# Healthy Eating Index 2015 and Major Dietary Patterns in Relation to Incident Hypertension; A Prospective Cohort Study

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# Abstract

**Background:** Since hypertension (HTN) is responsible for more than half of all deaths from cardiovascular disease, it is important to know the nutritional factors that reduce its risk. Although little information is known about it in the Kurdish population. This study was aimed to evaluate healthy eating index (HEI) 2015 and major dietary patterns in relation to incident HTN.

**Methods:** This case- cohort study was designed using data from Ravansar non- communicable diseases (RaNCD) cohort study (294 participants with incident HTN and 1295 participants as representative random sub-cohort). HEI 2015 and major dietary patterns were extracted using data from their dietary intake and three major dietary patterns were identified including plant- based, high protein, and unhealthy dietary patterns. To analysis of association between HEI 2015 and major dietary patterns with incident HTN Cox proportional hazards regression models were applied.

**Results:** There was a positive significant correlation between HEI 2015 and plant- based diet (r=0.492). The participants in the highest quartile of HEI-2015 had a 39% lower risk of incident HTN, compared to participants in first quartile in both crude and adjusted model (HR: 0.61; 95% CI: 0.46-0.82) and (HR: 0.7; 95% CI: 0.51–0.97), respectively. Furthermore, participants who were the highest tertile of plant- based dietary pattern were lower risk of incident HTN in both crude and adjusted models (HR: 0.69; 95% CI: 0.54–0.9) and (HR: 0.7; 95% CI: 0.53–0.94), respectively. However, other two identified dietary patterns had no significant association with incident HTN.

**Conclusions:** We found evidence indicating higher adherence to HEI 2015 and plant- based diet had protective effects on incident HTN. The HEI 2015 emphasizes limited sodium intake and adequate intake of vegetables and fruits.


# Background

Hypertension (HTN) is a worldwide health problem that is a major cause of cardiovascular diseases (CVDs) and premature death, affecting approximately one billion adults worldwide [1, 2]. By 2030, it is estimated that 41% of American adults will have been diagnosed with HTN [3]. Evidence indicates that CVDs mortality is rising in Iran, in contrast to trends reported in the USA and northern Europe [4], that in Iran's population, 24% of women and 22% of men suffer from HTN [2]. HTN is a multifactorial disease caused by a complex combination of dietary, lifestyle, and genetic risk factors [5]. The high prevalence of HTN can be attributed to sedentary behavior, obesity, smoking, family history, and an unhealthy diet [2, 5, 6]. Nevertheless, it is a curable and well- modifiable disease, as the controlled HTN led to improve the life quality and the prognosis and prevent its clinical complications [2, 7]. The main strategies for the prevention and management of HTN are lifestyle changes such as physical activity, weight loss, and dietary modifications [2, 8, 9].

Dietary modifications play a vital role in the prevention and management of HTN [1]. There have been numerous studies conducted over the past few decades that highlight the importance of dietary

modification in the development and control of HTN [8–11]. In recent years, several indices have been developed to examine the health of dietary patterns. Due to the interaction of nutrients in foods, it is often impossible to separate the effects of specific dietary components. Accordingly, the use of these indices and dietary patterns has evolved as a way to assess the effects of overall dietary intake [10, 12, 13]. Since 1995 the healthy eating index (HEI) is a dietary index developed to assess the quality of the diet and to assess diet in accordance with Dietary Guidelines for Americans (DGA). The HEI is updated every five years by the evidence-based recommendations of the United States Department of Agriculture (USDA) and Health and Human Services (HHS) [14, 15]. The latest version of this index is the HEI 2015 index, which mentions two important parts in nutrition guidelines: first, adequacy and second, moderation for dietary intakes. The first part consists of 9 food items including total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids and the second part that means limitation intake is related to these 4 food items including refined grains, sodium, added sugars, and saturated fats [14, 16].

Despite the tremendous increase in the prevalence of HTN in Iran [17], there are no standard quantitative dietary guidelines to evaluate dietary patterns and their relationships with HTN [5]. Moreover, there is little information is known about the relation between HTN and HEI 2015 and major dietary patterns in the Kurdish population. The Ravansar Non-Communicable Disease cohort study [18] provided this opportunity to evaluate diet pattern and HTN associations from an epidemiological standpoint. Therefore, the current study was designed to investigate the HEI 2015 and major dietary patterns in relation to incident HTN.

