The relationship between erectile dysfunction and osteoporosis: a population-based study in Southern China

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Abstract

Aim: To investigate the association of erectile dysfunction (ED) and osteoporosis in all-aged (18-87 years) males, and by comparing models with or without ED, explore the ability of ED to assess the prevalence of osteoporosis. Methods: We performed a cross-sectional study in Southern China based on the community population from March to July 2015 and 998 eligible individuals ages form 18 to 87 years were included. The diagnosis of ED was based on self-reporting and osteoporosis was defined as a bone mineral density (BMD) of 2.5 standard deviations or below (T score [?]-2.5). Odds ratios (OR) and 95% confidence intervals (95%CI) were calculated in logistic regression model. Lasso regression model was used for feature selection. Receiver operating characteristics (ROC) curve analysis was used to evaluate the ability of the different models to assess the prevalence of osteoporosis. Results: The prevalence of osteoporosis was 1.70-fold higher in the ED group compared with the non-ED group (OR: 1.70, 95%CI: 0.99-2.87, P=0.051) after adjustment in total population. AUC in model with biochemical indices including low density lipoprotein cholesterol (LDL-C) and fasting plasma glucose (FPG), further plus ED was 0.73 (95% CI: 0.68-0.79), which was significantly higher than model only with non-invasive basic clinical parameters (AUC: 0.70, 95% CI: 0.65-0.80). Model included only biochemical indices evaluated the AUC from 0.70 to 0.72 (P=0.050), and further plus ED can significantly evaluated the ability of diagnosis osteoporosis (P=0.017). Conclusions: We found that patients with ED had an increased risk of osteoporosis among the all-age (18-87 years) male population, and the diagnosis ability for osteoporosis significantly evaluated when plus ED. For assessing osteoporosis in male population, the information about ED should be collected.

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Summary

Aim: To investigate the association of erectile dysfunction (ED) and osteoporosis in all-aged (18-87 years) males, and by comparing models with or without ED, explore the ability of ED to assess the prevalence of osteoporosis.

Methods: We performed a cross-sectional study in Southern China based on the community population from March to July 2015 and 998 eligible individuals ages form 18 to 87 years were included. The diagnosis of ED was based on self-reporting and osteoporosis was defined as a bone mineral density (BMD) of 2.5 standard deviations or below (T score [?]-2.5). Odds ratios (OR) and 95% confidence intervals (95%CI) were calculated in logistic regression model. Lasso regression model was used for feature selection. Receiver operating characteristics (ROC) curve analysis was used to evaluate the ability of the different models to assess the prevalence of osteoporosis.

Results: The prevalence of osteoporosis was 1.70-fold higher in the ED group compared with the non-ED group (OR: 1.70, 95%CI: 0.99-2.87, P =0.051) after adjustment in total population. AUC in model with biochemical indices including low density lipoprotein cholesterol (LDL-C) and fasting plasma glucose (FPG), further plus ED was 0.73 (95% CI: 0.68-0.79), which was significantly higher than model only with non-invasive basic clinical parameters (AUC: 0.70, 95% CI: 0.65-0.80). Model included only biochemical indices evaluated the AUC from 0.70 to 0.72 (P=0.050), and further plus ED can significantly evaluated the ability of diagnosis osteoporosis (P=0.017).

Conclusions: We found that patients with ED had an increased risk of osteoporosis among the all-age (18-87 years) male population, and the diagnosis ability for osteoporosis significantly evaluated when plus ED. For assessing osteoporosis in male population, the information about ED should be collected.

Keywords: erectile dysfunction, osteoporosis, older male population, obesity population, non-diabetes population, diagnosis ability of model

What's known

ED and osteoporosis were closely associated with age, with significant effects on the quality of life in men. Hence, the association of ED and osteoporosis has attracted attention of the public and researchers alike. The relationship between ED and osteoporosis has been recently questioned. Although amount of studies reported that ED is associated with increased prevalence of osteoporosis, theses researches mainly focus on [?] 40 aged male populations.

