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RESEARCH

Dietary patterns associated with the risk of osteoporosis in postmenopausal women

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Abstract

The purpose of this study is to investigate the association between dietary patterns and the risk associated with osteoporosis in Jordanian postmenopausal women recently diagnosed with osteoporosis. A case–control study design was used to determine nutrient intake, and dietary and lifestyle patterns. Two hundred Jordanian postmenopausal women were enrolled; 100 patients newly diagnosed with osteoporosis, and 100 osteoporosis-free controls, according to the inclusion criteria. Case and control groups were selected from visitors to the University of Jordan Hospital and the Jordanian Osteoporosis Prevention Society. The case-to-control ratio was (1:1). Four dietary patterns were identified in this study and they include: 'High-Fruits and Vegetables', 'Traditional', 'Unhealthy/Western', and 'High-Proteins', which accounted for 44.7% of the total variance in food intake. The 'High-Fruits and Vegetables' dietary pattern showed a decreased likelihood of osteoporosis risk in the fourth quartile [Q4: AOR 0.375, 95% CI (0.154–0.9150), $P = 0.031$]. On the other hand, the 'Unhealthy/Western' and 'High-Protein' dietary patterns were positively associated ([Q3: AOR 2.834, 95%CI (1.081–7.430), $P = 0.034$] and [AQ3: OR 2.601, 95% CI (1.983–6.882), $P = 0.045$], respectively) with osteoporosis risk in the third quartile. The present results suggest that the 'High-Fruits and Vegetables' dietary pattern may exert a protective effect on the risk of osteoporosis while 'Unhealthy/Western' and 'High-Protein' dietary patterns showed positive effects on the risk of osteoporosis.

Keywords Dietary patterns, Osteoporosis, Postmenopausal women, Case–control study

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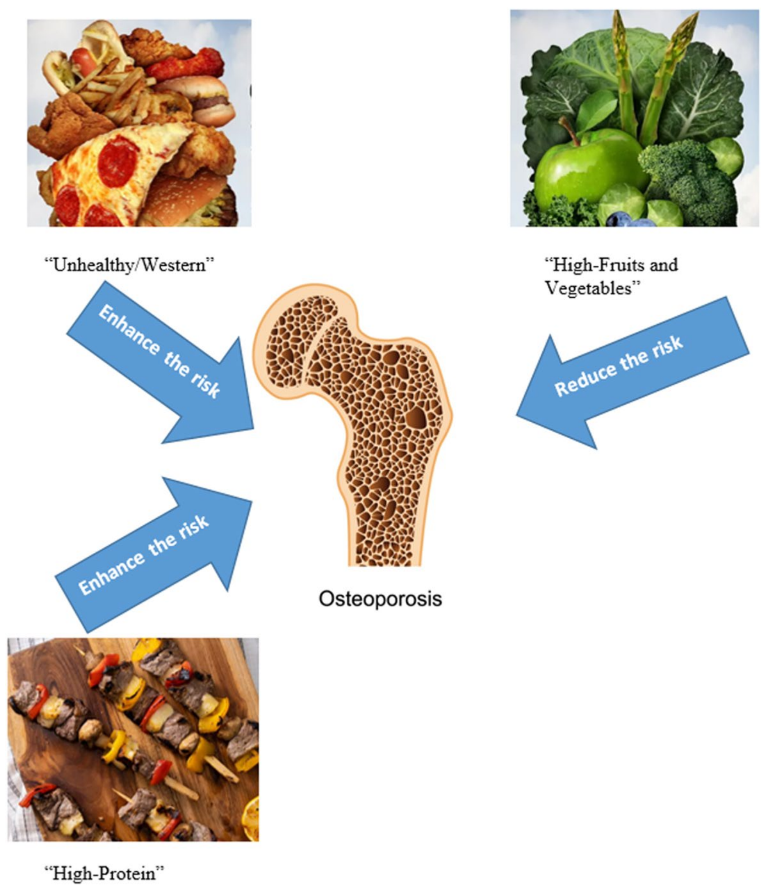
Graphical Abstract