## Methods

# Study design and participants

This present case- cohort study was applied on data from the RaNCD cohort study in which Kurdish population-based study was started as prospective study for evaluating non-communicable diseases in October 2014 in Ravansar, Kermanshah Province, western Iran. The RaNCD cohort study is a part of the Prospective Epidemiological Research Studies in Iran (PERSIAN) mega cohort study with 10047 participants (4764 men and 5283 women) aged 35-65 years in which recruitment phase was began from October 2014 to January 2017 and followed until January 2021. Ethical approval for the RaNCD cohort study has been granted by the Ethics Committee of Kermanshah University of Medical Sciences, Kermanshah, Iran (No: KUMS.REC.1394.318), and written informed consent was completed from all participants prior to contribution. The protocols of these studies have already been published [18, 19].

The study participants included the adults with complete and reliable dietary data from national validated semi- quantitative 130 items food frequency questionnaire (FFQ) [18, 20]. Initially 1295 participants without incident HTN were randomly considered as representative sub-cohort (20% of the base population). Among the rest, we excluded participants with hypertension (n= 1452), CVDs (n=512), thyroid (n=139), and cancer (n=18) diseases, as well as, pregnant women (n=134) due to possible dietary

changes. Additionally, incident CVDs (n=134) were excluded from this study. Furthermore, the participants whose calories intake were not in the normal range (800-4200 Kcal/day for men and 600- 3500 Kcal/day for women) (n=796), were excluded in the study. Finally, among 294 participants with incident HTN were remained and were selected as case group.

# Data sources/ measurements

We obtained data required for this analysis from RaNCD cohort study including demographics, socioeconomic factors and current lifestyle, such as physical activity (metabolic equivalent of task (MET) hour per day), educational level, smoking status (never, current, or former smoker), anthropometric indices, dietary intake, and medical history. The details of the measurement methods are described in the study of the RaNCD cohort profile [18].

# Anthropometric measurements

The height and weight of participants were measured with the least clothing and without shoes with the automatic stadiometer BSM 370 (Biospace Co., Seoul, Korea) and InBody 770 device (Inbody Co, Seoul, Korea), respectively in the study site in Ravansar in a standing position. Waist circumference (WC) measuring was applied using non-stretched and flexible tape in standing position at the level of the iliac crest. Body mass index (BMI) was computed by dividing weight in kg into height square in meter.

# Healthy eating index 2015

HEI 2015 was calculated based on RaNCD FFQ data using method described by Krebs-Smith et al [16]. HEI 2015 include 13 items including whole fruits, total fruits, total protein foods, total vegetables, seafood and plant proteins, greens and beans, whole grains, dairy products, fatty acids, refined grains, sodium, added sugars and saturated fats. The first nine is emphasized that they should be consumed in adequate quantities, and participants with the highest intake were given the highest point. The last four should be considered in moderation in their consumption and participants with the lowest intake were given the highest point. For scoring the first six, the amount consumed is given a point from zero to 5 and the rest of the range of points is from zero to ten. Finally, the score from each item is added together and the final HEI score is between zero and 100. (Table 1)

Table 1

Healthy eating index - 2015[1]

| Component | Standard for maximum score | Standard for minimum score of zero | Maximum points |
|---|---|---|---|
| Adequacy:<br>**Total Fruits** | ≥0.8 cup equivalent per 1,000 kcal | No Fruit | 5 |
| **Whole Fruits** | ≥0.4 cup equivalent per 1,000 kcal | No Whole Fruit | 5 |
| **Total Vegetables** | ≥1.1 cup equivalent per 1,000 kcal | No Vegetables | 5 |
| **Greens and Beans** | ≥0.2 cup equivalent per 1,000 kcal | No Dark-Green Vegetables or Legumes | 5 |
| **Whole Grains** | ≥1.5 cup equivalent per 1,000 kcal | No Whole Grains | 10 |
| **Dairy** | ≥1.3 cup equivalent per 1,000 kcal | No Dairy | 10 |
| **Total Protein Foods** | ≥2.5 cup equivalent per 1,000 kcal | No Protein Foods | 5 |
| **Seafood and Plant Proteins** | ≥0.8 cup equivalent per 1,000 kcal | No Seafood or Plant Proteins | 5 |
| **Fatty Acids** | (PUFAs + MUFAs)/SFAs ≥2.5 | (PUFAs + MUFAs)/SFAs ≤1.2 | 10 |
| Moderation: | | | |
| **Refined Grains** | ≤1.8 ounce equivalent per 1,000 kcal | ≥4.3 ounce equivalent per 1,000 kcal | 10 |
| **Sodium** | ≤1.1 grams per 1,000 kcal | ≥2.0 grams per 1,000 kcal | 10 |
| **Added Sugars** | ≤6.5% of energy | ≥26% of energy | 10 |
| **Saturated Fats** | ≤8% of energy | ≥16% of energy | 10 |
| Total score | | | 100 |

[1] Intakes between the minimum and maximum standards are scored proportionately.

[2] Includes 100% fruit juice.

[3] Includes all forms except juice.

