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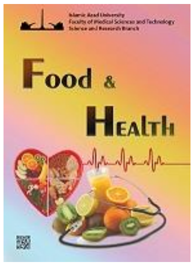

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Relationship between major dietary patterns and Osteoporosis in Iranian post-menopausal women: A case-control study

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ABSTRACT

Osteoporosis is a common skeletal disorder affecting many post-menopausal women, characterized by a bone mineral density (BMD) 2.5 standard deviations or more below peak bone mass in young adults. Diet may influence osteoporosis pathogenesis. This case-control study investigated associations between major dietary patterns and osteoporosis risk in Iranian post-menopausal women. Researchers recruited 220 osteoporotic cases and 220 non-osteoporotic controls from Tehran hospitals and clinics via convenience sampling. Demographic, anthropometric, medical history, physical activity, and dietary intake data were collected via interviewer-administered questionnaires, including a 147-item food frequency questionnaire (FFQ) to assess dietary patterns. Nutrient intakes and physical activity levels were compared between groups. Principal component analysis identified two predominant dietary patterns ("mixed" and "Western") from 33 food groups. Cases exhibited higher BMI and lower physical activity than controls (p<0.001). After adjusting for confounders, the highest Western pattern tertile was associated with 3.87 times greater osteoporosis odds than the lowest tertile (95% CI: 1.30-7.03). Thus, a Western dietary pattern may elevate osteoporosis risk in Iranian post-menopausal women.

1. Introduction

Osteoporosis and low bone density are significant risk factors for morbidity and mortality among the elderly (1). They are strongly associated with the risk of fractures, particularly in the pelvis, vertebrae, and distal radius (2). Global statistics indicate that over 5 million people experience bone fractures due to Osteoporosis, and approximately 30% to 40% of women over the age of 50 are affected by osteoporosis (3). The mortality rate associated with osteoporotic fractures is estimated to be around 20% (4). In Iran, studies have shown a prevalence rate of approximately 6% for Osteoporosis (5). The occurrence of Osteoporosis in different populations is influenced by various factors, including menopause, race, body mass index, low calcium and vitamin D intake, sedentary lifestyle, and smoking (6). Additionally, the likelihood of developing osteoporosis increases with age. Protective factors against Osteoporosis include abstaining from alcohol and tobacco, avoiding medications that negatively impact bone mass (e.g., raloxifene, dexamethasone, corticosteroids), and ensuring adequate intake of calcium, vitamin D, and other relevant nutrients such as omega-3 fatty acids, phosphorus, magnesium, and potassium (7-9). Given the relationship between osteoporosis risk and lifestyle, it is possible to prevent or mitigate the disease through dietary modifications (10, 11). Considering the significant complications of Osteoporosis and its potential association with lifestyle, nutrition, and physical activity (12), diet plays a crucial role in maintaining bone health. In addition to calcium and vitamin D, other nutrients such as phosphorus, vitamin K, and magnesium contribute to overall bone health (13). However, examining the association between nutrient intake and disease outcomes independently may yield invalid results, as nutrients are typically not consumed in isolation (14). Therefore, recent studies have increasingly focused on investigating the impact of dietary patterns as independent factors. The aim of this study was to

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explore the potential relationship between major dietary patterns and Osteoporosis among post-menopausal Iranian women.

2. Materials and methods

2.1. Study design and participants

This case-control study included a total of 440 post-menopausal women. The case group consisted of 220 women with Osteoporosis who met the eligibility criteria and were selected randomly from referrals to Shariati Hospital, private clinics, and health centers. The control group comprised 220 women without Osteoporosis who were accompanying the patients. Informed written consent was obtained from all participants. The study was conducted at Islamic Azad University, Science and Research Branch in Tehran, Iran, and the ethical approval code was IR.IAU.SRB.REC.1396.119.

2.2. Dietary intake assessment

The participants' dietary intake over the past year was assessed using a semi-quantitative Food Frequency Questionnaire (FFQ) that was validated and reliable (15).

2.3. Assessment of covariates

Demographic information, including age, sex, level of education, history of any specific diseases, and medication and supplement use, was collected at the beginning of the study through a general information questionnaire and face-to-face interviews.

