Association Between Obesity and Bone Mineral Density in Middle-Aged Adults

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Research Article

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Abstract

Background

The relationship between obesity and bone mineral density (BMD) varies in different studies. Our aim in this study was to explore the association between obesity (Body mass index ≥ 30) and BMD among adults 40-59 years of age.

Methods

This study was conducted on a sample of 2218 participants (986 men and 1232 women) aged from 40 to 59 years, from the National Health and Nutrition Examination Survey (NHANES) 2011-2018. The independent variable was Body mass index (BMI) and the dependent variable was lumbar BMD. We performed weighted multivariate linear regression models and smooth curve fittings to evaluate the associations between BMI and lumbar BMD.

Results

The BMI was positively associated with lumbar BMD, after adjusting for other covariates (β 0.006; 95% confidence interval (CI) 0.003-0.008). An inverted U-shaped association between the BMI and lumbar BMD was further identified, with the point of infection was at about 50 kg/m^2. On subgroup analyses, the relationship between BMI and lumbar BMD of women and blacks were inverted U-shaped.

Conclusion

Based on the result, it may be beneficial to appropriately increase BMI to promote BMD. However, considering the inverted U-shaped association, an excessive BMI may be harmful to bone health on women and blacks.

Introduction

Osteoporosis is a systemic skeletal metabolic disorder characterized by low bone mass density (BMD) and microarchitectural deterioration of bone tissue, with an increased risk of fragility fractures [1]. Osteoporosis and fragility fractures increasing the burden not only on the single subjects but also on healthcare systems [2].

Obesity has become a serious public health problem in the world, for obesity could be associated with several medical conditions [3]. Body mass index (BMI) can be used as a predictor for assessing obesity, which shows good resolution among different ages, genders and races [4]. High BMI is closely associated with BMD in both men and women. However, studies on the relationship between high BMI and BMD have found conflicting results. Some study demonstrated that high BMI is protected from osteoporosis [5], while an increasing number of data seems to show conflicting results [6]. Our aim in the study was to evaluate the association between obesity and BMD among adults 40-59 years of age, using a population-based database.

Methods

Study population

The National Health and Nutrition Examination Survey (NHANES) is a survey designed to provide large information about the nutrition and health conditions of the general population in America [7]. The data from 2011 to 2018 were combined in this paper. Of all the 5731 individuals aged from 40 to 59 years with all BMI and lumbar BMD data, 2218 participants remained for the final analysis after exclusion of 332 subjects with cancer and 3181 subjects (BMI�30). The survey protocols were approved by the ethics review board of the National Center for Health Statistics, and participants in the NHANES provided written consent.

Variables

The principal variables of the study were BMI (independent variable) and lumbar BMD (dependent variable). BMI was calculated as weight in kilograms divided by height in meters squared. Lumbar BMD was measured by dual-energy X ray absorptiometry. The categorical variables were included: sex, race/ethnicity, level of education, vigorous recreational activities, smoking behavior. The continuous covariates included: age, poverty to income ratio, waist circumference, blood urea nitrogen, lumbar BMD, total protein, serum glucose, cholesterol, phosphorus, and total calcium. The detailed information on BMI, lumbar BMD, and covariates were publicly available at NHANES.

Statistical analysis

All estimates were calculated accounting for NHANES sample weights. Weighted multivariate linear regression models and smooth curve fittings were used to evaluate the associations between BMI and lumbar BMD. Three models were conducted: Model 1, no adjustment for covariates; Model 2, adjusted for age and race/ethnicity; and Model 3, adjusted for all covariates. These models were refer to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [8]. All analyses were performed with EmpowerStats (http://www.empowerstats.com) and R package (http://www.Rproject.org).

Result

A total of 2218 participants, 40-59 years of age, were included in the analysis, with the weighted characteristics of the participants subclassified based on BMI quartiles (Q1: 30.0-31.8 kg/m^2; Q2: 31.9-

34.2 kg/m^2; Q3: 34.3-38.4 kg/m^2; and Q4: 38.5-65.8 kg/m^2), as shown in Table 1. There were significant differences in baseline characteristics between the BMI quartiles, with the exception of the covariates: age, sex, the income to poverty ratio, smoking behavior, total protein, and phosphorus.

