Dietary inflammatory index and osteoporosis: the National Health and Nutrition Examination Survey, 2017–2018

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Abstract

Purpose The dietary inflammatory index (DII) is a scoring system to quantify the inflammatory effects of nutrients and foods. Inflammation may affect bone health. The purpose of this study was to explore the relationships of DII with bone mineral density (BMD) and osteoporosis.

Methods This study involved 1023 women and 1080 men (age ≥ 50) in the US National Health and Nutrition Survey (NHANES), 2017–2018. Multivariable linear regression models were used to estimate the associations between DII and BMD. Association between DII and osteoporosis was tested with multivariable logistic regression models.

Results In women, DII was negatively associated with total hip and femoral neck BMD after adjusting for covariates ($P < 0.05$). In men, DII was negatively associated with lumbar spine BMD ($P < 0.05$). DII was positively associated with osteoporosis in women ($P < 0.05$). The odds ratios (ORs) (95% CI) for osteoporosis associated with DII quartiles 2, 3 and 4 vs. quartile 1 were 2.95 (1.08, 8.09), 5.63 (2.87, 11.04), and 6.14 (2.55, 14.78), respectively. No significant association was observed in men.

Conclusions Higher DII scores were associated with increased osteoporosis risk in women, while no association was found in men. Greater pro-inflammatory diets might be associated with lower BMD in both women and men.

Keywords Dietary inflammatory index · Osteoporosis · Bone-mineral density

Introduction

Osteoporosis is a common senile disease characterized by low bone mass and degradation of bone microstructure; osteoporosis can lead to increased bone fragility, fracture tendency, and risk of death [1]. Bone mineral density (BMD) is a common parameter for evaluating bone health [2]. A study has shown that the lifelong risk of osteoporotic fractures is 40–50% for women worldwide, and 13–22% for men [3]. Osteoporosis has affected about 200 million people all over the world, resulting in high disability rates and increased societal costs, thereby becoming a serious global burden [3]. A study in nine developed countries reported that up to 38% of women and 8% of men aged 50 years old or over had osteoporosis [4]. With the aging of the society, osteoporosis has become a serious public threat [5].

Ageing and hormone abnormality are the main cause of osteoporosis [6]. Other risk factors for osteoporosis include weight, calcium intake, smoking, and alcohol intake [7]. Dietary factors are also useful to maintain bone health and prevent fragility fractures [8]. Studies have found that people’s eating habits could influence inflammation, while chronic inflammation is closely related to osteoporosis [5, 9]. Several proinflammatory cytokines, such as TNF-α, IL-1, IL-17, and type III IFNs (IFN-λ) could activate osteoclasts, whereas other inflammatory cytokines, such as
IL-12, IL-18, IL-33, and type I IFNs (IFN-α/β), type II IFN (IFN-γ) inhibit bone loss [10, 11].

The dietary inflammatory index (DII), which is developed by Shivappa et al. through extensive literature search, is a scoring system to quantify the inflammatory effects of nutrients and foods [12]. It is created by assigning a score for each of 45 food parameters reported to regulate the levels of 6 specific inflammatory biomarkers (IL-1β, IL-4, IL-6, IL-10, TNF-α, and CRP) [13]. DII is standardized to global dietary intakes, which are allowed to be used in different cultures and dietary patterns [14]. Higher DII scores are associated with increased concentration of inflammatory biomarkers (such as CRP and TNF-α); this suggests that DII may be used to determine the association between dietary inflammatory potential and chronic disease [15, 16]. It is reported that there is a positive correlation between DII and fracture risk in adult Americans [17]. A meta-analysis indicates that high pro-inflammatory diets are significantly related to lower BMD of lumbar spine and total hip [13]. However, Cervo et al. found that there is no significant link between DII and BMD in older Australian men [18].

Due to the limited and inconsistent evidence on the association between DII and osteoporosis, we examined the associations between DII and BMD and osteoporosis using the nationally representative data from the US.

**Materials and methods**

**Study population and data collection**

Data for this research were extracted from the National Health and Nutrition Examination Survey (NHANES), which was conducted by the National Center for Health Statistics, including cross-sectoral, multi-stage, stratified, and aggregated probability samples of the US non-institutional population. The NHANES was approved by the National Center for Health Statistics Research Ethics Review Board and received written informed consent from all participants. In the present study, we focused on the participants who were aged ≥50 years in NHANES 2017–2018. Among the original 3069 participants, those with missing dietary data (n = 464), those with unreliable calorie intake (men <500 kcal or >8000 kcal; women <500 kcal, or >5000 kcal, n = 21), and those with missing BMD data (n = 368) were excluded. Finally, 2103 participants were involved in this study (Fig. 1).

