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Assessment of Nutrients Associated With the Risk of Osteoporosis in Postmenopausal Women: A Case-Control Study

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Abstract

Osteoporosis is a chronic bone disease characterized by the loss in bone density and modification in bone structure. These changes will increase bone fragility and the risk of fracture particularly among postmenopausal women. The purpose of this study is to explore the possible association between nutrient intake and the risk of suffering from osteoporosis in postmenopausal women who have recently been diagnosed with osteoporosis. A case-control study was designed to determine nutrients intake, as well as dietary and lifestyle patterns. One hundred patients who were newly diagnosed with osteoporosis, and 100 osteoporosis-free controls Jordanian postmenopausal women were enrolled in this study. The ratio of case to controls is 1:1. Several macro and micronutrients were identified as having a protective effect on the risk of osteoporosis. The intake of carbohydrates, vitamin B6 and phosphorus was associated with lower risk of osteoporosis in all quartiles. Moreover, Fiber, iron, magnesium, potassium, and zinc are protective in the third and fourth quartiles. A significant protective effect of fats, monounsaturated fats, and vitamins C consumption was detected in the fourth quartile. The present results suggest that a poor diet and a lack of a healthy lifestyle do have significant effects on the development of osteoporosis in postmenopausal women.

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Introduction

Osteoporosis is a health condition that weakens bones, making them fragile and more likely to break.[1] Fractures caused by osteoporosis can lead to complications such as long-term disability, a reduced quality of life-related to health, and increased mortality. The majority of osteoporosis-related fractures occur in postmenopausal women.[2] Several studies have been conducted in Middle East countries including Jordan where the prevalence of osteoporosis was13% among women over 40 years according to the WHO criteria.[3] Increased age, being female, postmenopausal status, reduced exposure to sunlight, hypogonadism or early ovarian failure, low body mass, racial history, rheumatoid arthritis, low bone mineral density (BMD), inadequate vitamin D consumption, low calcium, hypercyphosis, current smoking, substance misuse, immobilization and long-term use of certain drugs are all triggers of osteoporosis.[1]

A poor diet may play a role in the development of osteoporosis; thus, a nutrition focus is placed on macro and micronutrient intake.[4] Previous studies on macronutrient intake revealed that there is a negative effect of high protein intake on bone density and greater risk on hip fracture and femoral neck,[5] however more recent studies suggest the opposite. Current studies report that bone wellbeing also requires protein absorption and that around 50% of bone volume is composed of proteins and about a third of bone mass. Therefore, as mineralization occurs, proteins are incorporated into the organic bone matrix in the collagen structure, which suggest that protein is a key nutrient for bone formation.[5] In addition, calcium and vitamin D are important micronutrients in preventing osteoporosis as they are part of the bone mineral matrix and are essential for bone strength.[6] Vitamin D deficiency can exacerbate osteoporosis in elderly or postmenopausal women so in order to optimize the effectiveness of antiosteoporotic medications, sufficient concentrations of 25-hydroxyvitamin D (25(OH)D) are required.[7] Therefore, adequate intake of calcium and vitamin D is necessary for the growth of bone and preservation of bone density, which effectively reduces the risk of hip fracture in osteoporotic patients and diminishes the risk of falls in older adults. Phosphorus (P) is another critical element for human health and has several biochemical purposes, such as structural functions. Phosphorus is one of the most important components of cell membranes, nucleic acid sugar-phosphate, and hydroxyapatite in bones and teeth.[8] Other micronutrients such as potassium and magnesium, also play a significant role in the protection of bones.[9] Magnesium stimulates a proliferation of osteoblast; thus, a lack of magnesium is also associated with a decreased formation of bone.[10] Magnesium is also required in order to activate vitamin D, as most vitamin D enzymes require magnesium.[11] Previous studies show that low intakes of magnesium in older subjects contribute to an over release of calcium from the body, further exacerbating bone fragility and raising the risk of bone fractures and falls.[12] Apart from its proven function in blood coagulation, multiple studies have also shown that vitamin K plays a vital role in bone health. Vitamin K is necessary for osteocalcin carboxylation, which controls the accretion of bone minerals. Vitamin K also appears to facilitate osteocalcin transformations into osteocytes and restricts osteoclastogenesis.[13]