[4] Includes legumes (beans and peas)

[5] Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages

| Component | Standard for maximum score | Standard for minimum score of zero | Maximum points |
|---|---|---|---|
| [6] Includes seafood, nuts, seeds, soy products (other than beverages), and legumes (beans and peas) | | | |
| [7] Ratio of poly- and mono-unsaturated fatty acids (PUFAs and MUFAs) to saturated fatty acids (SFAs) | | | |

# Dietary pattern

The major dietary patterns were identified by principal component analysis to energy-adjusted foods intake using data from the RaNCD FFQ. Initially, we categorized all food items considering nutrients similarity into 31 food groups. (Table 2) In method of principal component analysis, the varimax rotation was applied to create a simple and distinct matrix, as well as kept uncorrelated factor variables called the major pattern. Also, the scree-plot was drawn to determine number of matrix components (the major dietary patterns). We selected the first three major dietary patterns with values greater than 1.5. Overall, each participant received a factor score for each dietary pattern based on the intake of weighed food groups by factor loading. Food groups with factor loadings more than 0.2 on a factor were used to describe more relationship between food groups and dietary patterns. To better display the associations, we trimmed three identified dietary patterns. Tertiles of factor scores were determined due to total participants and considered in the further analysis.

Table 2
Food groupings used in the dietary pattern analyses

| Food groups | Dietary components |
|---|---|
| Leafy vegetables | Cauliflower, lettuce, cucumber, onion, green bean, mushroom, pepper, garlic, turnip, others |
| Fresh fruits | Melon, watermelon, honeydew melon, plums, prunes, apples, cherries, sour cherries, peaches, nectarine, pear, fig, date, grapes, kiwi, pomegranate, strawberry, banana, persimmon, berry, pineapple, oranges, others |
| Dried fruits | Dried apricots, Dried berries, raisins, and other type dried fruits |
| Dairy | Milk, yogurt, yogurt drink (doogh), cheese, chocolate milk, crud |
| Tomato | Tomato |
| Carotene-rich vegetables | Yellow squash, carrot |
| Condiments | Condiments |
| Pickles | Pickles |
| Legumes | All type beans, peas,lentils, mung bean, soy |
| Whole grain | Dark breads (Iranian), wheat, barley |
| Starchy vegetables | Corn, eggplant, green peas, green squash |
| Vegetable oil | Vegetable oil |
| Natural juices | All fruit juices |
| Butter | Butter, margarine, mayonnaise |
| Olive | Olive and olive oil |
| Organ meat | Heart, kidney, liver, tongue, brain, offal |
| Read meat | Beef, lamb, minced meat |
| Fish | All fish types |
| Processed meat | Hamburger, sausage, delicatessen meat, pizza |
| Soft drink | Soft drink |
| Nuts | Almond, peanut, walnut, pistachio, hazelnut, seeds |
| Egg | Egg |
| Poultry | Chicken |
| Snack | Corn puffs, potato chips, French fries |

| Food groups | Dietary components |
|---|---|
| Sweets and desserts | Cookies, cakes, biscuit, muffins, pies, chocolates, ice, honey, jam, sugar cubes, sugar, candies, others |
| Tea and coffee | Tea and coffee |
| Hydrogenated fat | Hydrogenated fats, animal fats |
| Salt | Salt |
| Potato | Potato |
| Refined grain | White breads (lavash, baguettes), noodles, pasta, rice |

# Blood pressure

The systolic and diastolic blood pressure (SBP and DBP) measuring was performed after at least 4-5 minutes of rest by conventional sphygmomanometer and auscultation of the Korotkoff sounds in sitting position two times with 10 minutes interval and the mean of them was reported as the final blood pressure [18].

# Hypertension (HTN) incidence

The incident HTN was defined based on the codes I10 of the International classification of diseases Tenth Edition (ICD-10), which included SBP/DBP ≥ 140/90 mmHg and/or using anti-hypertensive medications in the time interval between baseline (first phase of Ravansar cohort which has been conducted from 2014) and hypertension diagnosis (from 2015 to 2021), which the overall duration of the follow-up was 85026 person-year.

# Statistical analysis

All statistical analysis was performed using Stata, version 14 (Stata Corp, College Station, TX) with P value <0.05 as significant level. Differences in the baseline quantitative and qualitative variables across quartile of HEI 2015 were assessed using the One-way analysis of variance (ANOVA) and Chi square tests, respectively. Correlation between major identified dietary patterns and HEI 2015 was determined by Person correlation and difference of HEI 2015 across tertiles of major identified dietary patterns was evaluated by the One-way ANOVA.

