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Adherence to the healthy nordic food index is associated with favorable obesity-related cardiometabolic risk factors among apparently healthy obese individuals

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Limited reports have highlighted the protective role of Healthy Nordic Food Index (HNFI) score against several chronic diseases like cancers and cardiovascular disorders. However, its beneficial role in obesity-related cardiometabolic risk factors is not well understood. In the current work, we examined the adherence to Nordic diet by estimating HNFI score and its association with metabolic syndrome and its components among Iranian population. In the current cross-sectional study, 339 individuals with obesity aged 20–50 years were recruited. Dietary intake was assessed by a validated food frequency questionnaire (FFQ). Enzymatic methods were used to assess serum lipids and glycemic markers. Blood pressure was measured by sphygmomanometer and body composition with bioelectrical impedance analysis (BIA). No significant differences were found in age, sex distribution, waist circumference, body mass index categories, socioeconomic status score, fat mass percentage, fat-free mass, basal metabolic rate across quartiles or physical activity of HNFI (all $P > 0.05$). Also, higher energy, saturated fatty acids, sugar, fiber, β-carotene, yogurt, milk, and potatoes was shown in higher HNFI categories ($P < 0.05$). Higher adherence to Nordic diet was accompanied with lower systolic blood pressure (SBP, $P < 0.001$), total cholesterol (P, 0.047) and low-density lipoprotein cholesterol (LDL-C) concentrations (P, 0.034) after adjusting for age, body mass index (BMI), physical activity level). In multinomial logistic regression analysis, HNFI showed no significant association with most obesity-related cardiometabolic risk factors. After adjustment for age and sex, participants in the third HNFI quartile had lower SBP, DBP, TC compared to participants in first HNFI quartile ($P < 0.05$). No significant associations were observed for FBS, TG, insulin, HOMA-IR, α-MSH, and AgRP (OR > 0.05). According to our results, higher adherence to Nordic diet was associated with favorable cardio-metabolic risk factors among apparently healthy adults with obesity. Further researches are warranted to better clarify these findings.

Keywords Healthy nordic food index, Obesity, Diet, Cardio-metabolic risk

Obesity is recognized as a chronic, progressive, and relapsing but manageable condition that is a complex, multifactorial neurobehavioral disease in which excessive accumulation of body fat leads to adipose tissue dysfunction and altered fat-related mechanical forces. These changes contribute to a wide range of adverse outcomes, including metabolic disturbances, biomechanical impairments, and negative psychosocial effects[1]. Obesity is a major risk factor for cardiometabolic diseases because it involves a complex interplay of hormonal, inflammatory, and hemodynamic mechanisms. As excess adiposity develops, it not only impairs adipocyte function but also promotes systemic insulin resistance, and it further activates the sympathetic nervous system as well as the renin–angiotensin–aldosterone system (RAAS). These changes act synergistically to increase sodium

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retention and induce vasoconstriction, and together they contribute to the development of hypertension[2]. In parallel, obesity-related dyslipidemia is characterized by elevated triglycerides, increased small dense LDL particles, and reduced HDL cholesterol, largely driven by increased hepatic VLDL production and impaired lipoprotein metabolism, thereby amplifying atherogenic risk[3]. Moreover, chronic low-grade inflammation and an excess of free fatty acids act in concert to disrupt insulin signaling in key metabolic tissues, and this combination predisposes individuals to insulin resistance, β-cell dysfunction, and ultimately the development of type 2 diabetes[4,5]. These metabolic abnormalities synergize with hypertension and dyslipidemia to accelerate the development of atherosclerosis and cardiovascular disease, and this process is further compounded by structural cardiac changes, endothelial dysfunction, and systemic inflammation. Consequently, obesity functions as a central driver of metabolic dysregulation, and it substantially elevates the risk of hypertension, type 2 diabetes, and cardiovascular morbidity[6].

In addition to these peripheral mechanisms, obesity is strongly associated with disruptions in central appetite-regulating pathways, and this is particularly evident in alterations of melanocortin signaling. Within this system, hormones such as melanocyte-stimulating hormone (α-MSH) and agouti-related peptide (AgRP) serve as critical regulators of energy balance and appetite, as they modulate both satiety and food intake; however, when these pathways are dysregulated, they contribute directly to the onset and progression of obesity[7].

One of the evaluation indices for diet quality is the Healthy Nordic Food Index (HNFI), which consists of 6 items from the traditional Nordic diet that is responsible for the health effects of the Nordic diet[8]; these six food items are fish, cabbages, barley, whole-grain bread, apples and pears, and root vegetables[9]. Other plant-based dietary patterns, including the Mediterranean and DASH, have some similarities with the Nordic Diet[10]. In the Nordic region, the Mediterranean dietary pattern is a healthier and more useful alternative to the existing diet and has more beneficial effects on public health[8]. The major specifications of the Mediterranean diet contain a variety of vegetables and fruits, whole-grain cereals, nuts, and legumes, olive oil, white meats such as fish and poultry; Recommended to consume less red meat; and moderate consumption of wine[11]. The diversity of agricultural and livestock products in the Nordic region is limited, but in terms of plant products like berries, cabbages, apples, pears, root vegetables, oats, and rye is rich; besides, the coastlines in these countries provide a high abundance of fish[12]. Vitamins C, K, folate, iron, dietary fiber, and other bioactive components are abundant in the HNFI components, which can help to prevent chronic diseases[13]. Furthermore, a new WHO report assessed the health benefits of a healthy Nordic diet and encouraged Nordic countries to investigate how it can be transformed into population-based dietary recommendations[14].

