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Adherence to planetary health diet index in relation to dietary diversity score and anthropometric indices among Iranian older adults

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Abstract

Background Ensuring a nutritious and sustainable diet for an expanding population presents a formidable challenge. In response to this pressing issue, the EAT-Lancet Commission has proposed a sustainable diet framework. This study aimed to investigate the relationship between Planetary Health Diet (PHDI), Dietary Diversity Score (DDS), and anthropometric indices among Iranian elders.

Methods In this cross-sectional study, 398 participants aged ≥ 60 y were included. Dietary data was collected using a validated 168-item food frequency questionnaire and the DDS was computed based on five distinct food groups. Anthropometric measurements were conducted by standard protocol to derive relevant indices. Binary logistic and linear regression models, adjusted for potential confounders, were employed to analyze the association between adherence to PHDI and outcomes of interest using SPSS version 26.

Result Subjects had a mean age of 63.28 years (SD = 3.58), ranging from 60 to 84 years, of whom 50% were females. PHDI was categorized into tertiles, with 34.7% of individuals in the highest tertile. Highest adherence to PHDI, compared to the lowest, was found to be inversely associated with a lower probability of high BMI (OR: 0.31, 95% CI: 0.17, 0.56), WC (OR: 0.53, 95% CI: 0.32, 0.90), and BRI (OR: 0.43, 95% CI: 0.25, 0.75) in fully adjusted models. Additionally, every 10-point increase in PHDI was linked to a 38%, 25%, and 28% decrease in odds of high BMI, WC, and BRI, respectively, after adjustments for potential confounders. Notably, no significant associations were observed between PHDI and other anthropometric indices or DDS in the fully adjusted model.

Conclusion In conclusion, this study reveals a negative association between adherence to EAT-Lancet recommendations (PHDI) and unfavorable anthropometric measures in Iranian older adults. These findings suggest that promoting diets aligned with the EAT-Lancet guidelines may support healthier aging and help prevent obesity-related health risks. Further, prospective studies are needed to confirm these results and inform public health strategies.

Keywords EAT-Lancet Commission, Planetary Health Diet Index, Dietary diversity, Anthropometric indices

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Introduction

The rate of climate change and its impact on human health are intensifying, demanding immediate solutions across diverse sectors, including the food system [1, 2]. According to the Food and Agriculture Organization and the World Health Organization (WHO), sustainable healthy diets are a “dietary patterns that promote all aspects of an individual’s health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable” [3]. A global transformation of the food system is urgently needed to achieve the goals of the Sustainable Development Agenda [4]. Following this idea, the EAT-Lancet Commission proposed the"Planetary Health Diet"[4]. This reference diet is designed to have a smaller environmental footprint while also promoting health and is renowned for its nutritional balance. In order to evaluate adherence to the Planetary Health Diet, Cacau et al. devised the Planetary Health Diet Index (PHDI) [5]. PHDI was linked to improved overall dietary quality and reduced greenhouse gas emissions [5]. The index could offer valuable insights into the degree to which the diets of different populations adhere to the Planetary Health Diet. Examining the adherence of populations to the Planetary Health Diet will aid in identifying potential dietary adjustments that could enhance the sustainability of the food system [6].

In recent years, a rise in life expectancy coupled with declining fertility and birth rates has led to a growing proportion of elderly individuals within the general population worldwide [7]. By 2050, it is estimated that Iran’s population of individuals aged 60 and above will reach 26 million [8]. Older adults have a higher risk of obesity due to age-related metabolic changes and reduced physical activity [9], which can adversely affect both health and environmental sustainability [10]. Also, it has been documented that older adults tend to have a monotonous diet, which is nutritionally inadequate and can cause diet related chronic diseases [11]. Based on the findings of the EAT-Lancet report, adherence to the guidelines for a nutritious and environmentally sustainable diet could potentially avert 11 million deaths each year by reducing the occurrence of obesity and non-communicable diseases like cardiovascular disease, cancer, and diabetes [12]. Moreover, increased dietary diversity has been shown to be protective against declines in various aspects of healthy aging, particularly physical functions, among middle-aged and older adults [13]. Dietary diversity, which could potentially enhance health outcomes by influencing body fat distribution [14], can also serve as an indicator of the nutritional adequacy and overall quality of one’s diet through the Dietary Diversity Score (DDS) [15]. Hence, we aimed to investigate the relationship between Planetary Health Diet adherence and dietary diversity.

The association between EAT-Lancet recommendations and various health outcomes has been widely investigated. Also, it has previously been shown that PHDI is linked to obesity indicators [16]. However, the extent to which the Iranian population adheres to EAT-Lancet recommendations remain unclear. Given the increasing elderly population and the significance of advocating for a sustainable and healthy diet in Iran, our study aimed to assess the adherence of the elderly population to the Planetary Health Diet Index. Additionally, we sought to investigate the association between adherence to this index and both dietary diversity score and anthropometric indices.

Methods

Study population and design

This research is a cross-sectional investigation carried out on 398 elderly individuals residing in Tehran. The participants were recruited from urban healthcare centers of Tehran University of Medical Sciences between October 2022 and May 2023, using the simple random sampling method. Individuals aged 60 and older, who self-reported the absence of chronic illnesses, were not using specific medications and were not changing their usual diet as a result of disease or per dietitian recommendation, were enrolled in our investigation. Abdominal obesity was the main dependent variable used to calculate study sample size (as the largest sample size would be obtained using this variable) [17]. We used the formula for comparing two proportions, as described by Fleiss in *Statistical Methods for Rates and Proportions* [18]. A total sample size of 396 participants was calculated. Considering potential dropouts, a minimum of 400 individuals were selected from the target population for the study.

