. P for trend was equal with P value because dietary patterns categorize to two groups.
[a] Defined as the absence of <2 of the following components: 1) TG ≤ 1.7 mmol/l,2) HDL-C ≥ 1.3 mmol/land no treatment,3) LDL-C ≤ 2.6 mmol/l and no treatment, 4)hs-CRP≤ 3.0 mg/l, 5) HOMA-IR ≤2.7.
[b] Unadjusted.
[c] Adjusted for BMI.
[d] Adjusted for BMI and Total Energy Intake.
[e] Additionally adjusted for age.
[f] Additionally adjusted for physical activity.

**Table 6**
Investigation association between major dietary patterns and possibility of abnormal metabolic status.

| Components of Karlelis criteria[a] | Healthy dietary Pattern | | Unhealthy dietary Pattern | | Western dietary Pattern | |
|---|---|---|---|---|---|---|
| | OR (95%CI) | P value | OR (95%CI) | P value | OR (95%CI) | P value |
| **TG** (mmol/L) | 0.66 (0.32–1.36) | 0.26 | 1.67 (0.86–3.25) | 0.12 | 0.86 (0.40–1.85) | 0.86 |
| **LDL** (mmol/L) | 0.77 (0.40–1.47) | 0.43 | 1.90 (1.04–3.47) | 0.03 | 0.88 (0.43–1.79) | 0.73 |
| **HDL** (mmol/L) | 1.25 (0.66–2.37) | 0.48 | 1.06 (0.59–1.91) | 0.84 | 1.24 (0.61–2.50) | 0.53 |
| **HOMA** | 0.71 (0.37–1.38) | 0.32 | 1.32 (0.74–2.42) | 0.35 | 2.53 (1.26–5.11) | 0.009 |
| **hs-CRP** (mg/L) | 0.56 (0.29–0.92) | 0.03 | 0.90 (0.49–1.65) | 0.74 | 1.94 (0.91–4.10) | 0.05 |

MUH: metabolic unhealthy; OR: odds ratio; CI: confidence interval.
FBS: fasting blood sugar; TG: triglyceride; Total-Chol: total cholesterol; HDL-C: high density lipoprotein cholesterol; LDL-C: low density lipoprotein cholesterol; HOMA; homeostatic model assessment; hs-CRP: high-sensitivity C-reactive protein.
Adjusted for BMI, age, Total Energy intake, physical activity.
In all multivariate models, the low adherence of dietary patterns score was considered as a reference.
[a] MUH components were: TG > 1.7 mmol/l, HDL-C < 1.3 mmol/land no treatment, LDL-C > 2.6 mmol/l and no treatment, hs-CRP> 3.0 mg/l, and HOMA-IR >2.7.

adjusted for BMI, age and total EI, a high adherence to the unhealthy dietary pattern increased the odds for the MUH phenotype 1.75-fold, in comparison to low adherence. However, after adjustment in the full model, the significance was lost. However, this study was not limited by controlling for PA, which tends to be associated with dietary patterns. Also, the analysis showed a direct relationship between high adherence to the UNHDP and increased levels of LDL, in line with other studies [40,41]. The unhealthy dietary pattern is highly loaded with hydrogenated fats, high-fat dairy and liver, brain and kidney. With these components, one would expect to find a positive association between this dietary pattern and the odds of the MUH phenotype and LDL levels.

The present results indicated that a high adherence to the HDP reduced the odds of high-level hs-CRP by 46%, after adjusting for confounder factors. The major foods contributing to the HDP were vegetables and fruits, which have been shown to be inversely related to inflammation markers, such as hs-CRP [42]. Overall, studies have indicated that a diet rich in fruits, vegetables, and low in saturated fatty acid and total fat may reduce markers of inflammation such as hs-CRP. The higher fiber and vitamin C content [43] of these foods may mediate their advantageous effects on hs-CRP levels. However, the cause of the inverse relation of the HDP to hs-CRP may not be confined to its fruit and vegetable content; other foods such as olives [44] and fish [45] in this pattern may contribute to the associations. Several studies have shown that intake of fish and seafood-based long-chain n-3 PUFAs are inversely associated with serum hs-CRP concentrations [46]. The Nurses' Health Study reported an inverse relation between a prudent dietary pattern and plasma concentrations of hs-CRP. The current analysis showed that participants who had high adherence to the HDP consequently had statistically significant high intakes of magnesium, calcium and total fiber, and low intakes of total fat and cholesterol. These components of HDP have been linked to lower levels of hs-CRP [47,48].