Introduction

Osteoporosis is a chronic bone disease, which is characterized by low bone density, fractures and bone tissue loss (Eastell et al. 2016). Fractures lead to long-term disability, reduced quality of life related to health complications, and increased mortality. The identification and treatment of individuals with low bone mineral density (BMD) may reduce the burden of fracture (Langsetmo et al. 2011). Many factors contribute to the development of osteoporosis including diet, physical activity, body mass index (BMI), age, smoking, fractures, hormone therapy uses renal problems, and time since menopause (Nahas et al. 2011).

Although poor diet may play a role in the development of osteoporosis, the nutrition research focus has shifted from the examination of single nutrients such as calcium and vitamin D to food groups such as dairy and fruit & vegetables and dietary patterns according to Hamidi et al. (2011).

A dietary pattern that is rich in fruit, vegetables, fat-reduced dairy products, whole grains, meat, fish, nuts and legumes has been found to have a beneficial impact on bone strength, which is directly linked to enhanced BMD and lower fracture risk. Recent findings have shown that Mediterranean diet adhesion is osteoporosis protective (Zupo et al. 2020). Animal experiments have demonstrated a major influence of antioxidant-rich fruits, on the length, number and thickening of the trabecular bones, and reducing trabecular separation by stimulation of bone formation and suppression of bone resorption (Shen et al. 2012).

Up to the authors' knowledge, few studies have been conducted about women's osteoporosis in Jordan, but no single study investigated the dietary patterns associated with osteoporosis among postmenopausal women. Therefore, the present study aimed to investigate the association between dietary patterns and osteoporosis risk among newly diagnosed Jordanian postmenopausal women.

Materials and methods

Study design and sample recruitment

A case–control study design was used to determine dietary patterns as risk factors for osteoporosis in a selected sample of Jordanian postmenopausal women. In this study, a sample of 200 Jordanian postmenopausal women was enrolled. Of the 200 participants, 100 patients were recently diagnosed (up to 3 months) with osteoporosis and 100 were osteoporosis-free controls. Cases and controls included random visitors from the University of Jordan Hospital and the Jordanian Osteoporosis Prevention Society (JOPS). The case–control ratio was 1:1. Cases and controls were matched by age. The inclusion criteria of cases were females who are newly diagnosed with osteoporosis, postmenopausal women 50 years older, and Jordanian nationality. For controls, non-osteoporotic Jordanian females aged 50 years or older were included in this study. The exclusion criteria for both cases and controls include a history of osteoporosis treatment (e.g. osteoporosis medication and hormone replacement therapy), menopause hormone use, and metabolism disorders or autoimmune disease (e.g. diabetes mellitus, thyroid disease, chronic or severe liver disease, chronic renal failure, and malignancy).

Setting

Data was collected at the hospital for all participants. The University of Jordan Hospital, which offers services for osteoporosis patients, was chosen for this study (with the approval of the University, IRB approval no. 2019/287). Additionally, the Jordanian Osteoporosis Prevention Society (JOPS) was another setting for enrolling osteoporosis cases. Eligible cases who were selected from JOPS were invited to participate in the study and to visit an assigned laboratory to give their blood sample, complete the questionnaire, and have their bone mineral density measured (T-score). A private room in good physical condition was used to carry out the interviews. In addition, a consent form was used to inform patients about the study and its outcomes. During each participant's interview, interviewers explained the purpose of the study and allowed participants to read the formal consent form before signing it. The potential risks and potential benefits were explained in detail knowing that the present study presents no risk.

Instruments and tools

A personal information sheet composed of questions related to age, sex, marital status, education, employment, anthropometric measurements (weight, height, and waist circumference), smoking status, duration of breastfeeding previous, and current health problems was used to collect the information.