$$\boldsymbol{m'} = \frac{[\boldsymbol{ca/2\sqrt{(r_{+1})\overline{p}\overline{Q}}} - \boldsymbol{C_{1-B}\sqrt{r_1P_1Q_1 + p_2Q_2}}]^2}{\boldsymbol{r(p2 - p1)2}}$$

$$\boldsymbol{m} = \frac{\acute{m}}{\boldsymbol{4}}\left(\boldsymbol{1} + \sqrt{\boldsymbol{1} + \frac{\boldsymbol{2(r+1)}}{\acute{m}\boldsymbol{r|P_2 - P_1|}}}\right)^{\boldsymbol{2}}$$

$$m' = \frac{(1.96\sqrt{1.32 \times 0.38 \ \times 0.68} - (-0.842)\ \sqrt{(0.32 \times 0.42 \times 0.58) + (0.26 \times 0.74)})^2}{0.32 \times (0.42 - 0.26)^2}$$

$$= 275$$

$$m = \frac{275}{4}\left(1 + \sqrt{1 + \frac{2 \times (1 + 0.32)}{275 \times 0.32|0.42 - 0.0.26|}}\right)^{2 \cong 300 = n_1}$$

$$n2 = (300 \times 0.32)^2 \cong 396 = n_1$$

The approval for this study was granted by the Tehran University of Medical Sciences Research Ethics Committee under the reference number IR.TUMS.MEDICINE.REC.1401.588, in adherence to the principles outlined in the Helsinki Declaration. Every participant in the study willingly provided written informed consent.

Dietary data

The dietary intake of participants was collected using a validated and reliable semi-quantitative 168-item Food Frequency Questionnaire (FFQ) [19, 20]. Participants were asked to recall the frequency and consumption amount of each food item over the previous year. These details were obtained through a face-to-face interview administered by a proficient and expert researcher. The FFQ included a comprehensive list of food items, each accompanied by standardized serving sizes, enabling participants to report their consumption frequency on a daily, weekly, monthly, or yearly basis. Taking into account the designated portion size and consumption frequency for each food item, all foods were computed on a daily scale and subsequently converted to grams per day using household measures [21]. Nutrient values, encompassing energy and other nutritional components for each item, were calculated utilizing Nutritionist 4 software (First Databank, Hearst Corp., San Bruno, CA, USA), which had been tailored for the analysis of Iranian foods.

Calculation of PHDI

The EAT-Lancet Commission on"Healthy Diets from Sustainable Food Systems"put forth a model diet known as the"Planetary Health Diet,"intending to promote both human health and environmental sustainability. The Planetary Health Diet Index (PHDI) was derived from the recommendations that were presented in the reference diet suggested by the EAT-Lancet Commission [4]. The method used to calculate the PHDI was developed by Cacau et al. [22]. The PHDI consists of 16 components, and the maximum achievable score is 150. A higher PHDI score reflects a higher level of adherence to the Planetary Health Diet. The PHDI utilized the recommended intake ranges and midpoints outlined in the 2500 kcal/d reference Planetary Health Diet [4]. Subsequently, these values were converted into the percentage of calories contributed by each food group to the overall diet. Food groups were categorized into adequacy, optimum, ratio, and moderation groups. This classification considered both the overall nutritional value of the foods for a generally healthful diet and their estimated environmental impacts [6]. Each food within the adequacy, optimum, and moderation categories is assigned a potential score of up to 10. Meanwhile, components in the ratio are assigned a maximum score of 5 to avoid overvaluing a specific dietary aspect during the assessment process.

Adequacy components, including nuts and peanuts, legumes, fruits, vegetables, and whole cereals, represent food groups where zero intake indicates lower dietary quality. However, intakes equal to or above the reference value are associated with a low probability of negative health or environmental impact. In the case of adequacy components, scores increase in direct proportion to intake until the recommended level is reached, with no deductions for surpassing this level (Table 1).

Optimum components, including eggs, fish and seafood, tubers and potatoes, dairy, and unsaturated oils, are characterized by a specific minimum intake level represented by midpoint values, which is favored over non-consumption. Nevertheless, approaching or exceeding an upper limit may gradually undermine both the sustainability and quality of the diet.

In the case of optimum components, scores are raised proportionally until reaching the desired intake level, and deductions are made proportionally until reaching the maximum intake level (Table 1).

The two ratio components within the PHDI signify the compositional distribution of dark green vegetables and red and orange vegetables relative to the total vegetable intake. These components align with the recommendations of EAT-Lancet, emphasizing the importance of diverse vegetable consumption. Values for these components were determined by calculating the ratios of energy intake from dark green vegetables to the total vegetable intake (multiplied by 100) and the ratio of energy intake

Table 1 Planetary health diet index components, standards for scoring (caloric densities), and corresponding point values

Planetary Health Diet Index (PHDI)			
components	**Scores**		
Adequacy	0 ⟷	10	
Nuts and Peanuts	0.0	11.6	
Legumes	0.0	11.3	
Fruits	0.0	5.0	
Non-starchy Vegetables	0.0	3.1	
Whole cereals	0.0	32.4	
Optimum	0 ⟷	10 ⟷	0
Eggs	0.0	0.8	1.5
Fish and Seafood	0.0	1.6	5.7
Tubers and Potatoes	0.0	1.6	3.1
Dairy	0.0	6.1	12.2
Unsaturated Oils	0.0	16.5	30.7
Ratio	0 ⟷	5 ⟷	0
DGV/total Ratio	0.0	29.5	100
ROV/total Ratio	0.0	38.5	100
Moderation	10 ⟷	0	
Red Meat	2.4	0.0	
Chicken and Substitutes	5.0	0.0	
Animal Fats	1.4	0.0	
Added Sugars	4.8	0.0	

from red and orange vegetables to the total vegetable intake (multiplied by 100). Scores ranged from 0% to the cutoff point, incrementally earning 0 to 5 points, while values surpassing the cutoff point received inversely scored points (Table 1).

Moderation components in the PHDI include red meat, chicken and substitutes, animal fats, and added sugars. Positive health and environmental impacts are more likely at low or nearly absent intake levels. Scoring for these components operates as follows: zero intake receives a maximum of 10 points, while an intake exceeding the upper limit scores 0 points. Intakes ranging from 0% to the upper limit are inversely scored, incrementally earning 0 to 10 points (Table 1).