In addition to nutrient intake, lifestyle factors can also contribute to the development of osteoporosis in postmenopausal women. This includes increased physical activity (PA) levels that have shown a positive correlation with improved health and quality of life.[14] Although the exact mechanism of osteogenesis through PA and exercise has yet to be thoroughly clarified because of the difficulties in testing in vivo cellular bone reactions, the process is likely to trigger anabolic or homeostatic effects in bone via mechanical translation.[15] Another modifiable lifestyle factor is smoking. Smoking is one of the most significant wellbeing risk factors and previous studies show that smoking is an independent risk factor for low BMD.[16] In addition, previous research has shown that increased BMI protects the bone density, and people with mild overweight have increased BMD levels, suggesting that BMI and gain in weight can be correlated with BMD.[17] More specifically, increased body weight was found to interact with the effect of endocrine modifications that can directly or indirectly affect the bone metabolism.[18] Particularly, low body weight or BMI are vulnerable to accelerated bone loss and low bone mass in postmenopausal female females, which are shown to play a key role in pathogenesis of osteoporosis.[19]

Osteoporosis is a significant public health issue for the elderly population. Around the globe, 8.9 million fractures occur annually, culminating in an osteoporotic fracture every three seconds. Postmenopausal osteoporosis is a growing disorder for elderly women as the world's demographic faces a pronounced aging of the population.[20] Up to the authors' knowledge, few studies have been conducted about osteoporosis in postmenopausal women in Jordan. However, no single study has investigated the association of nutrient intake with osteoporosis among postmenopausal women. Therefore, the present study investigated the association between macro and micronutrient intake and therisk of developing osteoporosis among newly diagnosed Jordanian postmenopausal women.

Materials and Methods

Study Design a Sample Recruitment

A case-control study was designed to determine nutrient intake as risk factors for osteoporosis in a sample of Jordanian postmenopausal women. In this study, a sample of 200 Jordanian postmenopausal women was enrolled. Of those 200 participants, 100 were recently diagnosed (up to 3 months) with osteoporosis and 100 controls with no previous history of osteoporosis. Cases and controls were visitors from the Jordan University Hospital and the Jordanian Osteoporosis Prevention Society (JOPS). The case to control ratio was one to one (1:1) and were matched based on age. The inclusion criteria for cases were females who were newly diagnosed with osteoporosis, postmenopausal women who were 50 years or older, and Jordanian nationals. For controls, non-osteoporotic Jordanian women who were 50 years or older were included in this study. The exclusion criteria for both cases and controls include a previous 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 collection for all participants was conducted in a hospital setting. The University of Jordan Hospital was chosen as the location for this study as it is well-equipped for services for osteoporosis patients in this study (IRB approval No. 2019/287). In addition, the Jordanian Osteoporosis Prevention Society (JOPS) served as another location to enroll osteoporosis cases. Eligible cases who were selected from JOPS were then invited to participate in the study. Once enrolled, participants were assigned to a specific laboratory to give their blood sample, completed questionnaires, and had their bone mineral density measured. A private room in good physical condition was used to conduct interviews. Additionally, a consent form was obtained to inform participants of potential study risks and outcomes. During each interview conducted with participants, a study team member explained the purpose of the study and allowed participants to read the formal consent form before participation. Further, potential risks and benefits were explained in detail of the minimal risk study participation.

Instruments and Tools

Personal Information Sheet

This sheet is composed of demographic and anthropometric questions. This includes questions related to age, sex, marital status, education, employment, anthropometric measurements (weight, height, waist circumference), family income/ month, smoking status, duration of breastfeeding previous, and current health problems.

Dietary Assessment

Arabic Food Frequency Questionnaire (FFQ), which has been developed and tested previously for reproducibility and validity,[22] was used to determine the nutrients 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"onaverage", 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[22] 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.

Bone Mineral Density Scan

A portable hand-held ultrasound bone densitometer (FURUNO CM-200 light) was used to measure BMD. This instrument was also usedin previous studies by Basheer *et al.* to investigate the relationship between vitamin D and BMD among coeliac patients. This instrument works by the transfer of precise ultrasound waves by the foot to assess BMD.[22] The machine then prints out a report with a T-score and is known for its high accuracy, easy to use nature, and a short turnover time.

