Association of Serum 25-(OH)-D3 with Osteosarcopenic Obesity: A Cross-Sectional Study of Older Chinese

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Abstract

Background Limited and inconsistent epidemiological evidence for the relationship between vitamin D level and risk of osteosarcopenic obesity. We aimed to find out the relationship between serum level of 25-(OH)-D_3 and osteosarcopenic obesity.

Methods This study was a cross-sectional study. Residents from nine communities of the Tiexi District of Shenyang City were enrolled from May to October 2017. We included 4,506 eligible participants (1,601 men) for analyses. Participants were asked for an overnight fast. Thereafter, Blood samples were collected, and serum level of 25-(OH)-D_3 was estimated using liquid chromatography–tandem mass spectrometry. We undertook logistic regression models adjusted for most known osteosarcopenic obesity risk factors. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated.

Results Our study included a total of 4,506 participants (2,905 women). In multivariable-adjusted analyses, compared to the lowest tertile, a higher 25-(OH)-D_3 level (OR was 0.77, 95% CI was 0.61, 0.98; and *P* for trend was 0.026) was inversely correlated with osteosarcopenic obesity. A positive association between vitamin D deficiency and osteosarcopenic obesity was found (OR was 1.33, 95% CI was 1.10, 1.62). Inverse relationships between serum level of 25-(OH)-D_3 and low bone mass, as well as low muscle mass were found (*P* values for trend were 0.035 and 0.014, respectively). However, vitamin D deficiency only showed a positive correlation with low muscle mass (OR=1.26, 95 %CI: 1.07, 1.44).

Conclusion An independent inverse dose-response association of serum 25-(OH)-D_3 level with osteosarcopenic obesity, as well as its compositions was found. Our findings implied that serum 25-(OH)-D_3 could be a good predictor of osteosarcopenic obesity in older northeastern Chinese.

Background

Osteosarcopenic obesity has emerged in recent years as a new syndrome consisting of osteopenia/osteoporosis, sarcopenia, and obesity [1, 2]. All three unfavorable compositions share a consistent causality, i.e. aging, and are potentially interconnected [3–6]. It has been reported that aging-related low-grade chronic inflammation can deregulate the commitment of mesenchymal stem cell (MSC) lineages, leading to fat infiltration into bone and muscle [4, 7, 8]. Depending on the predominance of fat infiltration, impairments became differentiated, with osteosarcopenic obesity the most advanced impaired stage [1]. A study of 258 postmenopausal Caucasian women who were overweight/obese showed that 12.4% had osteosarcopenic obesity [9]. Another study from Korea showed that the prevalence of osteosarcopenic obesity among men and women around 60 years of age was 13.5% and 25.0%, respectively [10]. China has been experiencing the burden of aging, and the role of osteosarcopenic obesity in causing frailty, falls, as well as other metabolic abnormalities in old people cannot be overlooked [5, 11–13]. Mo et al. found that in women of southern Chinese minorities, the prevalence of osteosarcopenic obesity was higher in an older age group [13]. However, no epidemiological study of osteosarcopenic obesity has yet been undertaken in northern Chinese populations.

Vitamin D, a collective name for vitamins D_2 and D_3, plays an important role in promoting bone growth by accelerating calcium absorption [14]. 25-hydroxyvitamin D (25-(OH)D), including both 25-(OH)-D_2 and 25-(OH)-D_3, is the main existing form in human blood, and can be hydroxylated into the biologically active form, i.e. 1, 25-(OH)2-D [15, 16]. Findings from experimental studies showed that 25-(OH)-D could sustain the normal functions of skeletal muscle and adipose tissue, characterized by increasing protein production in muscle, restraining adipogenesis, and regulating the inflammatory response [17, 18]. Relationships between low 25-(OH)-D level and osteoporosis, or sarcopenia were also generally found in several epidemiological studies [19, 20]. However, whether serum level of 25-(OH)-D was correlated with osteosarcopenic obesity remained undetermined. As we know, only one study from South Korea has evaluated the relationship between 25-(OH)-D level and osteosarcopenic obesity to date [10]. Evidence has been presented showing that 25-(OH)-D_3 was a more significant nutritional and functional index of vitamin D compared to 25-(OH)-D_2 due to a higher blood level and longer half-life [21]. However, no study has disclosed the relationship between 25-(OH)-D_3 and osteosarcopenic obesity.