Bone mineral density scan was conducted using a portable hand-held ultrasound bone densitometer (FURUNO CM-200 light) to measure BMD as described by (Basheer et al. 2020) in order to investigate the relationship between vitamin D and BMD among celiac patients. The instrument's mechanism is to transfer precise ultrasound waves through the foot to assess bone density and then print a report indicating the T-score. Body weight and height were measured as prescribed by Lee & Nieman (2013). Body mass index (BMI) was calculated by the ratio of weight in kilograms to the square of height in meters (Lee & Nieman 2013).

For dietary assessment, Arabic Food Frequency Questionnaire (FFQ), which has been developed and tested previously for reproducibility and validity (Tayyem et al. 2014) was used to determine dietary patterns associated with the risk of osteoporosis. The FFQ questions track the information on the dietary history of study participants before osteoporosis diagnosis and assess the dietary habits of control participants. Data was collected during a face-to-face interview. Usual food intake was measured by "how frequently" and "on average", participants consumed one standard serving of specific food items in nine categories (< 1/month, 2–3/month, 1–2/week, 3–4/week, 5–6/week, 1/day, 2–3/day, 4–5/day, or 6/day). Food lists in the modified FFQ questions were classified based on types of foods: 21 items of fruits and juices; 21 items of vegetables, eight items of cereals, nine items of milk and dairy products, four items of beans, 16 items of meat such as red meat (lamb and beef), chicken, fish, cold meat, and others; four items of soups and sauces, five items of drinks, nine items of snacks and sweets, and 14 items of herbs and spices (Tayyem et al. 2014). For better portion size estimates, food models and standard measuring tools were used. Dietary intakes were analyzed using dietary analysis software (ESHA Food Processor SQL version 10.1.1; ESHA, Salem, OR, USA) with additional data on foods consumed in Jordan.

The 7-day Physical Activity Recall (PAR), developed by (Sallis et al. 1985) was used to measure physical activity levels. The 7-Day PAR is a structured interview that depends on the participant's recall of time spent engaging in physical activity over seven days (Sallis et al. 1985). Participants were asked to respond to a PAR question based on the way they used to behave before being diagnosed with osteoporosis.

Statistical analysis

Descriptive analyses were conducted to examine the frequency of different variables. Chi-square was used to detect the differences among categorical variables. T-test was conducted to find the difference between continuous variables of cases and controls and was presented as Mean ± SD. Principal Component Analysis on the entire population was conducted using a selected set of 69 selected food items to derive dietary patterns. Factors were retained based on an eigenvalue of > 1 for the scree plot and factor interpretability. Then, varimax rotation was applied to the factor-loading matrix to review the correlations between variables and factors. Nutrients with absolute rotated factor loadings > 0.30 were considered a significant contributor to the pattern and absolute rotated factor loading greater than 0.6 on a given factor was used to name the factors. Logistic regression was used to calculate adjusted odds ratio (AOR) and crude odds ratio (COR), confidence interval (CI), linear regression and *p*-value for trend with controlling for age, BMI, physical activity level, total energy intake, number of pregnancies and lactation, health problems, smoking, education level, marital status, and history of osteoporosis as potential confounders (Akdeniz et al. 2009). Table 1 shows the loading factor scores reflecting the correlation of food groups to dietary habits. Factor analysis revealed the following four dietary habits, 'High-Fruits and Vegetables'; 'Traditional'; 'Unhealthy'; 'High-Proteins' patterns, which were named after the food groups with the highest positive loadings. The 'High-Fruits and Vegetables' dietary pattern have high positive loadings for grape leaves, cooked vegetables, stuffed vegetables, fresh vegetables, peas, corn, cabbage salad, green beans, and strawberries. The 'Traditional' dietary pattern loaded highly in minced meat, labneh, onions, regular salad, chicken, melon, and cooked yogurt but negative loading for other fruits. The 'Unhealthy' dietary pattern presented high loadings for biscuits, Arabic sweets, bananas, fast food, and chocolates, but negative loading for margarine. The 'High-Proteins' dietary pattern displayed high loadings for cornflakes, burgers, roasted fish, beef mortadella, and sausages, but negative in boiled potatoes and whole wheat bread. The total variance explained was about 44.7% (17.6 in High-Fruits and Vegetables, 10.7 in Traditional, 8.7 in Unhealthy, and 7.806 in High-Proteins). The significance level was set at $p < 0.05$. All statistical analyses were conducted using SPSS version 20.0 (IBM SPSS Statistics for Windows, IBM Corporation) (SPSS, I., 2011).