Table 1
Weighted characteristics of study population based on BMI quartiles

BMI (kg/m^2)	**Q1 (30.0-31.8)**	**Q2 (31.9-34.2)**	**Q3 (34.3-38.4)**	**Q4 (38.5-65.8)**	***P* value**
Age (years)	49.31±5.60	49.79±5.95	49.53±5.75	49.37±5.58	0.4894
Sex (%)					0.7802
Men	61.59	45.05	46.18	44.59	
Women	57.31	54.84	53.82	55.41	
Race/ethnicity (%)					<0.0001
Non-Hispanic white	64.49	64.43	57.08	63.22	
Non-Hispanic black	11.64	11.87	19.43	19.89	
Mexican American	10.38	10.15	12.50	8.77	
Other race/ethnicity	13.49	13.55	10.99	8.11	
Waist circumference (cm)	104.68±6.54	109.54±7.15	115.13±7.90	130.67±12.06	<0.0001
Level of education (%)					0.0044
Less than high school	15.96	15.07	15.35	12.06	
High school	19.60	27.61	26.23	21.64	
More than high school	64.43	57.33	58.42	66.30	
Income to poverty ratio	3.18±1.62	3.17±1.61	3.00±1.62	3.06±1.60	0.2449
Vigorous recreational activities (%)					<0.0001
Yes	21.60	22.00	13.61	10.89	
No	78.40	78.00	86.39	89.11	
Smoked at least 100 cigarettes in life (%)					0.7802
Yes	42.69	45.05	46.18	44.59	
No	57.31	54.95	53.82	55.41	
Blood urea nitrogen (mmol/L)	5.01±1.64	4.84±1.61	4.63±1.48	4.87±2.11	0.0049
Total protein (g/L)	70.76±3.95	70.88±4.05	70.59±4.57	70.51±4.35	0.4786

Mean ± SD for continuous variables: the *P* value was calculated by the weighted linear regression model. % for categorical variables: the *P* value was calculated by the weighted chi-square test.

BMI (kg/m^2)	Q1 (30.0-31.8)	Q2 (31.9-34.2)	Q3 (34.3-38.4)	Q4 (38.5-65.8)	*P* value
Cholesterol (mmol/L)	5.36±1.10	5.26±1.04	5.16±1.19	4.92±0.97	<0.0001
Phosphorus (mmol/L)	1.17±0.17	1.18±0.18	1.18±0.18	1.18±0.18	0.7604
Total calcium (mmol/L)	2.34±0.08	2.33±0.08	2.32±0.09	2.31±0.09	<0.0001
Serum glucose (mmol/L)	5.93±2.39	5.84±2.36	6.33±3.03	6.52±2.71	<0.0001
Lumbar BMD (g/cm^2)	1.02±0.16	1.02±0.15	1.03±0.16	1.08±0.17	<0.0001
Mean ± SD for continuous variables: the *P* value was calculated by the weighted linear regression model. % for categorical variables: the *P* value was calculated by the weighted chi-square test.					

The association between BMI and lumbar BMD was positive in all three regression models (Table 2): model 1 (β 0.005; 95% confidence interval (CI) 0.004-0.006); model 2 (β 0.004; 95% CI 0.003-0.006); model 3 (β 0.006; 95%CI 0.003-0.008). On subgroup analyses, stratified by sex and race/ethnicity, reported in Table 2, the positive correlation of BMI with lumbar BMD remained in both men (β 0.013; 95% CI 0.008-0.018; P < 0.001) and women (β 0.003; 95%CI 0.000-0.006; P 0.044), as well as in whites (β 0.006; 95%CI 0.001-0.010; P 0.013), blacks (β 0.008; 95%CI 0.003-0.013; P 0.002), and Mexican Americans (β 0.006; 95%CI 0.000-0.012; P 0.037).

Table 2

Association between BMI (kg/m^2) and lumbar bone mineral density (g/cm^2).

