Original Article

The relationship between obesity indices and serum vitamin D levels in Chinese adults from urban settings

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Background and Objectives: With an increased incidence of obesity in China, this study sought to investigate the correlation between serum 25-hydroxyvitamin D levels and adiposity phenotypes in Chinese adults from urban settings. **Methods and Study Design:** A total of 1277 subjects aged 20-82 years old were recruited into this cross-sectional study. Anthropometric parameters and blood biochemistry panels were measured. Statistical analysis using partial correlation, multivariable regression and covariance were performed to assess the impact of obesity parameters on serum 25-hydroxyvitamin D levels. **Results:** After adjustment for age and gender, serum25-hydroxyvitamin D levels were found to be inversely related to body mass index, waist circumference, waist/hip ratio, body fat, body fat percentage and waist fat to hip fat ratio. In multivariable regression analysis, serum 25-hydroxyvitamin D levels were negatively associated with waist circumference, waist/hip ratio, body fat, body fat percentage and waist fat/hip fat ratio ($p<0.05$), while there was no correlation with body mass index ($p>0.05$). After inclusion of body fat, body fat percentage and waist fat to hip fat ratio in one model, only waist fat to hip fat ratio remained significantly associated with serum 25-hydroxyvitamin D levels ($p<0.05$). The covariance analysis results showed that abdominal obesity subjects had lower serum 25-hydroxyvitamin D levels compared to the counterpart group, as defined by waist circumference or waist/hip ratio ($p<0.05$). **Conclusion:** Our results affirm the relationship between serum 25-hydroxyvitamin D levels and abdominal obesity, suggesting that adiposity phenotypes were strongly linked to serum 25-hydroxyvitamin D levels.

Key Words: vitamin D, abdominal obesity, general obesity, body fat, urban adult

INTRODUCTION

Vitamin D, a fat-soluble vitamin, is essential for maintaining bone mineral homeostasis. It is synthesized in skin through ultraviolet B radiation or obtained from food and dietary supplements. Vitamin D plays important roles in a number of metabolic processes. It has been reported that vitamin D deficiency is associated with metabolic syndromes and coronary heart disease (CHD).[1,2] Recently, a series of studies have revealed the relationship between obesity and vitamin D levels. For example, Gutiérrez-Medina et al found that obese children had lower serum vitamin D levels and a high incidence of overweight was observed in vitamin D-deficient children.[3] Similarly, Cheng et al reported that there was a negative correlation between serum 25-hydroxyvitamin D (25-OH D) levels and waist circumference (WC), and high adiposity volumes, categorized by different body mass index (BMI), were associated with high prevalence of vitamin D deficiency.[4]

With the gradual improvement of living standards and healthcare, the prevalence of obesity is increasing in China. During the period between 1993 and 2009, general obesity and abdominal obesity in Chinese children increased from 6.1% to 13.1% and from 4.9% to 11.7%,

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respectively.[5] Furthermore, in a study of urban adults from the northeast of China, the incidence of general obesity and abdominal obesity were 15% and 37.6%, respectively.[6]

Vitamin D deficiency is very common in the Chinese population. Serum vitamin D levels can be affected by age, gender, ethnicity, diet, sun exposure and other factors.[7,8] Qiao et al reported that the incidence of vitamin D deficiency among the urban population living in the Guiyang area of China was 52.3%.[9] Interestingly, given the high prevalence of vitamin D deficiency and obesity in China, there also might be some relationship between the two factors in Chinese urban adults. However, the information regarding the putative relationship between serum vitamin D levels and adiposity phenotypes among Chinese population is very limited. Meanwhile Eastern and Western have different body builds, some correlation observed in the Western world may not be applicable to those in the Orient. Therefore, in this study, we aimed to investigate the relationship between adiposity phenotypes and serum vitamin D levels in Chinese adults from an urban setting and to further explore the association between body fat distribution and vitamin D status.

MATERIALS AND METHODS

Human subjects

One thousand eight hundred and sixty five individuals, aged 20 to 82 years old, were enrolled in this study between October and November 2009. All participants were urban residents living in Jinan (36° N), eastern China, and had lived there for more than five years. All subjects completed a self-reported questionnaire, including demographics, lifestyle habits, diet, medical history and current medication. Outdoor physical activity score was calculated by outdoor physical activity in daylight, duration of activity, and the type of activity as described.[10]

The exclusion criteria for subjects included (1) hepatic or renal dysfunctions; (2) history of sub-total gastrectomy, gastrointestinal fistulation or malignant tumor; (3) chronic diseases of the stomach and intestine; (4) usage of calcium, vitamin D supplements or other medications that influence vitamin D levels; (5) diagnosis of diabetes, dyslipidemia, hypertension and other cardiovascular diseases; (6) genetic diseases that predispose to obesity or some congenital diseases that may affect the growth and development, such as the deficiency of growth hormone or thyroid hormones; (7) diagnosis of Cushing syndrome or use of glucocorticoids; (8) pregnancy; (9) subjects with incomplete data. From 1865 individuals, 1277 adults fulfilled the inclusion criteria. The study was approved by the Ethics Committee of Provincial Hospital Affiliated to Shandong University, and all participants provided written informed consent.

