BMC Musculoskeletal Disorders

RESEARCH

Open Access

The association between dietary zinc intake and osteopenia, osteoporosis in patients with rheumatoid arthritis

Deyu Fang[1], Dawei Jiang[2], Guoxun Shi[1] and Yang Song[3*]

Abstract

Background Diet has been shown to be associated with rheumatoid arthritis (RA), of which osteoporosis is the most common and important complication, and zinc has been shown to inhibit the inflammatory response, but studies on the relationship between dietary zinc and osteoporosis in patients with RA are limited and inconclusive. In this study, we aimed to explore the relationship between dietary zinc intake and osteoporosis or osteopenia in patients with RA.

Methods Data on RA patients were derived from the National Health and Nutrition Examination Survey (NHANES) 2007 to 2010, 2013 to 2014, and 2017 to 2020. Weighted univariate and multivariate logistic regression models were performed to explore the association between dietary zinc intake and osteoporosis or osteopenia in RA patients. The relationship was further investigated in different age, body mass index (BMI), nonsteroidal use, dyslipidemia, diabetes, and hypertension population. All results were presented as odds ratios (ORs) and confidence intervals (CIs).

Results In total, 905 RA patients aged ≥ 40 years were included. After adjusting all covariates, higher dietary zinc intake was associated with lower odds of osteopenia or osteoporosis (OR = 0.39, 95%CI: 0.18–0.86) in RA patients. The relationship between dietary zinc intake ≥ 19.52 mg and lower odds of osteopenia or osteoporosis were also found in those aged ≥ 60 years (OR = 0.38, 95%CI: 0.16–0.91), BMI normal or underweight (OR = 0.16, 95%CI: 0.03–0.84), nonsteroidal use (OR = 0.14, 95%CI: 0.02–0.82), dyslipidemia (OR = 0.40, 95%CI: 0.17–0.92), diabetes (OR = 0.37, 95%CI: 0.14–0.95), and hypertension (OR = 0.37, 95%CI: 0.16–0.86).

Conclusion Higher dietary zinc intake was associated with reduced incidence of osteopenia or osteoporosis in patients with RA. Further longitudinal and randomized trials are necessary to validate our findings and explore the underling mechanisms. Adequate dietary zinc intake may beneficial to the bone health in RA patients.

Keywords Zinc, Rheumatoid arthritis, Osteoporosis, Osteopenia, NHANES

*Correspondence:
Yang Song
songy_docotor@hotmail.com
[1]Department of Rheumatology, Wuxi No.2 People's Hospital, Wuxi 214000, Jiangsu Province, R.P. China
[2]Huai'an Economic Development Zone Hospital, Huai'an 223010, Jiangsu Province, R.P. China
[3]Department of Orthopaedics, Huzhou Traditional Chinese Medicine Hospital, Affiliated to Zhejiang Chinese Medical University, 315 Nan Jie, Huzhou 313000, Zhejiang Province, P.R. China

Background

Rheumatoid arthritis (RA) is a chronic inflammatory autoimmune disease characterized by synovial inflammation, joint destruction and systemic complications [1]. Among the various extra-articular manifestations of RA, osteoporosis is one of the most prevalent complications [2]. The prevalence of osteoporosis in RA patients exceeds 30% [3, 4]. Osteoporosis in patients with RA not only increases the risk of fracture, but also leads to decreased quality of life and increased morbidity and mortality [5]. Although several factors contribute to the development of osteoporosis in RA, nutritional status (including dietary intake) has emerged as a potentially modifiable risk factor [5, 6].

Zinc, an essential micronutrient involved in bone metabolism and immune function, has attracted attention for its potential role in the pathogenesis of osteoporosis [7, 8]. Zinc is also an important antioxidant trace-element, and its deficiency could lead to immune dysfunction and inflammation [9, 10]. Decreases serum level of zinc have been found in patients with RA [11]. Moreover, negative correlation was observed between zinc intake and inflammatory marker PGE2 in patients with RA [12]. An animal study shows that zinc preparations inhibit the increase of inflammatory factors in RA rats [13]. In addition, zinc has been shown to inhibit osteoclasts resorption by osteoblasts, and zinc has an inhibitory effect on receptor activators of RANKL-induced osteoclast formation [14, 15]. Chronic inflammation and altered bone metabolism are hallmarks of RA, it is plausible to hypothesize that dietary zinc intake may influence the development and progression of osteoporosis in these patients.

While several studies have investigated the relationship between dietary zinc intake and bone health in the general population, there are no studies in patients with RA. Therefore, this study aims to explore the relationship between dietary zinc intake and osteoporosis in patients with RA, and to provide references for the management and prevention of osteoporosis.

Methods

Study design and participants

In this cross-sectional study, data of RA patients were extracted from the National Health and Nutrition Examination Survey (NHANES) database 2007–2010, 2013–2014, and 2017–2020. NHANES is a study that aims to assess the health and nutritional status of adults and children in the United States, acquiring information by interviews and physical examinations. The requirement of ethical approval for this was waived by the Institutional Review Board of Huzhou Traditional Chinese Medicine Hospital Affiliated to Zhejiang Chinese Medical University, because the data was accessed from NHANES (a publicly available database). The need for written informed consent was waived by the Institutional Review Board of Huzhou Traditional Chinese Medicine Hospital Affiliated to Zhejiang Chinese Medical University due to retrospective nature of the study. All methods were performed in accordance with the relevant guidelines and regulations.