Many studies indicate that a healthy Nordic diet has significant positive effects on markers of type 2 diabetes risk, including body weight and insulin sensitivity, also it caused a significant reduction of plasma levels of cholesterol, low-density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C), apolipoprotein A1 (apoA1) and apolipoprotein B (apo B) as a result reduction in cardiovascular risk[15,16]. Additionally, compared to the control diet, the healthy Nordic diet reduced ambulatory diastolic blood pressure and mean arterial pressure after 12 weeks[17].

Most of the studies have shown that the mean fish consumption among Iranian adults was 11.3 g/d[18]; also, the average per capita consumption of vegetables in Iran is 286 g per day[19], cabbage is commonly grown in the Urmia, west and east Azerbaijan and numerous other provinces in Iran[20]. Consumption of cereals and bread among Iranian population is 40% higher compared with other parts of the world and is the main food item (food staple) among Iranian population[19]. This is evidently clear that in Iran, people follow diets similar to those found in Nordic nations.

As a consequence of the availability of HNFI items in Iran and due to the Nordic diet's beneficial effects on some cardio-metabolic factors including systolic and diastolic blood pressure, total and low-density lipoprotein cholesterol, as well as type 2 diabetes risk factors such abdominal obesity and obesity-related inflammatory markers[21–23], Therefore, this study aimed to investigate the association between adherence to the Nordic diet and obesity-related cardiometabolic risk factors such as blood pressure, fasting glucose, lipid profile, insulin resistance, and appetite-regulating hormones such as α-MSH, AgRP in obese individuals. To our knowledge, this is among the first studies to comprehensively assess both conventional and novel markers of cardiometabolic health in relation to the Nordic dietary pattern.

Methods and materials
Patients and public involvement
This study is a cross-sectional study. participants included 339 participants with obesity from Tabriz. The participants were gathered from recent projects among patients with obesity in the mentioned university[24,25]. We invited all participants by public announcements and the age range of all 339 participants was between 20 and 50 years old and their body mass index was more than 30 kg/m². Exclusion criteria included pregnancy, lactation, menopause, recent bariatric surgery, cardiovascular disease, cancer, hepatic or renal diseases, diabetes mellitus, or consumption of drugs effective in reducing or increasing weight. Written consent was obtained from all participants and the Ethics Committee of Tabriz University of Medical Sciences, Iran approved the proposal of this study (code: IR.TBZMED.REC.1401.687).

General characteristics and anthropometric assessments
Participants answered a socio-demographic self-administered questionnaire including age, sex, smoking status, education attainment, marital status, occupation, medical histories, and family size; afterward, socioeconomic status (SES) score was calculated for each participant. Then by the bioelectrical impedance analysis (BIA) method, the body composition of participants was determined (Tanita, BC-418 MA, Tokyo, Japan). Other anthropometric data including height and weight were obtained using a wall-mounted stadiometer and a Seca scale (Seca co., Hamburg, Germany). Modified short form of the International Physical Activity Questionnaire

(IPAQ) was used to estimate the physical activity of participants[26]. Waist circumference (WC) was determined using a tape measure to the nearest 0.1 cm at the midpoint between the lower costal margin and the iliac crest, However, hip circumference (HC) was measured the part that yields the maximum diameter over the buttocks and was recorded to the nearest 0.1 cm. In the next step, BMI and waist-to-hip ratio (WHR) were calculated via available data. Blood Pressure monitoring was done with a standard mercury sphygmomanometer and then the mean of the two measurements was reported. Anthropometric parameters and other measurements taken by trained personnel.

Dietary assessments

The participants answered a validated semi-quantitative food frequency questionnaire (FFQ), modified for the Iranian population[27]. Participants have reported the frequency and amount of food items consumed every day, month, and yearly basis. Then, the Frequency of consumption of each item in the questionnaire is converted to grams. The collected data were used to construct Nordic diet scores. In our study, 6 nutrients were included in this index: fish, cabbages, barley, whole-grain bread, apples and pears, and root vegetables[28]. Due to the low consumption of barley in the Iranian population, we used frumenty instead of oats. Wholegrain bread including Iranian bread of "Sangak" and "Barbari"[29]. For HNFI diet score calculation, the consumption of each participant is compared with the median of each item, then one point per component was given to each individual who consumed more than this median value, and 0 point vice versa. The total HNFI score was calculated by adding these scores. The total healthy Nordic food index could take values from 0 (low adherence) to 6 (high adherence)[8].

Biochemical assessment

10 ml of venous blood samples were taken from each individual and the blood sample was centrifuged at 4500 rpm for 10 min to separate serum and plasma samples. Serum total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), and fasting blood sugar (FBS) were analyzed using a kit (Pars Azmoon, Tehran, Iran). additionally, low-density lipoprotein cholesterol (LDL-C) level was determined with the Friedewald Eq.([30]). We used Enzyme-linked immunosorbent (ELISA) assay kits to measure concentrations of serum insulin and Plasma α-MSH and AgRP levels. (Bioassay Technology Laboratory, Shanghai Korean Biotech, Shanghai City, China). The lowest detectable range for AgRP was 1.03 pg/ml and for α-MSH levels 5.07 ng/L respectively. Homeostatic model assessment for insulin resistance (HOMA-IR) was calculated with the following formula: fasting insulin (μ IU/ml) $\times$ fasting glucose (mmol/l) /22.5 and quantitative insulin sensitivity check index QUICKI as 1/ [log fasting insulin (μU/mL) + log glucose (mmol/L)].

Statistical analyses

Statistical tests were performed using SPSS version 21.0 with a significance level of < 0.05. Data are described as frequency (%) for categorical variables and mean ± standard deviation (SD) for continuous variables. The differences in discrete and continuous variables across different adherence to Nordic diet score categories were compared using the Chi-square test and one-way ANOVA respectively. ANCOVA was used for the comparison of biochemical variables after adjustment for confounders (BMI, age and physical activity). The association between HNFI diet score with quartiles of adherence to HNFI. For analysis, because of the ordinal nature of our grouping variable (e.g. HNFI quartiles) we used the Jonckheere-Terpstra test as a rank-based test that is used to determine statistically significant trend difference between an ordinal independent variable and a continuous or ordinal dependent variable[31].