Assessment of dietary diversity score (DDS)

The method employed for calculating the DDS follows the approach initially devised by Kant et al. [15]. Five food groups, comprised of bread and grains, vegetables, fruits, meats, and dairy, were taken into account. The selection of the five major food groups—grains, vegetables, fruits, meats, and dairy—was based on their fundamental role in achieving a balanced and diverse diet, as emphasized by dietary guidelines, such as the USDA Food Guide Pyramid and the Iranian dietary guidelines [23]. Similar classifications have been widely used in dietary diversity research [24]. The subgroups were initially defined based on Kant et al. [15] and later adapted based on Farhangi et al. [25] to better reflect Iranian dietary patterns. We further refined this classification by reassigning legumes and nuts from the vegetable group to the protein group, aligning with the PHDI and previous studies that categorized these foods as protein sources [11]. This adjustment ensures that individuals consuming only plant-based proteins receive an appropriate dietary diversity score. Food subgroups were defined accordingly: the bread and grain group were subdivided into five subgroups (refined bread, whole bread, macaroni, whole cereal/corn flake, rice), the vegetable group was divided into six subgroups (tomato, yellow vegetables, starchy vegetables, potato, green vegetables, other vegetables), fruits were categorized into two subgroups (citrus fruit/berries and fruit/fruit juice), the meat group comprised six subgroups (red meat, poultry, egg, fish, legumes, nuts), while three subgroups were designated for the dairy group (milk, yogurt, and cheese). To be considered a consumer of a particular food group, individuals must consume at least half a serving within a day, as per the quantity criteria outlined by the USDA food guide pyramid. Each food group was assigned a maximum score of 2. Consequently, the overall DDS ranged from 0 to 10 [25].

Assessment of anthropometric measures

Participant height and body weight were assessed by a skilled researcher. Body weight was assessed with the participant barefoot and wearing lightweight clothing, using a Seca model digital scale with a precision of 0.1 kg. The height measurement was obtained as the individual stood without shoes, aligning their head, buttocks, and heels against the wall, and looking straight ahead horizontally. This measurement was conducted using a tape measure with an accuracy of 0.1 cm. Waist circumference (WC) was measured at the midpoint between the lower rib margin and the iliac crest, using a non-stretchable measuring tape with a precision of 0.1 cm. Hip circumference was measured by placing a non-stretchable tape measure with a precision of 0.1 cm around the widest part of the hips.

Anthropometric indices

Anthropometric indices such as body mass index (BMI) and waist-to-height ratio (WHtR) can be readily computed. BMI was estimated by dividing body weight by the square of height (kg/m^2). A Body Shape Index (ABSI) offers a practical representation of the heightened risk associated with elevated WC, complementing both BMI and other established risk factors and estimated using this formula: $ABSI = WC/(BMI^{2/3} \times Height^{1/2})$. Furthermore, the Body Roundness Index (BRI) exhibits comparable or superior performance in predicting components of metabolic syndrome compared to both BMI and WC. BRI is calculated using the formula: $BRI = 364.2 - 365.5 \times (1 - [WC/2\pi]^2/[0.5 \times height)^2]^{½}$ [26]. The Conicity Index (CI) was developed as a measure to evaluate the distribution of body fat as an indicator of obesity and chronic disease. It was calculated using the formula: $(WC\ (m))/(0.109 \times \sqrt{(}body\ weight\ (kg))/(height\ (m)))$ [27]. The Abdominal Volume Index (AVI) was obtained using the formula $AVI = (2\ (wc)^2 + 0.7\ (wc\text{-}hip)^2)/1000$.

Assessment of other variables

Demographic details and lifestyle information was collected using structured questionnaires. Each participant was interviewed regarding the following variables using a sociodemographic questionnaire: gender, age, marital status (single or married), educational attainment (below high school, high school and above), and income (≤ 20 million rials (≤$476), 20 to 60 million rials ($476 to $1,429), and ≥60 million rials (≥$1,429)). Educational level was assessed based on the number of completed school years. Lifestyle data included smoking habits. Participants were specifically asked about their smoking status, indicating whether they were smokers or non-smokers.

The International Physical Activity Questionnaire (IPAQ), used to evaluate the physical activity levels of the elderly, has undergone validation and reliability assessments in 12 countries up to the year 2000, including in Iran. [28, 29]. The final results of this assessment confirm the effectiveness of the questionnaire as a suitable tool for measuring physical activity in diverse contexts and languages. Consisting of seven inquiries, this survey evaluates the frequency and duration of an individual's involvement in physical activities. Participants reported their engagement levels in four categories over the past week: 1) intense activity; 2) moderate activity; 3) walking; and 4) sitting. To precisely calculate Metabolic Equivalent of Task (MET) per minute, the duration of physical activity was expressed in minutes. The total MET per minute for each person throughout a week was used to ascertain total weekly physical activity.

Statistical analysis

Initially, the percentage of calories from all 16 food groups proposed by EAT-Lancet was calculated. Subsequently, the PHDI score was computed as discussed previously. Participants were categorized based on the tertiles of their PHDI scores.Participants were categorized into tertiles of PHDI to ensure adequate sample size in each group, maintaining statistical power for comparisons.

Continuous variables were reported as mean and standard deviation (SD), whereas categorical variables were presented as numbers and percentages. To evaluate differences in both qualitative and quantitative variables across PHDI tertiles, the Chi-square test and Analysis of Variance (ANOVA) were utilized, respectively. Adjustments for energy, gender, age, and the participants'nutrient intake was examined across PHDI tertiles. The information is conveyed as mean with corresponding standard errors (SE), and the analysis was performed using Analysis of Covariance (ANCOVA).