	Model 1 β (95% CI) *P* value	Model 2 β (95% CI) *P* value	Model 3 β (95% CI) *P* value
BMI (kg/m^2)	0.005 (0.004, 0.006) <0.001	0.004 (0.003, 0.006) <0.001	0.006 (0.003, 0.008) <0.001
BMI categories			
Q1 (30.0-31.8 kg/m^2)	Reference	Reference	Reference
Q2 (31.9-34.2 kg/m^2)	-0.007 (-0.026, 0.011) 0.437	-0.009 (-0.027, 0.010) 0.362	-0.003 (-0.023, 0.017) 0.774
Q3 (34.3-38.4 kg/m^2)	0.003 (-0.017, 0.022) 0.793	-0.002 (-0.021, 0.017) 0.829	-0.007 (-0.029, 0.016) 0.568
Q4 (38.5-65.8 kg/m^2)	0.054 (0.035, 0.073) <0.001	0.049 (0.030, 0.068) <0.001	0.034 (0.002, 0.066) 0.038
Subgroup analysis stratified by sex			
Men	0.008 (0.005, 0.010) <0.001	0.007 (0.005, 0.009) <0.001	0.013 (0.008, 0.018) <0.001
Women	0.003 (0.002, 0.004) <0.001	0.003 (0.002, 0.004) <0.001	0.003 (0.000, 0.006) 0.044
Subgroup analysis stratified by race/ethnicity			
Non-Hispanic white	0.005 (0.003, 0.007) <0.001	0.005 (0.003, 0.007) <0.001	0.006 (0.001, 0.010) 0.013
Non-Hispanic black	0.003 (0.001, 0.005) 0.004	0.004 (0.001, 0.006) 0.003	0.008 (0.003, 0.013) 0.002
Mexican American	0.005 (0.002, 0.008) <0.001	0.005 (0.002, 0.008) <0.001	0.006 (0.000, 0.012) 0.037
Other race/ethnicity	0.002 (-0.001, 0.004) 0.171	0.003 (-0.000, 0.005) 0.056	0.001 (-0.004, 0.007) 0.598

Model 1: no covariates were adjusted. Model 2: age, sex, and race/ethnicity were adjusted. Model 3: age, sex, and race/ethnicity, level of education, poverty to income ratio, vigorous recreational activities, smoking behavior, waist circumference, blood urea nitrogen, total protein, serum glucose, cholesterol, phosphorus, and total calcium were adjusted.

Smooth curve fittings and generalized additive models used to characterize the nonlinear relationship between BMI and lumbar BMD were shown in Figures 1-3. The association between BMI and lumbar BMD was an inverted U-shaped, the point of infection was about 50 kg/m^2. For a BMI < 50 kg/m^2, increase the BMI was associated with a increase lumbar BMD; by comparison, for individuals with a BMI > 50 kg/m^2, increase the BMI was associated with decrease in lumbar BMD. On subgroup analyses, stratified by sex and race/ethnicity, the relationship between BMI and lumbar BMD of women and blacks were inverted U-shaped.

Discussion

This cross-sectional study involving 2218 obese adults aged 40-59 showed a significantly positive association between high BMI and lumbar BMD. Of note, we identified an inverted U-shaped association between high BMI and BMD.

Currently, clinical researches regarding the correlation between obesity and BMD were limited and controversial. A study from US reported a significant positive association between the obesity and BMD existed in elder groups in both genders [9]. In a study of 502 northern Chinese men identified that, total body and regional BMD of obesity were significantly higher compared to normal weight ($P < 0.001$) [10]. Similar results were reported by Silva et al. in postmenopausal women and reported a lower prevalence of osteoporosis at lumbar spine and femoral neck in obese patients ($P < 0.001$) [11]. However, there were emerging literature to report opposite result. A study from India indicated that individuals with BMI ≥ 35kg/m^2 have a lower BMD than those with BMI ≥ 25-35kg/m^2. (0.723 gm/cm^2 versus 0.762 gm/cm^2; P 0.002) [12]. Another study from China on 8365 adolescents aged from 12-15 years old concluded that obese person had higher risks of having low BMD compared with normal weight in both genders [13]. A retrospective study from Spain showed that obese females had an increased risk of proximal fractures than those normal or underweight women (RR: 1.28; 95% CI: 1.04-1.58; P 0.018) [14].

In our study, we identified an inverted U-shaped association between BMD and high BMI, with a point of infection at about 50 kg/m^2. Excessive BMI may be harmful to bone health. By subgroup analyses, we found that the reason for this result were due to women and blacks. There are gender differences in the relationship between BMI and lumbar BMD. The Busselton Healthy Ageing Study showed that BMI is associated with reduced BMI in women but not in men [15]. One mechanism might explain the lower BMD found in women BMI > 50 kg/m^2 is the reduced estradiol. Menopause cause quick increase in bone turnover, bring higher bone resorption and leading to bone loss [16]. Racial difference in BMD have been described in adolescents and adults with normal weight and obesity in studies[17–20], differences in genetic risk factors, life style and other factors may explain the race-specific differences. Further studies are required to clarify the association between BMI and BMD among individuals of the women and black race.