2.4. evaluation of anthropometric variables

Weight was measured with minimal coverage and an accuracy of 100 grams using a Tefal digital scale. Height was measured without shoes while participants were leaning against a wall, with shoulders in a normal position, and an accuracy of 0.1 cm using a wall-mounted meter tape.

2.5. Physical activity

Physical activity level was assessed using the Met questionnaire, which categorizes physical activity intensity into nine levels, ranging from inactivity to intense activity.

2.6. Statistical analysis

Factor analysis with the principal component analysis (PCA) approach was performed to identify major dietary patterns. A total of 147 food items were classified into 33 food groups based on similarities in food composition and previous studies. Adjusted energy averages were calculated for each food group. The adequacy of the sample size and the performance of the factor analysis method were assessed using the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests. The number of factors (dietary patterns) was determined using the Scree plot and eigenvalues greater than 1. Varimax rotation was applied to the matrix, and the extracted dietary patterns were named based on the loading of food groups in each component with a factor loading greater than 0.1. Factor scores for each individual in each dietary pattern were calculated using a specific formula. Independent samples t-test and chi-square test were used to compare quantitative and categorical variables between the case and control groups. The normality of quantitative variables was tested using the Kolmogorov-Smirnov test. One-way ANOVA was performed to compare the means of quantitative variables among the tertiles of dietary patterns, and the chi-square test was used for categorical variables. The general linear model (ANCOVA) was used to calculate energy-adjusted means of dietary intake. Multivariable logistic regression analysis examined the relationship between the identified dietary patterns and Osteoporosis, calculating odds ratios (OR) and 95% confidence intervals (CI) in both crude and adjusted models. The trend of OR across increasing tertiles of dietary patterns was evaluated by considering the tertiles of each dietary pattern as an ordinal variable in the logistic regression model. Statistical analysis was performed using SPSS version 24, and p-values less than 0.05 were considered statistically significant.

3. Results

Table 1 presents the mean intakes of different food groups between the case and control groups. The case group showed significantly higher consumption of refined grains, pickles, high-fat dairy, fast food, visceral meats, saturated fats, simple sugars, sweets and desserts, industrial juices, tea, coffee, fruit compote, and processed meats compared to the control group. On the other hand, the control group had significantly higher consumption of low-fat dairy, whole grains, other vegetables, legumes, potatoes, tomatoes, and their products, eggs, yellow and orange vegetables, dried fruits, nuts and seeds, natural juices, fruits, dark green vegetables, and poultry. There were no significant differences in the consumption of red meat, cheese, fish, and seafood between the two groups. Table 2 displays the baseline characteristics of the participants. The mean age of the case group was 55.80±6.65 years, while it was 55.56±6.00 years in the control group. The case group had higher mean weight and BMI compared to the control group ($p< 0.001$). There was no significant difference in energy intake between the two groups. The case group also exhibited lower physical activity levels than the control group ($p< 0.001$). Through factor analysis, two dominant dietary patterns were identified: the mixed dietary pattern and the western dietary pattern. These patterns accounted for 31.44% of the total variance in consumption. The mixed dietary pattern, explaining 21.34% of the variance, included refined cereals, whole grains, potatoes, fast food, legumes, red meats, poultry, fish and seafood, low-fat dairy, high-fat dairy, cheese, pickles and salts, nuts and seeds, liquid oils, and other vegetables. The Western dietary pattern, explaining 10.1% of the variance, included sweets and desserts, processed meats, saturated fats, fruit compote, industrial juices, sauces, simple sugars, and coffee (Table 3). Table 4 presents the odds ratios (OR) for Osteoporosis. After adjusting for possible confounding variables (Model 4), individuals in the second category of the Western dietary pattern were significantly more likely to have Osteoporosis than those in the first category (CI=13.7-3.87-OR=3.87).

Table 1. Food grouping used in dietary pattern analysis.