Initially, RA patients were selected for our study. RA was determined according to the self-reported questionnaire "Has a doctor or other health professional ever told you that you had arthritis" and "Which type of arthritis was it". The exclusions were as follows: (1) age < 40 years old, (2) without information on dietary zinc intake, (3) without information on femoral neck, total femur, trochanter and intertrochanter, (4) missing data on urine albumin.

Dietary zinc intake assessment

Information on dietary zinc intake were obtained based on 24-h dietary recall interview which performed by trained dietary interviewers. Dietary zinc intake included zinc from dietary interview-individual foods and dietary supplement use 24-hour-total dietary supplements on first day. In large-scale surveys, 24-h recall is the most commonly used dietary intake survey method [16]. The decision to continue using the method at NHANES over the years was based on a consensus reached by the expert group at regular seminars to evaluate NHANES 'data collection methods [17]. Dietary zinc intake was grouped according to quartiles and categorized into < 7.04 mg, 7.04 to 10.98 mg, 10.98 to 19.52 mg and ≥ 19.52 mg groups.

Osteopenia, osteoporosis assessment

Dual-energy x-ray absorptiometry (DXA) was used to measure bone density in participants aged ≥ 40 years old. The left hip was routinely scanned unless the participants self-reported a fractured or operation. The femur scans provided bone measurements for total femur, femoral neck, trochanter and intertrochanter. Osteopenia was characterized as a T-score ranging from −2.5 to -1.0, while osteoporosis was defined as a T-score equal to or below −2.5 [18]. T-score for each site (total femur, femoral neck, trochanter and intertrochanter) is equal to their bone density minus the mean, divided by the standard deviation [19].

Assessment of potential covariates

Sociodemographic data were collected from NHANES, including age, gender, ethnicity, education level, poverty income ratio (PIR), marital status, smoking history, drinking history, menopause and body mass index (BMI). BMI was classified according to WHO standards and defined as obesity (≥ 30 kg/m^2), overweight (25 to 29.9 kg/m^2),

normal (18.5 to 24.9 kg/m^2) and underweight (<18.5 kg/m^2) [20]. Physical activity was converted to MET scores by referring to the scores recommended by NHANES. History of fracture was defined as choosing yes for Osteoporosis Questionnaire (OSQ)010a or OSQ010b or OSQ010c. Dietary intakes of energy, cacium, vitamin D, and magnesium are equal to the sum of the components from individual foods and the components from 24-hour-total dietary supplements on first day.

We also considered other diseases as potential confounders in the questionnaire and laboratory data, including diabetes, hypertension, dyslipidemia, Cardiovascular disease (CVD), Chronic kidney disease (CKD) and autoimmune disease. Bone mineral metabolism was measured by total 25-hydroxyvitamin D, serum calcium levels and serum phosphorus levels as serum markers of bone mineral metabolism. White blood cell count was performed by Beckman Coulter DxH-800 Analyzer. We also collected information about the drug use history of participants, including bone resorption inhibitor drug, antirheumatics drug, nonsteroidal drug, glucocorticoid drug, estrogens drug, thyroid hormones and anticoagulant drugs.

Statistical methods

NHANES applied a complex multistage sampling methodology, so we considered the proposed weighting methodology in all analysis. Kolmogorov-Smirnov was used to test the normality of quantitative data. Normally distributed measures were described as mean and standard error [Mean (SE)], and comparisons between two groups were made using weighted independent sample t tests; non-normal data were described as medians (interquartile range). Qualitative data were described by the number of cases and the constitutive ratio [N (%)], and comparisons between groups were conducted using the weighted chi-square tests. Potential covariates were screened using weighted univariate logistic regression model and backward stepwise. Osteopenia or osteoporosis was analyzed as a categorical variable. Weighted univariate and multivariate logistic regression models were performed to investigate the relationship between dietary zinc intake and osteopenia or osteoporosis in RA patients. All results were expressed as odds ratios (ORs) and 95% confidence intervals (CIs). The association were further investigated in different age, BMI, nonsteroidal use, dyslipidemia, diabetes, and hypertension population. SAS 9.4 was used for statistical analyses, and R version 4.2.2 was used for forest plot visualization. $P<0.05$ was considered statistical significance.

Results

Participants characteristics

A total of 1490 RA patients were included for our study. Then, patients were excluded of those age<40 years ($n=105$), without information on dietary zinc intake ($n=141$), without information on femoral neck, total femur, trochanter and intertrochanter ($n=330$), and missing data on urine albumin ($n=9$). Figure 1 illustrates our screening process. Finally, 905 RA patients were included for final analysis. Among them, mean age was 60.91 (0.48) years, and 494 (58.09%) were female. Totally, 484 (53.48%) RA patients had osteopenia or osteoporosis. Between patients with and without osteopenia or osteoporosis groups, statistical significances were observed in age, gender, race, PIR, marital status, CVD, CKD, BMI, total energy intake, serum phosphorus, bone resorption inhibitor drug, menopause, and zinc intake (all $P<0.05$). The characteristics of RA patients were summarized in Table 1.