This study has several limitations; first, causality cannot be inferred because of its cross-sectional design. Second, like any other measurement, dietary evaluation has its own measurement errors. Third, it is not possible to generalize about dietary patterns throughout the country, because dietary intakes in Tehran are somewhat different from those in other parts of the country. In addition, these dietary patterns were confined to women.

This study also has several strengths. It was the first study to evaluate the associations between major dietary patterns and the MUH phenotype, and it was a community-based study. Known potential confounding factors were measured and controlled for in the analysis. Since metabolic status is affected by sexual hormones, the study only focused on adult women.

## 5. Conclusion

Overall, these findings underscore the importance of the westernized diet and nutrition transition in the alarming prevalence of the MUH phenotype in developing countries. Identifying the associations between major dietary patterns and the MUH phenotype is new. In this study, a positive relationship was found between a WDP and UNHDP, and odds of the MUH phenotype.

## Conflicts of interest

There are no competing financial interests in relation to the current study.

## Authors' contributions

Atieh Mirzababaei (AM), Seyedeh Forough Sajjadi (SFS), Nasim Ghodoosi (NGh), Sara Pooyan (SP), Hana Arghavani (HA), Mir Saeed Yekaninejad (MSY), Khadijeh Mirzaei (KhM) designed there search; AM, SFS, NGh, SP and HA conducted the sampling; AM, MSY and KhM performed statistical analysis; AM and KhM wrote the paper, Khadijeh Mirzaei primary responsibility for final content. All authors read and approved the final manuscript.

## Funding

This study was supported by TUMS.

## Ethics approval and consent to participate

Each participant was informed completely regarding the study protocol and provided a written and informed consent form before taking part in the study. The study protocol was approved by the ethics committee of Tehran University of Medical Sciences (TUMS) with the following identification IR.TUMS.VCR.REC.1395.1234.

## Consent for publication

All authors approved the final manuscript and consent for publication.

## Sources of support

Tehran University of Medical Sciences.

## Acknowledgments

The authors thank the study participants for their cooperation and assistance in physical examinations. This study was supported by TUMS.

## References

[1] James PT, Rigby N, Leach R. The obesity epidemic, metabolic syndrome and future prevention strategies. Eur J Cardiovasc Prev Rehabil 2004;11(1):3–8.
[2] Willett WC. Is dietary fat a major determinant of body fat? Am J Clin Nutr 1998;67(3). 556S-62S.
[3] Pajunen P, Kotronen A, Korpi-Hyövälti E, Keinänen-Kiukaanniemi S, Oksa H, Niskanen L, et al. Metabolically healthy and unhealthy obesity phenotypes in the general population: the FIN-D2D Survey. BMC Publ Health 2011;11(1):754.
[4] Hinnouho G-M, Czernichow S, Dugravot A, Batty GD, Kivimaki M, Singh-Manoux A. Metabolically healthy obesity and risk of mortality. Diabetes Care 2013;36(8):2294–300.
[5] Bell JA, Kivimaki M, Hamer M. Metabolically healthy obesity and risk of incident type 2 diabetes: a meta-analysis of prospective cohort studies. Obes Rev 2014;15(6):504–15.
[6] Velho S, Paccaud F, Waeber G, Vollenweider P, Marques-Vidal P. Metabolically healthy obesity: different prevalences using different criteria. Eur J Clin Nutr 2010;64(10):1043–51.
[7] Soverini V, Moscatiello S, Villanova N, Ragni E, Di Domizio S, Marchesini G. Metabolic syndrome and insulin resistance in subjects with morbid obesity. Obes Surg 2010;20(3):295–301.
[8] Wildman RP, Muntner P, Reynolds K, McGinn AP, Rajpathak S, Wylie-Rosett J, et al. The obese without cardiometabolic risk factor clustering and the normal weight with cardiometabolic risk factor clustering: prevalence and correlates of 2 phenotypes among the US population (NHANES 1999-2004). Arch Intern Med 2008;168(15):1617–24.
[9] Seo MH, Rhee E-J. Metabolic and cardiovascular implications of a metabolically healthy obesity phenotype. Endocrinol Metabol 2014;29(4):427–34.
[10] Moon S, Oh C-M, Choi M-K, Park Y-K, Chun S, Choi M, et al. The influence of physical activity on risk of cardiovascular disease in people who are obese but metabolically healthy. PLoS One 2017;12(9), e0185127.
[11] Shaharyar S, Roberson LL, Jamal O, Younus A, Blaha MJ, Ali SS, et al. Obesity and metabolic phenotypes (metabolically healthy and unhealthy variants) are significantly associated with prevalence of elevated C-reactive protein and hepatic steatosis in a large healthy Brazilian population. J Obes 2015;2015.
[12] Bray GA, Paeratakul S, Popkin BM. Dietary fat and obesity: a review of animal, clinical and epidemiological studies. Physiol Behav 2004;83(4):549–55.
[13] Newby P, Tucker KL. Empirically derived eating patterns using factor or cluster analysis: a review. Nutr Rev 2004;62(5):177–203.