**Calculation of DII**

The development and validation of the DII have been presented in detail elsewhere [12]. Briefly, The Z-score is created by subtracting the global average daily intake and divided by the standard deviation, converting it to a percentile score, which is then doubled and subtracted by “1” to achieve a symmetrical distribution. Then, the percentile value is multiplied by the corresponding overall inflammation effect score, we can get an individual “overall DII score” by adding up each DII score. In the present study, we used two 24-h dietary recalls (24HRs) to obtain dietary information. 27 of the 45 food parameters were used for the calculation of the DII score, which included carbohydrates; protein; fat; alcohol; fiber; cholesterol; saturated, monounsaturated, and polyunsaturated fatty acids; omega3 and omega6 polyunsaturated fatty acids; niacin; vitamins A, B1, B2, B6, B12, C, D, E; iron; magnesium; zinc; selenium; folic acid; beta carotene; and caffeine. Importantly, even if the nutrients applied for the calculation of DII are <30, the DII scores are still available [12]. A low DII is indicative of...
an anti-inflammatory diet, and a high DII of a pro-inflammatory diet. To control for the effect of total energy intake, the DII was calculated per 1000 calories of food consumed [19].

**BMD measurement and osteoporosis diagnosis**

The BMD of lumbar spine, femoral neck, and total hip were measured by dual-energy X-ray absorptiometry (DXA). Briefly, the hip and lumbar spine BMD measurements were performed by the Hologic QDR-4500A fan-beam densitometers (Hologic; Bedford, MA) and analyzed by Hologic APEX, version 4.0, software. The detailed DXA measurement agreement is publicly available at http://www.cdc.gov/nchs/nhanes/. Total hip, lumbar spine, and femoral neck BMD were converted into T-scores using the formula: T-score = (BMD respondent−mean BMD reference group)/SD reference group [20]. Any T scores at total hip, lumbar spine, or femoral neck BMD ≤ −2.5 were used to define osteoporosis; T scores < −1 and ≥ −2.5 were used to define osteopenia [21].

**Covariate ascertainment**

The following covariates that adjusted in multivariable models were summarized as follows: continuous variables consisted of age, calcium intake (g/day), and serum phosphate (mg/dL). Categorical variables included gender (women, men), marital status (single, living with partner), race (Hispanic, non-Hispanic white, non-Hispanic black, and other race), BMI group (<25 kg/m², 25–30 kg/m², ≥30 kg/m²) and BMI was calculated using the formula: body weight (kg) divided by body height squared (m²). Three classifications of smokers were created: for the present analysis, variables from the “Smoking—Cigarette Use” questionnaire were used, where participants are asked if they have smoked 100 cigarettes in their lives. If someone answered “no”, they were classified as a never smoker. If someone answered “yes,” they were further subclassified by an additional question, which asks if they is a current smoker. If someone answered that they have smoked >100 cigarettes in life and also stated that they were not a current smoker, they were classified as former smoker. If someone answered “yes” to both questions, they were classified as a current smoker.

**Statistical analysis**

Characteristics of participants in the present study by osteoporosis status were descriptively analyzed for all individuals as well as by sex. The continuous variables were expressed as means with standard deviation or median [P₂₅, P₇₅] and compared by the t test or Mann-Whitney U test, respectively. The categorical variables were presented as counts and percentages and compared by Chi-square test. Multivariable linear regression models were used to estimate the associations between DII and BMD; DII was treated as continuous variable in the model. The association between DII and osteoporosis was tested with multivariable logistic regression models. In the model, DII was then categorized into quartiles, with quartile 1 serving as the referent group. The P for trend was tested by treating the median value of DII in each quartile as a continuous variable. Subgroup analyses by age and BMI were also performed. After removing participants with osteoporosis, the association between DII and osteopenia was also performed with multivariable logistic regression models.

Survey sampling weight was considered in all analyses. All analyses were performed with SPSS (version 24.0; IBM SPSS Statistics, Armonk, NY, USA) and R (version 4.1; R Foundation for Statistical Computing). P < 0.05 was considered statistically significant.