Body mass parameters

Anthropometric parameters including body weight, height, WC, and hip circumference of all subjects were measured by a trained professional. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). According to the classification of the World Health Organization (WHO), a BMI ≥30 kg/m^2 was defined as general obesity.[11] WC was measured at the midpoint between the lower rib and upper margin of the iliac crest, and a WC ≥90 cm in men or a WC ≥80 cm in women was considered representative of abdominal obesity.[12] Hip circumference was measured horizontally at the widest portion of the buttocks. Waist to hip ratio (WHR) was calculated as WC divided by the hip circumference, and a WHR ≥0.90 in men or a WHR ≥0.85 in women was classified as that representing abdominal obesity.[13] Body fat, body fat percentage and waist fat to hip fat ratio were measured by bioelectrical impedance analysis with InBody720 body composition analyzer (Biospace, Seoul, Korea).

Clinical laboratory tests

Blood samples were collected in coagulation-promoting vacuum tubes (Becton Drive, Franklin Lakes, USA) from all subjects after overnight fasting and left undisturbed at room temperature for 30 minutes (mins), to allow coagulation. Serum was separated from red blood cells by centrifugation at 1,000-2,000 x g for 10 mins at 4℃ and stored at -80℃. The serum levels of creatinine, alanine aminotransferase, calcium, fasting blood glucose, total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides were measured by an automatic biochemical analyzer (Olympus AU5400, Japan). The glomerular filtration rate (eGFR) was calculated using the formula as follows: $eGFR=175\times(\text{serum creatinine, mg/dL})^{-1.234}\times(\text{age, years})^{-0.179}\times(0.79 \text{ if female})$.[14] As serum 25-OH D is the primary metabolite of vitamin D and widely regarded as an indicator for serum vitamin D status,[15] serum levels of 25-OH D were determined by enzyme immunoassay (Immunodiagnostic System Ltd, UK) in the Clinical Laboratory of Provincial Hospital affiliated to Shandong University. The intra-day and inter-day coefficients of variation (CV) were 3.8-4.7% and 4.1-5.3% respectively for the serum 25-OH D levels.

Statistical analyses

Data were analyzed using SPSS 18.0 (Chicago, IL, USA) and expressed as mean±standard error (SE). Partial correlation analysis was used to evaluate the relations between clinical parameters and serum 25-OH D levels after adjustment for age and gender. To evaluate the correlations between obese parameters and serum 25-OH D levels, multivariate linear regression analysis was conducted to examine the independent effect of each obesity parameter on serum 25-OH D levels after adjusting for potential confounding factors. An independent t test and analysis of covariance (ANCOVA) were used to compare the serum 25-OH D levels between the subjects with and without general obesity or abdominal obesity as defined by BMI, WC and WHR. In addition, a p value less than 0.05 was considered statistically significant.

RESULTS

The basal characteristics of all subjects in this study are shown in table 1. The mean age was 46.3±0.4 years old and males accounted for 32.7% of the sample. In general, the average concentration of serum 25-OH D was 40.4±0.3 nmol/L in this study.

To investigate the correlations between serum 25-OH

D levels and obesity, we conducted partial correlation analysis on the clinical data obtained from all subjects, as shown in table 2. After adjusting for age and gender, serum 25-OH D levels were inversely related to BMI (*r*= -0.057, *p*=0.042), WC (*r*=-0.084, *p*=0.003) and WHR (*r*=-0.099, *p*<0.001), body fat (*r*=-0.073, *p*=0.009), body fat percentage (*r*=-0.072, *p*=0.010) and waist fat to hip fat ratio (*r*=-0.107, *p*<0.001) (Table 2). For the analysis of blood chemistry data from subjects, serum 25-OH D levels were negatively correlated with serum glucose contents (*r*=-0.069, *p*=0.013) and serum Log triglycerides levels (*r*=-0.075, *p*=0.007), but positively correlated with outdoor physical activity score (*r*=0.098, *p*<0.001) and serum calcium contents (*r*=0.152, *p*<0.001) (Table 2). No significant correlations were found between serum 25-OH D levels and height, weight, eGFR, total cholesterol, HDL cholesterol, LDL cholesterol, systolic blood pressure, and diastolic blood pressure (Table 2).