[14] Kant AK. Dietary patterns and health outcomes. J Am Diet Assoc 2004;104(4):615–35.
[15] McNaughton SA, Mishra GD, Stephen AM, Wadsworth ME. Dietary patterns throughout adult life are associated with body mass index, waist circumference, blood pressure, and red cell folate. J Nutr 2007;137(1):99–105.
[16] Kim JA, Kim SM, Lee JS, Oh HJ, Han JH, Song Y, et al. Dietary patterns and the metabolic syndrome in Korean adolescents. Diabetes Care 2007;30(7):1904–5.
[17] Preis SR, Massaro JM, Hoffmann U, D'Agostino RBSr, Levy D, Robins SJ, et al. Neck circumference as a novel measure of cardiometabolic risk: the Framingham Heart study. J Clin Endocrinol Metabol 2010 Aug;95(8):3701–10. PubMed PMID: 20484490. Pubmed Central PMCID: PMC2913042. Epub 2010/05/21. eng.
[18] Committee IR. Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ)-short and long forms. 2005. http://www.ipaq.ki.se/scoring.pdf.
[19] Mirzaei K, Hossein-Nezhad A, Keshavarz SA, Eshaghi SM, Koohdani F, Saboor-Yaraghi AA, et al. Insulin resistance via modification of PGC1alpha function identifying a possible preventive role of vitamin D analogues in chronic inflammatory state of obesity. A double blind clinical trial study. Minerva Med 2014;105(1):63–78.
[20] Ghaffarpour M, Houshiar-Rad A, Kianfar H. The manual for household measures, cooking yields factors and edible portion of foods, vol. 7. Tehran: Nashre Olume Keshavarzy; 1999. p. 213.
[21] Esmaillzadeh A, Kimiagar M, Mehrabi Y, Azadbakht L, Hu FB, Willett WC. Dietary patterns and markers of systemic inflammation among Iranian women. J Nutr 2007;137(4):992–8.
[22] Food U, Administration D. National nutrient database for standard reference Release, vol. 24; 2012.
[23] Esmaillzadeh A, Mirmiran P, Azizi F. Whole-grain intake and the prevalence of hypertriglyceridemic waist phenotype in Tehranian adults. Am J Clin Nutr 2005;81(1):55–63.
[24] Esmaillzadeh A, Azadbakht L. Major dietary patterns in relation to general obesity and central adiposity among Iranian women. J Nutr 2008;138(2):358–63.
[25] Muñoz-Garach A, Cornejo-Pareja I, Tinahones FJ. Does metabolically healthy obesity exist? Nutrients 2016;8(6):320.
[26] Yoo HK, Choi EY, Park EW, Cheong Y-S, Bae RA. Comparison of metabolic characteristics of metabolically healthy but obese (MHO) middle-aged men according to different criteria. Kor J Fam Med 2013;34(1):19–26.
[27] Phillips CM, Dillon C, Harrington JM, McCarthy VJ, Kearney PM, Fitzgerald AP, et al. Defining metabolically healthy obesity: role of dietary and lifestyle factors. PLoS One 2013;8(10). e76188. PubMed PMID: 24146838. Pubmed Central PMCID: PMC3798285. Epub 2013/10/23. eng.
[28] Yudkin JS, Stehouwer C, Emeis J, Coppack S. C-reactive protein in healthy subjects: associations with obesity, insulin resistance, and endothelial dysfunction: a potential role for cytokines originating from adipose tissue? Arterioscler Thromb Vasc Biol 1999;19(4):972–8.
[29] Blankenberg S, Barbaux S, Tiret L. Adhesion molecules and atherosclerosis. Atherosclerosis 2003;170(2):191–203.
[30] Zheng R, Zhou D, Zhu Y. The long-term prognosis of cardiovascular disease and all-cause mortality for metabolically healthy obesity: a systematic review and meta-analysis. J Epidemiol Community Health 2016. jech-2015-206948.
[31] Aung K, Lorenzo C, Hinojosa MA, Haffner SM. Risk of developing diabetes and cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese individuals. J Clin Endocrinol Metabol 2014;99(2):462–8.
[32] Zuniga YL, Rebello SA, Oi PL, Zheng H, Lee J, Tai ES, et al. Rice and noodle consumption is associated with insulin resistance and hyperglycaemia in an Asian population. Br J Nutr 2014 Mar 28;111(6):1118–28. PubMed PMID: 24229726. Epub 2013/11/16. eng.