Food Group	Examples
Refined grains	White breads, White rice, Spaghetti, Vermicelli, Noodles, Baguette bread
Whole grains	Iranian dark breads, Barley, Corn, Whole grain biscuit
Potato	Non-fried potato
Fast foods	Pizza, French fries, Crackers, Potato chips, Salty snacks
Sweets and desserts	Cakes, Chocolates, Gaz (Iranian sweet), Cookies, Halva
Legumes	Lentils, Kidney beans, Chickpeas, Soybeans, Mung bean, Split peas
Red meats	Beef, Veal, Sheep meat, Minced meat, Ground meat
Poultry	Poultry without skin, Chicken
Fish and seafood	Fish, Tuna fish
Organ meats	Lamb liver, Lamb kidneys, Lamb heart, Lamb tongue, Lamb brain
Processed meats	Beef sausages, Hamburger
Eggs	Eggs
Low fat dairy	Low fat milk, Regular yogurt, Dough
High fat dairy	High-fat milk, Cocoa milk, High-fat yogurt, Creamy yogurt, Chocolate ice cream, Vanilla ice cream, Kashk
Cheese	Cheese, Cream cheese
Saturated fat	Butter, Animal fats, Margarine, Solid hydrogenated vegetable oil
Tomatoes and its products	Tomato sauce, Tomato
Salt and Pickles	Salt, Salty olives, Pickles
Natural juices	Orange juice, Apple juice, Melon juice
Dried fruits	Dried figs, Raisins, Dried berries, Dehydrated peach, Dehydrated apricot
Canned fruits	Canned pineapple, Canned mixed fruit
Industrial juices	Fruit juice packed, Industrial lemon juice, Sugar, and non-sugary drinks
Sauces	Mayonnaise
Fruits	Varieties of fresh fruits: Green tomatoes, Figs, Kiwi, Persimmons, Pomegranates, Dates, Strawberries, Cantaloupe, Melons, Watermelons, Pears, Apricots, Cherries, Apples, Peaches, Nectarines, Grapes, Plums, Bananas, White berries, Grapefruits, Oranges, Tangerines, Lemons, Sour Lime
Dark green vegetables	Cooked beans, Cooked vegetables, Parsley, Cooked celery, Green peas, Cooked green beans, Cooked spinach, Sweet peppers, Lettuce, Cucumbers, Vegetable (basil), Cabbage, Squash
Yellow and orange vegetables	Baked Carrot, Raw Carrot, Pumpkin
Other vegetables	Garlic, Onion, Fried onions, Turnips, Cooked mushrooms, Cooked eggplants
Nuts and seeds	Peanuts, Almonds, Walnuts, Pistachios, Hazelnuts, Sunflower seeds
Liquid oils	Olive oil, Liquid oils
Simple sugar	White granulated sugar, Sugar, Honey, Jam, Candy
Tea	Tea
Coffee	Coffee
Condiments	Green pepper powder, Turmeric

Regarding the tertiles of dietary patterns, the highest tertile of the mixed dietary pattern showed significantly higher mean weight than the lowest tertile. The mean weight and BMI significantly differed across tertiles of the Western dietary pattern (p for trend < 0.001). However, there was no significant difference in mean age and BMI among the tertiles of the mixed dietary pattern. The mean age did not significantly differ across tertiles of the Western dietary pattern. Women in the highest tertile of the mixed dietary pattern had higher physical activity levels than those in the lowest tertile (p for trend< 0.001). There were significant differences in tobacco use between the Western and mixed dietary patterns, and alcohol consumption was significantly different in the mixed dietary pattern (Table 5).

4. Discussion

This study aimed to investigate the relationship between major dietary patterns and the risk of Osteoporosis in the Middle East, specifically in Iran. We found a significant direct relationship between the Western dietary pattern and Osteoporosis, but no significant relationship was observed with the mixed dietary pattern. Various demographic variables differed between participants with and without Osteoporosis, including age, weight, BMI, education, pregnancy number, age at the first pregnancy, duration of lactation, and consumption of oral contraceptive pills. Consistent with previous studies, we found a positive relationship between BMI and bone mineral density (BMD), indicating that individuals with higher BMI had higher BMD (16). Pregnancy affects bone mass, and previous studies have reported a significant decrease in bone density with increasing pregnancies (17). However, our study did not find a relationship between the number of pregnancies and Osteoporosis. Education levels have also been associated with osteoporosis risk, with some studies reporting adverse effects

Table 2. Characteristics, energy and dietary intakes of participants with and without Osteoporosis.