Results

This study included 200 Jordanian postmenopausal women aged 50–85 of which 100 were recently diagnosed with osteoporosis (cases) and 100 were non-osteoporotic (controls). Table 2 shows the general characteristics of the study participants. More than 80% of cases and about 75% were married. The educational level was similar in both groups as 31% of cases and 26% of controls were at the primary level, while 40% of cases and 35% of controls were at the high school education level. Additionally, 4% of osteoporotic women and 16% of non-osteoporotic were at the bachelor level. Ninety-one percent of cases and 88% of controls were non-smokers, but 2% of cases and 7% of controls report smoking hookah. BMI was mostly between overweight (34%, 45%) and obese (47%, 34%) status. Physical activity intensity was centred on the category of minimally active due to the high age of the study population. Therefore, only 17% of cases and 24% of controls were under the category of health-enhancing physical activity. Significant differences between cases and controls were detected in height (158.8 ± 6.2 for cases, 161.0 ± 5.6 for controls, $P = 0.012$) and bone density T-score (-2.6 ± 0.40 for cases, -0.9 ± 0.60 for controls, $P = 0.001$). No significant differences were found in other parameters including age, BMI, weight, serum Vitamin D, physical activity, smoking and duration of breastfeeding.

Table 3 shows the multivariate odds ratios of having osteoporosis across the four dietary patterns. The highest quartile of the 'High-Fruits and Vegetables' dietary pattern indicates a decreased likelihood of the risk of osteoporosis [Q4: AOR 0.375, 95% CI (0.154–0.9150), *P-trend* = 0.001] compared to the other quartiles. The 'Traditional' dietary pattern did not show any likelihood of increased risk of osteoporosis in any of the quartiles. 'Unhealthy/Western' and 'High-Proteins' dietary patterns revealed a significant risk of osteoporosis in the third quartile [Q3: AOR 2.834, 95%CI (1.081–7.430), *P-trend* = 0.856]; [Q3: AOR 2.601, 95% CI (1.983–6.882), *P-trend* = 0.230] respectively. However, the risk of osteoporosis was insignificant in both 'Unhealthy/Western' and 'High-Proteins' dietary patterns in the fourth quartile. The same *P-trend* significance status was obtained for both AORs and CORs in all dietary patterns.

Discussion

In this study, we looked at the risk of osteoporosis among Jordanian postmenopausal women 50 years of age and older. Data in this case–control study suggested that there was a significant association between the risk of osteoporosis and dietary patterns as well as lifestyle behaviors. The probability of developing osteoporosis in postmenopausal women was studied by comparing macro-micronutrients, daily activities, and some biochemical parameters.

Significant differences in educational status were found in this study. Four percent of osteoporotic women and 16% of non-osteoporotic were at the bachelor level. Indeed, Ho et al. (2005) demonstrated that increased

Table 1 Factor loading matrix for the two major dietary patterns identified in the study sample