Associations between dietary zinc intake and osteopenia/osteoporosis in patients with RA

The relationship between dietary zinc intake and osteopenia/osteoporosis was shown in Table 2. In model 2 after adjusting age, race, PIR, BMI, total energy intake, and bone resorption inhibitor drug, higher dietary zinc intake was related to lower incidence of osteopenia/osteoporosis (OR=0.99, 95%CI: 0.97-1.00) in RA patients. When dietary zinc intake as categorical variable, higher dietary zinc intake (≥19.52 mg) was associated with decreased odds of osteopenia or osteoporosis (OR=0.39, 95%CI: 0.18–0.86).

Associations between dietary zinc intake and osteopenia/osteoporosis in different age, BMI, nonsteroidal use, dyslipidemia, diabetes, and hypertension groups

To further explore whether the association between dietary zinc intake and the odds of osteopenia/osteoporosis differed across populations, subgroup analysis was performed. As shown in Table S1 and Fig. 2, dietary zinc intake<7.04 mg group as the reference, dietary zinc intake≥19.52 mg was associated with lower odds of osteopenia or osteoporosis in those aged≥60 years (OR=0.38, 95%CI: 0.16–0.91), with BMI normal or underweight (OR=0.16, 95%CI: 0.03–0.84), nonsteroidal use (OR=0.14, 95%CI: 0.02–0.82), dyslipidemia (OR=0.40, 95%CI: 0.17–0.92), diabetes (OR=0.37, 95%CI: 0.14–0.95), and hypertension (OR=0.37, 95%CI: 0.16–0.86). Moreover, dietary zinc intake 10.98–19.52 mg was also related to lower incidence of osteopenia or osteoporosis in those with BMI normal or underweight (OR=0.10, 95%CI: 0.03–0.40), nonsteroidal use (OR=0.10, 95%CI: 0.02–0.42), and diabetes (OR=0.39, 95%CI: 0.17–0.88). Anyway, the results indicated that

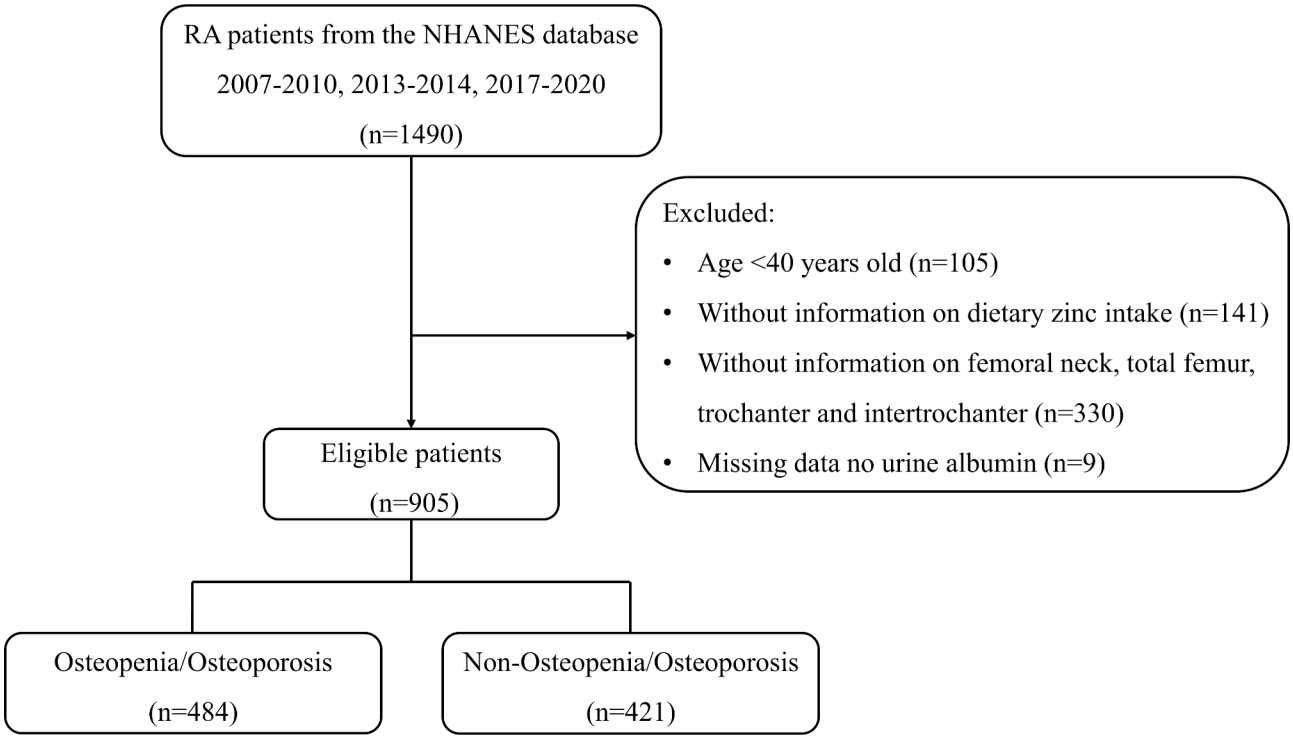

Fig. 1 The screening process of RA patients

higher dietary zinc intake was associated with lower occurrence of osteopenia/osteoporosis in patients with RA.