**Results**

**Characteristics of study participants**

The characteristics of participants by osteoporosis status are presented in Table 1. There were 2103 participants (1023 women and 1080 men) in the study. As compared with non-osteoporosis individuals, osteoporotic patients were older, thinner, higher calcium intake, and more likely to be non-Hispanic white (P < 0.05). There were no significant differences in DII score between the osteoporosis and non-osteoporosis groups. In women, people with osteoporosis were older and more likely to be Non-Hispanic white than those without osteoporosis (P < 0.05). Women with osteoporosis had a higher mean DII score than those without osteoporosis (P < 0.05). In addition, women and men with BMI < 25 kg/m² had higher proportion of osteoporosis than those with BMI ≥ 25 kg/m² (P < 0.05).

**BMD according to DII**

The BMD according to DII is shown in Table 2. In women, DII was negatively associated with total hip and femoral neck BMD after adjusting for covariates in model 2 (P < 0.05). In men, DII was negatively associated with lumbar spine BMD (P < 0.05), but no association was observed for total hip and femoral neck BMD (P > 0.05).

**Risk of osteoporosis according to DII**

The analysis results of the adjusted odds ratios (ORs) for risk of osteoporosis according to the quartiles of DII are shown in Table 3 and Fig. 2. In women, DII was
Table 1 Characteristics of study participants according to osteoporosis in women and men (n(%)/M[P_{25}, P_{75}]/ X ± S)

| Variables                      | Osteoporosis | Without osteoporosis | P-value |
|--------------------------------|--------------|----------------------|---------|
| All individuals                |              |                      |         |
| N(2103)                        | 196          | 1907                 | <0.001  |
| Age (years)                    | 68.5[62.00, 79.75] | 62.00[56.00, 69.00] |         |
| Race, N(%)                     |              |                      | 0.054   |
| Hispanic                       | 42(10.0)     | 435(11.9)            |         |
| Non-hispanic white             | 92(74.1)     | 719(69.5)            |         |
| Non-hispanic black             | 23(5.0)      | 457(10.0)            |         |
| Other race                     | 40(11.0)     | 296(8.5)             |         |
| Marital status, N(%)           |              |                      | 0.038   |
| Single                         | 90(42.6)     | 737(31.6)            |         |
| Live with others               | 106(57.4)    | 1170(68.4)           |         |
| BMI, kg/m², N(%)               |              |                      | <0.001  |
| <25                            | 95(45.8)     | 392(20.2)            |         |
| 25–30                          | 64(31.0)     | 699(33.4)            |         |
| ≥30                            | 37(23.2)     | 816(46.4)            |         |
| Smoker, N(%)                   |              |                      | 0.566   |
| Never                          | 117(59.2)    | 1015(55.4)           |         |
| Former                         | 50(24.2)     | 607(31.0)            |         |
| Current                        | 29(16.6)     | 285(13.5)            |         |
| Calcium intake (mg/day)^a       | 469.12[349.47, 579.91] | 432.31[330.51, 562.71] | 0.017   |
| Serum phosphate (mg/dL)        | 3.70[3.40, 4.10] | 3.70[3.40, 4.00]     | 0.335   |
| DII                            | −0.16 ± 0.14 | −0.20 ± 0.06         | 0.537   |
| Women                           |              |                      |         |
| N(1023)                        | 156          | 867                  | <0.001  |
| Age (years)                    | 69.0[62.0, 79.8] | 62.0[56.0, 69.3]     |         |
| Race, N(%)                     |              |                      | 0.015   |
| Hispanic                       | 36(10.7)     | 206(12.2)            |         |
| Non-hispanic white             | 70(74.4)     | 311(68.7)            |         |
| Non-hispanic black             | 14(2.6)      | 220(10.6)            |         |
| Other race                     | 36(12.3)     | 130(8.5)             |         |
| Marital status, N(%)           |              |                      | 0.626   |
| Single                         | 75(42.2)     | 416(38.7)            |         |
| Live with others               | 81(57.8)     | 451(61.3)            |         |
| BMI, kg/m², N(%)               |              |                      | 0.001   |
| <25                            | 76(45.5)     | 168(22.0)            |         |
| 25–30                          | 48(30.5)     | 289(31.0)            |         |
| ≥30                            | 32(24.0)     | 410(47.0)            |         |
| Smoker, N(%)                   |              |                      | 0.742   |
| Never                          | 102(61.2)    | 589(64.5)            |         |
| Former                         | 33(23.3)     | 184(24.3)            |         |
| Current                        | 21(15.5)     | 94(11.2)             |         |
| Calcium intake (mg/day)^a       | 475.85[349.47, 575.70] | 430.23[330.43, 560.10] | 0.114   |
| Serum phosphate (mg/dL)        | 3.70[3.40, 4.00] | 3.50[3.20, 3.90]     | 0.103   |
| DII                            | −0.13 ± 0.14 | −0.18 ± 0.06         | 0.059   |
| Men                             |              |                      |         |
| N(1080)                        | 40           | 1040                 | 0.085   |
| Age (years)                    | 69.50[61.00, 80.00] | 63.00[57.00, 71.00] |         |
positively associated with the risk of osteoporosis in all models \( (P < 0.05) \). The significantly increased ORs (95% CI) of model 2 between the risk of osteoporosis and DII across quartiles 2, 3 and 4 compared with quartile 1 were 2.95 (1.08, 8.09), 5.63 (2.87, 11.04), and 6.14(2.55, 14.78), respectively. No significant association was observed in men \( (P > 0.05) \). Association between DII and osteopenia was not found in both women and men \( (P > 0.05) \) (Table S2).