Therefore, in this study, we aimed to find out (1) if a dose-response association of serum 25-(OH)-D_3 with osteosarcopenic obesity existed in northeastern Chinese community-dwelling residents; and (2) if 25-(OH)-D_3 was also correlated to compositions of osteosarcopenic obesity.

Methods

Participants

This study was undertaken in Shenyang City, Liaoning Province, China. Community-dwelling residents in this study were recruited from nine communities of Tiexi District of Shenyang City from May to October 2017 [22]. In brief, we randomly selected 6,812 residents older than 55 years of age. They were invited to complete questionnaires and undergo physical examinations, as well as biochemical tests. Baseline characteristics were used to complete the following cross-sectional analyses. Participants for whom a variable value was not available, or who showed extreme values for gender, fat percentage, bone mass density, muscle mass density, or serum 25-(OH)-D_3, were excluded. In the end, 4,506 participants (1,601 males) were eligible for the following analyses. We hereby stated that all undertaken methods and designments accorded with the World Medical Association Declaration of Helsinki–Ethical Principles for Medical Research Involving Human Subjects. This study was approved by the Ethics

Committee of China Medical University (Shenyang, China, AF-SOP-07-1.0-01). We informed objectives and relevant issues to participants before undertaking this study. All participants were also asked to complete consent forms.

Serum 25-(oh)-d Measurements

Participants were asked for an overnight fast. Blood were collected using standard venipuncture. Serum was separated using double centrifugation. 25-(OH)-D_3 in serum was estimate using liquid chromatography–tandem mass spectrometry. We defined less than 20 ng/mL of 25-(OH)-D_3 as vitamin D deficiency [24].

Determination Of Osteosarcopenic Obesity

Information was collected by measurements. We used dual-energy X-ray absorptiometry (Discovery-W, Hologic Inc, Waltham, MA, USA) to estimate the body compositions. Bone mineral density was examined according to the recommendations of the International Society for Clinical Densitometry of 2007.

Low bone mass was defined as less than − 1.0 of a T-score, using World Health Organization criteria.

Appendicular skeletal muscle mass was measured. We defined low muscle mass using the following cutoff point: more than 1 standard deviation (SD) lower than the mean in men and women (less than 20.24 for men, and less than 13.93 for women).

The fat in the upper 40% of body was estimated to define obesity (greater than 27.50% and 35.96% in men and women, respectively).

We divided adverse body compositions into 4 categories (0, 1, 2, and 3 components).