What's new

- We included a large sample which included the all-aged (18-87 years) adult male population in our study to explore the relationship between ED and the risk of osteoporosis and compared models with or without ED for assessing the prevalence of osteoporosis. For all-aged adult male population to assessing the prevalence osteoporosis, the information of ED should be collected.
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1 Introduction

Erectile dysfunction (ED) is defined as the inability of a man to achieve or maintain an erection sufficient for satisfactory sexual function [1]. ED belongs to a neurovascular process dependent on the health of the central and peripheral nervous systems and the vascular health of the erectile tissue [2]. It has been equally well-established that the incidence of ED increases with age [3]. Approximately 50% of all men above 40 years old experience some degree of ED and an estimated 322 million men were expected to suffer from ED by 2025 [4, 5]. ED is a facet of men's health that open a window into certain chronic diseases, such as cardiovascular disease (CVD), chronic kidney disease (CKD), diabetes mellitus (DM), hypertension, metabolic syndrome, psychological distress and osteoporosis [6-8]. Several important take-home messages are quite clear. The large amount of time between the diagnosis of ED and other diseases provides healthcare providers with a window of opportunity for intervention and possible prevention.

Osteoporosis is defined as age-related bone loss[9]. It has been recognized as an important public health concern for aging females, especially for post-menopausal women, whereas the risk to men is real and likely underappreciated[10]. Up to one third of fractures occur in men, and fracture-related morbidity and mortality is higher in men than in women[11]. Osteoporosis is a systemic metabolic bone disease which exposes patients to fragility fractures [12], which is a withering event in which subsequent pain, decreased quality of life, functional disability and morbidity can contribute to high medical expenditures and even mortality[13]. It is important to predict the risk of osteoporotic fractures via the use of risk factor analysis.

ED and osteoporosis were closely associated with age, with significant effects on the quality of life in men. Hence, the association of ED and osteoporosis has attracted attention of the public and researchers alike. The relationship between ED and osteoporosis has been recently questioned. An analysis of 95 men with ED and 82 men without ED indicated that the men with ED had a higher risk for osteoporosis[14]. Moreover, a study based on 4460 patients aged [?]40 years diagnosed with ED and 17480 age-matched patients without ED showed that patients with a history of ED, particularly younger men, had a higher risk of osteoporosis[15]. However, 76 men aged [?]50 years concluded that the frequencies of osteoporosis and ED increased with age, but the association between these conditions seems to be independent of each other[16]. There were only a small number of studies concerning the relationship between ED and osteoporosis, and most of these studies had a limited scope because of a small sample size. A research based on the National Health Insurance (NHI) program database clarified that ED was associated with a high risk of osteoporosis and hip fractures based on a large sample size, however they only enrolled patients aged [?]40 years[17]. As far as we knowledge, no previous studies have investigated the diagnosis ability of ED for prevalence of osteoporosis. Therefore, we included a large sample which included the all-aged (18-87 years) adult male population in our study to explore the relationship between ED and the risk of osteoporosis and compared models with or without ED for assessing the prevalence of osteoporosis. Further clarification the association of ED with the risk of osteoporosis would probably shed light on the prevention and treatment of related diseases.

1.1 Aim

The aim of this study was to investigate the association of erectile dysfunction (ED) and osteoporosis in all-aged (18-87 years) males, and by comparing models with or without ED, explore the ability of ED to assess the prevalence of osteoporosis.

2 Methods

2.1 Study population and design

We performed a cross-sectional study among communities in Guangzhou, China, from March to July, 2015. This study population was obtained from the research project of the National Health and Family Planning Commission of China, titled-"National Survey of Thyroid Diseases and Diabetes". This project has been set up as a multicenter prospective observational study aiming to evaluate chronic diseases in the Chinese population. Inclusion criteria: 1) 18-79 years old; 2) The Han ethnicity of the Chinese population; 3) Permanent residents, who lived in those regions [?]5 years. Exclusion criteria: 1) Pregnant women; 2) Those who suffer from severe diseases such as hepatic cirrhosis, chronic renal failure or evident cardiac insufficiency; 3) individuals who received medicines influencing thyroid function or hormones, such as iodine, amiodarone, somatostatin and glucocorticoids, within the past three months. A multistage stratified cluster random sampling method was used to select a representative sample. In the first stage, the districts of Guangzhou city were divided into rural areas and urban areas; In the second stage, one rural area and one urban area were randomly selected; In the third stage, one community was sampled from both rural and urban groups using a random selection; Finally, one adult resident was randomly selected from each household of the selected communities. During the recruitment phase, a total of 2767 residents were invited to participate via examination notices or home visits. In total, 2720 subjects signed the consent form and agreed to participate in the survey. 1567 females and 155 male with missing information regarding ED or osteoporosis were excluded. Finally, 998 eligible individuals were included in the data analyses. The flow chart for data analysis is shown in **Figure 1** . All participants provided informed consent before being recruited into the

study. The study protocol was in accordance with the principles of the Helsinki Declaration II and our study was approved by the Ethics Committee of the Sun Yat-sen Memorial Hospital (2014[3]).