After stratifying by age, significant differences were observed in women \( (P < 0.05) \) and the OR among those younger than 65 years old was higher than that of those older than 65 years old in Q4 after adjusting for all covariates (Fig. 3 and Table S3). There was no association

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**Table 1** (continued)

| Variables                | Osteoporosis | Without osteoporosis | P-value |
|--------------------------|--------------|----------------------|---------|
| Race, N(%)               |              |                      |         |
| Hispanic                 | 6(6.3)       | 229(11.6)            | 0.445   |
| Non-hispanic white       | 21(72.7)     | 408(70.3)            |         |
| Non-hispanic black       | 9(16.2)      | 237(9.5)             |         |
| Other race               | 4(4.8)       | 166(8.5)             |         |
| Marital status, N(%)     |              |                      | 0.149   |
| Single                   | 15(44.6)     | 321(24.9)            |         |
| Live with others         | 25(55.4)     | 719(75.1)            |         |
| BMI, kg/m², N(%)         |              |                      | 0.021   |
| <25                      | 19(47.1)     | 224(18.5)            |         |
| 25–30                    | 16(33.3)     | 410(35.7)            |         |
| ≥30                      | 5(19.6)      | 406(45.9)            |         |
| Smoker, N(%)             |              |                      | 0.686   |
| Never                    | 15(49.5)     | 426(46.8)            |         |
| Former                   | 17(28.2)     | 423(37.5)            |         |
| Current                  | 8(22.2)      | 191(15.7)            |         |
| Calcium intake (mg/day)# | 420.24[338.65, 524.28] | 398.29[304.56, 526.23] | 0.169 |
| Serum phosphate (mg/dL)  | 3.60[3.30, 3.90] | 3.40[3.10, 3.80]   | 0.435   |
| DII                      | −0.05 ± 0.29 | 0.26 ± 0.05          | 0.198   |

#Data were adjusted for energy intake (kcal/day)

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**Table 2** Adjusted \( \beta \) [95% CI] from multivariable linear regression models between DII and BMD

| BMD                      | Women | Men |
|--------------------------|-------|-----|
| Total hip BMD (g/cm²)    |       |     |
| model 1                  | −0.007(−0.012, −0.001) | 0.021 | −0.007(−0.016, 0.002) | 0.102 |
| model 2                  | −0.009(−0.014, −0.003) | 0.005 | −0.005(−0.015, 0.004) | 0.253 |
| Lumbar spine BMD (g/cm²) |       |     |
| model 1                  | −0.006(−0.016, 0.005)  | 0.302 | −0.021(−0.035, −0.007) | 0.005 |
| model 2                  | −0.009(−0.020, 0.001)  | 0.085 | −0.020(−0.034, −0.007) | 0.006 |
| Femoral neck BMD (g/cm²) |       |     |
| model 1                  | −0.007(−0.013, −0.001) | 0.032 | −0.004(−0.013, 0.005) | 0.335 |
| model 2                  | −0.009(−0.015, −0.002) | 0.011 | −0.003(−0.013, 0.007) | 0.495 |

\( \beta \) partial regression coefficient, CI confidence interval, BMD bone-mineral density