Cox proportional hazards regression model were used to calculate hazard ratios (HRs) stratified by HEI 2015 and major identified dietary patterns, with hypertension as the event and the time interval between

baseline (first phase of RaNCD cohort) and hypertension diagnosis as the time covariate. The models were adjusted for confounding variables including Model II: adjusted for sex and age; Model III: adjusted for Model II plus SES, education level, physical activity, diabetes; Model IV: adjusted for Model III plus BMI and energy intake and finally reported as HR with 95% confidence interval (CI).

# Results

In current prospective study, the representative random sub-cohort of 1295 participants were selected for this case cohort study. After exclusions, 294 incident HTN were occurred. The mean of weight, BMI, and WC in cases were significantly higher than sub-cohort group. In addition, the mean of PA in cases was significantly lower than sub-cohort group (P<0.001). 48.83% of the participants were male in which there was no significant difference between two studied groups in term of gender (P<0.001). Baseline characteristics of the study population in both studied groups are shown in Table 3.

Table 3
Baseline characteristics in cases and sub cohort groups

| **Determinants** | **Total (n=1587)** | **Cases (n=294)** | **Sub cohort (n=1291)** | **P value** |
|---|---|---|---|---|
| Age (year) | 46.5±7.89 | 50.43±7.34 | 45.59±7.74 | <0.001 |
| Gender, male, % | 48.83 | 38.1 | 51.35 | <0.001 |
| SES, % | | | | |
| Weak | 33.18 | 36.52 | 32.38 | 0.393 |
| Moderate | 33.43 | 31.4 | 33.85 | |
| Good | 33.37 | 32.08 | 33.77 | |
| Weight (kg) | 72.25±13.07 | 73.61±13.3 | 71.94±13 | 0.049 |
| BMI ($kg/m^2$) | 27.23±4.42 | 28.47±4.35 | 26.95±4.39 | <0.001 |
| WC (cm) | 96.67±10.03 | 99.33±9.39 | 96.06±10.07 | <0.001 |
| PA (MET/ day) | 40.99±8.18 | 39.77±7.2 | 41.27±8.37 | <0.001 |
| Energy intake (Kcal/day) | 2518.97±689.9 | 2416.42±721.05 | 2541.25±716.19 | 0.007 |
| Smoking, % | 18.54 | 19.59 | 18.31 | 0.289 |
| Diabetic, % | 6.5 | 5.34 | 11.64 | <0.001 |
| *BMI: body mass index; WC: waist circumference; PA: physical activity; SES: socioeconomic status | | | | |
| P- value was obtained independent samples T and Chi square tests. | | | | |

The results of food groups intake led to identify three major dietary patterns including plant- based, high protein, and unhealthy dietary patterns. The plant- based dietary pattern was characterized by higher adhere to leafy vegetables, starchy vegetables, carotene-rich vegetables, tomato, potato, legumes, nuts, olive, vegetable oil, fresh and dried fruits, and fruit juice. Another major dietary pattern as high protein diet was tended to higher intake to red and white meat, legumes, egg, whole, and refined grains. In addition, unhealthy dietary pattern was identified with higher factor loading of salt, sweet, dessert, butter, hydrogenated fat, soft drink, refined grain, tea, and coffee. (Table 4)

Table 4
Factor loading of food groups in all dietary patterns

| Food groups | Plant- based dietary pattern | High protein dietary pattern | Unhealthy dietary pattern |
|---|---|---|---|
| Leafy vegetables | .684 | - | - |
| Fresh fruits | .637 | .221 | |
| Pickles | .491 | - | .205 |
| Starchy vegetables | .445 | - | - |
| Condiments | .441 | - | .300 |
| Dried fruits | .436 | - | - |
| Tomato | .407 | - | - |
| Carotene-rich vegetables | .396 | .268 | |
| Nuts | .393 | .214 | - |
| Vegetable oil | .380 | - | -.341 |
| Dairy | .357 | - | - |
| Natural juices | .336 | .224 | - |
| Organ meat | - | .665 | - |
| Red meat | - | .637 | - |
| Fish | - | .545 | - |
| Processed meat | - | .448 | - |
| Legumes | .293 | .423 | - |
| Poultry | - | .373 | - |
| Soft drinks | - | .365 | .339 |
| Egg | - | .342 | - |
| Refined grains | - | .327 | .254 |
| Whole grains | .218 | .262 | - |
| Sweets and desserts | - | - | .658 |
| Hydrogenated fats | - | - | .561 |
| Tea and coffee | - | - | .544 |

Values < 0.2 have been removed for clarity

| Food groups | Plant- based dietary pattern | High protein dietary pattern | Unhealthy dietary pattern |
|---|---|---|---|
| **Salt** | - | - | .353 |
| **Potato** | .246 | - | .311 |
| **Butters** | .234 | .231 | .300 |
| **Olive** | .272 | - | -.275 |
| **Snack** | .213 | - | .263 |
| **Variance %** | 13.72 | 6.55 | 5.4 |
| Values < 0.2 have been removed for clarity | | | |

Table 5 showed the correlation between HEI 2015 and the major identified dietary patterns. According to it, there was a positive significant correlation between HEI 2015 with plant- based (r= 0.492) and high protein (r= 0.255) diets, while there was an inverse significant correlation between HEI 2015 and unhealthy diet (r= -0.473).