We have assessed the normality of residuals using the Kolmogorov–Smirnov test and Q-Q plots, confirming that the distribution was normal. Multivariable binary logistic regression methods were utilized to investigate the relation between DDS, BMI, WC, BRI, ABSI, CI, and AVI with PHDI in both crude and adjusted models. We considered ABSI, BRI and AVI cut-off points to be 0.08, 5.20, and 17.30, respectively, based on a previous study in the Iranian population [30]. Given the strong association between a waist circumference (WC) above 95 cm and cardiovascular disease (CVD), the cut-off point for WC was established at 95 cm [31]. Also, BMI above 27.5 kg/m^2 was considered as BMI cut-off point since in various Asian populations, further benchmarks for public health intervention were identified, with a BMI of 27.5 kg/m^2 or above serving as a critical indicator of high-risk status [32]. For CI and dietary diversity score, participants were categorized into tertiles. As there are no predefined cut-off points for these two variables, we considered the last tertiles as the outcome of interest.

The adjusted model included following confounders: age, gender, energy intake, physical activity, marital status, socio-economic status, household size, smoking status, and supplement intake. BMI was further adjusted when DDS was considered as the dependent variable. Odds ratios and 95% confidence intervals were computed using the first tertile of PHDI as the reference. In the multivariable logistic regression models, PHDI tertiles were treated as ordinal variables to assess the trend across these tertiles. We also used a linear regression approach for examining the relation between PHDI and DDS. In the linear regression analysis, both exposure (PHDI) and outcome (DDS) were treated as continuous variables. Adjustments were made for age, gender, energy intake, physical activity, marital status, socio-economic status, household size, smoking status, supplement intake and BMI. Additionally, multicollinearity was assessed, and all variance inflation factor (VIF) values were below 5, indicating no significant multicollinearity concerns.

The analyses were carried out using SPSS version 26 (IBM Corp, Armonk, NY, USA), and statistical significance was determined for *P*-values below 0.05.

Result

A total of 1,100 elderly individuals were initially contacted. Among them, 387 did not meet the inclusion criteria, leaving 713 eligible individuals. Of these, 313 did not attend the interview, resulting in a final sample of 400 participants. Therefore, the participation rate, calculated based on those who met the inclusion criteria, was 56.1%.

A sample of 398 participants, constituting an equal distribution of men and women (50% each) were included in this study. The participants had a mean (SD) age of 63.28 (3.58) ranging from 60 to 84 years and an average (SD) weight of 76.43 (10.39) kg. PHDI yielded an average score of 56.6, with individual scores ranging from 27 to 82.

Table 2 presents the characteristics of study participants across PHDI tertiles. In contrast to the first tertile, individuals in the third tertile were more likely to be female (56.50% vs. 40.30%). Also, they were less likely to be married (87.1% vs. 74.6%). Participants in the top tertile of PHDI displayed relatively lower BMI (28.16 ± 4.36 vs. 29.97 ± 4.35) kg/m^2 and waist circumference (96.86 ± 10.47 vs. 100.66 ± 1.81) cm than those in the bottom tertile. No other significant differences were observed across PHDI tertiles in terms of participants' characteristics.

Table 2 General characteristics of participants across tertiles of PHDI[1] (Planetary Health Diet Index)

	PHDI tertiles			*P*-value[2]
	53 ≥ T1 (*n* = 139)	53 < T2 < 61 (*n* = 121)	T3 ≥ 61 (*n* = 128)	
Age (years)	63.07 ± 3.40	63.23 ± 3.85	63.55 ± 3.44	0.53
Gender (women) (percent)	40.30	53.70	56.50	0.01
Weight (kg)	80.43 ± 10.46	76.14 ± 9.56	72.65 ± 9.58	< 0.001
BMI (kg/m^2)	29.97 ± 4.35	29.33 ± 4.01	28.16 ± 4.36	0.002
Waist circumference (cm)	100.66 ± 11.80	97.02 ± 10.46	96.86 ± 10.47	0.006
Hip circumference (cm)	107.83 ± 10.28	107.81 ± 9.65	106.38 ± 10.16	0.39
Education (high school and above) (percent)	36.7	40.5	46.4	0.25
Smoking status (yes) (percent)	21.6	20.7	20.3	0.96
Physical activity (600 MET.min/wk ≤) (percent)	48.2	57.9	50.0	0.26
Supplementation use (yes) (percent)	26.6	37.2	38.4	0.07
Marital status (married) (percent)	87.1	76.9	74.6	0.02
Number of family members (> 2) (percent)	48.2	57.9	53.6	0.20
Socioeconomic status (last tertile) (percent)	28.7	35.5	32.6	0.57

[1] Data are presented as mean ± SD or *n* (%)

[2] Obtained from the ANOVA for continuous variables and Chi-square test for categorical variables

Abbreviation: *PHDI* Planetary Health Diet Index, *BMI* Body Mass Index, *SES* Socioeconomic Status