Physical Activity Level

The 7-day Physical Activity Recall (PAR), developed by Sallis *et al.* was used to measure physical activity level.[23] The 7-Day PAR is a structured interview dependent on a participant's recall of the amount of time spent on physical activity over the course of seven days.[23] Participants are asked to respond to PAR questions according to the way they used to behave before their osteoporosis diagnosis.

Anthropometric Measurements

body weight and height were measured according to the methods by Lee & Nieman.[24] Body mass index (BMI) was calculated by take the ratio of weight in kilograms to the square of height in meters[24]

Biochemical Analysis

Non–fasting blood samples were drawn from all participants in a lab to determine 25-hydroxy vitamin D (25-OH vitamin D) levels.This was done by collecting at least three milliliters (ml) of blood from each participant by a lab technician. Technicians used a three ml syringe and a plain tube with gel and then ran the sample through a centrifugation system. Blood samples were then transported to another lab to determine the serum vitamin D concentrations. Serum vitamin D concentrations were determined using chemiluminescent immunoassay (LIAISON XL, Italy) which has been shown to be an accurate and sensitive measure of vitamin D concentration. Serum vitamin D concentrations were classified using the following cut-points: deficient (<20 ng/ml), insufficient (20-29 ng/ml) and sufficient or normal (≥30 ng/ml). All lab tests for this study were financed by the University of Jordan.

Statistical Analysis

Descriptive analyses were conducted to examine the frequency of different variables. A chi-square test was conducted to detect differences among the categorical variables. Further, t-test's were used to find the difference between continuous variables of cases and controls and are presented as Mean±SD. A logistic regression was used to calculate odds ratios (OR), confidence intervals (CI), and determine p-values for covariates. In our linear regression model, we controlled for the following variables: age, BMI, physical activity level, total energy intake, number of pregnancies and lactation, health problems, smoking, education level, marital status, and history of osteoporosis.[25] 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 includes 200 Jordanian postmenopausal women ranging from 50-85 years old. Of these 200 women, 100 were recently diagnosed with osteoporosis (cases) and 100 were non-osteoporotic (controls). Table 1 displays the general characteristics of the study participants. In our sample, a little over 80% of cases report being married at the time of enrollment while around 75% of controls are married.Reported education level was similar in both groups with 31% of cases and 26% of controls witha primary level of marriage and 40% of cases and 35% of controls completed at least a high school education. Ninety-one percent of cases and 88% of controls are non-smokers, however 2% of cases and 7% of controls report smokinghookah. The BMI status of the women in our sampleare mostly between overweight (34%, 45%) and obese (47%, 34%). The stated physical activity intensity was mainlycaptured as"minimally active", due to the high age of the study population. Therefore, roughly 17% of cases and 24% of controls reported regular a level of health-enhancing physical activity.

In addition, we found significant differences between cases and controls 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) (Table 1.). However, no significant differences were found in other parameters such as age, BMI, weight, serum vitamin D levels, physical activity, smoking and duration of breastfeeding.

Table 1: Socio-demographic, lifestyle, anthropometric and biochemical characteristics of the study participants

Variables	Cases n=100	Controls n=100	P- Value
	n (%)		
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
Smoking			
Non-smoker	91(91)	88(88)	
Smoker	9(9)	12(12)	0.491
Argeala			
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**
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/m²)	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
Argeala 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

Abbreviations: HEPA, Health enhancing physical activity BMI, body mass index.
P-value was set as less than 0.05

Table 2shows the dietary characteristics of the study population. Wefound a significant difference between cases and controls in the skipped meals. Regarding breakfast, 25% of cases and 21% of controls report skipping breakfast, while 12% of cases and 2% of controls skip lunch, and 38% of cases and 49% of controls skip dinner (P = 0.009). Additionally, we observe significant differences in vitamin or mineralsupplementswith 77% of cases and 58% of controls reported consuming vitamins and/or minerals (P=0.004). Moreover, vitamin D supplement intake is significantlydifferent between cases and controls (P=0.002) as well as doses and years consumed (P< 0.05).