Variables	Case (n = 220)	Control (n = 220)	P-value*
Age (year)	55.80±6.64	55.56 ±6.00	<0.685
Weight (kg)	74.81±11.91	71.01 ±9.84	<0.001
BMI (kg/m2)	29.08 ±4.13	27.91 ±5.46	<0.011
Number pregnancies	3.06±1.380	3.16±1.307	<0.436
Age of the first pregnancy	21.33±4.751	20.70 ± 5.055	<0.184
The term of breastfeeding	29.48 ±25.959	33.50 ±31.333	<0.143
Drug for contraceptives	14.97±30.838	13.32 ± 27.285	<0.553
Taking oral contraceptive	4.44± 8.122	4.08±8.059	<0.642
Physical activity	1531.86±830.59	2299.99±2043.76	<0.001
Marital status	179 (7.7%)	16 (7.3%)	<0.856
Dual history	9 (4.1%)	3 (1.4%)	<0.079
Lactation	200 (90.9%)	190 (86.4%)	<0.133
Smoking	35 (15.9%)	0 (0.00)	<0.001
Alcohol	29 (13.2%)	5 (2.3%)	<0.001
Birth control pills	76(34.5%)	71(32.03%)	<0.542
Level of education			<0.264
Undergraduate	180(81.8%)	166(75.5%)	
Graduate	38(17.3%)	51(23.2%)	
Postgraduate	2(0.9%)	3(1.4%0	
Physical activity, MET-h/wk	1531.86±830.59	2299.99±2043.76	<0.001
Energy intake (Kcal)	2744.62± 895.11	2638.51±875.37	<0.200
Carbohydrate % of total energy	52.63±8.20	56.98±9.48	<0.001
Protein, % of total energy	12.62 ±2.64	14.39±3.31	<0.001
Fat, % of total energy	34.78±8.15	28.06±6.35	<0.001
Caffeine, mg/1000 kcal	48.71±38.05	35.57±35.58	<0.001

-Resulted from independent t-test for quantitative variables and chi-square for test for categorical variables
-Quantitative variables are reported as mean ± SD, Qualitative variables: frequency (percentage)
[a] Obtained from the general linear model and adjusted for energy intake and age (means ± SEM).

Table 3. Factor loading matrix for the two major dietary patterns.

Food groups	mixed	western
Refined grains	0.656	
Whole grains	0.174	-0.135
potato	0.936	
Fast foods	0.254	
Sweets and desserts		0.673
Legumes	0.953	
Red meats	0.114	
Poultry	0.936	
Fish and seafood	0.746	
Processed meat		0.439
Eggs		-0.423
Low fat dairy	0.778	
fatty dairy product	0.156	-0.133
cheese	0.600	
Saturated fat		0.594
Tomato and its product		-0.446
Salty and Pickles	0.843	
Natural juices		-0.135
Dried fruits		-0.270
Canned fruits		0.468
Industrial juices		0.799
Liquid oils	0.155	-0.133
Sauce		0.417
Nuts and seeds	0.143	-0.212
Dark green vegetables		
fruits		-0.116
Yellow and orange vegetables		-0.335
Simple sugars		0.544
spices	0.752	
Other vegetables	0.970	
Tea		
coffee		0.530

Cumulative percentage of variance explained by two dietary patterns was%
factor loadings <0.10 were excluded.

of lower education levels on Osteoporosis (17, 18). Our findings revealed that the physical activity level was significantly lower in patients with Osteoporosis than in those without Osteoporosis. Physical activity is crucial in increasing bone mass, and decreased daily physical activity has been linked to increased bone loss (19). Studies have also observed an increased risk of pelvic fractures in Asian women who migrated to urban areas and adopted inactive lifestyles (20). Moreover, recent studies have shown improvements in bone health with severe exercise (21), consistent with our findings. Regarding dietary factors, we found differences in food group consumption between the two groups. Drinking black tea has been shown to protect against Osteoporosis, with studies in Iran and India reporting a beneficial effect on bone mineral density due to nutrients like flavonoids found in tea (22). The relationship between dietary lipids and bone health depends on the degree of saturation and the length of fatty acids. Diets containing saturated fatty acids have been found to reduce calcium absorption and bone mineral content (23), which aligns with our results. Studies have also demonstrated a positive correlation between calcium, potassium, vitamin C, magnesium, and BMD, highlighting the importance of fruits and vegetables as sources of these nutrients (24, 25). The components of fruits and vegetables, such as antioxidants and anti-inflammatory compounds like vitamin C and beta-carotene, have been suggested to benefit bone health (26-28), consistent with our findings. While one study reported that high meat consumption at a young age reduced the risk of forearm fracture in post-menopausal women (29), we did not find a correlation between meat consumption and bone

Table 4. Multivariate adjusted odds ratio (OR) and 95% confidence interval (CI) for Osteoporosis among tertiles of dietary patterns.