As we used a nationally representative data and performed subgroup analyses. Therefore, our results may be different from those previously reported. Moreover, it is important to acknowledge the limitations of the study. First, the study was a cross-sectional research which limits the accurate inference of the relationship between high BMI and lumbar BMD among middle-aged adults, thus further RCT researches are necessary to strengthen the exact relationship between obesity and BMD. Second, there maybe other confounding factors that we did not adjust for, which could affect the result. Third, participants with cancer or malignancy were not include in the study, therefore, the conclusion of the research could not be used for these people.

Conclusions

The finding revealed an inverted U-shaped association between BMI and lumbar BMD among fat middle-aged adults, suggesting that it may be beneficial to appropriately increase BMI levels to promote bone health. However, for women and blacks, excessive high BMI may be harmful to BMD.

Abbreviations

BMI
Body mass index
BMD
Bone mineral density
NHANES
National Health and Nutrition Examination Survey

Declarations

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Authors’ contributions

Yue Li contributed to data collection, analysis, and writing of the manuscript.

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Ethics approval and consent to participate

The ethics review board of the National Center for Health Statistics approved all NHANES protocols and written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

I declare that there is no competing interests.

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Figures

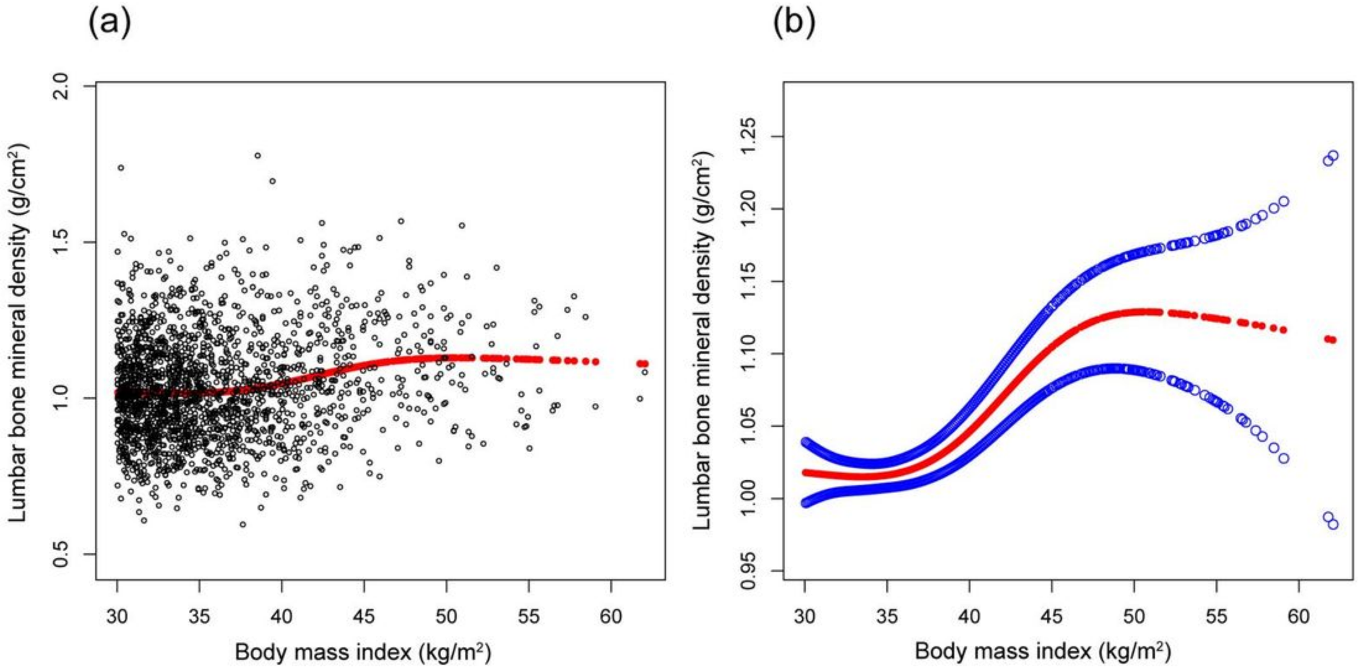

Figure 1

The associations between BMI and lumbar BMD. (a) Each black point represents a sample. (b) Solid red line represents the smooth curve fit between variables. Blue bands represent the 95% of confidence interval from the fit. Adjusted for age, sex, and race/ethnicity, level of education, poverty to income ratio, vigorous recreational activities, smoking behavior, waist circumference, blood urea nitrogen, total protein, serum glucose, cholesterol, phosphorus, and total calcium.