Model 1: Adjusted for age, race, BMI

Model 2: Adjusted for marital status, smoker, calcium and serum phosphate in addition to model 1
Table 3  Associations between DII and osteoporosis: multivariable logistic regression analyses

| Variables | DII OR (95% CI) | P for trend |
|-----------|-----------------|-------------|
|           | Q1(≤−1.24) | Q2(−1.24−−0.00) | Q3(−0.00−1.30) | Q4(1.30+) |
| Women     |               |             |               |           |
| Model 1   | reference      | 2.56(0.98, 6.65) | 4.77(2.44, 9.35) | 4.72(2.03, 10.98) | <0.001 |
| Model 2   | reference      | 2.95(1.08, 8.09) | 5.63(2.87, 11.04) | 6.14(2.55, 14.78) | <0.001 |
| Men       |               |             |               |           |
| Model 1   | reference      | 2.23(0.45, 11.09) | 0.28(0.06, 1.33) | 0.73(0.17, 3.09) | 0.121 |
| Model 2   | reference      | 2.45(0.49, 12.33) | 0.24(0.04, 1.40) | 0.82(0.16, 4.23) | 0.306 |

OR odds ratio, CI confidence interval
Model 1: Adjusted for age, race, BMI
Model 2: Adjusted for marital status, smoker, calcium, and serum phosphate in addition to model 1

Fig. 2 Forest plot of stratified analyses of the associations between Dietary Inflammatory Index (DII) and osteoporosis

Fig. 3 Forest plot of age-stratified analyses of the associations between Dietary Inflammatory Index (DII) and osteoporosis
in men ($P > 0.05$) (Fig. 3 and Table S4). Subgroups analysis by BMI is shown in Fig. 4 and Tables S5 and S6. In the subgroup BMI < 25 kg/m², the association between DII and osteoporosis was found in women ($P < 0.05$), but not in men ($P > 0.05$).

**Discussion**

Our results revealed that higher DII, indicating more pro-inflammatory diets, were associated with higher osteoporosis risk in women, while no association was found in men. An increased DII was associated with lower total hip and femoral neck BMD in women. There was a negative association between DII and lumbar spine BMD in men.

Consistent with previous findings, our study suggested that higher inflammation levels lead to higher osteoporosis rate and lower BMD [22–26]. Pro-inflammatory diets could contribute to poor musculoskeletal health by several mechanisms [18]. For instance, the effect of pro-inflammatory diet on osteoclast activity increases systemic inflammation [27]. IL-1 and IL-6 have uncoupled bone remodeling by enhancing bone resorption and suppressing bone formation [26]. Moreover, existing studies demonstrated that inflammatory cytokines directly mediate bone loss by stimulating the formation and maturation of osteoclast or indirectly by promoting the release of ligand-RANKL [28].

A large number of studies have indicated that diet, as the key source of biologically active ingredients, could mediate inflammation response [29]. A previous study found that the diet with high inflammatory components was significantly associated with an increased risk of osteoporosis in women, but not in men [5]. A study including both men and women aged 45–79 years indicated that a more pro-inflammatory diet was associated with higher incidence of fractures in women, but not in men [24], which was consistent with our findings. However, another study in China reported that a pro-inflammatory diet was associated with a higher risk of osteoporotic hip fracture in both men and women [30]. Despite this fact, most evidence has been observed in postmenopausal women [6, 22, 23]. A study has shown that menopause increased the risk of osteoporosis and fracture [31]. 80% of individuals with osteoporosis are women; among the 196 patients with osteoporosis in our study, 156 (79.6%) were women. This is largely due to the marked loss in BMD that begins at menopause, secondary to the marked decrease in estrogen related to the loss of ovarian function [32]. Moreover, estrogen plays a key role in regulating the production and activity of inflammatory cytokines like IL-1, IL-6 and TNF-α [33]. Previous studies have also suggested that due to the influence of sex hormones and genetic difference between men and women, women account for the majority of patients with osteoporosis, which is an age-related degenerative disease [34, 35]. Sex hormones alter the immune response, resulting in different

![Fig. 4 Forest plot of BMI stratified analyses of the associations between Dietary Inflammatory Index (DII) and osteoporosis](image_url)
disease phenotypes according to sex [36]. Therefore, further investigations are needed to clarify the association between DII and the risk of osteoporosis in men.

In subgroup analysis by age, DII was positively associated with osteoporosis in women. However, after adjusting for all covariates, the OR of those <65 years old was higher than that of those ≥65 years old, possibly due to the rapid bone loss in the first few years of post-menopause [37]. In the analyses of BMI stratified subgroups, we found that DII was positively linked with osteoporosis in women when BMI < 25 kg/m². According to the previous study, a BMI of 25 kg/m² was identified as the reference point, below which, the risk of hip and any bone osteoporotic began to increase [38].