Table 5
The correlation between healthy eating index 2015 and major identified dietary patterns

| Major dietary pattern | Categories | HEI | P* | r | P** |
|---|---|---|---|---|---|
| | | Mean± SD | | | |
| Plant- based dietary pattern | T1 | 46.65±6.06 | <0.001 | 0.492 | <0.001 |
| | T2 | 51.91±6.14 | | | |
| | T3 | 55.68±6.91 | | | |
| High protein dietary pattern | T1 | 48.8±7.23 | <0.001 | 0.255 | <0.001 |
| | T2 | 51.63±6.68 | | | |
| | T3 | 53.83±7.34 | | | |
| Unhealthy dietary pattern | T1 | 55.5±6.86 | <0.001 | -0.473 | <0.001 |
| | T2 | 50.85±6.63 | | | |
| | T3 | 47.91±6.56 | | | |
| P* was obtained one way ANOVA. | | | | | |
| P** was obtained Pierson correlation. | | | | | |

This present study showed that the participants in the highest quartile of HEI-2015 had a 39% lower risk of incident HTN, compared to participants in first quartile (HR: 0.61; 95% CI: 0.46-0.82). After adjustment for potential confounders including age, gender, SES, education, physical activity, diabetes, BMI, and

energy intake this association was remined (HR: 0.7; 95% CI: 0.51–0.97). (Table 6) (Figure 1, A) Similarly, among the major identified dietary patterns, participants who were the highest tertile of plant- based dietary pattern were lower risk of incident HTN in both crude and adjusted models (HR: 0.69; 95% CI: 0.54–0.9) and (HR: 0.7; 95% CI: 0.53–0.94), respectively. (Figure 1, B) However, other two identified dietary patterns had no significant association with incident HTN. (Table 6) (Figure 1, C **and D)**

Table 6
Hazard ratio of incident hypertension according to healthy eating index 2015

| Dietary pattern | categories | N | N. of cases | Hazard ratio (95% CI) | | | |
|---|---|---|---|---|---|---|---|
| | | | | **Model I** | **Model II** | **Model III** | **Model IV** |
| Quartiles of HEI 2015 | Q 1 | 479 | 84 | Ref. | Ref. | Ref. | Ref. |
| | Q 2 | 337 | 59 | 0.84 (0.63, 1.12) | 0.94 (0.70, 1.27) | 0.98 (0.72, 1.34) | 0.97 (0.71, 1.34) |
| | Q 3 | 391 | 82 | 0.70 (0.53, 0.93) | 0.75 (0.57, 0.98) | 0.74 (0.55, 0.99) | 0.71 (0.52,0.95) |
| | Q 4 | 380 | 69 | 0.61 (0.46, 0.82) | 0.71 (0.52, 0.94) | 0.69 (0.51, 0.96) | 0.7 (0.51, 0.97) |
| Tertiles of plant-based diet | T1 | 442 | 87 | Ref. | Ref. | Ref. | Ref. |
| | T2 | 433 | 97 | 0.9 (0.69, 1.16) | 1.03 (0.78, 1.34) | 1 (0.76, 1.31) | 1 (0.76, 1.34) |
| | T3 | 420 | 110 | 0.69 (0.54, 0.9) | 0.71 (0.55, 0.92) | 0.68 (0.52, 0.9) | 0.7 (0.53, 0.94) |
| Tertiles of high protein diet | T1 | 400 | 129 | Ref. | Ref. | Ref. | Ref. |
| | T2 | 426 | 104 | 0.82 (0.67, 1.04) | 0.84 (0.66, 1.08) | 0.89 (0.69, 1.15) | 0.94 (0.72, 1.23) |
| | T3 | 469 | 61 | 0.83 (0.64, 1.09) | 0.95 (0.7, 1.29) | 1 (0.74, 1.37) | 1.1 (0.81, 1.57) |
| Tertiles of unhealthy diet | T1 | 430 | 99 | Ref. | Ref. | Ref. | Ref. |
| | T2 | 420 | 110 | 1.03 (0.81, 1.32) | 1.07 (0.84, 1.37) | 1.08 (0.83, 1.39) | 1.15 (0.89, 1.5) |
| | T3 | 444 | 85 | 1.06 (0.82, 1.38) | 1.04 (0.8, 1.35) | 1.02 (0.78, 1.34) | 1.25 (0.9, 1.73) |