Statistical Analyses

Continuous characteristics were shown using mean and SD, and compared among subgroups based on tertiles of 25-(OH)-D_3 using analysis of variance (ANOVA). Categorical characteristics were shown using percentages. We compared percentages using chi-square tests. The relationship between the serum level of 25-(OH)-D_3 and osteosarcopenic obesity, as well as its compositions, was estimated using multivariable logistic regression. The odds ratio (OR) and 95% confidence interval (95% CI) are given. Three regression models were used as follows: Crude Model; Model I (adjusted for age); and Model 2 (adjusted for age; diastolic blood pressure [DBP]; systolic blood pressure [SBP]; alanine aminotransferase [ALT]; creatinine; triglycerides [TG]; high density lipoprotein cholesterol [HDL-C]; fasting blood glucose [FBG]; gender; pension status; education; regular exercise; smoking status; drinking status). Consistent analyses were repeated when estimating associations of vitamin D deficiency with osteosarcopenic obesity, as well as for compositions. Using multinomial logistic regression models, we estimated the relationship between osteosarcopenic obesity compositions and tertiles of 25-(OH)-D_3, and vitamin D deficiency. We also undertook subgroup analyses using SBP (< 139 or ≥ 139 mmHg), DBP (< 80 or ≥ 80 mmHg), ALT (< 17.65 or ≥ 17.65 U/L), creatinine (< 67.60 or ≥ 67.60 μmol/L), TG (< 1.41 or ≥ 1.41 mmol/L), HDL-C (< 1.31 or ≥ 1.31 mmol/L), FBG (< 5.60 or ≥ 5.60 mmol/L), age (< 60 or ≥ 60 years), education (≤ junior high school or > junior high school), gender (female or male), regular exercise (yes or no), smoking status (yes or no), drinking status (yes or no), and pension status (yes or no) to detect the relationship between any 25-(OH)-D_3, deficiency of serum vitamin D_3 and osteosarcopenic obesity. A two-tailed α level of 0.05 was used as statistical significance. All analyses were completed using SPSS 21.0 software (IBM, ASiaAnalytics, Shanghai, China).

Results

A total of 4,506 participants (2,905 females; 1,601 males) were recruited. The mean age was 67.62 (6.51) years for females and 68.63 (6.91) years for males. Those in the highest tertiles of 25-(OH)-D_3 level tended to be younger, male, undertook regular exercise, non-smokers, non-drinkers, and to have higher levels of education, ALT, and creatinine compared with participants in the lowest tertiles (Table 1).

Table 1
Baseline characteristics of participants according to tertiles of 25-(OH)-D3

Characteristic	25-(OH)-D3			
	Tertile 1	Tertile 2	Tertile 3	P-value
N	1513	1500	1493	
SBP (mmHg)	140.25 ± 20.42	138.51 ± 20.13	137.77 ± 19.58	0.680
DBP (mmHg)	79.86 ± 11.90	80.70 ± 11.35	81.09 ± 11.35	0.493
ALT (U/L)	20.23 ± 15.54	21.33 ± 15.58	21.76 ± 16.04	**0.008**
Creatinine (μmol/L)	68.06 ± 25.18	69.11 ± 19.26	73.97 ± 31.46	**0.043**
TG (mmol/L)	1.68 ± 1.06	1.69 ± 1.08	1.70 ± 1.08	0.319
HDL-C (mmol/L)	1.38 ± 0.43	1.38 ± 0.45	1.38 ± 0.46	0.489
FBG (mmol/L)	6.12 ± 1.79	6.14 ± 1.83	6.08 ± 1.62	0.851
Age (years)				**0.042**
< 60	112 (7.40)	143 (9.53)	146 (9.78)	
≥ 60	1401 (92.60)	1357 (90.47)	1347 (90.22)	
Education				**< 0.001**
≤Primary school	280 (19.79)	210 (15.12)	184 (13.28)	
Junior high school	611 (43.18)	657 (47.30)	670 (48.34)	
Senior high school	299 (21.13)	303 (21.81)	303 (21.86)	
≥Junior college	225 (15.90)	219 (15.77)	229 (16.52)	
Gender				**< 0.001**
Male	391 (25.84)	528 (35.20)	682 (45.68)	
Female	1122 (74.16)	972 (64.80)	811 (54.32)	
Regular exercise				**< 0.001**
No	405(28.87)	283 (20.55)	241 (17.50)	
Yes	998 (71.13)	1094 (79.45)	1136 (82.50)	
Smoking status				**< 0.001**
No	168 (12.61)	181(14.29)	222 (18.06)	
Yes	1164 (87.39)	1086 (85.71)	1007 (81.94)	
Drinking status				**< 0.001**
No	124 (9.70)	176 (14.81)	203 (17.98)	
Yes	1153 (90.30)	1012 (85.19)	926 (82.02)	
Pension				0.138
No	132 (9.33)	103 (7.42)	127 (9.16)	

Values are mean ± standard deviation (SD) or n (%).