	Model 1	Model 2	Model 3	Model 4	P-trend
Mixed dietary pattern					0.05
First category (reference)	1.00	1.00	1.00	1.00	
Second category	0.85 (0.53-1.37)	0.78 (0.49-1.27)	0.80 (0.49-1.30)	0.58 (0.34-1.00)	
Western dietary pattern					<0.001
First category (reference)	1.00	1.00	1.00	1.00	
Second category	2.63 (1.58-4.37)	2.64 (1.58-4.39)	2.58 (1.54-4.32)	3.87 (2.13-7.03)	

Results are from logistic regression. Values are OR (95% CI)
Model 1: Age-adjusted effect.
Model 2: Adjusted for age and body mass index.
Model 3 Adjusted for age, body mass index, number of pregnancies, duration of lactation, duration of contraceptive use, and level of education.
Model 4: Adjusted for age, BMI, number of pregnancies, duration of lactation, duration of contraceptive use, level of physical activity, and energy intake

Table 5. General Characteristics, energy, and dietary intakes of participants among tertiles of dietary patterns scores

Variables	Mixed dietary pattern			p-trend*	Western dietary pattern			p-trend*
	Tertile1 (n=146)	Tertile2 (n=147)	Tertile3 (n=147)		Tertile1 (n=147)	Tertile2 (n=146)	Tertile3 (n=147)	
Age (year)	56.03± 6.504	55.18± 6.454	55.84± 6.036	0.481	55.88± 6.02	55.73± 6. 28	55.43± 6.70	0.821
Weight (kg)	71.007±10.268	73.95±11.04	73.76± 11.070	0.039	69.65± 9.49	70.38±10.22	78.68± 11.16	<0.001
BMI (kg/m2)	27.73± 3.84	28.99± 4.25	28.76± 6.147	0.062	27.30±4.00	27.34± 3.66	30.84± 5.81	<0.001
Education				0.943				0.402
Undergraduate	117(80.1%)	116(78.9%)	113(76.9%)		110(74.8%)	117(80.1%)	119(81.0%)	
Graduate	28(18.2%)	29(19.7%)	32(21.8%)		36(24.5%)	26(17.8%)	27(18.4%)	
Postgraduate	1(0.7%)	2 (1.4%)	2(1.4%)		1(0.7%)	3(2.1%)	1(0.7%)	
Marital status				0.495				0.510
Married	133(91.1%)	135(91.8%)	139(94.6%)		137(93.2%)	137 (93.8%)	133(90.5%)	
Single	13(8.9%)	12(8.2%)	8(5.4%)		10(6.8%)	9(6.2%)	14(9.5%)	
Number of pregnancies	3.10±1.33	3.04±1.40	3.20±1.29	0.604	3.20± 1.36	3.13± 1.32	3.01± 1.34	0.496
Dual history	5(3.4%)	1(0.7%)	6(4.1%)	0.165	5(3.4%)	5(3.4%)	2(1.4%)	0.460
The age of the first pregnancy	21.11±5.16	21.52±5.29	20.42±4.15	0.154	20.54±5.13	20.75 ±4.83	21.76± 4.69	0.077
Taking an oral contraceptive Pill	45(30.8%)	50(34.0%)	52(35.4%)	0.603	45(30.6%)	44(30.1%)	58(39.5%)	0.235
Duration of contraceptive pill	12.77± 28.71	17.52±30.72	12.15±27.65	0.224	10.45±21.56	14.76±31.34	17.24±32.87	0.129
The last time you take an oral contraceptive pill	5.34 ±9.52	3.84 ±7.00	3.61±7.45	0.141	4.45±8.49	4.53±8.67	3.80 ±7.01	0.699
lactating	13(80.9%)	133(90.5%)	127(86.4%)	0.535	126(85.7%)	131(89.7%)	133(90.5%)	0.384
The term breastfeeding	29.77 ±28.42	34.41± 30.03	30.28±27.90	0.318	32.16±32.16	28.37 ±25.03	33.93 ±28.67	0.242
physical activity	1691.3±1057.4	1850.2 ±2205.4	2204.6±1277.2	0.019	1996.9±1199.4	2070.9±2341.1	1680.9± 881.2	0.087
Smoking use	17(11. 6%)	13(8.8%)	5(3.4%)	0.030	5(304%)	9(6.2%)	21(14.3%)	0.002
alcohol consumption	19(13.0%)	10(6.8%)	5(3.4%)	0.008	9(6.1%)	10(6.8%)	15(10.2%)	0.377
Physical activity, MET-h/wk**	1691.32±1057.45	1850.25±2205.45	2204.68±1277.29	0.019	1996.90±1199.40	2070.98±234113	1680.94±881.27	0.087
Energy intake (Kcal)	2188.41±817.77	2764.72±799.80	3118.16±783.64	0.967	2204.58±775.39	2598.90±790.55	3270.59±743.55	0.688
Carbohydrate, % of total energy	56.13 ±8.16	54.88±7.31	53.40±11.24	<0.001	58.61±8.06	54.55±9.72	51.24±7.97	0.003
Protein, % of total energy	13.26±2.39	13.60±2.41	13.67±4.21	<0.001	15.09±3.08	13.66±2.86	11.77±2.47	0.282
Fat, % of total energy	33.29±8.50	32.81±6.99	28.17±7.58	0.020	27.45±5.95	31.45±8.06	35.36±7.42	0.007
Caffeine, mg/1000 kcal	56.99±47.49	38.30±27.93	31.24±28.75	<0.001	45.93±46.38	38.92±31.55	41.56±32.20	<0.001