Dietary Patterns				
Food Groups	**High-Fruits and Vegetables**	**Traditional**	**Unhealthy/ Western**	**High-Proteins**
Grape Leaves	.806			
Cooked Vegetables	.734			
Stuffed Vegetable	.695			
Fresh Vegetable	.690			
Peas	.670	.303		
Corn	.637			
Cabbage Salad	.636			.390
Green Beans	.630	.314		
Strawberry	.612		.365	
Carrot	.586			
Fried Fish	.558			.515
Orange	.556	.398		
Mixed Vegetables	.535			
Grapes	.527			
Colored Pepper	.508			
Broccoli	.502		.447	
Peach	.500			
Cooked Cabbage	.489			
Boiled Potato	.473			-.336
Pear	.429			
Lettuce	.428	.346		
Other Fruits	.412	-.351	.344	
Roasted Sheep Meat	.393	.381		.304
Sweet Potato	.382			
Milk	.367			
Bulgur	.364			
Buttermilk	.317			
Minced Meat	.320	.607		.417
Labneh		.598		
Regular Salad	.368	.587		
Onion		.567		
Chicken		.525		.444
Melon		.511		
Cooked Yogurt		.504		.378
Yogurt		.490		
White Cheeses		.474		
Corn Oil		.473	.336	
Egg		.447		
Olive Oil		.420	.411	
Cauliflower	.339	.415		
Apple	.356	.409		
Watermelon	.371	.397		
Cooked Rice		.369		
Pizza		.319		
Cake			.718	
Biscuits			.667	
Arabic Sweet			.544	
Banana	.331		.528	

Table 1 (continued)

Dietary Patterns				
Food Groups	**High-Fruits and Vegetables**	**Traditional**	**Unhealthy/ Western**	**High-Proteins**
Fast Food	.428		.512	
Chocolate		.376	.492	
Nuts		.453	.462	
Dried Fruit	.347		.456	
Candies			.446	.398
Chips			.436	
Artificial Fruit Juice			.417	
Margarine			-.412	
Grapefruit	.319		.399	
Cooked Beans			.349	.326
Soft Drinks Diet		-.325	.325	
Cornflakes				.650
Burger				.628
Roasted Fish				.618
Beef Mortadella				.598
Sausage				.542
Whole Wheat Bread				-.483
Canned Tuna				.454
Pizza Meat				.426
White Bread				.373
Mayonnaise				.346
The variance of Intake Explained (%)	**17.616**	**10.684**	**8.654**	**7.806**

schooling is associated with better BMD and a lower prevalence of osteoporosis in Chinese postmenopausal women. Colon-Emeric et al. (2003) reported a connection between educational levels and the risk of hip fracture in non-Hispanic ambulatory white males. Other studies, such as those conducted by Quah et al. (2011) and Guilley et al. (2011), have attributed the occurrence of hip fractures to low socioeconomic status. In contrast, no major link between BMD and educational level was found in a cross-sectional study of healthy volunteers in Taiwan (Shaw et al. 1993).

The main findings in these measurements showed significant differences in height between osteoporotic and control groups. Lai et al. (2018) showed that an adult's height is associated with several risk diseases, one of which is hip fractures. In contrast, Compston et al. (2017) reported in their study that greater height is a risk factor for osteoporosis explaining that higher height can increase the risk of fracture, including greater falling impact, and increased cortical porosity.

Four dietary patterns including 'High-Fruits and Vegetables', 'Traditional', 'Unhealthy/Western', and 'High-Protein' were identified. The 'High-Fruits and Vegetables' pattern had a higher positive loading for grape leaves, cooked vegetables, stuffed vegetables, peas, corns, cabbage salad, green beans, and strawberries. The 'Traditional' patterns showed the greatest loading for minced meat, labneh, regular salad, onions, chicken, melon, and cooked yogurt. The third pattern, which is 'Unhealthy/Western', presented high loadings for biscuits, Arabic sweets, bananas, chocolates, and fast food. The last pattern, which represents 'High-Proteins', showed higher loadings in the burger, roasted fish, beef mortadella, and sausages.