Table 3 PHDI components, food and nutrient items across tertiles of PHDI

	PHDI tertiles			P-value[1]
	53 ≥T1 (*n* = 139)	**53 <T2 <61 (*n* = 121)**	**T3 ≥61 (*n* = 128)**	
Energy (kcal)	55.38 ± 2069.45	2281.10 ± 58.97	2245.42 ± 55.40	0.01
PHDI components				
Red meat (gram/day)	38.66 ± 1.80	32.00 ± 1.91	27.87 ± 1.79	< 0.001
Nuts (gram/day)	5.13 ± 1.17	6.54 ± 1.24	13.56 ± 1.17	< 0.001
Legumes (gram/day)	17.77 ± 1.04	23.61 ± 1.69	22.14 ± 1.03	< 0.001
Chicken and poultry (gram/day)	28.94 ± 1.59	23.96 ± 1.69	18.58 ± 1.58	< 0.001
Fish and sea food (gram/day)	2.34 ± 0.42	2.92 ± 0.45	5.17 ± 0.42	< 0.001
Egg (gram/day)	35.10 ± 1.98	29.33 ± 2.10	21.97 ± 1.97	< 0.001
Fruits (gram/day)	323.45 ± 14.23	344.39 ± 15.09	389.82 ± 14.16	< 0.001
Vegetables (gram/day)	295.64 ± 13.43	336.26 ± 14.25	380.09 ± 13.36	< 0.001
Whole cereal (gram/day)	39.98 ± 4.55	61.87 ± 4.82	79.24 ± 4.52	< 0.001
Starchy vegetables (gram/day)	45.22 ± 1.71	38.58 ± 1.82	34.00 ± 1.70	< 0.001
Dairy (gram/day)	284.96 ± 16.76	269.67 ± 17.77	242.75 ± 16.67	0.20
Vegetable oil (gram/day)	10.49 ± 0.56	12.53 ± 0.60	12.96 ± 0.56	0.01
Animal oil (gram/day)	14.03 ± 8.12	15.95 ± 15.12	12.05 ± 9.15	0. 01
Added sugar (gram/day)	51.04 ± 2.62	40.65 ± 2.85	35.91 ± 2.67	< 0.001
Dark/Green vegetables (gram/day)	32.87 ± 2.19	51.20 ± 2.33	51.85 ± 2.18	< 0.001
Red/Orange vegetables (gram/day)	109.39 ± 7.34	116.12 ± 7.79	131.93 ± 7.30	0.08
Macronutrients				
Protein (percent of total calories)	12.74 ± 0.18	12.74 ± 0.20	12.39 ± 0.18	0.33
Carbohydrate (percent of total calories)	61.69 ± 0.55	63.31 ± 0.58	64.81 ± 0.55	< 0.001
Total fat (percent of total calories)	27.43 ± 0.55	27.42 ± 0.58	25.28 ± 0.55	0.01
Saturated fat (percent of total calories)	22.87 ± 0.57	21.49 ± 0.61	18.24 ± 0.57	< 0.001
W3 (gram/day)	0.40 ± 0.01	0.38 ± 0.01	0.41 ± 0.01	0.65
Total fiber (gram/day)	16.53 ± 0.38	18.51 ± 0.40	20.33 ± 0.38	< 0.001
Micronutrients				
Calcium (mg/day)	789.98 ± 23.29	802.01 ± 24.70	779.79 ± 23.17	0.80
Iron (mg/day)	140 ± 0.22	15.83 ± 0.24	16.48 ± 0.22	< 0.001
Magnesium (mg/day)	232.69 ± 4.74	242.47 ± 5.03	248.32 ± 4.72	0.07
Zinc (mg/day)	7.42 ± 0.14	7.39 ± 0.15	7.09 ± 0.14	0.22
Vitamin A (IU/day)	1173.8 ± 59.93	1205.94 ± 63.57	1272.93 ± 89.62	0.49
Vitamin E (mg/day)	13.95 ± 0.49	15.10 ± 0.52	15.75 ± 0.49	0.03
Vitamin C (mg/day)	126.22 ± 4.94	135.22 ± 5.24	153.20 ± 4.92	0.001
Vitamin K (mg/day)	121.63 ± 4.76	125.84 ± 5.05	132.24 ± 4.74	0.28
Vitamin B12 (mg/day)	3.08 ± 0.10	2.93 ± 0.11	2.73 ± 0.10	0.08
Vitamin B9 (mg/day)	295.33 ± 10.92	294.51 ± 11.58	304.94 ± 10.86	0.70
Riboflavin (mg/day)	1.84 ± 0.05	1.76 ± 0.05	1.70 ± 0.05	0.17
Niacin (mg/day)	20.62 ± 0.48	20.74 ± 0.51	21.18 ± 0.48	0.69

[1] Obtained from ANCOVA

All values are means ± standard error (SE); energy, protein, carbohydrate and fat are adjusted for age and gender; all other values are adjusted for age, gender and energy intake

Abbreviation: *PHDI* Planetary Health Diet Index

Dietary intakes of participants across tertiles of PHDI are demonstrated in Table 3. The average (SD) total daily energy intake was 2194.81 (668.89) kcal. Notably, participants in the third tertile of the PHDI exhibited a significantly higher energy intake compared to those in the first tertile. Examining PHDI components, there was a significant decrease in the consumption of red meat, chicken, eggs, starchy vegetables, animal oil, and

Table 4 Prevalence of metabolic risk factors and higher dietary diversity score among the tertiles of PHDI

	PHDI tertiles			P-value[1]
	53 ≥ T1 (n = 139)	53 < T2 < 61 (n = 121)	T3 ≥ 61 (n = 128)	
BMI	71.2	62.8	57.2	0.05
WC	70.5	57.9	58.0	0.04
DDS	25.8	37.2	34.1	0.3
CI	35.3	28.9	34.8	0.4
AVI	67.6	71.1	69.6	0.8
BRI	66.2	57.9	54.3	0.10
ABSI	62.6	58.7	71.0	0.10

[1] obtained from Chi-square

Cut-off values: Body mass index (BMI) ≥ 27.5, waist circumference (WC) ≥ 95, abdominal volume index (AVI) ≥ 3.17, body roundness index (BRI) ≥ 5.20, body shape index (ABSI) ≥ 0.08, conicity Index (CI): placement in the third tertile of dietary diversity is reported as the dependent variable

Abbreviation: *PHDI* Planetary Health Diet Index, *BMI* Body Mass Index, *WC* Waist Circumference, *DDS* Dietary Diversity Score, *CI* Conicity Index, *AVI* Abdominal Volume Index, *BRI* Body Roundness Index, *ABSI* A Body Shape Index

added sugar across PHDI tertiles, whereas the intake of nuts, legumes, fish, fruits, vegetables, whole cereals, vegetable oil, and dark-green vegetables showed significant increases. Regarding macronutrient intake, individuals in the highest PHDI tertile displayed a significantly greater consumption of carbohydrates and total fiber, coupled with lower intake of total fat and saturated fat. Furthermore, subjects in the highest PHDI tertile had significantly higher intakes of iron, vitamin E, and vitamin C. No other significant differences were found.

Within the study population, the prevalence of obesity or overweight was 63.8%. Abdominal obesity was observed in 57.8% of individuals. Moreover, 64.3%, 59.5%, and 69.3% of participants exhibited an unfavorable ABSI, BRI, and AVI, respectively. As illustrated in Table 4, individuals in the highest tertile of PHDI exhibited a lower prevalence of obesity/overweight (57.2% versus 71.2%; $p = 0.05$) and abdominal obesity (58.0% versus 70.5%; $p < 0.04$) when compared to those in the lowest category. Differences were not significant for other anthropometric indices.