Multiple linear regression analysis showed that serum 25-OH D levels were negatively correlated with WC (β=-0.080, *p*=0.015) and WHR (β=-0.123, *p*<0.001), but not with BMI (β=-0.033, *p*=0.277) (Table 3). In these three models, it showed that age, gender, serum calcium, fasting glucose, and outdoor physical activity score were significant independent predictors of serum 25-OH D levels (*p*<0.05). To further study the effects of body fat composition on serum 25-OH D levels, we performed multiple linear regression analysis using serum 25-OH D levels as the dependent variable and other factors including age, gender, serum calcium, fasting glucose, triglycerides and outdoor physical activity score, as independent variables. Table 4 showed that serum 25-OH D levels were negatively correlated with three body fat parameters; body fat (model 1, β=-0.060, *p*=0.036), body fat percentage (model 2, β= -0.071, *p*=0.035), and waist fat to hip fat ratio (model 3, β=-0.131, *p*=0.001), when these body fat parameters were individually introduced to the regression model. However, when these three body fat parameters were included in the same model (model 4), only waist fat to hip fat ratio remained significantly associated with serum 25-OH D levels (β=-0.131, *p*=0.001), while body fat and body fat percentage were no longer significantly correlated with serum 25-OH D levels (β=0.080, *p*=0.140; and β=0.060, *p*=0.289, respectively) (Table 4).

Serum 25-OH D levels associated with adiposity phenotypes are presented in table 5. There was no significant difference in the levels of serum 25-OH D between the non-obesity and obesity subjects in general obesity group or abdominal obesity group (*p*>0.05 for all comparison groups). After adjusting for the confounding factors, including age, gender, serum calcium, fasting glucose, triglycerides and outdoor physical activity score, serum 25-OH D levels were significantly higher in non-obese than abdominally obese subjects (WC, 41.3±0.48 nmol/L vs 39.6±0.46 nmol/L, *p*=0.017; WHR, 41.1±0.44 nmol/L vs 39.4±0.53 nmol/L, adjusted *p*=0.017), while no significant difference in serum 25-OH D levels was observed between the non-obese and generally obese subjects (BMI, 40.5±0.34 nmol/L vs 39.3±1.19 nmol/L, *p*=0.347).

Table 1. Clinical characteristics of the subjects

Characteristics	Mean±SE
Age (years)	46.3±0.4
Male (%)	32.7
Height (cm)	163±0.2
Weight (cm)	66.2±0.3
BMI (kg/m^2)	25.0±0.1
WC (cm)	83.2±0.3
WHR	0.8±0.0
Body fat (kg)	21.5±0.2
Body fat percentage (%)	31.7±0.2
Waist fat to hip fat ratio	0.9±0.0
Serum calcium (mmol/L)	2.5±0.0
eGFR (mL/min)	99.3±0.6
Fasting glucose (mmol/L)	5.5±0.0
Total cholesterol (mmol/L)	5.3±0.0
HDL cholesterol (mmol/L)	1.5±0.0
LDL cholesterol (mmol/L)	3.3±0.0
Triglycerides (mmol/L)	1.2 (0.8, 1.7)
Systolic blood pressure (mmHg)	120±0.5
Diastolic blood pressure (mmHg)	78.4±0.3
Serum 25-OH D (nmol/L)	40.4±0.3
Outdoor physical activity score (hours/week)	3.0±0.1

BMI: body mass index; WC: waist circumference; WHR: waist/hip ratio; eGFR: estimated glomerular filtration rate; HDL: high-density lipoprotein; LDL: low-density lipoprotein; 25-OH D: 25-hydroxyvitamin D.
Data are presented as mean±standard error (SE), median or percentage.