Discussion

In this study, we found that higher dietary zinc intake was associated with reduced incidence of osteopenia or osteoporosis in patients with RA. The association was also found in those aged≥60 years, BMI normal or underweight, using nonsteroidal, dyslipidemia, diabetes, and hypertension in RA patients.

The association between dietary zinc intake and osteopenia or osteoporosis previously reported were consistent with our results. In two studies, low dietary zinc intake was associated with an increased risk of osteoporosis in postmenopausal women in Iran and Brazil participants [21, 22]. Similarly, the same association were found in men [23]. Furthermore, Shahriarpour et al. [24] reported higher dietary anti-oxidants (including zinc) can help reduce the likelihood of osteoporosis in women. Kennedy et al. [25] also reported a lower plasma zinc in RA patients than the control group. Contrast, dietary zinc intake was found no association with phalangeal osteoporosis in women in a China study [23]. Such inconsistent findings may be due to differences in target populations, locations, and sample sizes. In our study, higher dietary zinc intake was associated with lower occurrence of osteopenia or osteoporosis in RA patients.

The relationship between higher dietary zinc intake and lower odds of osteopenia or osteoporosis were also reported in subgroups aged≥60 years, with BMI normal or underweight, nonsteroidal use, dyslipidemia, diabetes, and hypertension, further indicated the potential benefits on bone health of adequate dietary zinc intake. Osteoporosis is an age-related disease, and the old are more prone to age-related bone loss and an increased need for bone nutrients like zinc [22]. Besides, BMI has been shown to correlated with bone strength and bone mass [26]. Underweight has been found to have an impact on bone metabolism in older patients [27]. Dyslipidemia, diabetes and hypertension are all associated with an increased risk of low bone mineral density and are risk factors for osteoporosis [28, 29]. In addition, treatment of RA patients with (nonsteroidal anti-inflammatory drugs) NSAIDs decreases serum zinc and increases the incidence of cardiovascular CVD [30]. In these cases, ensuring adequate zinc intake could help slow the negative effects on bone health associated with these conditions. Further research is needed to explore the underlying mechanisms and to establish precise dietary recommendations for optimal zinc intake for these specific patient groups.

The mechanism by which dietary zinc influences osteopenia/osteoporosis is not fully understood. However, several mechanisms may could explain the association. Firstly, zinc has been shown to stimulate osteoblast differentiation and mineralization, promoting bone formulation [31]. Zinc can directly activate aminoacyl-tRNA

Table 1 Characteristics of RA patients

Variables	Total ($n=905$)	Osteopenia/Osteoporosis ($n=484$)	*P*
Age, years, Mean (S.E)	60.91 (0.48)	64.24 (0.64)	< 0.001*
Gender, n (%)			0.046#
Female	494 (58.09)	288 (63.55)	
Male	411 (41.91)	196 (36.45)	
Race, n (%)			< 0.001#
White	360 (65.71)	222 (71.11)	
Black	283 (17.79)	115 (12.21)	
Others	262 (16.51)	147 (16.68)	
Education level, n (%)			0.356#
Above or some college graduate	393 (47.99)	210 (46.13)	
Below of some college graduate	512 (52.02)	274 (53.87)	
PIR, ratio, Mean (S.E)	2.61 (0.08)	2.39 (0.10)	0.020*
Marital status, n (%)			0.024#
Married/Living with Partner	502 (60.75)	261 (59.11)	
Never married	77 (8.07)	31 (5.67)	
Widowed/Divorced/Separated	326 (31.18)	192 (35.22)	
Smoking, n (%)			0.454#
No	403 (43.03)	213 (41.52)	
Yes	502 (56.97)	271 (58.48)	
Drinking consumption, n (%)			0.606#
High drinking	175 (22.94)	89 (23.51)	
Low drinking	297 (33.71)	148 (30.43)	
Never drinking	218 (22.49)	131 (24.46)	
Unknown	215 (20.85)	116 (21.60)	
Physical, n (%)			0.067#
<750	169 (18.84)	91 (19.53)	
≥750	435 (48.21)	214 (43.59)	
Unknown	301 (32.95)	179 (36.89)	
History of fracture, n (%)			0.183#
No	759 (78.99)	389 (75.38)	
Yes	146 (21.01)	95 (24.62)	
25OHD2 + 25OHD3, n (%)			0.532#
<50 nmol/L	178 (19.89)	94 (21.25)	
≥50 nmol/L	380 (60.34)	192 (57.85)	
Unknown	347 (19.76)	198 (20.91)	
Diabetes, n (%)			0.968#
No	313 (40.36)	176 (40.25)	
Yes	592 (59.64)	308 (59.75)	
Hypertension, n (%)			0.433#
No	226 (25.66)	114 (23.85)	
Yes	679 (74.34)	370 (76.15)	
Dyslipidemia, n (%)			0.096#
No	155 (17.34)	88 (19.82)	
Yes	750 (82.66)	396 (80.18)	
CVD, n (%)			0.023#
No	493 (55.46)	247 (50.92)	
Yes	412 (44.54)	237 (49.08)	
CKD, n (%)			0.024#
No	677 (78.32)	348 (74.32)	
Yes	228 (21.68)	136 (25.68)	
Autoimmune disease, n (%)			0.103#
No	147 (21.14)	59 (17.65)	