The multivariable-adjusted ORs for DDS are detailed in Table 5. Notably, no significant association was identified between DDS and PHDI categories in either crude (OR: 1.27, 95% CI: 0.76, 2.12) or maximally-adjusted (OR: 1.12, 95% CI: 0.60, 2.09) models. Considering each 10-point increase in PHDI, a significant positive association was observed with DDS (OR: 1.28, 95% CI: 1.02, 1.60). However, after accounting for potential confounders, this association did not retain statistically significant (OR: 1.24, 95% CI: 0.94, 1.64).

The association between each 10-point increase in PHDI and dietary diversity score components, as revealed by linear regression analysis, is delineated in Table 6. Significant direct associations were observed between every 10-point increase in PHDI and the scores of dietary diversity for grains (β: 0.04, 95% CI: 0.01, 0.07), vegetables (β: 0.03, 95% CI: 0.00, 0.06), and fruits (β: 0.02, 95% CI: 0.01, 0.03) in the adjusted model. Conversely, an inverse significant relationship was noted between every 10-point increase in PHDI and the protein dietary diversity score in the adjusted model (β: –0.03, 95% CI: –0.07, –0.00). However, there was no significant relationship between every 10-point increase in PHDI and the total dietary diversity score in the adjusted model (β: 0.03, 95% CI: –0.04, 0.12).

Table 7 presents the multivariable-adjusted ORs for anthropometry indices across categories of PHDI. When compared to the lowest tertile, individuals in the highest tertile of PHDI demonstrated a 69% reduction in the odds of obesity/overweight after adjusting for all potential confounders (OR: 0.31, 95% CI: 0.17, 0.56).

Table 5 Odds ratio and 95% confidence intervals (CIs) of higher dietary diversity score in tertiles of PHDI

	PHDI tertiles			P_{trend}[1]	Every 10 points of PHDI
	53 ≥ T1 (n = 139)	53 < T2 < 61 (n = 121)	T3 ≥ 61 (n = 128)		
DDS[2]					
Crude	1.00	1.46 (0.87–2.46)	1.27 (0.76–2.12)	0.35	1.28 (1.02–1.60)
Model 1	1.00	1.19 (0.64–2.20)	1.10 (0.60–2.01)	0.76	1.22 (0.93–1.60)
Model 2	1.00	1.20 (0.60–2.23)	1.12 (0.60–2.09)	0.76	1.24 (0.94–1.64)

[1] Obtained from Binary logistic regression

[2] Odds ratio for placement in the third tertile of dietary diversity is reported as the dependent variable

Model 1: Adjusted for age, gender, energy intake, physical activity, marital status, socio-economic status, household size, smoking status, and supplement intake

Model 2: Further adjusted for body mass index (BMI)

Abbreviation: *PHDI* Planetary Health Diet Index, *DDS* Dietary Diversity Score

Table 6 The relationship between Each 10 point of PHDI and dietary diversity score and sub-scores

Dietary diversity sub-scores	Each 10 point of PHDI			
	β[1]	CI	*P*	R^2
Grain DDS				
Crude	0.04	0.01–0.07	0.002	0.02
Adjusted[2]	0.04	0.01–0.07	0.002	0.14
Vegetable DDS				
Crude	0.04	0.01–0.07	0.006	0.01
Adjusted	0.03	0.00–0.06	0.03	0.25
Fruit DDS				
Crude	0.03	0.02–0.04	< 0.001	0.05
Adjusted	0.02	0.01–0.03	< 0.001	0.27
Protein DDS				
Crude	−0.02	−0.05–0.01	0.2	0.003
Adjusted	−0.03	−0.07– −0.00	0.02	0.20
Dairy DDS				
Crude	−0.01	−0.06–0.03	0.56	0.001
Adjusted	−0.02	−0.07–0.02	0.27	0.10
Total DDS				
Crude	0.09	−0.003–0.1	0.05	0.009
Adjusted	0.03	−0.04–0.12	0.34	0.35

[1] Obtained from linear regression

[2] Adjusted for age, gender, energy intake, physical activity, marital status, socio-economic status, household size, smoking status, supplement intake and BMI

Abbreviation: *PHDI* Planetary Health Diet Index, *DDS* Dietary Diversity Score

The likelihood of abdominal obesity was also 47% lower in the third tertile of PHDI, compared to the first tertile, in the adjusted model (OR: 0.53, 95% CI: 0.32, 0.90). Participants in the highest PHDI tertile exhibited a lower odds ratio of high BRI after controlling confounders (OR: 0.43, 95% CI: 0.25, 0.75). In the adjusted model, every 10-point increase in PHDI was inversely associated with odds ratios of higher BMI (OR: 0.62, 95% CI: 0.48, 0.81), waist circumference (OR: 0.75, 95% CI: 0.59, 0.94), and BRI (OR: 0.72, 95% CI: 0.56, 0.91). A significant trend was observed for BMI, WC and BRI across tertiles of PHDI in both crude and adjusted models. In the adjusted model, individuals in the highest tertile of PHDI exhibited increased odds ratios for CI (1.04, 95% CI: 0.62–1.75) and ABSI (1.66, 95% CI: 0.97–2.86), while displaying lower odds for AVI (0.94, 95% CI: 0.54–1.65) compared to those in the lowest tertile. However, none of these associations were statistically significant.

Discussion

This study is the first to investigate the association between how a dietary index assesses adherence to EAT-Lancet recommendations and dietary diversity and anthropometric indices in the Iranian population. As a result, an inverse association was identified between adherence to planetary health diet recommendations, as evaluated by PHDI, and anthropometric indices such as BMI, WC, and BRI. This implies that a greater adherence to EAT-Lancet recommendations is linked to a lower likelihood of being overweight or obese. Both conditions are significant factors associated with other chronic diseases, including diabetes and cardiovascular diseases, particularly in older adults. However, we observed no relationship between PHDI and dietary diversity score as well as other anthropometric indices after considering all confounders.