Results

A total of 339 participants were divided into quartiles based on Nordic diet adherence categories: first quartile (0–2 points, $N=96$), second quartile (3 point, $N=72$), third quartile (4 point, $N=90$) and fourth quartile (5–6 points, $N=81$). The general characteristics of the study population stratified by adherence to Nordic diet are presented in Table 1. Distribution of Healthy Nordic Food Index scores in study population presented in Fig. 1. The population of individuals who scored 4 was the maximum (26.54%), while the lowest population was in the score zero category (2.35%). There were no significant differences in characteristics of participants across four groups. Adherence to Nordic diet showed no significant relationship with anthropometric data such as BMI, WC, FFM, FM. The comparison of energy and macronutrient intakes of the study population by HNFI showed that energy, saturated fatty acids, sugar, fiber, β-carotene, yogurt, milk, potatoes, processed meat intake increased among participants who achieved higher HNFI, whereas intake levels of carbohydrate, protein, fat and other dietary intakes did not differ between four adherence categories (Table 2).

The median intake of HNFI components as follows: whole grain bread (111.10 gr/day), fish (6.37 gr/day), cabbages (3.10 gr/day), oatmeal (3.53 gr/day), apples, and pears (83.71 gr/day) and root vegetables (47.04 gr/day); Table 3 shows the increasing intake of all of six components of this intake in higher adherence categories.

Among apparently healthy participants with obesity, higher HNFI was associated with lower SBP, TC, and LDL-C levels after adjusting for confounders, including energy intake, age, BMI, and physical activity (P,<0.001, 0.047 and 0.034 respectively). While the overall ANCOVA indicated a significant association of HNFI quartiles with SBP, TC, and LDL-C levels, pairwise comparisons between quartiles, adjusted for confounders, did not reach statistical significance after Bonferroni correction ($P > 0.05$). No significant differences were observed in serum insulin, HOMA-IR, QUICKI, α-MSH, and AgRP across quartiles of HNFI adherence (Table 4).

Multinomial logistic regression was implemented to assess the association between obesity-related cardiometabolic risk factors and HNFI across quartiles, with the lowest quartile (Q1) considered as the reference. As shown in Table 5, no statistically significant were observed between SBP and HNFI in crude model and model that adjusted for age, BMI, sex, physical activity, SES, and energy intake. However, in the model adjusted just for age and sex HNFI in the third quartile was inversely associated with SBP, DBP, TC and LDL ($P < 0.05$). FBS, TG

Variable		Quartiles of Healthy Nordic Food Index score								P-value**	P-Trend ***
		Q1 (n = 96) HNFI = 0–2		Q2 (n = 72) HNFI = 3		Q3 (n = 90) HNFI = 4		Q4 (n = 81) HNFI = 5–6			
		Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Age (y)		40.30	9.93	38.94	7.46	42.21	8.36	41.60	9.96	0.273	0.184
Sex *	Male	53		45		53		44		0.720	
	Female	43		27		37		37			
WC (cm)		106.39	8.94	106.04	9.54	107.41	9.64	106.96	10.66	0.810	0.517
BMI (kg/ m²)		32.54	5.15	32.39	4.72	32.73	4.92	32.94	4.55	0.907	0.534
SES score		9.83	2.70	9.58	2.35	10.00	2.67	10.31	2.27	0.585	0.265
FM (%)		35.54	9.82	33.08	10.20	32.72	8.45	33.82	8.34	0.443	0.329
FFM (%)		59.79	11.65	64.40	12.59	62.95	12.37	62.32	12.76	0.370	0.401
BMR (kcal)		1830.67	324.22	1950.33	350.71	1907.67	349.92	1940.17	518.20	0.567	0.833
PA (MET-min/week)		1307.41	234.22	1819.05	3237.47	2828.88	408.72	2514.74	3133.52	0.082	0.065