**Model I**: Unadjusted; **Model II**: Adjusted for sex and age; **Model III**: Adjusted for Model II plus SES, education level, physical activity, T2DM; M**odel IV**: Adjusted for Model III plus BMI and energy intake

Furthermore, we observed that among the HEI- 2015 components, participant who had higher score of total fruits, fatty acids, and sodium, were lower risk of HTN incident (HR: 0.93; 95% CI: 0.85-0.99), (HR:

0.96; 95% CI: 0.92-0.99), and (HR: 0.96; 95% CI: 0.92-0.99), respectively. Other the HEI- 2015 components had no significant association with HTN incident. (Table 7)

Table 7
Relationship between the HEI- 2015 components and HTN incidence

| Components of HEI 2015 | Crude | Model 1 |
|---|---|---|
| | HR (CI 95%) * | HR (CI 95%) * |
| Total Fruits | 0.92 (0.85-0.99) | 0.93 (0.85-0.99) |
| Whole Fruits | 0.92 (0.84-1) | 0.94 (0.85-1.03) |
| Total Vegetables | 1.02 (0.93-1.12) | 1.02 (0.93-1.12) |
| Greens and Beans | 0.98 (0.91-1.07) | 0.96 (0.88-1.04) |
| Whole Grains | 1.07 (0.98-1.18) | 1.06 (0.96-1.17) |
| Dairy | 0.99 (0.95-1.02) | 0.99 (0.95-1.03) |
| Total Protein Foods | 0.95 (0.87-1.04) | 0.96 (0.87-1.06) |
| Seafood and Plant Proteins | 1.04 (0.9-1.21) | 1.13 (0.97-1.33) |
| Fatty Acids | 0.96 (0.93-0.99) | 0.96 (0.92-0.99) |
| Refined Grains | 0.93 (0.84-1.02) | 0.91 (0.83-1.01) |
| Sodium | 0.94 (0.91-0.98) | 0.96 (0.92-0.99) |
| Added Sugars | 0.98 (0.93-1.03) | 1 (0.95-1.05) |
| Saturated Fats | 1 (0.97-1.04) | 1.01 (0.97-1.05) |
| *Adjusted for all variables in Table 6. | | |

# Discussion

In this large prospective Kurdish population-based study, we extracted three major dietary patterns using principal component analyses method in which among them plant- based dietary pattern had a significant positive correlation with HEI 2015. In addition, high protein diet had relatively a significant positive correlation with HEI 2015, while unhealthy dietary pattern had a significant inverse correlation with HEI 2015. We found that greater adherence to HEI 2015 and plant- based dietary pattern was inversely associated with risk of incident HTN. Moreover, among the HEI- 2015 components higher score of total fruits, fatty acids, and sodium were each associated with reduced risk of incident HTN. No significant association was found between other two identified dietary patterns (high protein and unhealthy dietary patterns) and incident HTN.

HTN contributes as one of the most important risk factors for CVDs and their mortality. Diet modification is an effective strategy to prevent it [21]. Understanding national dietary patterns and their relationship to the risk of chronic non-communicable diseases overcomes the challenge of examining individual foods or nutrients and considering their common effects [22]. In this regard, limited data are available from Kurdish dietary patterns, and to the best of our knowledge, the major dietary patterns were identified and were compared to HEI 2015. In addition, the association between them and incident HTN was evaluated.

This present study showed that higher adherence to HEI 2015 had preventive effect on incident HTN. Among the major identified dietary patterns, the plant- based and high protein diets were consistent with the HEI 2015. Similarly, greater adherence to plant- based pattern which emphasized the higher intake of vegetables, especially leafy vegetables, fresh fruits, legumes, and whole grains was decreased incident HTN. While high protein diet had no association with incident HTN. The results from a systematic review and meta-analysis of 15 prospective cohort studies showed that higher diet quality characterized by HEI 2005, 2010, and the alternate healthy eating index (AHEI) was significantly related to decrease all causes mortality including CVDs, cancer, type 2 diabetes [23]. Hu et al. presented that greater following HEI 2015 was significantly reduced CVDs incidence (HR: 0.84; 95% CI: 0.76–0.93) and CVDs mortality (HR: 0.68; 95% CI: 0.58–0.8) [24]. However, HTN was not assessed in these studies. Another systematic review and meta-analysis of 15 randomized clinical trial demonstrated that vegetarian diet lowered both systolic and diastolic blood pressure compared to the omnivorous diet [25]. A case cohort study after 1.61 years follow up of 686 vegetarians showed that they were 34% less likely to develop HTN than people who did not follow a vegetarian diet (Odds Ratio(OR): 0.66; 95% CI: 0.5–0.87) [26]. In study by Song et al. showed that women who consumed higher legumes and whole grain was lower at risk of HTN incidence (HR: 0.77; 95% CI: 0.59–1) [27]. In contrast the results of Thai cohort study indicated that dietary pattern characterized by greater adherence of vegetables, fruits, soybean products, and milk was not associated with HTN (OR: 0.99; 95% CI: 0.86–1.15) [21]. Similarly, in the Mexican Teachers' cohort study was observed that there was no significant association between dietary pattern was tended to vegetable, fruits, and legumes and HTN (OR: 0.94; 95% CI : 0.84,-1.05) [22].