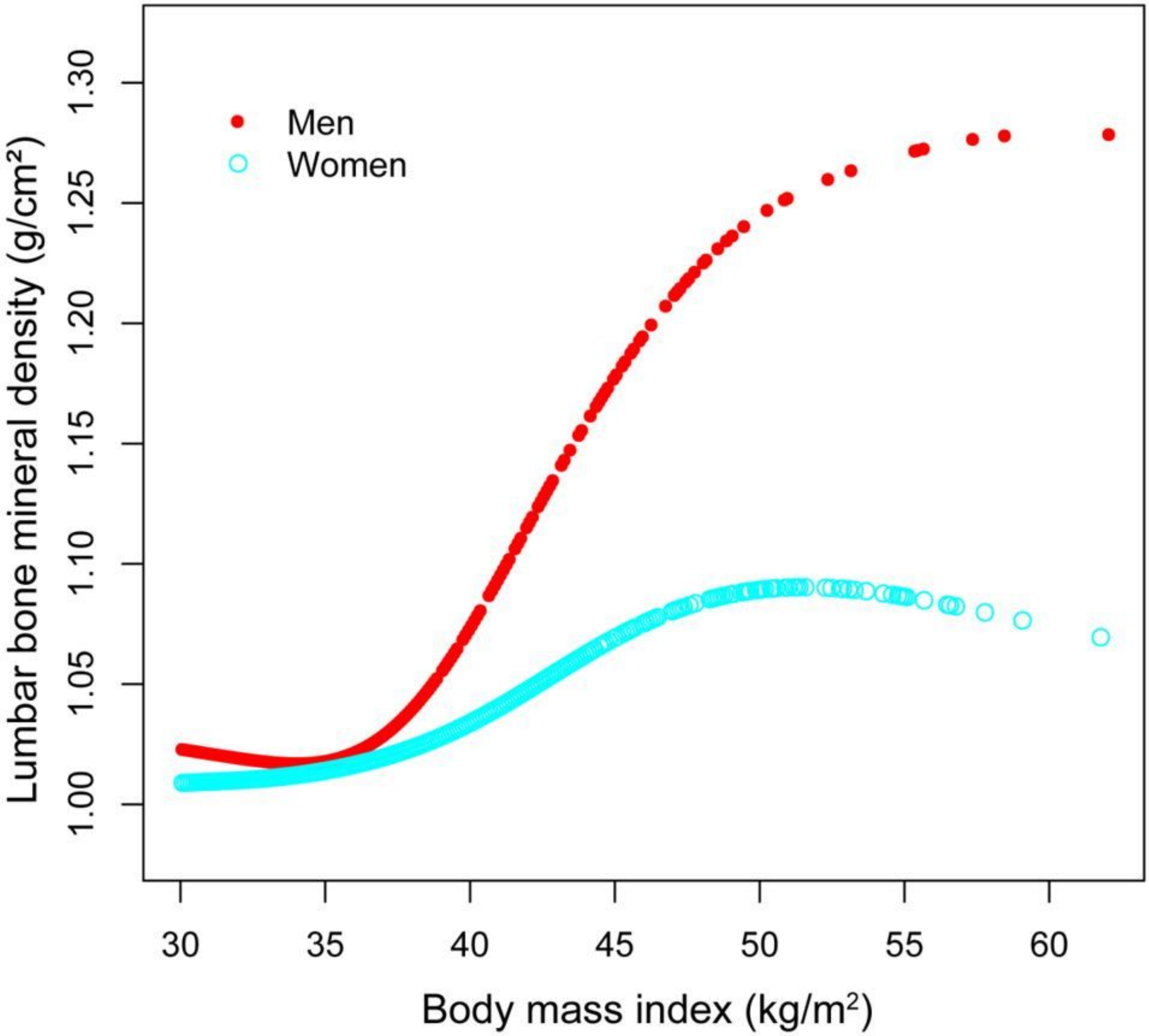

Figure 2

The association between BMI and lumbar BMD stratified by sex. Age, and race/ethnicity, level of education, poverty to income ratio, vigorous recreational activities, smoking behavior, waist circumference, blood urea nitrogen, total protein, serum glucose, cholesterol, phosphorus, and total calcium were adjusted.