Values of polytomous variables may not sum to 100% due to rounding.

Abbreviations:

25-(OH)D, 25-hydroxyvitamin D; ALT, alanine aminotransferase; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high density lipoprotein cholesterol; SBP, systolic blood pressure; TG, triglycerides.

In multivariable-adjusted analyses (including adjustments for age, DBP, SBP, ALT, creatinine, TG, HDL-C, FBG, gender, pension status, education, regular exercise, smoking status, and drinking status), comparing the highest to lowest tertile, a higher 25-(OH)-D_3 level (OR was 0.77, 95% CI was 0.61, 0.98; *P* for trend = 0.026) was negatively associated with osteosarcopenic obesity. A positive relationship between vitamin D deficiency and osteosarcopenic obesity was found even after adjustment for all relative characteristics in Model II (OR was 1.33, 95% CI was 1.10, 1.62; Table 2).

Characteristic	25-(OH)-D3			
	Tertile 1	Tertile 2	Tertile 3	P-value
Yes	1283 (90.67)	1286 (92.58)	1260 (90.84)	

Values are mean ± standard deviation (SD) or n (%).

Values of polytomous variables may not sum to 100% due to rounding.

Abbreviations:

25-(OH)D, 25-hydroxyvitamin D; ALT, alanine aminotransferase; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high density lipoprotein cholesterol; SBP, systolic blood pressure; TG, triglycerides.

In multivariable-adjusted analyses (including adjustments for age, DBP, SBP, ALT, creatinine, TG, HDL-C, FBG, gender, pension status, education, regular exercise, smoking status, and drinking status), comparing the highest to lowest tertile, a higher 25-(OH)-D_3 level (OR was 0.77, 95% CI was 0.61, 0.98; *P* for trend = 0.026) was negatively associated with osteosarcopenic obesity. A positive relationship between vitamin D deficiency and osteosarcopenic obesity was found even after adjustment for all relative characteristics in Model II (OR was 1.33, 95% CI was 1.10, 1.62; Table 2).

Table 2
Relationship between 25-(OH)-D3 and osteosarcopenic obesity in different models

Exposure	Crude Model[a]	Model I[b]	Model II[C]
	OR (95% CI)	OR (95% CI)	OR (95% CI)
25-(OH)-D3			
Tertile 1	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Tertile 2	0.79 (0.65–0.96)	0.81 (0.66–0.98)	0.78 (0.62–0.99)
Tertile 3	0.68 (0.56–0.83)	0.69 (0.57–0.84)	0.77 (0.61–0.98)
P for trend	< 0.001	< 0.001	0.026
Deficiency of serum vitamin D3			
No	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Yes	1.46 (1.24–1.72)	1.44 (1.22–1.69)	1.33 (1.10–1.62)

[a]No adjustment.

[b]Adjusted for age (< 60 years, ≥ 60 years).

[c]Adjusted for Age (< 60 years, ≥ 60 years); DBP (mmHg); SBP (mmHg); ALT (U/L); Creatinine (μmol/L); TG (mmol/L); HDL-C (mmol/L); FBG (mmol/L); Gender (female, male); Pension status (Yes, No); Education (≤ primary school, junior high school, senior high school and ≥ junior college); Regular exercise (Yes, No); Smoking status (Yes, No); Drinking status (Yes, No).