Table 2: Dietary characteristics of the study participants (N=200; cases = 100, controls = 100)

Variables	Cases n(%)	Controls n(%)	P-Value
Number of Main Meals Per Day			
One meal	4(4)	1(1)	
Two meals	76(76)	73(73)	0.332
Three meals	20(20)	25(25)	
More than three meals	0(0)	1(1)	
Skipped Meals Per Day			
No meals skipped	21(21)	24(41)	
Breakfast	25(25)	21(21)	
Lunch	12(12)	2(2)	
Dinner	38(38)	49(49)	0.009
Breakfast and lunch	0(0)	2(2)	
Breakfast and dinner	4(4)	0(0)	
Lunch and dinner	0(0)	2(2)	
Number of Snacks Per Day			
One snack	37(37)	37(37)	

Two snacks	38(38)	38(38)	
Three Snacks	8(8)	13(13)	0.563
More than three snacks	2(2)	3(3)	
Does not take snacks	15(15)	9(9)	
Number of Meal Eaten Out of Home			
Does not eat out of home	54(54)	40(40)	
Less than one time per month	31(31)	47(47)	0.094
1-3 times per month	14(14)	13(13)	
4-6 times per week	1(1)	0(0)	
Daily Water Amount			
(1-3) Cups	17(17)	13(13)	
(3-5) Cups	44(44)	30(30)	0.069
More than 5 Cups	26(26)	42(42)	
Don't know	13(13)	15(15)	
Breastfeeding			
Yes	81(81)	80(80)	0.858
No	19(19)	20(20)	
Vitamins or Minerals Supplements			
Yes	77(77)	58(58)	0.004
No	23(23)	42(42)	
Vitamin C Supplement			
Never	91(91)	85(85)	
Less than once per month	2(2)	10(10)	
1-3 times per month	3(3)	3(3)	0.110
1-3 times per week	0(0)	0(0)	
4-6 times per week	2(2)	0(0)	
Everyday	2(2)	2(2)	
Vitamin C Supplement Dose			
Never	91(91)	85(85)	
Less than 500 mg	2(2)	5(5)	
500-999 mg	2(2)	0(0)	
1000-1499 mg	0(0)	1(1)	0.289
1500-1999 mg	0(0)	1(1)	
2000 mg or more	0(0)	0(0)	
Don't know	5(5)	8(8)	
Years Consuming Vitamin C Supplement			
Never	91(91)	85(85)	
Less than one year	8(8)	14(14)	
1-4 years	1(1)	1(1)	0.398
5-9 years	0(0)	0(0)	
10 years or more	0(0)	0(0)	
Calcium Supplement			
Never	68(68)	74(74)	
Less than once per month	7(7)	8(8)	
1-3 times per month	4(7)	6(6)	0.487
1-3 times per week	4(4)	1(1)	
4-6 times per week	1(1)	0(0)	
Everyday	16(16)	11(11)	
Calcium Supplement Dose			
Never	68(68)	74(74)	
Less than 500 mg	12(12)	6(6)	

500-599 mg	3(3)	8(8)	
600-999 mg	2(2)	0(0)	0.189
1000 mg or more	2(2)	3(3)	
Don't know	13(13)	9(9)	
Years Consuming Calcium Supplement			
Never	68(68)	74(74)	
Less than one year	22(22)	11(11)	
1-4 years	6(6)	12(12)	0.045
5-9 years	4(4)	1(1)	
10 years or more	0(0)	2(2)	
Vitamin D Supplement			
Never	91(91)	75(75)	
Less than once per month	0(0)	0(0)	
1-3 times per month	2(2)	16(16)	0.002
1-3 times per week	1(1)	4(4)	
4-6 times per week	0(0)	0(0)	
Everyday	6(6)	5(5)	
Vitamin D Supplement Dose			
Never	91(91)	75(75)	
1000 IU	4(4)	2(2)	
5000 IU	3(3)	5(5)	0.001
50000 IU	2(2)	18(18)	
Years Consuming Vitamin D Supplement			
Never	91(91)	75(75)	
Less than one year	4(4)	8(8)	
1-4 years	5(5)	15(15)	0.020
5-9 years	0(0)	0(0)	
10 years or more	0(0)	2(2)	
Vitamin B6 Supplement			
Yes	6(6)	2(2)	0.149
No	94(94)	98(98)	
Vitamin B Complex Supplement			
Yes	2(2)	8(8)	0.052
No	98(98)	92(92)	
Fish Oil			
Yes	9(9)	9(9)	1.000
No	91(91)	91(91)	
Iron			
Yes	11(11)	14(14)	0.521
No	89(89)	86(86)	

Data are presented as the number of participants with the percentages given in parentheses. Chi-square was used to find the statistical differences between the two groups, and the difference was considered statistically significant at P≤0.05.