Table 1. General characteristics of the study population by dietary healthy nordic food index score. HNFI, Healthy Nordic Food Index score; WC, Waist circumference; FM, fat mass; BMR, basal metabolic rate; PA, physical activity; SES, socioeconomic status. All data are mean (± SD) except sex that is presented as the number and percent of males in each group. * Number of participants in each sex category ** P values derived from One-Way ANOVA with *Tukey's* post hoc comparisons). *** P trends derived from Jonckheere-Terpstra test.
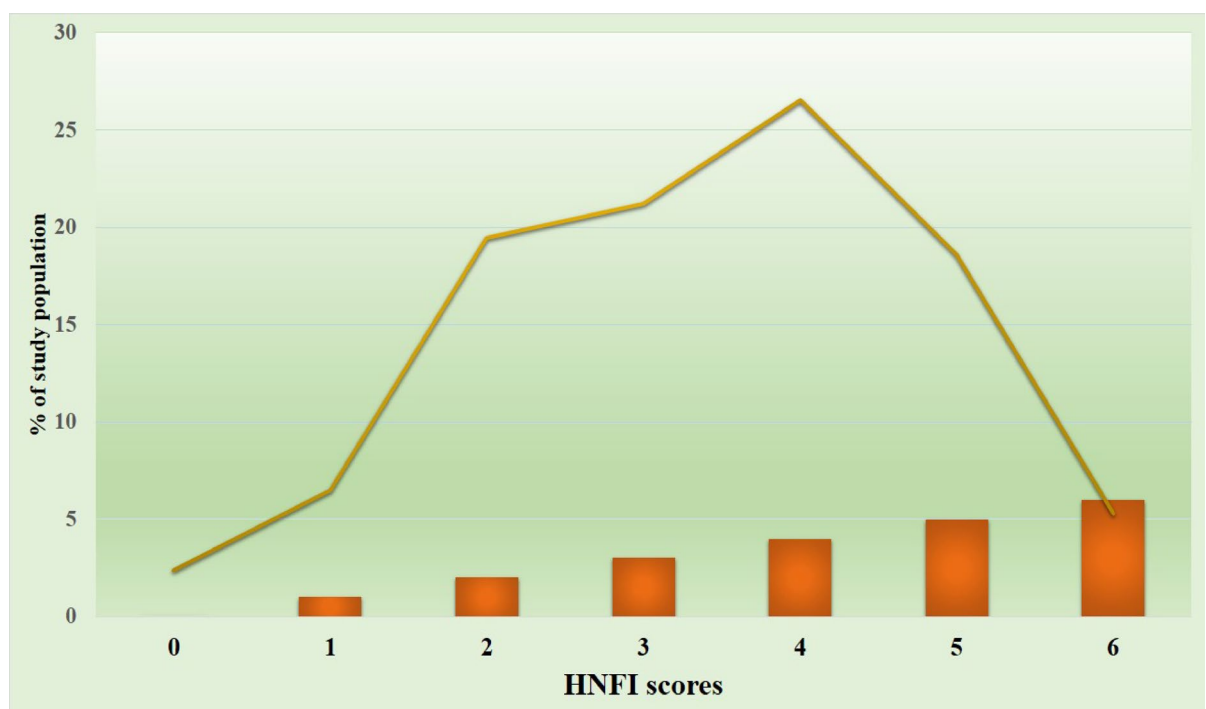

Fig. 1. Distribution of Healthy Nordic Food Index scores in study population.

and TC revealed non-significant associations with HNFI across quartiles ($P > 0.05$). In the multivariable-adjusted model, LDL-C exhibited an inverse association in the third quartile (OR, 0.983, 95% CI: 0.969–0.997, $P = 0.020$). For HDL-C, an inverse association was noted in the age-sex–adjusted model, which became nonsignificant after further adjustment (OR, 0.994, 95% CI: 0.994–1.046, $P = 0.805$). No significant associations were found between HNFI and insulin, HOMA-IR, α-MSH, or AgRP levels in any model.

Discussion

In this current cross-sectional study, the adherence of the Iranian population to the Nordic diet was assessed by the FFQ questionnaire then the relationship of adherence to the Nordic diet and obesity-related cardiometabolic risk factors have been investigated. For both men and women, the Danish Diet, Cancer, and Health cohort

| Variable | Quartiles of Healthy Nordic Food Index score | | | | | | | | P-value* | P-value** | P-Trend*** |
| | Q1 (n=96) HNFI=0–2 | | Q2 (n=72) HNFI=3 | | Q3 (n=90) HNFI=4 | | Q4 (n=81) HNFI=5–6 | | | | |
	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Energy (kcal/d)	2490.57	880.61	3038.99	1073.94	3063.86	907.23	3536.50	1318.87	**<0.001**	0.63	
CHO (%)	56.41	7.34	59.10	6.57	57.86	7.04	58.70	6.49	0.26	0.29	0.11
Protein (%)	12.47	2.08	12.81	2.02	13.35	1.83	13.31	1.91	0.08	0.69	0.06
Fat (%)	33.47	6.93	30.74	6.42	31.27	7.51	31.04	6.50	0.21	0.37	0.13
SFA (g/d)	27.25	1.77	25.10	15.67	29.03	11.18	34.30	17.59	**<0.001**	0.09	**<0.001**
PUFA (g/d)	0.87	0.36	0.88	0.38	0.89	0.35	0.822	0.27	0.74	0.42	0.50
MUFA (g/d)	1.20	0.33	1.20	0.37	1.24	0.33	1.14	0.25	0.47	0.65	**<0.001**
Fiber (g/d)	59.63	31.04	70.63	48.06	77.18	42.65	79.79	50.85	**<0.001**	0.34	**<0.001**
Fruits (g/day)	688.13	544.15	666.11	616.46	620.69	566.36	775.40	593.19	0.40	0.43	0.55
Vegetables (g/day(	358.16	339.77	345.50	182.65	322.95	212.25	316.92	206.33	0.51	0.82	0.38
Legumes (g/day)	75.67	81.06	70.67	69.75	61.50	57.48	59.40	54.51	0.32	0.36	**0.03**
Red processed meat (g/day)	26.94	30.33	35.01	32.20	31.53	27.04	29.69	32.24	0.39	0.13	0.44
white meat (g/day)	39.52	36.78	36.90	27.10	37.55	35.29	39.27	30.42	0.94	0.24	0.86
Yogurt (g/d)	103.92	98.18	152.22	171.40	154.01	179.35	209.22	291.11	**<0.001**	0.87	**<0.001**
Milk (g/d)	100.32	110.78	121.21	120.09	145.41	125.26	162.48	137.86	**<0.001**	0.09	**<0.001**
Potatoes (g/d)	14.82	16.53	21.17	20.01	29.86	39.30	36.50	44.26	**<0.001**	0.78	**<0.001**
Nuts (g/d)	4.91	6.15	8.58	15.45	7.12	8.67	8.73	10.58	0.05	0.53	**<0.001**
Cheese (g/d)	28.57	36.92	28.57	36.92	24.62	14.44	26.23	15.15	0.72	0.87	0.43
Processed meat (g/d)	30.02	27.78	30.02	27.78	35.59	29.61	39.16	34.49	0.95	**<0.001**	0.70
Caffeine (mg/d)	204.85	157.10	204.85	157.10	190.31	131.35	225.29	190.31	0.43	0.18	**0.02**
Sugar (g/d)	132.77	75.16	164.60	68.76	175.11	63.85	203.42	76.25	**<0.001**	0.13	**<0.001**
β-Carotene (mg/d)	4176.00	3907.13	5775.03	5284.87	6436.12	3966.31	7202.47	4315.63	**<0.001**	0.11	**<0.001**