Plant- based diets are generally higher in term of diet quality than non-plant-based diets due to their high content of fiber, antioxidants, potassium, and low content of saturated fat and sodium [28-30]. Plant-based diet prevents incident HTN with beneficial effects on blood viscosity, vasodilation and reduced insulin resistance [25, 31]. Also, with its antioxidant and anti-inflammatory properties and the content of useful fibers, it changes the colony and strains of the intestinal microflora and improves blood pressure by affecting the renin-angiotensin system and baroreceptors [30, 32]. Hence, researchers have referred to it as the dietary approaches to stop hypertension (DASH) diet to prevent hypertension, which emphasizes limiting sodium intake and increasing potassium intake through the consumption of vegetables and fruits [33, 34]. Legumes, fruits and vegetables are enriched antioxidants and important vitamins including fiber, vitamin C, potassium, folic acid, magnesium, flavonoids, and carotenoids and have a beneficial synergistically effects on lowering blood pressure through improving endothelial function and their antioxidative properties causing vasodilation [35, 36].

Our findings from the component of HEI 2015 showed that greater score of total fruits, fatty acids, and sodium was associated with lower risk of incident HTN. This means that limiting the intake of sodium and enough intake of unsaturated fatty acids compared to saturated fatty acids, as well as enough intake fruits, reduces the developing of HTN. Moreover, in this study higher adherence to unhealthy diet was inversely related with HEI 2015 and increased risk of incident HTN. Although, this association was not significant even with controlling potential confounders variables. In study by Mendonça et al. on Spanish adult reported that higher adherence to diet with high content of saturated fats and salt and low content of fresh vegetables and fruits as ultra-processed foods was significantly increased risk of incident HTN (HR: 1.21; 95% CI: 1.06- 1.37) [37]. The modern diet is associated with the intake of processed foods, also known as the Western diet. This pattern is associated with increased intake of calorie, sodium, saturated fats, and decreased potassium [38, 39]. In fact, high sodium intake is the main cause of increased hypertension, which inhibits the sodium pump and stimulates the sodium-calcium exchanger type 1 (NCX1), resulting in increased intracellular calcium concentration, which causes vasoconstriction [40, 41]. Additionally, high sodium intake reduces the synthesis of nitric oxide (NO) and increases the plasma level of the endogenous NO inhibitor, which reduces vasodilation [42, 43]. On the other hand, reducing potassium intake, in addition to affecting the sodium pump, inhibits potassium channels in the cell membrane and increases intracellular calcium in which eventually leads to HTN [44, 45]. All of these factors contribute to the developing of HTN [41].

Other two components of HEI 2015 had preventive effects of incident HTN were total fruits and fatty acids. Adequate intake of fruits in addition to high content of antioxidants, vitamins, minerals and fiber as healthy diet items play a role in weight control and anthropometric indicators and reduce systemic blood pressure [35, 46]. Unsaturated fatty acids, especially omega-3 fatty acids, play an important role in vascular vasodilation by increasing the bioavailability of NO and have anti-inflammatory effects [47].

# Strengths and limitations

This study was the first to be conducted on the large Kurdish population- based study in which allows causal inferences and generalize findings for the entire Kurdish population. In this present study we introduced the major dietary pattern using principal component analyses method and compared with HEI 2015, as well as using validated FFQ that was completed by trained nutritionist led to likely reduce of dietary intake reminders compared to self-report dietary intake. Furthermore, we considered potential confounders variables in all analyses and we did not include some condition because of possible changes in their diet. Nevertheless, this present study suffered from some limitations. Since the duration of the follow-up was short, the incidence was low and we were unable to perform analyzes by gender.

## Conclusions

To conclude, our findings supported the association between the HEI 2015 and incident HTN. Among the major identified dietary patterns, plant- based and high protein diets were positively correlated with HEI

2015, while unhealthy diet was inversely correlated with HEI 2015. Similarly, the plant- based diet, as well as greater score of total fruits, fatty acids, and sodium was preventively associated with incident HTN. Furthermore, other two dietary pattern had no significant association with incident HTN.

## Declarations

# Ethics approval and consent to participate:

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Written informed consent was obtained from each studied subject after explaining the purpose of the study. The right of subjects to withdraw from the study at any time and subject's information is reserved and will not be published.

# Consent for publication:

Not applicable

# Availability of data and materials:

Data will be available upon request from the corresponding author.