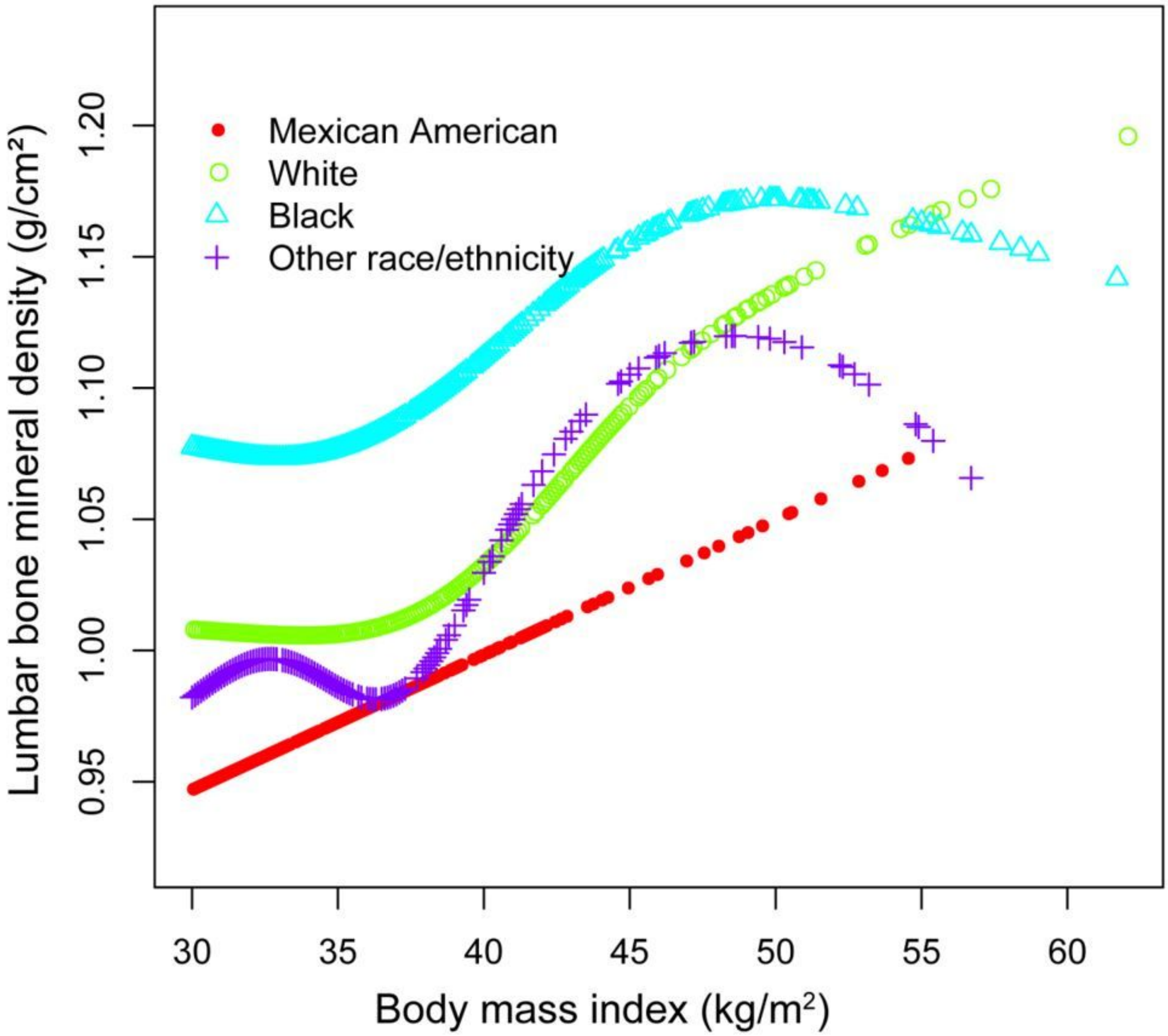

Figure 3

The association between BMI and lumbar BMD stratified by race/ethnicity. Age, sex, level of education, poverty to income ratio, vigorous recreational activities, smoking behavior, waist circumference, blood urea nitrogen, total protein, serum glucose, cholesterol, phosphorus, and total calcium were adjusted.