Table 2. Correlations of clinical parameters and serum 25-OH D adjusted for age and gender

	25-OH D	
	r	*p* value
Height	0.010	0.726
Weight	-0.048	0.089
BMI	-0.057	0.042
WC	-0.084	0.003
WHR	-0.099	<0.001
Body fat	-0.073	0.009
Body fat percentage	-0.072	0.010
Waist fat to hip fat ratio	-0.107	<0.001
Serum calcium	0.152	<0.001
eGFR	0.042	0.132
Fasting glucose	-0.069	0.013
Total cholesterol	-0.031	0.272
HDL cholesterol	0.053	0.059
LDL cholesterol	-0.039	0.160
Log Triglycerides	-0.075	0.007
Systolic blood pressure	-0.014	0.623
Diastolic blood pressure	-0.012	0.661
Outdoor physical activity score	0.098	<0.001

BMI: body mass index; WC: waist circumference; WHR: waist/hip ratio; eGFR: estimated glomerular filtration rate; HDL: high-density lipoprotein; LDL: low-density lipoprotein; 25-OH D: 25-hydroxyvitamin D.
p less than 0.05 is considered statistically significant.

DISCUSSION

This study found that the levels of 25-OH D were closely related to WC, WHR and BMI when adjusted by age and gender. When we further adjusted the analysis, it was found that the serum 25-OH D levels remained significantly relevant to WC and WHR, but no longer to BMI. Moreover, this study showed that serum 25-OH D levels were significantly associated with body fat, body fat percentage and waist fat to hip fat ratio when these factors

Table 3. Multiple regression analysis of confounding factors for serum 25-OH D levels

	β	*p* value
Model 1		
Age	0.132	<0.001
Gender	-0.129	<0.001
Serum calcium	0.173	0.001
Fasting glucose	-0.085	0.004
Triglycerides	-0.062	0.039
Outdoor physical activity score	0.110	<0.001
BMI	-0.033	0.277
Model 2		
Age	0.139	<0.001
Gender	-0.152	<0.001
Serum calcium	0.166	<0.001
Fasting glucose	-0.088	0.002
Outdoor physical activity score	0.110	<0.001
WC	-0.080	0.015
Model 3		
Age	0.149	<0.001
Gender	-0.177	<0.001
Serum calcium	0.173	<0.001
Fasting glucose	-0.078	0.007
Outdoor physical activity score	0.113	<0.001
WHR	-0.123	<0.001

BMI: body mass index; WC: waist circumference; WHR: waist/hip ratio.
All models adjusted for age, gender, serum calcium, fasting glucose, triglycerides, outdoor physical activity score and BMI.

Table 4. Multiple regression analysis between serum 25-OH D levels and body fat indices

	Model 1		Model 2		Model 3		Model 4	
	β	*p* value	*β*	*p* value	*β*	*p* value	*β*	*p* value
Body fat	-0.060	0.036	—	—	—	—	0.080	0.140
Body fat percentage	—	—	-0.071	0.035	—	—	0.060	0.289
Waist fat to hip fat ratio	—	—	—	—	-0.131	0.001	-0.131	0.001

All models are adjusted for age, gender, serum calcium, fasting glucose, triglycerides, outdoor physical activity score. Body fat, body fat percentage and waist fat to hip fat ratio were considered separately in models 1, 2 and 3. In model 4, all of the three body fat indices were used.

were analyzed independently. However, when body fat, body fat percentage and waist fat to hip fat ratio were included in the same model, only waist fat to hip fat ratio correlated with serum 25-OH D levels. Taken together, our results provide compelling evidence for a correlation between the serum 25-OH D levels and adiposity phenotypes. Compared with general obesity measured by BMI, abdominal obesity measured by WC and WHR was closely related to serum levels of 25-OH D independently of possible confounding factors.

Rajakumar et al reported that the levels of 25-OH D, in a study of 237 children of mixed ethnicity aged between 8 and 18, were negatively associated with BMI, percentage of total body fat, abdominal subcutaneous adipose tissue (SAT) and visceral adipose tissue, and that the relationship between 25-OH D levels and BMI or SAT became non-significant after adjustment for age, gender, race, season and pubertal status.[16] In addition, Young et al showed that vitamin D levels were inversely associated with BMI, SAT and visceral adipose tissue in 917 Hispanics and 439 African-Americans.[17] Similar data were obtained from a study of Caucasian women, which showed a negative correlation of serum 25-OH D levels with BMI, WHR, body fat, fat mass and fat-free mass.[18] In Korean adults, Han et al also found that body fat mass was inversely associated with serum 25-OH D levels.[19]

Our present study found that three indicators of abdominal obesity i.e. WC, WHR and waist fat to hip fat ratio, were explicitly relevant to serum 25-OH D levels, compared to general obese indices e.g. BMI, body fat and body fat percentage, indicating that serum 25-OH D levels were associated with body fat distribution. The differences between our data and other studies may be explained by the fact that Eastern Asians are more likely to have a big trunk of fat located in the abdomen as compared to other ethnicities, including Caucasian, Hispanics, Blacks and Southeast Asians.[20,21]