Table 1 (continued)

Variables	Total ($n=905$)	Osteopenia/Osteoporosis ($n=484$)	P
Yes	3 (0.64)	1 (0.32)	
Unknown	755 (78.22)	424 (82.03)	
BMI, kg/m^2, Mean (S.E)	29.49 (0.38)	27.36 (0.48)	< 0.001*
BMI, n (%)			< 0.001#
Obesity	365 (42.44)	140 (29.21)	
Overweight	302 (32.78)	160 (33.37)	
Underweight/Normal	238 (24.79)	184 (37.42)	
Total energy intake, kcal, Mean (S.E)	2017.41 (48.65)	1856.15 (53.24)	< 0.001*
Calcium, mg, Mean (S.E)	1183.97 (42.82)	1147.08 (55.58)	0.295*
Vitamin D, mcg, Mean (S.E)	17.03 (1.42)	17.42 (2.12)	0.739*
Magnesium, mg, Mean (S.E)	331.31 (12.07)	321.46 (18.23)	0.393*
WBC, 10^9/L, Mean (S.E)	7.34 (0.13)	7.31 (0.15)	0.819*
NLR, Mean (S.E)	2.41 (0.07)	2.52 (0.10)	0.133*
Serum calcium, mmol/L, Mean (S.E)	2.35 (0.00)	2.35 (0.00)	0.751*
Serum phosphorus, mmol/L, Mean (S.E)	1.22 (0.01)	1.23 (0.01)	0.035*
Bone resorption inhibitor drug, n (%)			< 0.001#
No	867 (95.07)	450 (90.83)	
Yes	38 (4.93)	34 (9.17)	
Antirheumatics drug, n (%)			0.086#
No	817 (86.25)	427 (82.17)	
Yes	88 (13.75)	57 (17.83)	
Nonsteroidal drug, n (%)			0.062#
No	786 (85.50)	435 (88.36)	
Yes	119 (14.50)	49 (11.64)	
Glucocorticoid drug, n (%)			0.804#
No	832 (90.65)	437 (90.25)	
Yes	73 (9.35)	47 (9.75)	
Estrogens drug, n (%)			0.808#
No	887 (95.80)	476 (96.11)	
Yes	18 (4.20)	8 (3.89)	
Thyroid hormones, n (%)			0.362#
No	804 (87.27)	425 (85.95)	
Yes	101 (12.73)	59 (14.05)	
Anticoagulant drug, n (%)			0.655#
No	879 (98.12)	469 (97.92)	
Yes	26 (1.88)	15 (2.08)	
Menopause, n (%)			0.004#
Inapplicable	411 (41.91)	196 (36.45)	
No	158 (18.71)	82 (15.55)	
Yes	336 (39.38)	206 (48.00)	
Zinc, mg, Mean (S.E)	16.42 (0.65)	14.99 (0.82)	0.011*
Zinc, n (%)			0.034#
<7.04	232 (20.24)	140 (24.94)	
7.04–10.98	230 (24.49)	121 (25.03)	
10.98–19.52	217 (25.41)	110 (26.10)	
≥19.52	226 (29.87)	113 (23.94)	

* t-test; # chi-square test; S.E: standard error

RA: rheumatoid arthritis; PIR: poverty income ratio; CVD: cardiovascular disease; CKD: chronic kidney disease; BMI: body mass index; WBC: white blood cell; NLR: neutrophil-to-lymphocyte ratio

Table 2 Associations of dietary zinc intake with osteopenia or osteoporosis in RA patients

Variables	Model 1		Model 2	
	OR (95%CI)	*P*	OR (95%CI)	*P*
Zinc	0.98 (0.97–0.99)	0.021	0.99 (0.97-1.00)	0.157
Zinc				
<7.04	Ref		Ref	
7.04–10.98	0.64 (0.33–1.24)	0.183	0.56 (0.29–1.09)	0.086
10.98–19.52	0.64 (0.36–1.16)	0.145	0.58 (0.26–1.29)	0.181
≥19.52	0.40 (0.24–0.66)	< 0.001	0.39 (0.18–0.86)	0.019

Ref: reference, OR: odd ratio, CI: confidence

Model 1: crude model

Model 2: adjusting age, race, PIR, BMI, total energy intake, and bone resorption inhibitor drug

synthase (a rate-limiting enzyme in the translation of protein synthesis translation also stimulates cellular protein synthesis) [14]. Secondly, zinc possesses antioxidant properties and reduce bone resorption by inhibiting osteoclasts through inhibition of the RANKL/OPG pathway [32]. Meanwhile, zinc deficiency also increased the mitochondria-mediated apoptosis in osteoblasts [33]. Finally, RA and osteoporosis are inflammatory diseases, and zinc can play a role as an effector of the immune system and inflammation in both diseases [3, 9].