Table 2. The comparison of energy and dietary intakes of participants in different quartiles by healthy nordic food index score. HNFI, Healthy Nordic Food Index score; CHO, carbohydrate; PUFA, poly unsaturated fatty acid, SFA, saturated fatty acids, MUFA, mono unsaturated fatty acids; *P values derived from One-Way ANOVA with *Tukey's* post hoc comparisons. ** P values derived from ANCOVA model after adjusting for energy intake, BMI, age and physical activity. *** P trends derived from Jonckheere-Terpstra test. Bold values are statistically significant.

| Variable | Healthy Nordic Food Index score | | | | | | | | | P-value* | P- Trend** |
| | | Q1 (n=96) HNFI=0–2 | | Q2 (n=72) HNFI=3 | | Q3 (n=90) HNFI=4 | | Q4 (n=81) HNFI=5–6 | | | |
	Median	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Whole grain bread	111.10	84.31	82.53	138.71	105.89	154.64	101.30	170.55	124.30	**<0.001**	**<0.001**
Fish	6.37	4.79	5.69	7.54	11.78	11.98	14.32	16.98	17.85	**<0.001**	**<0.001**
Cabbages	3.10	3.63	6.32	8.22	10.52	11.12	14.57	17.91	25.16	**<0.001**	**<0.001**
Oatmeal	3.53	4.32	8.16	6.70	14.68	11.71	17.66	14.26	18.88	**<0.001**	**<0.001**
Apples/pears	83.71	58.95	72.95	102.02	107.70	101.11	85.08	154.43	91.86	**<0.001**	**<0.001**
Root vegetables	47.04	32.29	22.40	51.61	43.66	68.92	48.85	89.31	57.28	**<0.001**	**<0.001**

Table 3. The comparison of the healthy nordic food index score and its components. Food group consumption is expressed in grams per day, HNFI, Healthy Nordic Food Index score; * P values derived from ANCOVA model after adjusting for energy intake, BMI, age and physical activity. The P-values for adjusted and unadjusted models were similar. Therefore only one column is shown here to avoid recentness. ** P trends derived from Jonckheere-Terpstra test. Bold values are statistically significant.

research discovered an inverse relationship between a healthy Nordic index and the risk of type two diabetes mellitus (T_2DM)[32]. In similar large Danish cohort research of men and women, adherence to a healthy Nordic diet was related with a decreased incidence of stroke, the findings of that study show that a healthy Nordic diet based on traditional Nordic items could be proposed as a regional alternative to the Mediterranean diet for stroke prevention[33]. In a population-based study conducted among Iranian adults with type 2 diabetes, adherence to the Nordic diet was found to be significantly associated with cardiovascular risk factors such as obesity, LDL levels, and blood pressure. Individuals with lower adherence exhibited higher levels of LDL-cholesterol, elevated

Variable	Quartiles of Healthy Nordic Food Index score								P-value*	P-value **	P- Trend ***
	Q1 (n=96) HNFI=0–2		Q2 (n=72) HNFI=3		Q3 (n=90) HNFI=4		Q4 (n=81) HNFI=5–6				
	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
SBP (mmHg)	124.77	15.25	123.11	13.73	120.76	19.38	122.20	16.01	0.406	**< 0.001**	0.196
DBP (mmHg)	83.29	10.55	81.87	11.44	79.62	14.29	81.86	9.90	0.202	0.734	0.194
FBS (mg/dl)	91.03	11.97	93.40	31.60	94.31	16.83	92.38	14.42	0.696	0.725	0.531
TC (mg/dl)	197.52	37.03	189.58	35.63	188.18	41.85	184.42	33.35	0.147	**0.047**	0.093
TG (mg/dl)	157.44	101.11	153.00	92.27	155.52	99.50	136.33	75.82	0.446	0.060	0.189
HDL (mg/dl)	44.88	9.53	41.29	9.11	43.58	9.64	43.82	9.47	0.110	0.063	0.668
LDL (mg/dl)	128.16	32.24	122.27	28.65	121.86	36.59	121.02	28.60	0.188	**0.034**	0.289
Insulin (Miu/L)	15.01	8.57	13.85	10.02	19.38	20.61	15.13	8.74	0.100	0.492	0.650
HOMA-IR	3.48	2.09	3.45	3.37	4.52	4.54	3.35	1.99	0.124	0.662	0.783
α- MSH (ng/L)	216.33	168.42	205.70	152.91	204.03	161.97	241.58	181.49	0.674	0.518	0.336
AgRP (Pg/ml)	31.35	18.58	31.30	16.95	29.23	19.64	32.13	19.66	0.886	0.328	0.682

Table 4. Biochemical parameters of the study population by healthy nordic food index score. HNFI, Healthy Nordic Food Index score; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; HOMA-IR, homeostatic model of insulin resistance; QUICKI, quantitative insulin sensitivity check index); α-MSH, melanocyte-stimulating hormone; AgRP, agouti-related peptide; P values for the *crude model were derived from one-way ANOVA with Tukey's post hoc comparisons. **P values for the adjusted models were derived from ANCOVA with Bonferroni post hoc comparisons adjusting for energy intake, age, BMI, and physical activity. energy intake, BMI, age and physical activity. *** P trends derived from Jonckheere-Terpstra test. Bold values are statistically significant.