According to the findings of the current study, it was observed that our population achieved only half of the possible points of PHDI (ranging from 0 to 150 points, with a mean score of 56.6 points). indicating a relatively low adherence to the recommendations of the"healthy and sustainable"dietary pattern. A possible reason for this observation could be due to a shift towards a Western dietary pattern and increase of red meat consumption in the past 30 years in Iran because of an increase in living standards and the efficiency of food production [33]. Moreover, it has been shown that in the Middle East region, there has been a decline in the contribution of grains and fruits to energy intake, while the contribution of oil and meat to the overall diet has increased in the last 45 years [34]. However, it is noteworthy that there has been a recent decrease in red meat consumption, which can be attributed to economic crises and the rise in food prices [35]. The findings of this study highlight that the intake of grains and nuts falls significantly below the EAT-Lancet recommendations. While, not only do legumes act as a sustainable substitute for red meat, but their favorable effects on soil quality, biodiversity, and soil enrichment through nitrogen fixation are particularly noteworthy [36]. In accordance with our results, a systematic review examining the present dietary habits in Iran and the essential adjustments for shifting towards a more environmentally friendly diet found that having a sustainable dietary pattern includes a lower consumption of red meat, eggs, sweets, and refined grains and an increased intake of whole grains and legumes [37].

Previous studies exploring the relationship between EAT-Lancet recommendations and obesity indicators align with our findings. One study conducted on the Brazilian adult population revealed that there is an inverse relationship between adherence to planetary health diet recommendations, evaluated by PHDI, and risk of obesity, overweight and abdominal obesity [16]. In an examination involving a representative sample of 11,506 Mexican adults aged 20 to 59 years, encompassing both genders, Shamah-Levy et al. observed a diminished prevalence of excess weight and obesity among individuals

Table 7 Odds ratio and 95% confidence intervals (CIs) of metabolic risk factors in tertiles of PHDI

	PHDI tertiles			P_{trend}[1]	Every 10 points of PHDI
	53 ≥ T1 (*n* = 139)	53 < T2 < 61 (*n* = 121)	T3 ≥ 61 (*n* = 128)		
BMI					
Crude	1.00	0.68 (0.40–1.14)	0.54 (0.32–0.89)	0.01	0.78 (0.62–0.97)
Adjusted	1.00	0.44 (0.24–0.80)	0.31 (0.17–0.56)	< 0.001	0.62 (0.48–0.81)
WC					
Crude	1.00	0.57 (0.34–0.95)	0.57 (0.35–0.94)	0.03	0.77 (0.62–0.96)
Adjusted	1.00	0.53 (0.31–0.91)	0.53 (0.32–0.90)	0.02	0.75 (0.59–0.94)
CI					
Crude	1.00	0.74 (0.44–1.26)	0.98 (0.59–1.60)	0.90	1.07 (0.86–1.33)
Adjusted	1.00	0.79 (0.46–1.36)	1.04 (0.62–1.75)	0.81	1.10 (0.88–1.39)
AVI					
Crude	1.00	1.17 (0.69–1.90)	1.09 (0.65–1.81)	0.72	1.03 (0.82–1.29)
Adjusted	1.00	1.13 (0.63–2.01)	0.94 (0.54–1.65)	0.81	0.95 (0.74–1.21)
BRI					
Crude	1.00	0.70 (0.42–1.16)	0.60 (0.37–0.98)	0.04	0.82 (0.66–1.01)
Adjusted	1.00	0.52 (0.30–0.92)	0.43 (0.25–0.75)	0.003	0.72 (0.56–0.91)
ABSI					
Crude	1.00	0.84 (0.51–1.41)	1.43 (0.86–2.37)	0.10	1.17 (0.94–1.45)
Adjusted	1.00	0.91 (0.53–1.56)	1.66 (0.97–2.86)	0.06	1.25 (0.99–1.57)

[1] Obtained from Binary logistic regression

Adjusted: for age, gender, energy intake, physical activity, marital status, socio-economic status, household size, smoking status, and supplement intake

Cut-off values: Body mass index (BMI) ≥ 27.5, waist circumference (WC) ≥ 95, abdominal volume index (AVI) ≥ 3.17, body roundness index (BRI) ≥ 5.20, body shape index (ABSI) ≥ 0.08; conicity Index (CI): placement in the third tertile of dietary diversity is reported as the dependent variable

with a higher adherence to EAT-Lancet recommendations, which was evaluated by a 13-component index [38]. The European Prospective Investigation into Cancer and Nutrition (EPIC)-Oxford study, found a BMI reduction of 1.4 kg/m^2 in individuals scoring ≥ 12 points on the EAT-Lancet diet using a binary index among participants in the UK [39]. Several studies have also explored the association between adherence to EAT-Lancet recommendations and different health outcomes. A meta-analysis of clinical studies revealed that adherence to EAT-Lancet recommendations is associated with lower risk of diabetes, CVDs and mortality [40].

There is limited research on the association between PHDI and health outcomes in low- and middle-income countries. A study on 6,465 Iranian adults from the PERSIAN cohort found that higher PHDI adherence was linked to better diet quality, lower environmental impacts, and reduced risk of metabolic syndrome [41]. Similarly, a case–control study on 71 colorectal cancer patients and 142 controls in Tehran showed an inverse relationship between higher PHDI scores and colorectal cancer odds [42]. Additionally, studies on plant-based diets have shown associations with obesity-related outcomes. For instance, a study on 6,833 Iranian households identified dietary patterns linked to variations in BMI [43]. Our findings contribute to this growing evidence, highlighting the link between PHDI and health outcomes.

One of the characteristics of a sustainable diet involves eating a variety of foods, such as diverse fruits and vegetables, to help protect biodiversity [4, 44]. Biodiversity impacts the nutritional richness of dietary patterns. Preserving biodiversity can contribute to maintaining a diverse range of agricultural products, enhancing the resilience of food systems, and increasing the variety of foods consumed on a larger scale [45]. Even some indices designed to assess the sustainability and health of dietary patterns utilized diversity scores as a component [46]. Previous studies have also demonstrated a significant relationship between dietary diversity and diet quality in various age groups, particularly in the elderly [47–49]. This implies that assessing dietary diversity serves as an effective criterion for measuring the adequacy of a diet in terms of receiving various nutrients [11].