In our study, the 'High-Vegetables and Fruits' dietary pattern showed a significant protective effect on osteoporosis in the fourth quartile [Q4: OR 0.375, 95% CI (0.154–0.915)]. A favorable relationship between bone density and fruit and vegetable consumption has been observed in many studies. The connection between dietary potassium and magnesium (i.e., fruit and vegetable intakes) and supplements to changes in BMD was investigated by Tucker et al. (1999). Potassium, magnesium and the consumption of fruits and vegetables in the different locations were all correlated with BMD ($P < 0.05$). In addition, Okubo et al. (2006) found that after adjusting for many conflicting factors, the "Healthy" trend, defined by high intakes of green and dark yellow vegetables, mushrooms,

Table 2 Socio-demographic, lifestyle, anthropometric and biochemical characteristics of the study participants

Variables	Cases $n=100$ n (%)	Controls $n=100$	*p*- Value
Age (years)			
(50–60) yr	70(70)	77(77)	
(60–70) yr	26(26)	16(16)	0.550
> 70 yr	4(4)	7(7)	
Marital Status			
Married	81(81)	77(77)	
Single	6(6)	1(1)	0.206
Divorced	3(3)	6(6)	
Widow	10(10)	16(16)	
Educational Level			
Illiterate	12(12)	5(5)	
Primary	31(31)	26(26)	
High school	40(40)	35(35)	
Diploma	13(13)	18(18)	0.002
Bachelor	4(4)	16(16)	
Master	0(0)	0(0)	
Work Status			
Employee	15(15)	7(7)	
Unemployed	85(85)	93(93)	0.020
Cigarette Smoking			
Non-smoker	91(91)	88(88)	
Smoker	9(9)	12(12)	0.491
Argila/Hookah Smoking			
Non-smoker	98(98)	93(93)	0.089
Smoker	2(2)	7(7)	
Sleeping Hours Weekday			
Short (4–6)	55(55)	43(43)	
Moderate (6–8)	42(42)	53(53)	0.085
Long (8–12)	3(3)	4(4)	
Sleeping Hours Weekend			
Short (4–6)	6(6)	12(12)	
Moderate (6–8)	89(89)	76(76)	0.453
Long (8–12)	5(5)	12(12)	
BMI			
Underweight	1(1)	0(0)	
Normal	18(18)	21(21)	
Overweight	34(34)	45(45)	0.196
Obese	47(47)	34(34)	
Physical Activity			
Inactive	0(0)	0(0)	
Minimally active	83(83)	76(76)	0.222
HEPA active	17(17)	24(24)	
Family History of Osteoporosis			
Yes	31(31)	14(14)	
No	40(40)	55(55)	0.258
Don't know	29(29)	31(31)	
	Mean ± SD		*P*-Value

Table 2 (continued)

Variables	Cases $n=100$ n (%)	Controls $n=100$	*p*- Value
Age (Yr.)	56.5 ± 6.5	55.9 ± 7.3	0.550
Height (Cm)	158.8 ± 6.2	161.0 ± 5.6	0.012
Weight (Kg)	75.2 ± 14.6	74.5 ± 11.9	0.708
BMI (kg/m^2)	29.7 ± 5.4	28.8 ± 4.6	0.196
Bone Density (T-score)	-2.6 ± 0.40	-0.9 ± 0.60	0.001
Physical Activity (MET/Week)	2451.9 ± 671.2	2503.5 ± 776.3	0.222
Number of cigarettes per day	0.94 ± 3.5	1.7 ± 5.2	0.190
Years of smoking	1.7 ± 6.3	2.4 ± 7.3	0.470
Argila/Hookah per day	0.04 ± 0.24	0.15 ± 0.73	0.089
Duration of breastfeeding (month)	12.1 ± 7.9	11.2 ± 7.2	0.393