systolic blood pressure, and a greater prevalence of obesity[34]. Many investigations have shown consumption of a diet rich in whole grain and fish was associated with an increase of HDL-c and reduction of postprandial insulin and triglycerides responses[35–37]. Moreover, high amounts of fiber in a diet appears to enhance insulin secretion, serum insulin level, improved β-cell function, and reduced insulin resistance and blood glucose level[38,39]. Insulin resistance plays a key role in the development of metabolic disorders such as T2DM and cardiovascular diseases, with higher HOMA-IR levels consistently linked to an increased risk of T2DM in both healthy and metabolically compromised individuals[40]. Furthermore, adherence to the Nordic dietary pattern has been linked to favorable metabolic outcomes. In one study, participants following the healthy Nordic diet showed significant reductions in fasting insulin concentrations and HOMA-IR[15]. Similarly, a meta-analysis of two studies found that stronger adherence to this dietary pattern was linked to better insulin sensitivity, as shown by lower HOMA-IR values[41]. In contrast, our results did not show a significant connection between following the Nordic diet and HOMA-IR levels. This suggests that the diet's effect on insulin resistance may differ among populations or be influenced by specific dietary habits or lifestyle factors.

Studies demonstrated that the health benefits of cruciferous vegetables such as cabbages are associated with the anti-inflammatory effects of these vegetables[42]. The positive effect of cruciferous vegetables in preventing cardiovascular diseases has been recently discussed[43]. Sulforaphane and iso-thiocyanate in this family of vegetables are responsible for the health effects of these vegetables that reduce oxidative stress and inflammation in the circulatory system via the activation of transcription factors[44]. Oatmeal as another component of HNFI, significantly increased the short-chain fatty acids (SCFA) concentration in the intestine by fermentation, then lessens obesity and related metabolic disorders while modifying intestinal microbial composition[45]. Some of suggested possible mechanistic pathways of the positive effects of HNFI score on human health is presented in Fig. 2. Root vegetables such as special carrots are a rich source of beta-carotene, it is proven that β-Carotene has antioxidant capacity so it has preventive effects on diseases such as obesity and T_2DM[46].

Interestingly, our study our study found that higher adherence to the Nordic diet was associated with increased intakes of sugar, saturated fatty acids, and processed meat. Several considerations may explain this finding. Firstly, many Nordic diet adherence scores prioritize the consumption of positive dietary components but do not sufficiently penalize higher intakes of nutritionally unfavorable foods. Secondly, cultural and regional adaptations of the Nordic diet frequently incorporate traditional foods rich in saturated fat and processed meats, including sausages, cured meats, and cream-based dishes, which may elevate SFA and processed meat intake despite an otherwise healthy dietary pattern[47]. Thirdly, higher overall energy intake among participants in higher quartiles of HNFI may partly drive the absolute increases in sugar and saturated fat consumption, as total caloric intake can influence nutrient intake levels. Notably, when adjusting for confounders such as energy intake, body mass index, and physical activity, the initially observed associations between adherence to the Nordic diet and intake of sugar and SFAs lost significance. This complexity highlights the challenge of dietary pattern assessment and supports calls for refining Nordic diet indices to incorporate both beneficial and detrimental components to more accurately capture overall diet quality.

The present study evaluated the association of Nordic dietary pattern scores and obesity-related cardiometabolic risk factors to investigate whether does adhere to the Nordic diet has beneficial health effects