Optimizing dietary zinc intake may represent a simple and cost-effective approach to mitigate the odds of osteoporosis or osteopenia in RA patients, particularly in osteoporosis or osteopenia in patients. Furthermore, incorporating zinc supplementations as adjunctive therapy alongside conventional RA treatment modalities warrants further investigation to determine its efficacy in preserving bone density and reducing fracture risk.

Several limitations should be acknowledged in this study. The cross-sectional design restricted our ability to

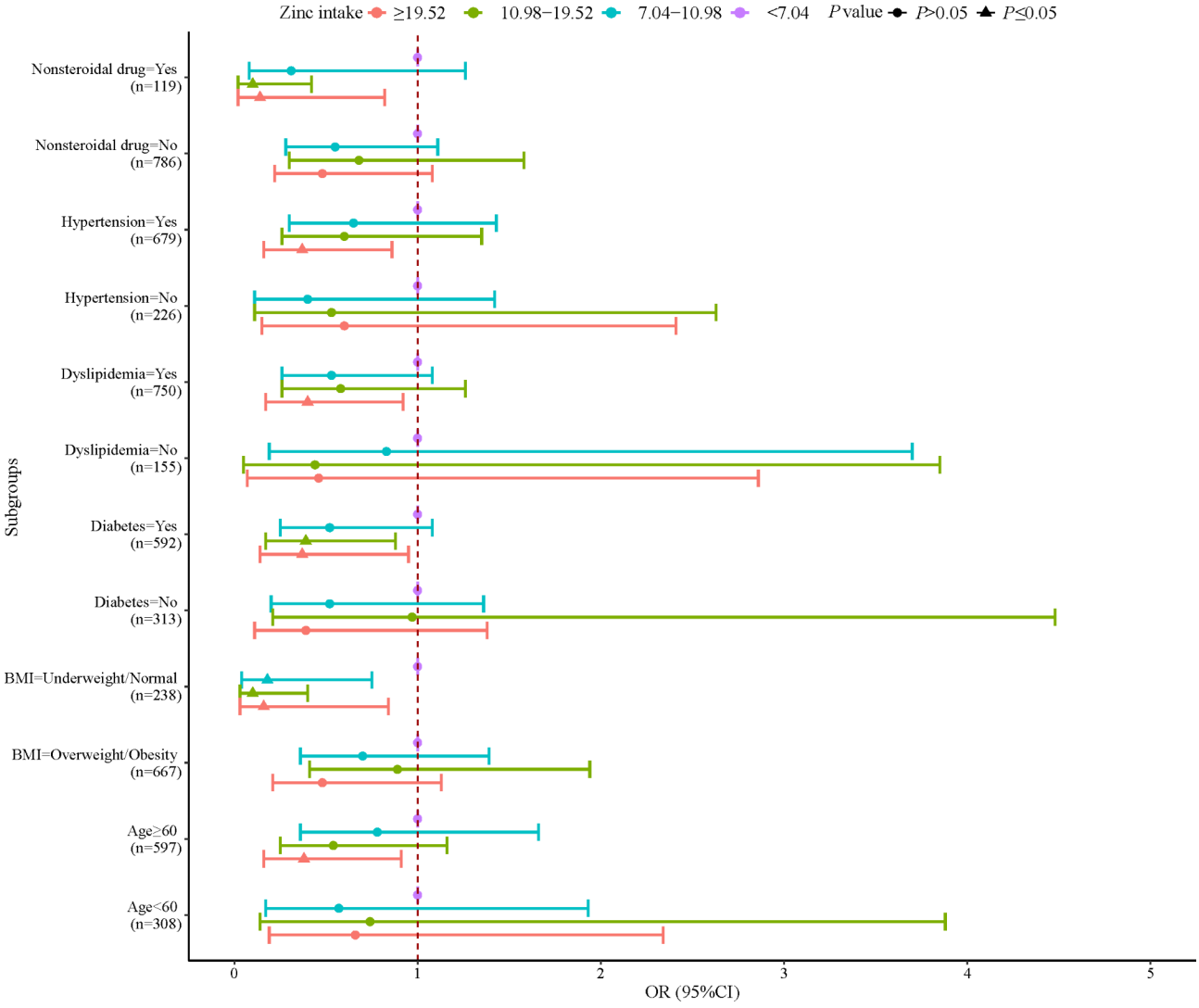

Fig. 2 Associations between dietary zinc intake and osteopenia/osteoporosis in different age, BMI, nonsteroidal use, dyslipidemia, diabetes, and hypertension groups

establish a causal relationship between dietary zinc intake and osteoporosis/osteopenia. In addition, relying on self-reported diagnoses of RA might lead to misdiagnose or miss diagnosis of some patients, although previous studies have confirmed the acceptable accuracy of questionnaire [34]. Additionally, it was difficult to determine the RA activity and bone metabolism markers of RA due to the limitation of data availability, which should be considered carefully when generalizing our conclusion. More prospective and experimental studies are needed to further validate the findings of our study.