With the in-depth exploration of the mechanism of bone diseases, studies on inflammatory and BMD at different sites have been leaping forward [13]. A meta-analysis study indicated that diets with high pro-inflammatory components might reduce the BMD of lumbar spine and total hip [13], and another study reported that the higher DII score was associated with a decrease in hip BMD in women [22].

Our study found that increased DII was associated with lower total hip and femoral neck BMD in women. These discrepancies regarding the affected area could be partly explained due to differences in the relationship between BMD with bone mineral content and bone area size [39]. In addition, there was a negatively association between DII and BMD in lumbar spine in men. This may be due to the whole bone strength depends on the relative proportions of cortical and trabecular tissue [40–42]. Males had a relatively higher proportion of trabecular bone at the lumbar spine, a lower proportion of cortical bone, and greater bone loss in the trabecular bone compared with other sites [43–45]. The above associations varied by sex as well as by site may relate to differences between men and women in nutrient intake, vertebral structure, spinal loading, and factor-of-risk [46].

More prospective studies involving populations of diverse genders are expected to verify the universality of the results.

There was no association between DII and osteopenia in our study. There may be some reasons: 1) Osteopenia is a term to define bone density that is not normal but also not as low as osteoporosis, thus, inflammation may not have a significant impact on the outcome. 2) The uncertainty of dietary intake and the interaction between different dietary nutrients may affect the association between DII and osteopenia. Dietary information was based on one 24HRs self-report which may not account for day-to-day variability in diet and may lead to imprecise estimates [47]. In addition, mixtures of multiple nutrients, as well as their interactions, may also influence this association [48]. 3) In addition to diets, aging, genetics and other hormonal factors also play a crucial role in bone mass regulation and preservation [49].

Previous studies have mostly focused on the relationship between specific nutrients or dietary patterns and the risk of osteoporosis or BMD. It was reported that intake of red meat and butter might increase the concentration of CRP, E-selectin, and soluble vascular cell adhesion molecule, reflecting rising systemic inflammation [29]. Another study of 3236 Scottish women aged 50–59 found that eating more fruits and vegetables might reduce bone loss and dietary patterns rich in processed foods were linked with reduced BMD [50]. These studies may have some limitations. On one hand, the real effects of the food or nutrient may be weakened or aggravated because of dietary correlations [51]. On the other hand, adherence to a specific diet pattern may not be a practical choice for most people due to differences in dietary culture and availability [52]. DII considers the full spectrum of food ingredients that regulate inflammation. It reflects the relationship between diet and BMD more accurately than individual nutrients [51]. In addition, it is more reliable to assess the quantitative relationship between diet quality and osteoporosis, rather than dietary patterns, which are not quantitative [25].

There were some limitations in this study. First, the causality deduction between DII and BMD was limited, because it was a cross-sectional study. Second, even if BMD represented the accumulation of bone changes that reflected long-term diet exposure for many years, the DII was calculated using 24HRs recall data. Thirds, due to the differences between the individuals being included and excluded, there might be potential selection bias. Fourth, there were too few cases of osteoporosis in men to make precise conclusions. Despite these limitations, this study has several strengths. First, our data were adjusted for several demographic factors, lifestyles, and dietary factors as confounders. Second, the data in this study were based on a nationally representative random sample of the general population of US, so we could extrapolate our results to the general population.

In conclusion, diets with higher inflammatory potentials were significantly associated with increased risk of osteoporosis in women, though not significantly in men. Increased DII was associated with lower total hip, and femoral neck BMD in women. In men, DII was only negatively correlated with BMD at lumbar spine. Therefore, the intake of foods with less inflammation to prevent osteoporosis has become increasingly important.

Author contributions SZ and WG: Data curation, Conceptualization, Methodology, Software, Formal analysis, Validation, Writing - Original draft preparation, Writing - review & editing. JL, MS, JF, and LT: Writing - Review & Editing, Investigation. YH, YW, YZ, and YX, Resources, Supervision. SY and LJ: Writing - Review & Editing.
Supervision, Conceptualization, Project administration. All authors agreed with the final version of the manuscript.

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**Compliance with ethical standards**

**Conflict of interest** The authors declare no competing interests.

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