Variable		Quartiles of Healthy Nordic Food Index score						
		Q1 (n=96)	Q2 (n=72) HNFI=3		Q3 (n=90) HNFI=4		Q4 (n=81) HNFI=5–6	
		HNFI=0–2	OR(CI)	P-value	OR(CI)	P-value	OR(CI)	P-value
SBP (mmHg)	Model I	1 REF	0.993 (0.974–1.013)	0.503	0.985 (0.967–1.003)	0.096	0.990 (0.972–1.009)	0.289
	Model II		0.994 (0.973–1.015)	0.554	**0.979 (0.960–0.999)**	**0.038**	0.985 (0.985–1.005)	0.140
	Model III		0.996 (0.960–1.031)	0.833	0.993 (0.960–1.027)	0.695	1.004 (0.970–1.040)	0.809
DBP (mmHg)	Model I	1 REF	0.989 (0.963–1.016)	0.424	**0.973 (0.949–0.998)**	**0.036**	0.989 (0.964–1.015)	0.405
	Model II		0.990 (0.962–1.019)	0.514	**0.967 (0.991–1.061)**	**0.015**	0.983 (0.956–1.011)	0.229
	Model III		0.983 (0.941–1.028)	0.454	**1.001 (1.000–1.001)**	**0.005**	1.014 (0.972–1.058)	0.524
FBS (mg/dl)	Model I	1 REF	1.008 (0.990–1.026)	0.389	1.010 (0.993–1.027)	0.255	1.005 (0.987–1.024)	0.585
	Model II		1.009 (0.991–1.027)	0.340	1.009 (0.992–1.027)	0.290	1.004 (0.985–1.023)	0.669
	Model III		1.025 (0.991–1.059)	0.148	1.022 (0.990–1.056)	0.186	1.007 (0.970–1.044)	0.732
TC (mg/dl)	Model I	1 REF	0.994 (0.986–1.002)	0.167	0.994 (0.986–1.002)	0.133	0.994 (0.986–1.002)	0.147
	Model II		0.994 (0.986–1.003)	0.201	0.993 (0.986–1.001)	0.108	0.993 (0.985–1.002)	0.111
	Model III		0.999 (0.985–1.012)	0.836	**0.986 (0.974–1.000)**	**0.042**	0.988 (0.974–1.001)	0.076
TG (mg/dl)	Model I	1 REF	1.000 (0.996–1.003)	0.771	1.000 (0.997–1.003)	0.895	0.997 (0.994–1.001)	0.128
	Model II		0.999 (0.996–1.003)	0.719	1.000 (0.997–1.002)	0.749	0.997 (0.993–1.001)	0.091
	Model III		1.004 (0.995–1.012)	0.390	1.004 (0.996–1.011)	0.357	1.000 (0.991–1.009)	0.996
HDL (mg/dl)	Model I	1 REF	0.959 (0.927–0.992)	0.045	0986 (0.957–1.016)	0.361	0.989 (0.959–1.020)	0.470
	Model II		**0.960 (0.926–0.995)**	**0.024**	0.987 (0.957–1.019)	0.424	0.987 (0.956–1.020)	0.440
	Model III		0.994 (0.994–1.046)	0.805	0.983 (0.937–1.031)	0.480	0.987 (0.939–1.039)	0.622
LDL (mg/dl)	Model I	1 REF	0.992 (0.983–1.002)	0.117	0.994 (0.985–1.003)	0.184	0.995 (0.986–1.004)	0.294
	Model II		0.993 (0.983–1.002)	0.135	0.994 (0.985–1.003)	0.163	0.995 (0.985–1.004)	0.253
	Model III		0.997 (0.982–1.012)	0.660	**0.983 (0.969–0.997)**	**0.020**	0.987 (0.973–1.002)	0.084
Insulin (mIU/l)	Model I	1 REF	0.987 (0.948–1.027)	0.509	1.023 (0.993–1.054)	0.128	1.001 (0.967–1.036)	0.950
	Model II		0.989 (0.950–1.031)	0.610	1.023 (0.992–1.055)	0.149	1.000 (0.965–1.035)	0.982
	Model III		1.003 (0.952–1.056)	0.922	1.024 (0.978–1.072)	0.313	1.013 (0.964–1.065)	0.600
HOMA-IR	Model I	1 REF	0.995 (0.862–1.150)	0.949	1.096 (0.977–1.229)	0.119	0.979 (0.850–1.127)	0.768
	Model II		1.005 (0.869–1.162)	0.949	1.092 (0.970–1.229)	0.146	0.970 (0.840–1.120)	0.677
	Model III		1.072 (0.892–1.289)	0.457	1.100 (0.923–1.311)	0.288	1.019 (0.834–1.247)	0.851
α- MSH (ng/L)	Model I	1 REF	1.000 (0.997–1.002)	0.764	1.000 (0.997–1.002)	0.701	1.001 (0.999–1.003)	0.482
	Model II		0.999 (0.997–1.002)	0.698	0.999 (0.997–1.002)	0.685	1.001 (0.999–1.003)	0.459
	Model III		0.999 (0.997–1.002)	0.628	0.999 (0.997–1.002)	0.521	1.000 (0.998–1.003)	0.821
AgRP (Pg/ml)	Model I	1 REF	1.000 (0.997–1.023)	0.989	0.993 (0.972–1.016)	0.562	1.002 (0.982–1.023)	0.842
	Model II		0.997 (0.974–1.021)	0.814	0.992 (0.970–1.015)	0.495	1.002 (0.982–1.024)	0.815
	Model III		0.996 (0.972–1.020)	0.743	0.990 (0.967–1.013)	0.389	0.999 (0.977–1.022)	0.954

Table 5. Biochemical variables of study participants by quartiles of HNFI. HNFI, Healthy Nordic Food Index score; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure; FBS, fasting blood glucose; TC, Total Cholesterol; TG, Triglyceride; HDL-C, High-Density Lipoprotein Cholesterol; LDL-C, Low-Density Lipoprotein Cholesterol; HOMA-IR, Homeostatic Model Assessment for Insulin Resistance; OR, odds ratio; CI, confidence interval. The multivariate multinomial logistic regression was used for the estimation of ORs and confidence interval (CI). Model I: crude, Model II: adjusted for age and sex, and Model III: adjusted for age, BMI, sex, physical activity, SES, and energy intake. Bold values are statistically significant.

on this this risk factors or not? In our study, we observed a significant reduction in TC, LDL-C and SBP in highest versus lowest quartiles of HNFI score. Moreover, a non-significant reduction was also observed for DBP, TG values and a non-significant increase in insulin and α- MSH values in highest versus lowest quartiles of HNFI score. In multinomial logistic regression analyses, no statistically associations were found between HNFI quartiles and most cardiometabolic risk factors in crude or adjusted analyses. However, in the age- and sex-adjusted model, the third quartile of HNFI showed inverse associations with SBP, DBP, TC, and LDL, although the observed significant associations disappeared after adjusting.

In conclusion, a diet consisting of fiber, fish, fresh vegetables, and fruits like HNFI score was associated with better cardio-metabolic risk factors[48,49].