Conclusion

Higher dietary zinc intake was associated with lower occurrence of osteoporosis or osteopenia in patients with RA. Subgroup analyses further suggested the importance of considering individual characteristics and comorbidities when evaluating the potential benefits of zinc intake in patients with RA. Further research, including longitudinal studies and randomized controlled trials, are necessary to validate our findings and explore the underlying mechanisms in more detail. If confirmed, the incorporation of moderate zinc intake into management and prevention strategies for osteoporosis/osteopenia in RA will have significant clinical implications.

Abbreviations

RA	Rheumatoid arthritis
NHANES	National Health and Nutrition Examination Survey
DXA	Dual-energy x-ray absorptiometry
PIR	Poverty income ratio
BMI	Body mass index
CVD	Cardiovascular disease
CKD	Chronic kidney disease
SE	Standard error
ORs	Odds ratios
CIs	Confidence intervals

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12891-024-07768-5.

Supplementary Material 1

Acknowledgements

Not applicable.

Author contributions

YS conceived and designed this study. DYF wrote this paper. DWJ and GXS analyzed data. YS, DYF and DWJ revised the manuscript. All authors have read and approved the final manuscript.

Funding

This study was supported by the research project "Study on the clinical value of circulating miR-155 level for diagnosis and severe assessment of knee osteoarthritis (KOA) patients" (2023GYB51).

Data availability

The datasets generated and/or analyzed during the current study are available in the NHANES database, https://wwwn.cdc.gov/nchs/nhanes/.

Declarations

Ethics approval and consent to participate

The requirement of ethical approval for this was waived by the Institutional Review Board of Huzhou Traditional Chinese Medicine Hospital Affiliated to Zhejiang Chinese Medical University, because the data was accessed from NHANES (a publicly available database). The need for written informed consent was waived by the Institutional Review Board of Huzhou Traditional Chinese Medicine Hospital Affiliated to Zhejiang Chinese Medical University due to retrospective nature of the study. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 19 April 2024 / Accepted: 9 August 2024
Published online: 05 September 2024

References

1. Radu A-F, Bungau SG. Management of rheumatoid arthritis: an overview. Cells. 2021;10:2857.
2. Jin S, Hsieh E, Peng L, Yu C, Wang Y, Wu C, et al. Incidence of fractures among patients with rheumatoid arthritis: a systematic review and meta-analysis. Osteoporos Int J Establ Result Coop Eur Found Osteoporos Natl Osteoporos Found USA. 2018;29:1263–75.
3. Adami G, Saag KG. Osteoporosis pathophysiology, epidemiology, and screening in rheumatoid arthritis. Curr Rheumatol Rep. 2019;21:34.
4. Chen T-X, Zhang Z-L, Yang S-P, Zhu Y-Q. Frequency of osteoporosis in Chinese patients with rheumatoid arthritis: a meta-analysis. Arch Osteoporos. 2023;18:24.
5. Baker R, Narla R, Baker JF, Wysham KD. Risk factors for osteoporosis and fractures in rheumatoid arthritis. Best Pract Res Clin Rheumatol. 2022;36:101773.
6. Di Renzo L, Gualtieri P, De Lorenzo A. Diet, Nutrition and Chronic Degenerative diseases. Nutrients. 2021;13:1372.
7. Amin N, Clark CCT, Taghizadeh M, Djafarnejad S. Zinc supplements and bone health: the role of the RANKL-RANK axis as a therapeutic target. J Trace Elem Med Biol Organ Soc Min Trace Elem GMS. 2020;57:126417.
8. Wessels I, Fischer HJ, Rink L. Dietary and physiological effects of Zinc on the Immune System. Annu Rev Nutr. 2021;41:133–75.
9. Bonaventura P, Benedetti G, Albarède F, Miossec P. Zinc and its role in immunity and inflammation. Autoimmun Rev. 2015;14:277–85.
10. Wong CP, Ho E. Zinc and its role in age-related inflammation and immune dysfunction. Mol Nutr Food Res. 2012;56:77–87.
11. Ma Y, Zhang X, Fan D, Xia Q, Wang M, Pan F. Common trace metals in rheumatoid arthritis: a systematic review and meta-analysis. J Trace Elem Med Biol Organ Soc Min Trace Elem GMS. 2019;56:81–9.
12. Arablou T, Aryaeian N, Djalali M, Shahram F, Rasouli L. Association between dietary intake of some antioxidant micronutrients with some inflammatory and antioxidant markers in active rheumatoid arthritis patients. Int J Vitam Nutr Res Int Z Vitam- Ernahrungsforschung J Int Vitaminol Nutr. 2019;89:238–45.
13. Gad SS, Fayez AM, Abdelaziz M, Abou El-Ezz D. Amelioration of autoimmunity and inflammation by zinc oxide nanoparticles in experimental rheumatoid arthritis. Naunyn Schmiedebergs Arch Pharmacol. 2021;394:1975–81.
14. Yamaguchi M. Role of nutritional zinc in the prevention of osteoporosis. Mol Cell Biochem. 2010;338:241–54.
15. Ceylan MN, Akdas S, Yazihan N. Is zinc an important Trace element on bone-related diseases and complications? A Meta-analysis and systematic review from serum level, Dietary Intake, and supplementation aspects. Biol Trace Elem Res. 2021;199:535–49.
16. Foster E, Lee C, Imamura F, Hollidge SE, Westgate KL, Venables MC, et al. Validity and reliability of an online self-report 24-h dietary recall method (Intake24): a doubly labelled water study and repeated-measures analysis. J Nutr Sci. 2019;8:e29.
17. Ahluwalia N, Dwyer J, Terry A, Moshfegh A, Johnson C. Update on NHANES Dietary Data: Focus on Collection, Release, Analytical considerations, and uses to inform Public Policy. Adv Nutr Bethesda Md. 2016;7:121–34.