# Competing interests:

The authors have no conflict of interest to disclose.

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# Authors' contributions:

S. Moradi and Y. Pasdar equally contributed to the conception and design of the research; F. Njafi, B. Hamzeh, and Y. Pasdar contributed to data collection; F. Najafi, R. Safari, and M. Darbandi contributed to the acquisition and analysis of the data; S. Moradi, R. Safari, and M. Darbandi contributed to the interpretation of the data; and S. Moradi, Y. Pasdar and E. Mohammadi contributed to draft the

manuscript. All authors are in agreement with the manuscript and declare that the content has not been published elsewhere.

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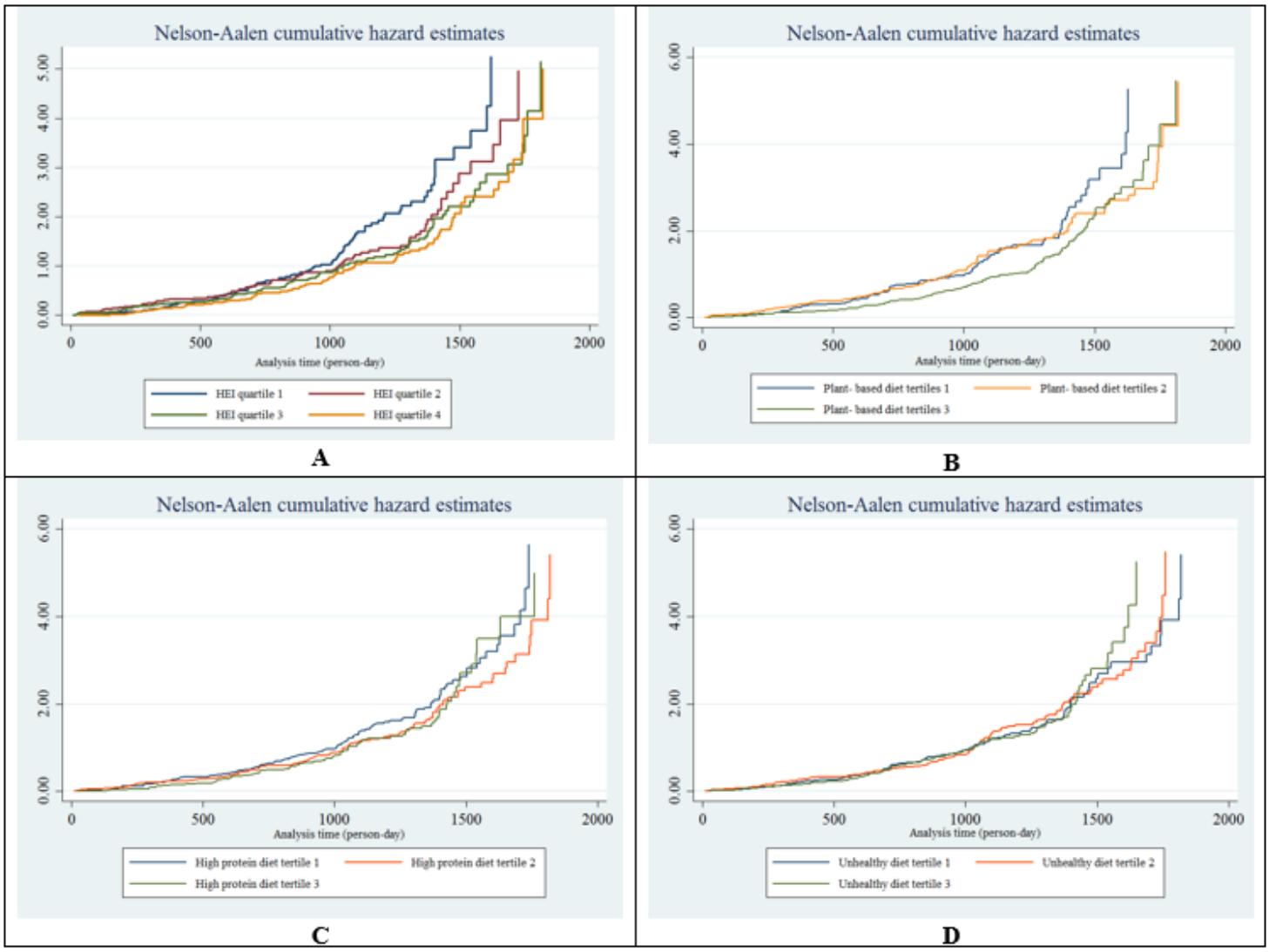
# Figures




## Figure 1

Estimates of the cumulative baseline hazard functions for the hypertension data by A: HEI; B: plant-based diet; C: high protein diet; D: unhealthy diet