Further, Table 3 summarizes daily intakes of macro and micronutrients of the study population. The control group shows a significantly higher intake of energy from fats (P = 0.037), carbohydrates (P = 0.001), fibers (P = 0.001), sugars (P = 0.001), monounsaturated fat (P = 0.022), and water (P = 0.009) compared to cases. However, the case group shows a significantly higher intake of caffeine (P = 0.029). Additionally, this group has a significantly higher intake of vitaminA (P = 0.001), ß-carotene (P = 0.014), B6 (P = 0.009), vitamin C (P = 0.024), and vitamin E (P = 0.019). For mineral intake, cases

had a significantly higher intake ofcopper (P = 0.049), iodine (P = 0.006), iron (P = 0.001), magnesium (P = 0.001), phosphorus (P = 0.001), potassium (P = 0.001), and zinc (P = 0.036).

Table 3: Adjusted macro and micronutrient intake of study participants (N=200; cases = 100, controls = 100)

Energy and Adjusted Macronutrients	Cases Mean±SD	Controls Mean±SD	p-value
Energy(Kcal)	1379.2±759.0	1533.7±755.3	0.457
Fat calories	473.12±.12	507.4±.10	0.037
Saturated fat calories	109.3±.14	112.1±.18	0.914
Protein(g)	48.3±.12	52.6±.13	0.080
Carbohydrates(g)	181.02±.09	208.8±.07	0.001
Fiber(g)	11.8±.16	14.3±.13	0.001
Soluble fiber(g)	1.3±.22	1.3±.17	0.651
Sugar(g)	54.7±.21	67.2±.21	0.001
Other carbohydrate(g)	74.4±.15	77.0±.20	0.804
Fat(g)	52.8±.12	56.7±.10	0.036
Saturated Fat(g)	12.1±.14	12.4±.18	0.928
Monounsaturated Fat(g)	11.8±.14	13.3±.17	0.022
Polyunsaturated Fat(g)	6.9±.15	7.9±.26	0.566
Trans-Fat(g)	1.1±.39	1.0±.49	0.296
Cholesterol (mg)	123.5±.25	133.4±.25	0.315
Water(ml)	800.8±.27	929.2±.18	0.009
Omega-3(g)	.33±.26	.35±.24	0.212
Omega-6(g)	3.2±.16	3.5±.21	0.633
Caffeine (mg)	60.7±.44	46.9±.39	0.029
Adjusted Micronutrients			
Vitamin A (RAE)	334.3±.23	929.2±.17	0.001
Retinol (RE)	199.7±.26	256.9±.34	0.569
ß-carotene (µg)	969.3±.30	1338.4±.33	0.014
Vitamin B1(mg)	1.0±.14	1.1±.28	0.747
Vitamin B2 (mg)	1.1±.20	1.2±.25	0.166
Vitamin B3(mg)	10.7±.16	11.5±.14	0.154
Vitamin B6(mg)	.62±.26	.80±.29	0.009
Vitamin B12 (µg)	1.3±.24	1.6±.30	0.488
Vitamin C (mg)	73.6±.27	93.4±.27	0.024
Vitamin D (µg)	.39±.42	.54±.51	0.691
Vitamin E-α-Tocopherol (mg)	3.2±.29	3.8±.18	0.019
Folate (µg)	226.1±.13	250.2±.17	0.203
Folic acid (µg)	273.6±.16	306.1±.19	0.127
Vitamin K (µg)	101.5±.40	108.0±.50	0.451
Calcium (mg)	505.3±.15	546.1±.15	0.346
Copper (mg)	.52±.22	.63±.26	0.049
Fluorine (mg)	.53±.65	.38±.59	0.405
Iodine (µg)	29.2±.25	36.9±.23	0.006
Iron (mg)	8.8±.12	10.4±.12	0.001

Magnesium (mg)	119.1±.13	138.5±.12	0.001
Phosphors (mg)	527.7±.09	605.7±.12	0.001
Potassium (mg)	1403.9±.16	1752.5±.12	0.001
Selenium (mcg)	41.8±.18	44.6±.18	0.246
Sodium (mg)	1680.4±.15	2030.0±.22	0.058
Zinc (mg)	3.3±.12	3.7±.14	0.032

Data are given as the mean ± SD
Independent t-test was used to detect the statistically differences between the two groups and are considered statistically significant at $P \leq 0.05$.