2.2 Clinical and biochemical measurements

We used a questionnaire administered by an interviewer to obtain information. The questionnaire primarily included demographic factors, lifestyle factors, medical history and family history. The Mandarin Chinese language was used to design the questionnaire, and the questionnaire was administered in Chinese by investigators who could speak Mandarin Chinese as well as Cantonese, and they have received uniform training on the administration of the questionnaire. Education was divided into three levels: low (primary school and illiteracy), median (middle and high school) and high (university and above). Total yearly income for family was classified into three groups: [?]10,000 yuan/year, 10,000-50,000 yuan/year and [?]50,000 yuan/year. Smoking habits were classified as "never", "occasionally" (<1 time/day currently or in the past 6 months), and "frequently" ([?]1 times/day currently or in the past 6 months). Alcohol consumption habits were classified as "never", "occasionally" (alcohol consumption for socializing currently or in the past 6 months), and "frequently" ([?]3 times/week or alcohol consumption everyday currently or in the past 6 months).

All participants completed the anthropometrical measurements with the assistance of trained staff using standard protocols. Height and weight were measured using standard protocols, without shoes or outerwear. Body weight and height were measured twice during the examination and recorded to the nearest 0.1 kg and 0.1 cm and the average of two weight and height measurements were used for analysis. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). BMI was used to describe general obesity, subjects were categorized as underweight (<18.5 kg/m^2), normal weight (18.5 to 23.9 kg/m^2), overweight (24.0 to 27.9 kg/m^2), or obese ([?]28.0 kg/m^2). Waist circumference (WC) was measured to the nearest 0.1 cm at the umbilicus. WC [?] 80.0 cm in females and [?] 85.0 cm in males were defined as central obesity. In addition, repeated blood pressure measurements were performed by the same observer three times with a 5 min interval between readings using an automated electronic device (OMRON, Omron Company, Dalian, China). The average of three blood pressure measurements were collected and used for analysis. Hypertension was diagnosed by systolic blood pressure (SBP) greater than or equal to 140 mmHg and/ or diastolic blood pressure (DBP) greater than or equal to 90 mmHg, or diagnosed by a doctor as hypertension. Participants were examined in the supine position with the neck hyperextended. Thyroid ultrasonography of all participants was performed by the same certified sonographer using 7.5 MHz ultrasound probes (Logiq 500 Pro, GE Medical Systems, WI, and USA). Thyroid nodules were defined as discrete lesion(s) within the thyroid gland that is palpable and/or ultrasonographically distinct from the surrounding thyroid parenchyma[18].

Venous blood samples were collected and stored at -80 for laboratory tests after an overnight fasting of at least 10 hours. Measurements of fasting plasma glucose (FPG), oral glucose tolerance test (OTGG), triglycerides (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), alanine aminotransferase (ALT) and creatinine (Cr) were performed using an autoanalyser (Beckman CX-7 Biochemical Autoanalyser, Brea, CA, USA). HemoglobinA1c (HbA1c) was assessed by high-performance liquid chromatography (Bio-Rad, Hercules, CA). Diabetes was diagnosed according to the 1999 WHO diagnostic criteria, fasting blood glucose (FBG) [?]7.0 mmol/L and/ or oral glucose tolerance test (OGTT) [?]11.1 mmol/L, or diagnosed by a doctor as diabetes.

2.3 Definition of ED and osteoporosis

The diagnosis of ED was based on the response of “Never Able” or “Sometimes Able” to the question “Ability to get and keep an erection for satisfactory intercourse,” in unified standard questionnaire or the use of ED medication. In the progress of analysis, "Never Able" was defined as ED and "Sometimes Able" was defined as non-ED. Bone mineral density (BMD) of the root bone was measured using a clinical ultrasound bone densitometer (Sahara Clinical Bone Sonometer, 35 Crosby Drive, Bedford, Hologic, Inc, USA) according to the standard protocol. According to the WHO diagnostic criteria, osteoporosis was defined as a BMD of 2.5 standard deviations or more below the mean value for young adults (T score [?]-2.5)[19].