Abbreviations: 25-(OH)D, 25-hydroxyvitamin D; ALT, alanine aminotransferase; CI, confidence interval; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high density lipoprotein cholesterol; OR, odds ratio; TG, triglyceride

We found that 25-(OH)-D_3 was negatively associated with both low bone mass and low muscle mass (Table 3, *P* values for the trend were 0.035 and 0.014, respectively). However, we only found a positive association of vitamin D deficiency with low muscle mass (OR = 1.26, 95% CI: 1.07, 1.44). In Table 4, we showed that after adjustment for all confounders in Model II, participants in the largest tertile of 25-(OH)-D_3 level had lower ratios of no less than two compositions for osteosarcopenic obesity (OR was 0.60, 95% CI was 0.39, 0.93 for 2 vs. 0; OR = 0.52, 95% CI: 0.32, 0.82 for 3 vs. 0). We found a positive association between vitamin D deficiency and two and three compositions relative to 0 compositions even adjusted for all confounders (OR = 1.45, 95% CI: 1.02, 2.07 for 2 vs. 0; OR = 1.83, 95% CI: 1.25, 2.68 for 3 vs. 0). We generally found similar relationship between serum level of 25-(OH)-D_3 and osteosarcopenic obesity in stratified analyses (Supplemental Tables 1 and 2).

Table 3
Association between 25-(OH)-D3 and major components in osteosarcopenic obesity

Components	OR (95% CI)*
Low bone mass	
25(OH)D3	
Tertile 1	1.0 (Reference)
Tertile 2	0.95 (0.75–1.22)
Tertile 3	**0.77 (0.61–0.98)**
P for trend	**0.035**
Deficiency of serum vitamin D3	
No	1.0 (Reference)
Yes	1.20 (0.98–1.46)
Low muscle mass	
25(OH)D3	
Tertile 1	1.0 (Reference)
Tertile 2	**0.78 (0.65–0.93)**
Tertile 3	**0.80 (0.67–0.96)**
P for trend	**0.014**
Deficiency of serum vitamin D3	
No	1.0 (Reference)
Yes	**1.26 (1.07–1.44)**
Obesity	
25(OH)D3	
Tertile 1	1.0 (Reference)
Tertile 2	0.93 (0.78–1.11)
Tertile 3	0.86 (0.72–1.03)
P for trend	0.106
Deficiency of serum vitamin D3	
No	1.0 (Reference)
Yes	1.12 (0.96–1.30)

*Adjusted for age (< 60 years, ≥ 60 years); DBP (mmHg); SBP (mmHg); ALT (U/L); Creatinine (μmol/L); TG (mmol/L); HDL-C (mmol/L); FBG (mmol/L); Gender (female, male); Pension status (Yes, No); Education (≤ primary school, Junior high school, senior high school and ≥ junior college); Regular exercise (Yes, No); Smoking status (Yes, No); Drinking status (Yes, No). Abbreviations: 25-(OH)D, 25-hydroxyvitamin D; ALT, alanine aminotransferase; CI, confidence interval; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high density lipoprotein cholesterol; OR, odds ratio; TG, triglycerides

Table 4
Relationship between 25-(OH)-D3 and risk of multiple adverse body compositions in different models

Exposure	Adverse body composition[d]								
	1 vs. 0			2 vs. 0			3 vs 0		
25-(OH)-D3	Crude Model[a]	Model I[b]	Model II[C]	Crude Model[a]	Model I[b]	Model II[C]	Crude Model[a]	Model I[b]	Model II[C]
25-(OH)-D3									
Tertile 1	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Tertile 2	**0.68 (0.47–0.98)**	**0.68 (0.47–0.98)**	0.72 (0.47–1.12)	**0.59 (0.41–0.84)**	**0.59 (0.41–0.85)**	0.69 (0.45–1.05)	**0.51 (0.34–0.74)**	**0.52 (0.35–0.76)**	**0.56 (0.35–0.89)**
Tertile 3	**0.65 (0.45–0.93)**	**0.65 (0.45–0.93)**	0.75 (0.48–1.16)	**0.49 (0.34–0.70)**	**0.49 (0.35–0.70)**	**0.60 (0.39–0.93)**	**0.39 (0.26–0.57)**	**0.39 (0.27–0.58)**	**0.52 (0.32–0.82)**
P for trend	**0.024**	**0.025**	0.211	**< 0.001**	**< 0.001**	**0.023**	**< 0.001**	**< 0.001**	**0.005**
Deficiency of serum vitamin D3									
No	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Yes	**1.43 (1.06–1.92)**	**1.43 (1.06–1.92)**	1.30 (0.91–1.86)	**1.70 (1.27–2.27)**	**1.68 (1.26–2.25)**	**1.45 (1.02–2.07)**	**2.25 (1.64–3.08)**	**2.21 (1.61–3.03)**	**1.83 (1.25–2.68)**

[a]Not adjusted.