We calculated ORs and their corresponding CI for nutrient intake of our study sample. In Table 4, we summarize that the odds of carbohydrates [Q2: OR 0.226, 95% CI (0.082-0.621)]; [Q3: OR 0.040, 95% CI (0.013-0.123)]; [Q4: OR 0.052, 95% CI (0.017-0.158)], vitamin B6 [Q2: OR 0.136, 95% CI (0.044-0.422)]; [Q3: OR 0.082, 95% CI (0.024-0.279)]; [Q4: OR 0.126, 95% CI (0.034-0.459)], and phosphorus [Q2: OR 0.232, 95%CI (0.089-0.602)]; [Q3: OR 0.147, 95%CI (0.055-0.394)]; [Q4: OR 0.176, (0.068-0.454)], show a protective effect at all quartiles. Moreover, fiber, iron, magnesium, phosphorus, potassium, and zinc are protective in the third and fourth quartiles. In addition, we see a significant protective effect amongfats, monounsaturated fats, and vitamin C in the fourth quartile while vitamin E shows a protective effect in the second quartile. On the other hand, we see a significant risk effect in the caffeine at the second and third quartiles [Q2: OR 3.011, 95% CI (1.229-7.376)]; [Q3: OR 2.975, 95% CI (1.192-7.426)]

Discussion

The aim of this study was to identify the association of nutrient intake and risk of osteoporosis among Jordanian postmenopausal women who are 50 years or older. Data in this case-control study suggests that there was a significant association between the risk of osteoporosis and nutrient intake as well as some modifiable lifestyle factors. We used data on macro and micronutrient intake, daily physical activity, and some biochemical measures to determine the probability of developing osteoporosis in postmenopausal women.

In our study, we found that there are significant differences in educational status. Four percent of osteoporotic women and 16% of non-osteoporotic completed up to thebachelor's level. Previous studies revealedthat a high education level is associated with better BMD and a lower prevalence of osteoporosis in Chinese postmenopausal women.[26] Furthermore, another study reported a connection between educational levels and the risk of hip fracture in non-Hispanic ambulatory white males.[27]

The main findings from our anthropometric measures shows a significant difference in height between osteoporotic and control groups. Similarly, another study reports that an adult's height is associated with several risk diseases including hip fractures.[28] Compston *et al.* (2017) illustrated that a higher height is a risk factor for osteoporosis asthey found that a higher height can increase the risk of fractures, including a greater fall impact, and increased cortical porosity.[29]

Furthermore, our analysis found that serum vitamin D and osteoporosis have no major effect. This can be explained due to the majority of our participants report avitamin D deficiency; thusa number of our participants regularly take vitamin D supplements. These results agree with those found by Hyassat *et al.* (2017) who also did not find any significant effect of vitamin D levels due to a vast majority of participants taking vitamin D supplements.[30] According to Simeonova *et al.*(2020), 39% of their osteoporotic group reportednormal vitamin D levels, 34 % with insufficient vitamin D levels, and 27% with avitamin D deficiency.[31] However, according to Tian *et al.*, low vitamin D levels are not associated with an elevated risk of low bone mineral density.[32]

Regarding the dietary habits among the study participants, our results show a significant difference between osteoporotic postmenopausal women and vitamins and minerals supplementation especially vitamin D supplements. Seventy seven percent of the osteoporotic group and 58% of non-osteoporotic