2.4 Statistical analysis

Demographics and baseline characteristics of subjects were presented as mean ± standard deviation for continuous data with normal distribution and median (IQR) for continuous data with skewed variables, and compared by Student's t -test and Mann-Whitney U test, respectively. Categorical data were presented as percentages and compared using the Chi-square or Fisher's exact test, as appropriate. Odds ratios (ORs) and 95% confidence intervals (95% CI) were calculated in unadjusted and multivariate-adjusted logistic regression model analyses. Stepwise multivariate logistic regression analysis was used to explore the independent influencing factors of osteoporosis and ED. Least absolute shrinkage and selection operator (LASSO) logistic regression, which is suitable for the regression of high-dimensional data, was used to select important preoperative indices for predicting postoperative hypokalemia. LASSO logistic regression analysis was performed using the glmnet R package. Receive operating characteristic (ROC) analysis was performed to assess the accuracy of the different models for osteoporosis. All statistical assessments were performed using RStudio statistical programming language (version 3.1.6). Two-tailed $P<0.05$ were considered indicative of statistical significance.

3 Results

3.1 Basic characteristics of subjects based on status of osteoporosis

Out of the 998 participants, a total of 172 cases were reported to have ED, where the percentage was 16.1%, and the percentage of osteoporosis was 10.5% (112/998) in this study. The median age of this population was 44 years (Range: 18˜87 years). The distribution of socio-economic and clinical biochemical characteristics according to the group with osteoporosis were presented in **Table 1** . Compared with the non-osteoporosis population, the osteoporosis population presented with a higher SBP, DBP, TC and LDL-C (all $P<0.05$). The osteoporosis group was closely correlated with a low percentage of education, but a high percentage of smoking and alcohol consumption (all $P<0.05$). Importantly, as shown in **Figure 2** , the bone density in ED was lower than that in non-ED group (-1.9 *vs.* -1.2, $P<0.001$) and the percentage of osteoporosis in the ED group was higher when compared with the non-ED group (31.25% *vs.* 13.77%, $P<0.001$).

3.2 Associations of ED and osteoporosis and comparison of different models for assessing the prevalence of osteoporosis

As shown in **Table 2,** we performed logistic regression analysis to explore the associated of ED and osteoporosis. ED can be used as risk factor for prevalence of osteoporosis, the prevalence of osteoporosis was 1.70-fold higher in the ED group compared with the non-ED group (OR: 1.70, 95% CI: 0.99-2.87, $P=0.051$) after adjustment in total population.

The LASSO regression accurately identified the important candidates for assessing osteoporosis. As shown in **Figure 3A** , after the LASSO regression analysis, ten features with nonzero coefficients out of 20 clinical parameters (age, education, smoking, drinking, SBP, DBP, TC, LDL-C, HDL-C, TG, BMI, waistline, family history of diabetes, neck circumference, P, WHR, heart rate, PFG, OGTT2h and HbA1c) were selected as important candidates for assessing prevalence of osteoporosis. Of the 10 indices selected by LASSO regression by $\lambda=0.01$ included age, education, smoking, drinking, SBP, LDL-C, BMI, neck circumference, heart rate and FPG. Different models were established to assess the ability of diagnostic for prevalence of osteoporosis. Model 1 included age, education, smoking, drinking, SBP, neck circumference, BMI and heart rates, which all of those were non-traumatic parameters. Model 2 further included LDL-C and FPG based on model 1. Model 3 were further included ED based on model 2. We constructed ROC curve to assess the ability of different models to assess the prevalence of osteoporosis (**Figure 3B**). The AUC for the ROC curves were 0.70 (95% CI: 0.65-0.80), 0.72 (95% CI: 0.67-0.78) and 0.73 (0.68-0.79) for model 1, model 2 and model 3, respectively. Compared to model 1, model 3 plus LDL-C, FPG and ED were significantly improved the diagnostic capabilities (P=0.017).