[33] Hadj Ahmed S, Kharroubi W, Kaoubaa N, Zarrouk A, Batbout F, Gamra H, et al. Correlation of trans fatty acids with the severity of coronary artery disease lesions. Lipids Health Dis 2018 Mar 15;17(1):52. PubMed PMID: 29544473. Pubmed Central PMCID: PMC5856295. Epub 2018/03/17. eng.
[34] Slattery ML, Edwards SL, Boucher KM, Anderson K, Caan BJ. Lifestyle and colon cancer: an assessment of factors associated with risk. Am J Epidemiol 1999;150(8):869–77.
[35] Schulze MB, Fung TT, Manson JE, Willett WC, Hu FB. Dietary patterns and changes in body weight in women. Obesity 2006 Aug;14(8):1444–53. PubMed PMID: 16988088. Epub 2006/09/22. eng.
[36] Khayyatzadeh SS, Bagherniya M, Fazeli M, Khorasanchi Z, Bidokhti MS, Ahmadinejad M, et al. A Western dietary pattern is associated with elevated level of high sensitive C-reactive protein among adolescent girls. Eur J Clin Invest 2018 Jan 27. PubMed PMID: 29377099. Epub 2018/01/30. eng.
[37] Schulze MB, Hoffmann K, Manson JE, Willett WC, Meigs JB, Weikert C, et al. Dietary pattern, inflammation, and incidence of type 2 diabetes in women–. Am J Clin Nutr 2005;82(3):675–84.
[38] Kim Y, Keogh JB, Clifton PM. Effects of two different dietary patterns on inflammatory markers, advanced glycation end products and lipids in subjects without type 2 diabetes: a randomised crossover study. Nutrients 2017 Mar 29;9(4). PubMed PMID: 28353655. Pubmed Central PMCID: PMC5409675. Epub 2017/03/30. eng.
[39] Brand-Miller JC, Holt SH, Pawlak DB, McMillan J. Glycemic index and obesity. Am J Clin Nutr 2002;76(1):281S–5S.
[40] Poggio R, Elorriaga N, Gutierrez L, Irazola V, Rubinstein A, Danaei G. Associations between dietary patterns and serum lipids, apo and C-reactive protein in an adult population: evidence from a multi-city cohort in South America. Br J Nutr 2017 Feb;117(4):548–55. PubMed PMID: 28382894. Epub 2017/04/07. eng.
[41] Chiu S, Williams PT, Krauss RM. Effects of a very high saturated fat diet on LDL particles in adults with atherogenic dyslipidemia: a randomized controlled trial. PLoS One 2017;12(2), e0170664.
[42] 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.
[43] Lowe G, Woodward M, Rumley A, Morrison C, Tunstall-Pedoe H, Stephen K. Total tooth loss and prevalent cardiovascular disease in men and women: possible roles of citrus fruit consumption, vitamin C, and inflammatory and thrombotic variables. J Clin Epidemiol 2003;56(7):694–700.
[44] Schwingshackl L, Christoph M, Hoffmann G. Effects of olive oil on markers of inflammation and endothelial function-A systematic review and meta-analysis. Nutrients 2015 Sep 11;7(9):7651–75. PubMed PMID: 26378571. Pubmed Central PMCID: PMC4586551. Epub 2015/09/18. eng.
[45] Ghasemi Fard S, Wang F, Sinclair AJ, Elliott G, Turchini GM. How does high DHA fish oil affect health? A systematic review of evidence. Crit Rev Food Sci Nutr 2018 Mar 1:1–44. PubMed PMID: 29494205. Epub 2018/03/02. eng.
[46] Micallef MA, Munro IA, Garg ML. An inverse relationship between plasma n-3 fatty acids and C-reactive protein in healthy individuals. Eur J Clin Nutr 2009 Sep;63(9):1154–6. PubMed PMID: 19352379. Epub 2009/04/09. eng.
[47] Lordan R, Tsoupras A, Mitra B, Zabetakis I. Dairy fats and cardiovascular disease: do we really need to be concerned? Foods 2018 Mar 1;7(3). PubMed PMID: 29494487. Epub 2018/03/02. eng.
[48] Mazidi M, Kengne AP, Mikhailidis DP, Cicero AF, Banach M. Effects of selected dietary constituents on high-sensitivity C-reactive protein levels in U.S. adults. Ann Med 2018 Feb;50(1):1–6. PubMed PMID: 28462631. Epub 2017/05/04. eng.