Key strengths of the present study include the first assessment of central appetite-regulating hormones, such as AgRP and α-MSH, alongside traditional metabolic markers. This integrated approach provides a more holistic understanding of the mechanisms underlying obesity. Moreover, the HNFI was carefully adapted to align with the dietary habits of the Iranian population, ensuring greater cultural and contextual relevance. Dietary intake was also evaluated using a validated and reliable FFQ tailored to the target population. In addition, multiple
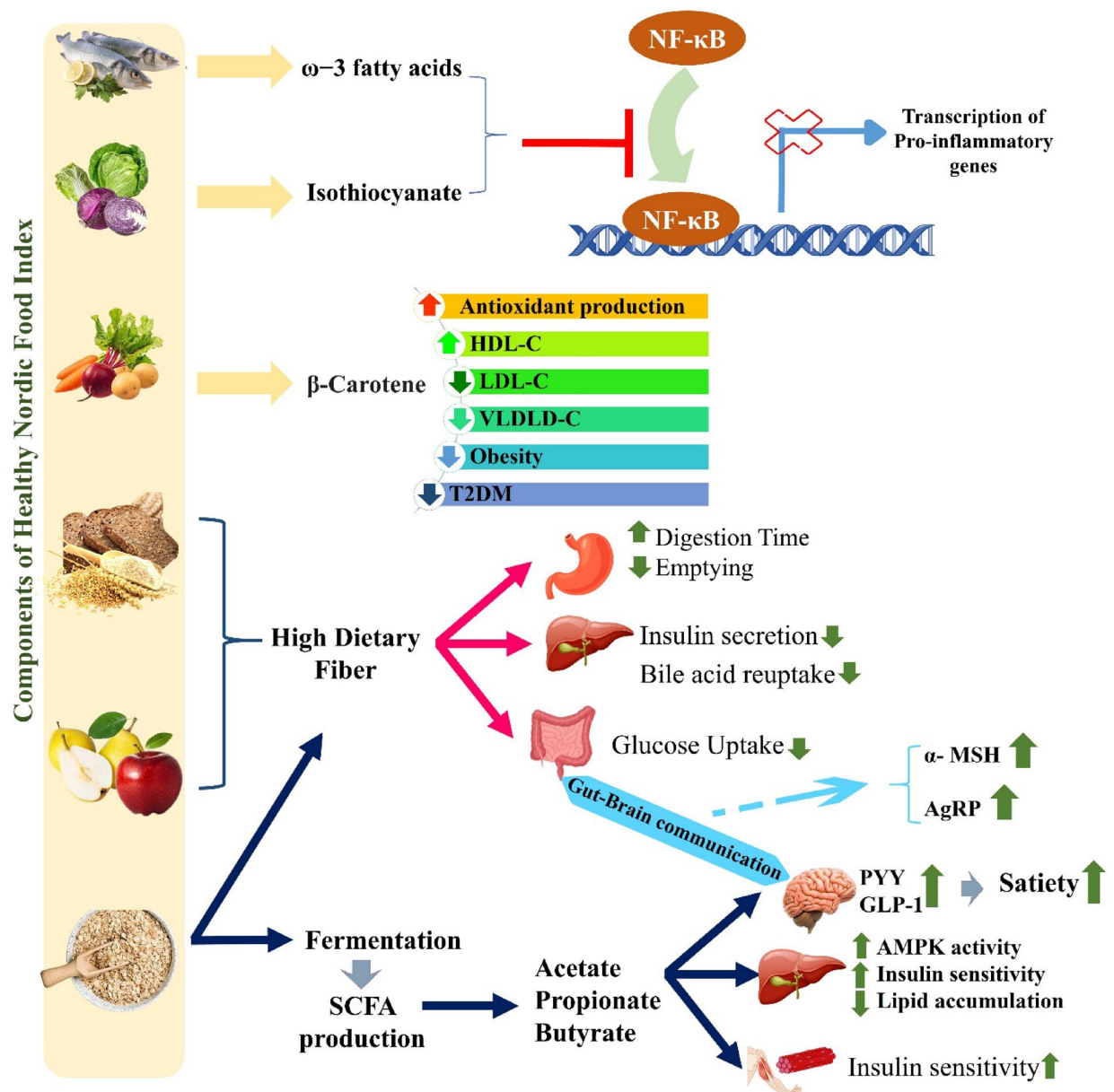
Fig. 2. Summarized beneficial effects of Healthy Nordic Food Index score (NF-kb, nuclear factor kappa-B; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; VLDL-C, very low density lipoprotein cholesterol; T2DM, type two diabetes mellitus; α-MSH, alpha-melanocyte stimulating hormone; AgRP, agouti-related peptide; PYY, peptide YY; GLP-1, glucagon like peptide-1; SCFA, short chain fatty acid; AMPK, adenosine mono-phosphate-activated protein kinase).

adjustment models were employed to account for potential confounders, thereby enhancing the rigor and credibility of the findings. Possible limitations of the current study should also be addressed; The design of the present study is cross-sectional, which itself causes limitations such as causal inference is difficult to make; the situation could have turned out differently if a different time frame had been picked, Variables are examined in cross-sectional studies at a specific point in time. Cross-sectional research cannot demonstrate causality without the ability to show temporal precedent. Additionally, the FFQ was not originally developed to assess compliance with a healthy Nordic diet, although it includes most of its food items that increase its validity and generalizability. Therefore, the unavailability of some of the Nordic diet components in the usual diet of the Iranian population, recall bias due to subjective nature of questionnaire-based data and the impossibility of causal inference due to cross-sectional design of the current study make us to interpret the obtained results with caution. Further longitudinal or interventional studies are warranted find more reliable and generalizable results.

Clinicians may consider recommending the Nordic dietary pattern as a complementary lifestyle strategy for patients with elevated cardiometabolic risk—especially those presenting with dyslipidemia, hypertension, or early signs of metabolic syndrome. From a clinical standpoint, these results highlight the potential value

of incorporating Nordic diet principles into standard dietary counseling and cardiac rehabilitation practices. Moreover, they underscore the need for additional randomized controlled trials to further confirm its effectiveness as an evidence-based nutritional approach for reducing cardiometabolic risk.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to some restrictions that applied by the ethical committee but are available from the corresponding author on reasonable request.

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Author contributions

MAF and NN were involved in manuscript writing, MAF also supervised the project, analyzed data, and revised the paper. All of authors read the article and agreed with its submission.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval and consent to participate

This study protocol has been approved by the ethics committee of the Tabriz University of Medical Sciences (registration code: IR.TBZMED.REC.1401.687). Written informed consent was obtained from all of the participants before participation in the study. All methods in the current research were performed in accordance with the declaration of Helsinki's guidelines and regulations.

Consent for publication

Not applicable.

Additional information

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