3.3 Association of ED and prevalence of osteoporosis in different subgroups

As shown in **Figure 4** , the associations of ED with increased osteoporosis were not consistently the same

in subgroups analyses. Significantly relationships of ED with osteoporosis were detected in age [?] 45 years, obesity and those with non-diabetes population. In subgroups analysis, no statistically significantly of interaction term between ED and each strata factor was detected.

4 Discussion

In this study, we discovered a relationship between ED and osteoporosis persisted after adjustment for potential confounding risk factors in total male population. To the best of our knowledge, this is the first large population-based cross-sectional study to investigate the association of ED and osteoporosis for the all-aged (18-87 years) male population. According to the results of this study, ED can be used as significantly assessing factor for the prevalence of osteoporosis in all-age adult male population. In addition, model with ED can significantly improve the diagnosis ability for prevalence osteoporosis in total population, which was further confirmed that the importance of ED for diagnosis osteoporosis. Early intervention is of great importance for osteoporosis, and the present findings might provide insights into ED for the prevention and early detection of osteoporosis.

Many researchers concluded that a significant association between ED and osteoporosis exists. In our study, ED was a significant risk factor associated with osteoporosis. Concordant with an observational cross-sectional study based on 119 recruited men with depressive, it is reported that a low BMD was significantly associated with ED[20]. Similar results were obtained in a population-based cohort study which included 4,696 elderly (60-74 years) Danish men, which revealed a higher risk of osteoporotic fracture risk in men with self-reported ED[21]. However, a study which included 76 men aged [?]50 demonstrated no association between ED and osteoporosis, which was conducted from one region with a small sample size (n=76), where the conclusion might not be completely applicable to our study. Our study firstly based on all-aged (18-87 years) male population to explore the relationship between ED and osteoporosis, and ED can be used as significantly assessing factor for the prevalence of osteoporosis.

Some biological hypotheses have been proposed for the mechanism which was responsible for the relationship between ED and osteoporosis. Firstly, androgens levels were lower in patients with ED than without ED, which plays an important role in the regulation of bone formation in men [22, 23]. Secondly, patients with ED have been highly associated with inflammation, and inflammatory cytokines may inhibit osteoblast growth, thus causing osteoporosis[24]. Thirdly, nitric oxide (NO) bioactivity is a possible pathogenic mechanism underlying the relationship between ED and osteoporosis. NO is crucial for penile engorgement and affect bone metabolism as well[25]. Fourth, the condition of endothelial function is indicative of early stage of atherosclerosis which is well established in both ED and osteoporosis, which potentially explains the relationship between ED and osteoporosis[26]. Furthermore, vitamin D which plays a major role in maintaining the bone health, has a negative association with the risk of ED by promoting endothelial dysfunction, which also might also play an important role in explaining the association between ED and osteoporosis[27]. Finally, traditional ED risk factors including diabetes mellitus, hypertension and dyslipidemia are known to be predictors of osteoporosis. We suggest that ED and osteoporosis share similar risk factors and a diagnosis of ED increases the risk of osteoporosis. However, these co-morbidities do not account for the complete relationship between ED and osteoporosis.

There were several limitations in this study which require consideration. (1) No causal inference can be drawn due to the cross-sectional design of the current study. Further prospective studies are needed to illustrate the precise relationship between ED and osteoporosis. (2) By including only Chinese subjects, the results of the present study might not be representative of other ethnic groups, especially those in developed or undeveloped countries. To some extent, however, the present study of the Chinese population was still a convenient sample and selection bias is inevitable. (3) Our assessment of ED was performed using interviews and not confirmed by a specialist. We are aware that conditions like ED are highly associated with social stigmas. As a result of this, it is likely that ED was under-reported by study participants. Furthermore, ED was evaluated only by asking "the ability to get and keep an erection for satisfactory intercourse?" and the answers were categorical (no/yes) and International Index of Erectile Function-5 items (IIEF-5) was not used in this study. However, no IIEF-5 was used in some of studies and the self-reported with categorical

(yes/no) has strong correlations with IIEF-5[28-30]. (4) Data on osteoporosis were obtained by ultrasound bone densitometer, as X-rays were harmful to the health of participants and were not part of this study. Ultrasound bone densitometer revealed a strong correlation compared to X-rays[31] and has been used mainly used to assess BMD in large epidemiology survey[32-34]. (5) No androgen tests were performed in this study, and we could not identify the prevalence of osteoporosis with the levels of androgen. However, studies had confirmed that androgen deficiency is strongly associated with ED [2, 35].