HEPA Health enhancing physical activity, BMI body mass index

P-value was set as less than 0.05

fish and shellfish, meat, fruits, and processed fish, was found to be positively associated with BMD ($P=0.048$) in premenopausal Japanese women. Another study showed a decreased likelihood of osteoporosis of the lumbar spine in the highest quintile of the 'Dairy and Fruit' dietary pattern compared with those in the lowest quintile after adjusting for many factors (OR 0·47, 95% CI 0·35, 0·65, P for trend < 0·0001) (Shin & Joung 2013). Moreover, in Scottish postmenopausal women "Healthy" patterns have been linked to lower bone resorption ($r=0.081$, $p<0.001$) with high consumption of fruits, vegetables, rice, pasta, white meat and fatty fish, and dairy products (Hardcastle et al. 2011). Animal studies have proposed that antioxidant-rich fruits may increase the trabecular bone volume, number, and thickness, and decrease trabecular separation through the stimulation of bone formation and suppression of bone resorption (Muñoz-Garach et al. 2020). Fruit and vegetables are rich in the micronutrients necessary for bone health, including potassium and magnesium, and vitamin K (Fabiani et al. 2019). Potassium and magnesium may contribute to the acid–base balance in the body which will prevent bone loss and reduce osteoporotic fracture risk. Moreover, vitamin C plays an important role in bone health, suppressing osteoclast activity and acting as a cofactor for osteoblast differentiation and collagen formation. Vitamin K is involved in bone health and osteoporosis prevention (Fabiani et al. 2019).

The dietary pattern of "Western/Unhealthy" appears to be marked by soft drinks, fast foods and sweets. Fats, saturated fats, sodium, additional sugar and phosphorous are included in these nutritious components, which are associated with a greater risk of low BMD and fracture

Table 3 Odds of osteoporosis across the quartiles of the dietary patterns among the study participants

Dietary pattern	Q1	Q2 OR (95% CI)	Q3 OR (95% CI)	Q4 OR (95% CI)	*P-trend*
High-Fruits and Vegetables	1 AOR	0.531 (0.225–1.253)	0.703 (0.292–1.694)	**0.375 (0.154–0.915)**	**0.001**
	1 COR	0.716 (0.327–1.568)	0.745 (0.339–1.637)	**0.404 (0.177–0.924)**	**0.001**
Traditional	1 AOR	1.475 (0.612–3.558)	1.902 (0.765–4.731)	0.710 (0.278–1.815)	0.633
	1 COR	1.357(0.597–3.084)	1.810(0.720–4.550)	0.531 (0.108–1.188)	0.644
Unhealthy/Western	1 AOR	0.912 (0.388–2.144)	**2.834 (1.081–7.430)**	1.364 (0.522–3.562)	0.856
	1 COR	0.689 (0.331–1.434)	2.187 (0.985–2.409)	0.722 (0.289–1.806)	0.846
High-Proteins	1 AOR	0.803 (0.346–1.868)	**2.601 (1.983–6.882)**	1.380 (0.542–3.514)	0.230
	1 COR	0.583 (0.254–1.339)	**2.312 (1.177–4.966)**	1.163 (0.405–3.064)	0.226

Adjusted for age, BMI, physical activity level, total energy intake, number of pregnancies and lactation, health problems, smoking, education level, marital status, and history of osteoporosis

The Control group was considered the reference group for dietary pattern analysis

AOR, COR and CI Adjusted odds ratio, crude odds ratio and confidence interval

Odd ratios are considered statistically significant at P ≤ 0.05

(Denova-Gutiérrez et al., 2018). Our study showed a significantly increased risk of osteoporosis in the third quartile [Q3: OR 2.834, 95%CI (1.081–7.430)]. Melaku et al. (2016) found a significant positive association between western dietary patterns and low BMD (PR = 1·68; 95% CI 1·02, 2·77). Similarly, the Western dietary pattern had a significantly higher risk of osteoporosis incidence in Korean postmenopausal women (RR, 1.46, 95% CI 1.02–2.10, p for trend = 0.043) (Park et al. 2012). In contrast, Fung & Feskanich (2015) concluded that neither a "Healthy" pattern nor a "Western" pattern had associations with the risk of hip fracture in postmenopausal women. Western dietary pattern is usually high in fat and saturated fats. A high-fat diet can affect bone remineralization, reducing the absorption of dietary calcium, and the resulting obesity may play a role in decreasing osteoblast differentiation and bone formation. Adequate protein intake is essential for bone matrix formation and maintenance, however, as animal proteins are rich in "sulfur amino acids," their metabolism contributes to endogenous acid production, and the acidic load produced is neutralized by calcium with bone resorption, which may progress to bone demineralization and osteoporosis (Fabiani et al. 2019).