Table 4: Association between osteoporosis risk and nutrient intakes

Nutrient	Q1	Q2OR (95 % CI)	Pvalue	Q3OR (95 % CI)	Pvalue	Q4OR (95 % CI)	Pvalue
Carbohydrates	1	0.226 (0.082-0.621)	0.004	0.040 (0.013-0.123)	0.001	0.052 (0.017-0.158)	0.001
Proteins	1	0.726 (0.294-1.797)	0.489	0.592 (0.274-1.419)	0.240	0.479 (0.202-1.134)	0.094
Fibers	1	0.415 (0.162-1.067)	0.086	0.270 (0.104-0.703)	0.007	0.129 (0.049-0.338)	0.001
Fats	1	0.973 (0.141-2.287)	0.949	0.654 (0.274-1.562)	0.339	0.391 (0.167-0.914)	0.030
Saturated Fat	1	0.688 (0.279-1.697)	0.417	0.427 (0.173-1.051)	0.064	1.007 (0.424-2.396)	0.987
Monounsaturated Fat	1	0.509 (0.212-1.222)	0.131	0.591 (0.236-1.475)	0.259	0.335 (0.139-0.811)	0.015
Poly unsaturated Fat	1	1.893 (0.724-4.954)	0.193	1.188 (0.467-3.023)	0.718	0.760 (0.318-1.813)	0.535
Trans Fatty Acids	1	0.765 (0.320-1.828)	0.546	0.797 (0.335-1.897)	0.608	1.196 (0.465-3.077)	0.711
Vitamin B6	1	0.136 (0.044-0.422)	0.001	0.082 (0.024-0.279)	0.001	0.126 (0.034-0.459)	0.002
Vitamin C	1	0.479 (0.193-1.190)	0.113	0.414 (0.162-1.056)	0.065	0.157 (0.061-0.405)	0.001
Vitamin E	1	0.377 (0.164-0.866)	0.021	0.501 (0.210-1.198)	0.120	0.653 (0.266-1.601)	0.352
Iron	1	0.614 (0.220-1.717)	0.353	0.124 (0.045-0.343)	0.001	0.174 (0.063-0.478)	0.001
Magnesium	1	0.702 (0.279-1.765)	0.452	0.117 (0.044-0.313)	0.001	0.274 (0.111-0.671)	0.005
Phosphorus	1	0.232 (0.089-0.602)	0.003	0.147 (0.055-0.394)	0.001	0.176 (0.068-0.454)	0.001
Potassium	1	0.705 (0.269-1.853	0.049	0.192 (0.072-0.514)	0.001	0.136 (0.053-0.350)	0.001
Calcium	1	1.400 (0.586-3.345)	0.448	0.773 (0.316-1.889)	0.572	0.761 (0.328-1.766)	0.525
Zinc	1	0.571 (0.235-1.388)	0.216	0.327 (0.139-0.768)	0.010	0.311 (0.127-0.763)	0.011
Caffeine	1	3.011 (1.229-7.376)	0.016	2.975 (1.192-7.426)	0.019	1.723 (0.729-4.071)	0.215

OR and CI: odd ratio and confidence interval.
Adjusted for age, BMI, marital status, education, smoking, health problems, physical activity, history of osteoporosis, breastfeeding, and calories.
Odd ratios considered statistically significant at $P \leq 0.05$

group reporting taking vitamins and/or minerals supplements. However, the non-osteoporotic group shows a significantly higher intake of vitamin D supplements than the osteoporotic group. In a study conducted by Morton*et al.*(2001), the authors found that vitamin C supplement users of postmenopausal women have a significantly higher BMD level at the femoral neck after controlling covariates.[33] They also observed a significantly high bone mass in the midshaft radius and total hip after adjusting for age and BMI and use of calcium supplements. Additionally, Knapen *et al.* (2013) reported that menaquinone-7 intake can significantly improve vitamin K status and reduce the decline in BMD at the lumber spine and femoral neck but not in total hip.[34] In contrast, Hamidi & Cheung (2011) documented that lower levels of dietary vitamin K were associated with an increased risk of fractures, but not an improvement in bone health in older adults.[35] In a randomized controlled study, zinc supplementation (25 mg/d of zinc for 18 months) shows a significant increase in BMD and BMC.[36] Additionally, studies regarding magnesium supplementation and bone mineral density are positivelycorrelated.[37,38,39] Moreover, fracture prevention clinical trials confirm a positive effect of calcium in tandem with vitamin D supplementation.[40] However, no clinically advantage was observed in a meta-analysison the effects of vitamin D supplementation on bone density.[41] However, two recent studies have shown that individuals with baseline levels of 25-hydroxyvitamin D (<30 nmol/L) have continued bone loss and that vitamin D supplementation can be a valuable solution.[42,43]