5 Conclusion

We found that patients with ED had an increased risk of osteoporosis among the all-age (18-87 years) male population. ED can be considered an early predictor of osteoporosis. This result suggests that physicians should be aware of the relationship between ED and osteoporosis and carry out early identification of such groups of patients. Because of the easy and noninvasive evaluation of osteoporosis, patients with ED should undergo BMD assessment, and men with osteoporosis should be evaluated for ED. Despite the limitations of this study, our results surface a new question about the relationship between ED and osteoporosis in the all-age (18-87 years) male population and we hope that our findings will stimulate other interested scholars to further investigate such associations in large cohorts.

DISCLOSURES

The authors have no conflict of interest.

AUTHOR CONTRIBUTIONS

All authors contributed towards data analysis, drafting and critically revising the paper, and agree to be accountable for all aspects of the work.

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AUTHOR'S CONTRIBUTIONS

YLL and LF supervised data generation and analysis, and drafted the manuscript. FWT, RM, WMC, ZJ, WC, TJY and ZXY were responsible for data collection. YL and XMT contributed to study design and interpreted the acquired data. All authors were involved in study conception and design, as well as data acquisition. All authors have read and approved of the final manuscript.

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Table 1 Association of socio-demographic characteristics with erectile dysfunction and osteoporosis	Table 1 Association of socio-demographic characteristics with erectile dysfunction and osteoporosis	Table 1 Association of socio-demographic characteristics with erectile dysfunction and osteoporosis	Table 1 Association of socio-demographic characteristics with erectile dysfunction and osteoporosis	Table 1 Association of socio-demographic characteristics with erectile dysfunction and osteoporosis	Table 1 Association of socio-demographic characteristics with erectile dysfunction and osteoporosis	Table 1 Association of socio-demographic characteristics with erectile dysfunction and osteoporosis
Characteristics	Subcategory	Total (n=998)	Osteoporosis Yes (n=112, 10.5%)	Osteoporosis No (n=886, 82.7%)	Osteoporosis z/χ^2	Osteoporosis *P*
Age (years)		44.0(31.0-56.0)	49.5(39.3-62.0)	42.0(29.0-55.0)	-5.280	**<0.001**
Education	Low	154(14.4)	28(25.2)	116(13.1)	22.539	**<0.001**
	Median	522(48.9)	62(55.9)	419(47.5)		
	High	391(36.6)	21(18.9)	348(39.4)		
Income	[?]10,000yuan	265(25.5)	24(22.0)	218(25.4)	0.600	0.741

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	10,000-50,000yuan	396(38.1)	43(39.4)	327(38.1)		
	>50,000yuan	378(36.4)	42(38.5)	313(36.5)		
Smoking	Never	580(54.2)	48(42.9)	491(55.4)	9.660	**0.008**
	Occasionally	78(7.3)	6(5.4)	70(7.9)		
	Frequently	413(38.6)	58(51.8)	325(36.7)		
Drinking	Never	275(25.7)	27(24.1)	101(11.4)	14.838	**0.001**
	Occasionally	653(61.1)	57(50.9)	557(62.9)		
	Frequently	140(13.1)	28(25.0)	227(25.6)		
BMI	Normal	510(47.8)	9(8.2)	43(4.9)	4.595	0.204
	Underweight	52(4.9)	51(46.4)	425(48.1)		
	Overweight	373(35.0)	42(38.2)	306(34.7)		
	Obesity	131(12.3)	8(7.3)	109(12.3)		
Central obesity	No	517(48.4)	53(47.3)	442(50.0)	0.285	0.593
	Yes	552(51.6)	59(52.7)	442(50.0)		
WHR		0.89(0.84-0.93)	0.90(0.84-0.93)	0.89(0.84-0.93)	-1.144	0.265
Blood pressure (mmHg)	SBP	131(121-144)	135(125-149)	130(1231-143)	-2.966	**0.003**
	DBP	77(70-85)	79(74-88)	77(70-85)	-2.510	**0.012**
Blood lipid (mmol/L)	TG	1.39(0.91-2.07)	1.32(0.87-2.11)	1.40(0.91-2.08)	-0.444	0.657
	TC	5.37(4.72-6.07)	5.56(4.82-6.40)	5.36(4.72-6.01)	-2.017	**0.044**
	LDL-C	3.12(2.56-3.75)	3.39(2.58-4.07)	3.10(2.54-3.69)	-2.558	**0.011**
	HDL-C	1.27(1.09-1.47)	1.26(1.07-1.53)	1.28(1.09-1.47)	-0.008	0.994
Blood sugar (mmol/L)	FPG	5.06(4.70-5.50)	5.10(4.76-5.54)	5.04(4.70-5.49)	-0.373	0.709
	OGTT	6.10(5.10-7.50)	6.30(5.37-7.49)	6.08(5.00-7.50)	-1.001	0.317
	HbA1c (%)	5.50(5.30-5.90)	5.60(5.30-5.80)	5.50(5.30-5.90)	-0.316	0.752
Blood uric acid (umol/L)		406.0(345.0-475.5)	394.0(331.0-476.5)	406.0(345.0-475.0)	-0.942	0.346
Alt (U/L)		20.0(15.0-29.0)	20.0(15.0-30.5)	20.0(15.0-29.0)	-0.385	0.701