18. Zhai T, Chen Q, Xu J, Jia X, Xia P. Prevalence and trends in Low Bone Density, Osteopenia and osteoporosis in U.S. adults with non-alcoholic fatty liver Disease, 2005–2014. Front Endocrinol. 2022;12:825448.
19. Looker AC, Orwoll ES, Johnston CC, Lindsay RL, Wahner HW, Dunn WL, et al. Prevalence of low femoral bone density in older U.S. adults from NHANES III. J Bone Min Res off J Am Soc Bone Min Res. 1997;12:1761–8.
20. Caballero B. Humans against obesity: who Will Win? Adv Nutr Bethesda Md. 2019;10 suppl1:S4–9.
21. Mahdavi-Roshan M, Ebrahimi M, Ebrahimi A. Copper, magnesium, zinc and calcium status in osteopenic and osteoporotic post-menopausal women. Clin Cases Min Bone Metab. 2015;12:18–21.
22. Grili daF PP, Vidigal CV, da Cruz GF, Albergaria B-H, Marques-Rocha JL, Pereira TSS, et al. Nutrient patterns and risk of Osteopenia in Postmenopausal Women. Nutrients. 2023;15:1670.
23. Xiong Y, Wang Y, Wu J, He H, Wang N, Lei G. [Cross-sectional association between dietary zinc intake and phalangeal osteoporosis]. Zhong Nan Da Xue Xue Bao Yi Xue Ban. 2019;44:784–9.
24. Shahriarpour Z, Nasrabadi B, Hejri-Zarifi S, Shariati-Bafghi S-E, Yousefian-Sanny M, Karamati M, et al. Oxidative balance score and risk of osteoporosis among postmenopausal Iranian women. Arch Osteoporos. 2021;16:43.
25. Kennedy AC, Fell GS, Rooney PJ, Stevens WH, Dick WC, Buchanan WW. Zinc: its relationship to osteoporosis in rheumatoid arthritis. Scand J Rheumatol. 1975;4:243–5.
26. Ang SB, Xia JY, Cheng SJ, Chua MT, Goh L, Dhaliwal SS. A pilot screening study for low bone mass in Singaporean women using years since menopause and BMI. Climacteric J Int Menopause Soc. 2022;25:163–9.
27. Li Y, Hui M, Chang X, Li M, Wang Y, Zhang B, et al. BMI reduction and vitamin D insufficiency mediated osteoporosis and fragility fractures in patients at nutritional risk: a cross-sectional study. Eur J Clin Nutr. 2018;72:455–9.
28. Azeez TA. Osteoporosis and cardiovascular disease: a review. Mol Biol Rep. 2023;50:1753–63.
29. Hofbauer LC, Busse B, Eastell R, Ferrari S, Frost M, Müller R, et al. Bone fragility in diabetes: novel concepts and clinical implications. Lancet Diabetes Endocrinol. 2022;10:207–20.
30. Rennie KL, Hughes J, Lang R, Jebb SA. Nutritional management of rheumatoid arthritis: a review of the evidence. J Hum Nutr Diet off J Br Diet Assoc. 2003;16:97–109.
31. Skalny AV, Aschner M, Silina EV, Stupin VA, Zaitsev ON, Sotnikova TI, et al. The role of Trace Elements and Minerals in osteoporosis: a review of Epidemiological and Laboratory findings. Biomolecules. 2023;13:1006.
32. Park J-H, Park SA, Kang Y-H, Hwa SM, Koh E-B, Hwang S-C, et al. Zinc sulfate stimulates osteogenic phenotypes in Periosteum-Derived cells and co-cultures of Periosteum-Derived cells and THP-1 cells. Life Basel Switz. 2021;11:410.
33. Guo B, Yang M, Liang D, Yang L, Cao J, Zhang L. Cell apoptosis induced by zinc deficiency in osteoblastic MC3T3-E1 cells via a mitochondrial-mediated pathway. Mol Cell Biochem. 2012;361:209–16.
34. Loprinzi PD. Dose-response association of moderate-to-vigorous physical activity with cardiovascular biomarkers and all-cause mortality: considerations by individual sports, exercise and recreational physical activities. Prev Med. 2015;81:73–7.

Publisher's Note