In this study, diet shows an important role on the risk of osteoporosis. Significant differences were detected in certain macro and micronutrients. Intakes of caffeine shows a significant risk of osteoporosis. This result agrees with similar results found in studies by Bijelic *et al.* (2017) and Hyassat *et al.* (2017) who reported a significant association between high intakes of caffeine and the risk of osteoporosis.[30, 44] In addition, we found that carbohydrate intakes have a protective effect of osteoporosis. However, no specific studies have shown a similar effect. Nakayama & Katayama(2005) found no evidence that suggests direct effects of carbohydrate intake and BMD.[45] However, there is evidence that suggests that certain indigestible carbohydrates, such as inulin and oligofructose, can improve the absorption of minerals from food, which can therefore be beneficial to bone mass.[45] Furthermore, in this study fiber intake shows protective effects of osteoporosis.This result is similar to one found by the Framingham Off spring Study, which summaries that a high dietary fiber (β = 0,06, p = 0,003) and fruit fiber (β = 0,10, p = 0,008) intake protects from a femoral neck bone deficiency in men, but not women in Q2–Q4.[46] Another study suggests that for women, there are no observed correlations with fiber intake on the loss of hipbone, however, vegetable fiber seems to protect women, but not men from spine bone loss.[46]

We also found protective effects with intakes of magnesium, iron and zinc against osteoporosis risk. These results agreed with Okyay *et al.* (2013) who revealed that a lower serum magnesium, iron, and zinc are significantly associated with osteoporosis.[47] On the other hand, Okyay *et al.*(2013) did not find any associations with phosphorus and potassium, in which our study did.[47] Similarly, Lee & Cho (2015) stated that a high phosphorus intake was associated with improved BMD.[48] In contrast, Vorland *et al.* (2017) reported that phosphate additives have negative effects on bone metabolism.[8] Furthermore, we found that vitamin B6 shows a protective effect on the risk of osteoporosis, which matches with results from Wang*et al.* that osteoporosis risk was found in low serum vitamin B6 group (< 19.2 µg/L) than those of higher concentrations (> 26.9 µg/L).[49] In addition, we also found that there is a protective effect with MUFA intake. This outcome is consistent with Martinez-Raminez *et al.* (2007) who reported a protective effect of MUFA.[50] The inverse correlation between MUFA and the risk of fracture that we described here can be due to the high level of MUFA-rich olive oil that is a staple food item for many in the Mediterranean. Monounsaturated 18-carbon oleic acid is the main fat contained in olive oil. Similarly, Trichopoulou *et al.* (1997) documented that MUFA intake was associated with a higher bone mineral density in his cross-sectional study conducted in Greece.[51]

We have also identified several strengths and drawbacks in our study. The FFQs for collecting dietary data from our population serves as a major strength of our research due to its reliable and accurate credibility. Despite the collection of dietary data during one time point, the FFQ has

been previously identified as a sufficient method to quantify intakes of macro and micronutrients. However, a drawback of FFQs tend to be prone to bias as data collection depends on the capacity and recollection of participants to provide reliable information about their food intake and physical exercise. Despite our efforts to monitor several potential confounding variables, we did not take into consideration the impact of cooking on the bioavailability of nutrients. Furthermore, since it is culturally prohibited, we did not measure alcohol consumption.

Our case-control study suggested that a poor diet and a lack of a healthy lifestyle do have significant effects on the development of osteoporosis in postmenopausal women. A poor diet quality that lacks an adequate amount of carbohydrates, fats, proteins, and water is more likely to have reduced bone mineral density, which can result in more fractures. However, a diet that is rich in vitamins and minerals such as ß-carotene, vitamin B6, vitamin C, vitamin E, iron, magnesium, phosphorus, potassium and zinc have a preventative effect towards osteoporosis in postmenopausal women.

Ethics Policies

This review did not request ethical approval.

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Conflict of Interest

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

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