A number of research studies have shown that adipose tissue is closely associated with serum vitamin D concentration. It was found that obese people carry a high proportion of fat, a major tissue for vitamin D storage, which may reduce the circulating vitamin D levels.[22] Supplementation of vitamin D significantly has been shown to reduce visceral adipose tissue in an obese group compared to a control group.[23] The expression of vitamin-D-25-hydroxylase CYP2J2 (an enzyme, which coverts cholecalciferol into the 25-OH D) in subcutaneous adipose tissues was lower in obese subjects than in lean subjects.[24]

Table 5. Serum 25-OH D levels between obesity and non-obesity groups

	25-OH D	*p* value	Adjusted 25-OH D	*p* value†
General obesity (BMI)				
No (n=1179)	40.5±0.35	0.296	40.5±0.34	0.347
Yes (n=98)	39.2±1.08		39.3±1.19	
Abdominal obesity (WC)				
No (n=610)	41.0±0.51	0.073	41.3±0.48	0.017
Yes (n=667)	39.8±0.43		39.6±0.46	
Abdominal obesity (WHR)				
No (n=754)	40.6±0.44	0.483	41.1±0.44	0.017
Yes (n=523)	40.1±0.51		39.4±0.53	

BMI: body mass index; WC: waist circumference; WHR: waist/hip ratio.
†*p* was adjusted for age, gender, serum calcium, fasting glucose, triglycerides and outdoor physical activity score by covariance analysis.

Plasma 25-OH D levels increased by 27% after weight loss.[24] However, the molecular mechanisms underlying the correlation between vitamin D and adiposity are not yet clear. Our present data showed that those adults with abdominal obesity had lower serum 25-OH D levels than non-obese adults, and may provide further information in elucidating the relationship between vitamin D content and adiposity.

Our findings suggest that adiposity phenotypes are closely associated with serum 25-OH D levels. Our study provides convincing data as we adjusted for several confounding factors ignored by other studies. To investigate the different types of obesity, we not only measured height, weight, WC and hip circumference, but also measured body fat mass using the bioelectrical impedance technique.

However, our study had certain limitations. Using a cross-sectional design, causal correlations between abdominal obesity and serum 25-OH D levels couldn't be fully established. Compared with bioelectrical impedance analysis, the dual energy X-ray absorptiometry (DEXA) or computed tomography (CT) for body fat measurement can provide more precise data and more information regarding fat mass and fat composition. As DEXA or CT emits radiation and is expensive and requires professional operation, we might consider them in the future study. It is necessary to measure adipose tissue distribution to assess vitamin D status in Chinese population. WC and WHR are promising and practical indicators to reflect abdominal obesity. This pilot study provides the preliminary data to aid the understanding of the relationship between serum vitamin D levels and adiposity in Chinese population.

Conclusions

Our study demonstrates that adiposity phenotypes are related to serum 25-OH D levels in urbanized Chinese adults.

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AUTHOR DISCLOSURES

The authors declare no conflicts of interest.

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Original Article

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中国城市成年人肥胖指数与血清维生素 D 的关系

背景与目的：在中国，肥胖发病率呈上升趋势，该研究主要探讨中国城市成年人血清 25-OH D 浓度与肥胖类型的关系。**方法与研究设计：**共有 1277 例年龄在 20-82 岁间的调查对象纳入该横断面研究，测定人体测量学及血生化相关指标，应用偏相关、多元线性回归、协方差等统计学方法，探讨肥胖参数与血清 25-OH D浓度的关系。**结果：**校正年龄和性别后，发现血清 25-OH D 与体重指数、腰围、腰臀比、体脂肪、体脂百分比和腰臀脂肪比呈显著负相关。多元线性回归分析显示，血清 25-OH D 与腰围、腰臀比、体脂肪、体脂百分比及腰臀脂肪比呈负相关（$p<0.05$），但与体重指数无统计相关性。但当体脂肪、体脂百分比及腰臀脂肪比全部进入回归方程时，仅腰臀脂肪比与血清 25-OH D 呈负相关（$p<0.05$）。根据腰围和腰臀比，将调查人群分为腹型肥胖组和非腹型肥胖组，协方差分析结果显示，腹型肥胖组血清 25-OH D 浓度明显低于非腹型肥胖组（$p<0.05$）。**结论：**研究结果发现血清 25-OH D 浓度与腹型肥胖有关，提示肥胖类型与血清 25-OH D 浓度具有密切相关性。

关键词：维生素 D、腹部肥胖、一般肥胖、体脂、城市成年人