- Results are from ANOVA for quantitative variables and chi-square for qualitative variables.
- Quantitative variables: mean ± SD and Qualitative variables: frequency (percentage)
- Values are obtained from a general linear model and are adjusted for energy intake and age (means ± SEM).

fracture risk, aligning with other studies. High intake of sweets has been associated with low BMD, as shown in recent studies (30), supporting our findings. Caffeine intake has been linked to increased urinary calcium excretion and a higher risk of hip fracture (31, 32). Long-term caffeine consumption is also associated with lower bone mineral density and increased fracture risk (33, 34). Conversely, catechin in tea may positively affect bone density (35). Our findings suggest a significant relationship between major dietary patterns and Osteoporosis. Previous studies have shown that a healthy dietary pattern is associated with higher BMD, while the Western dietary pattern is inversely related to bone health. This implies that post-menopausal women adopting a Western dietary pattern may have lower bone mass density (13, 36). In a 4-year study of Japanese elderly individuals, it was found that the meat pattern reduced the risk of bone fractures, while the vegetable pattern significantly increased the risk (13). Although this study contradicts our findings, it's important to consider that dietary patterns and their effects can vary depending on the population, geographic region, race, and cultural factors (37-39). Our study provides evidence supporting dietary strategies to improve bone health. Similar studies have typically used PCA factor analysis to explore the relationship between dietary patterns and bone health outcomes (30, 37, 40-45). While our study employed similar patterns, it is worth noting that results may vary across populations, geographic regions, and cultures. To our knowledge, this is the first case-control study investigating this relationship among the Iranian population (46, 47). One limitation of our study is the potential for individuals to inaccurately recall their usual diet when responding to the FFQ (food frequency questionnaire) (48-50). However, despite its flaws, the FFQ remains a valuable tool for dietary pattern measurement in epidemiological studies (50-53).

5. Conclusion

In conclusion, this case-control study found that a Western dietary pattern was significantly associated with increased odds of Osteoporosis among Iranian post-menopausal women. The Western pattern, characterized by higher intakes of sweets, processed meats, saturated fats, and sugary drinks, conferred nearly four times greater osteoporosis risk than a prudent pattern. Conversely, no significant relationship was observed between the "mixed" pattern and osteoporosis risk. These results prove that diet quality influences bone health in post-menopausal women. Larger prospective studies are still needed to confirm these findings in Iranian populations. Adopting a balanced, nutrient-dense dietary pattern emphasizing vegetables, whole grains, fruits, and unsaturated fats may help prevent Osteoporosis among at-risk women. Dietary modifications offer a promising strategy for reducing the public health burden of this condition.

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