Our results revealed an increased risk of osteoporosis in the third quartile of the 'High-Protein' dietary pattern. This is in agreement with several studies that showed a decreased bone mineral density with high animal protein and processed meat intake (Karamati et al. 2012; Okubo et al. 2006). A study by Karamati et al. (2012) showed that higher intakes of high-fat dairy products, organ meats, processed meat and non-refined cereals dietary patterns were more likely to have low BMD below the median in the lumbar spine and femoral neck (OR 2.29; 95% CI 1.05–4.96; $p = 0.04$), (OR 2.83, 95% CI 1.31–6.09; $p < 0.01$), respectively after adjusting factors. However, in Okubo et al. (2006) study, a diet characterized by high fat, oils, meat and processed meat tends to be inversely associated with BMD but the association was not significant ($P = 0.08$). Shin & Joung (2013) found no association between meat, alcohol, and sugars with BMD. It has been reported that consumption of highly proceed foods will increase sodium intake which will in turn induce higher calciuria. It is presumed that this increment in sodium intake will increase bone loss and bone remodelling. Additionally, an excessive intake of inorganic phosphorus, present in processed food additives, induces disruption of the calcium-phosphorus ratio, affecting the endocrine regulation of calcium homeostasis and may lead to acidosis. In an acidic environment, bone acts as a provider of alkali to maintain the acid–alkali balance, which leads to progressive bone loss (Muñoz-Garach et al. 2020). The unexpected results are the insignificant association between the fourth quartile of the two dietary patterns "Western/Unhealthy" and "High-Protein" even though the risk increased in both dietary patterns. This could be attributed to the increase in the intake of nutrients important for bone health such as calcium and vitamin D due to the increase in the consumption of these two dietary patterns. However, the increase in other dietary factors that affect adversely bone density counteracted the increase of nutrients necessary for preventing osteoporosis.

Our study has several strengths and drawbacks. The verified and accurate FFQs for collecting dietary data from our population are a major strength of our research. Despite the collection of dietary data at just one-time points, the FFQ has been identified as a sufficient method to quantify intakes of macro and micronutrients. This method of analysis significantly depends on the capacity and recollection of participants to provide reliable and conscientious knowledge from a time when the detail of their digested meal or physical exercise was not generally important to recall. Despite our efforts to monitor several potential confounding factors, we did not take into consideration the likely impact of cooking on the organic supply of the different nutrients. Additionally, the sample size is somehow small but all participants were newly diagnosed cases. Therefore, we cannot generalize the results for the whole population. Since it is culturally prohibited, we have not measured alcohol consumption.

In conclusion, four dietary patterns have been itemized among study participants namely: 'High-Fruits and Vegetables', 'Unhealthy/Western', 'High-Protein' and 'Traditional' dietary patterns. 'High-Fruits and Vegetables' dietary patterns exerted a protective effect against osteoporosis, while following 'Unhealthy/Western' and 'High-Protein' dietary patterns may increase the risk of osteoporosis. However, the 'Traditional' dietary pattern did not show any likelihood of increased risk of osteoporosis in any of the quartiles.

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Authors' contributions

RT conceived designed and supervised the study. RT and AA were responsible for cleaning, analysis and interpretation of the data. RT, RA and AA drafted, critically reviewed the manuscript and approved the final version.

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Availability of data and materials

Data are available upon request from the corresponding author Reema Tayyem (email: reema.tayyem@qu.edu.qa).

Declarations

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (IRB) of Jordan University Hospital. A written consent form was obtained from each participant.

Competing interests

The authors declare that they have no competing or conflict of interest.

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