[b]Adjusted for Age (< 60 years, ≥ 60 years).

[c]Adjusted for Age (< 60 years, ≥ 60 years); DBP (mmHg); SBP (mmHg); ALT (U/L); Creatinine (μmol/L); TG (mmol/L); HDL-C (mmol/L); FBG (mmol/L); Gender (female, male); Pension status (Yes, No); Education (≤ primary school, junior high school, senior high school and ≥ junior college); Regular exercise (Yes, No); Smoking status (Yes, No); Drinking status (Yes, No).

[d] Adverse body composition: numbers for low bone mass, low muscle mass, or obesity. 0 (normal; without low bone mass, low muscle mass, or obesity), 1 (having one of the components), 2 (having two of the components), and 3 (osteosarcopenic obesity; having all three components).

Abbreviations: 25-(OH)D, 25-hydroxyvitamin D; ALT, alanine aminotransferase; CI, confidence interval; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high density lipoprotein cholesterol; OR, odds ratio; TG, triglycerides

Discussion

In summary, we found a negative dose-response association between 25-(OH)-D_3 and osteosarcopenic obesity independent of other relevant characteristics. There was a relationship between vitamin D deficiency and osteosarcopenic obesity. Among compositions, only low bone and muscle mass were negatively associated with the serum level of 25-(OH)-D_3. In contrast with participants in the lowest tertile of 25-(OH)-D_3 level, those with higher 25-(OH)-D_3 tended to have a lower likelihood of no less than two compositions of osteosarcopenic obesity.

Osteosarcopenic obesity is a newly defined whole-body syndrome that correlates with several disorders, especially in older adults. A study of southern Chinese minorities found that osteosarcopenic obesity was positively associated with hypertension in women [12]. Results from the same population also showed a positive association of osteosarcopenic obesity with dyslipidemia in older women [13]. Therefore, determining the major determinants in the etiology of osteosarcopenic obesity would be helpful in predicting the risk of osteosarcopenic obesity, while relevant studies are limited. Vitamin D is an essential nutrient in bone metabolism in that it increases the circulating calcium level, which subsequently maintains the normal functions of neuromuscular junctions and hormone secretions [23, 24]. In addition, vitamin D can bind to receptors on muscle fibers, and increase fiber size [25, 26]. Negative relationship between the vitamin D level and osteoporosis, sarcopenia, and frailty was shown in numerous epidemiological studies [19, 20]. However, only one study has described the correlation between vitamin D and osteosarcopenic obesity [10].

In our study, we found that associations of osteosarcopenic obesity with both 25-(OH)-D_3 and vitamin D deficiency were statistically significant, which was consistent with the above-mentioned findings. Additionally, the correlation between 25-(OH)-D_3 and each single composition was also analyzed in our study. Only low bone mass and low muscle mass were relevant to 25-(OH)-D_3. An association with low muscle mass only was found

in terms of vitamin D deficiency. Transforming the continuous form (25-(OH)-D_3) into a dichotomous form (vitamin D deficiency) may have abolished the association with low bone mass. No statistically significant association of obesity with either 25-(OH)-D_3 or vitamin D deficiency was found. Although various epidemiological studies have disclosed that vitamin D level was negatively correlated with obesity, such a relationship has remained controversial to date. Sampling variance may partially explain our distinctive finding. On the other hand, the association of obesity with osteoporosis and sarcopenia showed a U-shaped curve, meaning that both high and low body weight/fat percentage may contribute to the occurrence of osteoporosis and sarcopenia, which closely correlated with vitamin D deficiency [27–29]. We postulate that such disorders relevant to both obesity and vitamin D deficiency may play roles as confounders.