The findings of our study revealed that an increase in the PHDI score in the unadjusted model correlates with an increase in the dietary diversity score. Nevertheless, this association loses significance upon adjusting for confounding variables. The EAT-Lancet diet includes a wide range of food groups, inherently promoting dietary diversity. However, it does not explicitly incorporate a scoring system that directly quantifies dietary diversity as an independent component. As a result, PHDI may not fully capture variations in dietary diversity. Additionally, dietary diversity is influenced by multiple factors, including socioeconomic status, cultural dietary habits, and food availability, which could have confounded the relationship between PHDI and dietary diversity. This implies that confounding variables, given their potential connection with dietary diversity, may play a significant role in the relationship between a healthy and sustainable dietary pattern and dietary diversity. One of these confounding factors is the socioeconomic status (SES). Previous studies have demonstrated a close relationship between dietary diversity in elderly individuals and their SES [50]. For example, it has been demonstrated that higher education levels and better economic status are associated with higher DDS and a healthier diet among the elderly [51]. Moreover, a cross-sectional study demonstrated a direct association between dietary diversity score and higher education, higher well-being index, and urban living [52]. Furthermore, previous studies have reported that a higher socioeconomic status can mitigate the declining trend in dietary diversity with increasing age [53].

Additionally, our findings revealed that for every 10-point increase in the PHDI, there was a corresponding increase in the DDS for grains, vegetables, and fruits, along with a decrease in the DDS for protein. This finding can explain the absence of an association between PHDI and total DDS, indicating that the positive correlation observed for mentioned components may be counterbalanced by negative correlation in protein DDS, leading to an overall neutral effect on the total DDS. The protein DDS comprises six food subgroups, with four of them representing animal protein sources (red meat, poultry, fish, and egg). As individuals align their dietary patterns more closely with the PHDI, which encourages a reduced emphasis on animal-based proteins, this shift contributes to the observed decrease in the protein DDS.

Our study has several strengths. The present study is the first to examine the adherence to the EAT-Lancet dietary pattern in Iran and its association with dietary diversity, and anthropometric indices. Another notable strength of this study lies in the application of the PHDI to evaluate adherence to the EAT-Lancet dietary pattern. The scoring system employed in this approach is scaled, distinguishing it from other scoring systems that are binary [39, 54]. Research suggests that utilizing this scoring method can yield more nuanced distinctions in the levels of adherence to a dietary pattern within a community [55]. Additionally, this scoring method, grounded in caloric density, allows us to observe an association that is independent of energy intake. However, there are some limitations worth mentioning. Firstly, this study used a cross-sectional analysis, allowing us to identify associations but not establish causation. Secondly, food consumption was evaluated through a FFQ, which has some limitations, including a finite food list and potential dietary misreporting bias. Thirdly, the study population is limited to older adults from Tehran, which may not represent the broader Iranian population or other regions with different dietary habits and socioeconomic conditions. Moreover, most participants in the study were from the south of Tehran, representing middle and low socioeconomic statuses. Hence, it's important to be cautious when applying these findings to other populations. Finally, the mean age of elderly participants was on the younger side, which may limit the generalizability to older individuals. This bias may stem from our inclusion criteria, which excluded individuals with chronic illnesses, medications, or diet changes—conditions more common in the older elderly population.

Adopting the Planetary Health Diet in countries like Iran faces challenges due to economic and cultural factors. Healthier diets are often more expensive, which can be a significant barrier in low- and middle-income settings [56, 57]. Also, the affordability of the EAT-Lancet diet has been shown to be challenging in low- and middle-income countries making it inaccessible for many in these regions [58]. Culturally, Iranian cuisine is rich in carbohydrates, with foods like rice and bread being staples, making it difficult to shift toward plant-based options [59]. To overcome these barriers, promoting locally grown, affordable plant-based foods and educating the public on the health and environmental benefits of the PHD can help. Additionally, incorporating PHD principles into familiar dishes may encourage greater acceptance.

In summary, our study demonstrates an inverse association between adherence to EAT-Lancet recommendations and anthropometric indices such as BMI, WC and BRI, suggesting a lower likelihood of being overweight or obese in the Iranian population. These findings indicate that adhering to the healthy and sustainable diet guidelines outlined by EAT-Lancet yields positive health outcomes by reducing the possibility of overweight or obesity, which can lead to morbidities like diabetes and hypertension especially in older adults. Moreover, given the observed low adherence among the study participants, there is an opportunity for public policies to formulate guidelines and recommendations, placing a specific emphasis on the proposals outlined by the EAT-Lancet Commission. Further prospective studies considering a more diverse population are needed to confirm these results and inform public health strategies.

Abbreviations

PHD	Planetary Health Diet Index
USDA	U.S. Department of Agriculture
FI	Food insecurity
DV	Daily value
FDA	Food and Drug Administration
BMI	Body Mass Index
WC	Waist Circumference
WHO	World Health Organization
ABSI	A Body Shape Index
BRI	Body Roundness Index
CI	Conicity Index
IPAQ	International Physical Activity Questionnaire
SES	Socioeconomic status
NHANES	National Health and Nutrition Examination Survey
HEI	Health Eating Index

Disclosure statement

None of the authors had any personal or financial conflicts of interest.

Authors' contributions

LA, ADM and MKD designed the study. MKD carried out the sampling. MKD, PNH and HA carried out interviews, extracted data from the medical records and imported the data for analysis. MKD performed the statistical analyses. MKD and RT drafted the manuscript. LA and ADM read and commented on the manuscript. NB reviewed and edited the manuscript. LA supervised the study. The final manuscript was approved by all the authors.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The approval for this study was granted by the Tehran University of Medical Sciences Research Ethics Committee under the reference number IR.TUMS.MEDICINE.REC.1401.588, in adherence to the principles outlined in the Helsinki Declaration. Every participant in the study willingly provided written informed consent.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

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