Deregulation of the commitment of the MSC lineage was considered to underlie the pathogenesis of osteosarcopenic obesity. As people grew older, low-grade chronic inflammation increased, which then induced high-level adipogenesis in bone and muscles [1, 2]. According to the type of tissue the fat infiltration favored, different compositions, such as osteopenic obesity, osteopenic sarcopenia, and sarcopenic obesity, emerged [1]. Eventually, all compositions can develop to osteosarcopenic obesity, the severest form. This potential mechanism may explain the results of our study. People with vitamin D deficiency showed greater likelihood of more severe subtypes of osteosarcopenic obesity (i.e. two or three compositions) relative to those with no composition.

Strengths

The strengths of our study were that both each single composition as well as composition counts were considered. Second, participants in our study were randomly selected from the same district, which may increase the generalizability of our findings to older Chinese in the Han ethnic group.

Limitations

There were several limitations. Due to a cross-sectional designment, the temporal association of 25-(OH)-D_3 with osteosarcopenic obesity could not be shown. Second, gender-stratified analyses were not made in postmenopausal women, characterized by dramatic changes in hormone levels, among whom the high risks of osteoporosis and sarcopenia have always been highlighted [30, 31]. However, in our study, no interaction, according to gender, between the association of osteosarcopenic obesity with the serum level of 25-(OH)-D_3 or vitamin D deficiency was found. We thought adjusting for gender as a regular confounder in regression models instead of gender-stratified analyses may have been enough. Third, despite specifying the serum level of 25-(OH)-D_3 instead of the overall vitamin D level in our study, the independent relationship between 25-(OH)-D_3 and osteosarcopenic obesity, as well as compositions may not be shown well without adjustments for 25-(OH)-D_2, as well as other vitamin D analogs. Finally, given that only older people were recruited in our study, the association of osteosarcopenic obesity with vitamin D in younger people, such as adolescents, remains unknown.

Conclusions

The independent negative dose-response associations of serum level of 25-(OH)-D_3 level with osteosarcopenic obesity, as well as its compositions were noted. Participants with vitamin D deficiency showed greater likelihood of osteosarcopenic obesity. Our findings implied that serum level of 25-(OH)-D_3 could be a good predictor of osteosarcopenic obesity, and that supplemental intake may perhaps help prevent the occurrence of osteosarcopenic obesity, especially in older northeastern Chinese.

Abbreviations

MSC: mesenchymal stem cell; 25-(OH)D: 25-hydroxyvitamin D; ANOVA: analysis of variance; OR: odds ratio; 95% CI: 95% confidence interval; DBP: diastolic blood pressure; SBP: systolic blood pressure; alanine ALT: aminotransferase; TG: triglycerides; HDL-C: high density lipoprotein cholesterol; FBG: fasting blood glucose.

Declarations

Ethics approval and consent to participate

We hereby stated that all undertaken methods and designments accorded with the World Medical Association Declaration of Helsinki–Ethical Principles for Medical Research Involving Human Subjects. This study was approved by the Ethics Committee of China Medical University (Shenyang, China, AF-SOP-07-1.0-01). We informed objectives and relevant issues to participants before undertaking this study. All participants were also asked to complete consent forms.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Difei Wang, Yanan Ma and Yuyan Liu designed and conducted research. Shen Zhang, Lu Cao and Yu He provided essential materials. Shuai Xu, Hong Liang, Feng Chen, and Jie Gao performed statistical analyses. Yanan Ma and Yuyan Liu wrote paper, and Difei Wang had primary responsibility for final content. All authors participated in preparation of the manuscript and approved the final version for publication. The authors declare that there is no duality of interest associated with this manuscript.

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