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Cr (umol/L)		108.0(101.0-11.6)	110.0(100.0-119.0)	108.0(101.0-116.0)	-1.270	0.204
Erectile dysfunction	No	899(83.94)	77(68.75)	764(86.23)	21.619	**<0.001**
	Yes	172(16.06)	35(31.25)	122(13.77)		

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Notes: BMI, Body mass index (kg/m^2); WHR, waist hip ratio; SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); TG, triglycerides (mmol/L); TC, total cholesterol (mmol/L); LDL-C, low-density lipoprotein cholesterol (mmol/L); HDL-C, high-density lipoprotein cholesterol (mmol/L); FPG, Measurements of fasting plasma glucose (mmol/L); OGTT, oral glucose tolerance test (mmol/L); HbA1c, HemoglobinA1c (%); ALT, alanine aminotransferase (U/L); Cr	Notes: BMI, Body mass index (kg/m^2); WHR, waist hip ratio; SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); TG, triglycerides (mmol/L); TC, total cholesterol (mmol/L); LDL-C, low-density lipoprotein cholesterol (mmol/L); HDL-C, high-density lipoprotein cholesterol (mmol/L); FPG, Measurements of fasting plasma glucose (mmol/L); OGTT, oral glucose tolerance test (mmol/L); HbA1c, HemoglobinA1c (%); ALT, alanine aminotransferase (U/L); Cr	Notes: BMI, Body mass index (kg/m^2); WHR, waist hip ratio; SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); TG, triglycerides (mmol/L); TC, total cholesterol (mmol/L); LDL-C, low-density lipoprotein cholesterol (mmol/L); HDL-C, high-density lipoprotein cholesterol (mmol/L); FPG, Measurements of fasting plasma glucose (mmol/L); OGTT, oral glucose tolerance test (mmol/L); HbA1c, HemoglobinA1c (%); ALT, alanine aminotransferase (U/L); Cr	Notes: BMI, Body mass index (kg/m^2); WHR, waist hip ratio; SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); TG, triglycerides (mmol/L); TC, total cholesterol (mmol/L); LDL-C, low-density lipoprotein cholesterol (mmol/L); HDL-C, high-density lipoprotein cholesterol (mmol/L); FPG, Measurements of fasting plasma glucose (mmol/L); OGTT, oral glucose tolerance test (mmol/L); HbA1c, HemoglobinA1c (%); ALT, alanine aminotransferase (U/L); Cr	Notes: BMI, Body mass index (kg/m^2); WHR, waist hip ratio; SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); TG, triglycerides (mmol/L); TC, total cholesterol (mmol/L); LDL-C, low-density lipoprotein cholesterol (mmol/L); HDL-C, high-density lipoprotein cholesterol (mmol/L); FPG, Measurements of fasting plasma glucose (mmol/L); OGTT, oral glucose tolerance test (mmol/L); HbA1c, HemoglobinA1c (%); ALT, alanine aminotransferase (U/L); Cr	Notes: BMI, Body mass index (kg/m^2); WHR, waist hip ratio; SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); TG, triglycerides (mmol/L); TC, total cholesterol (mmol/L); LDL-C, low-density lipoprotein cholesterol (mmol/L); HDL-C, high-density lipoprotein cholesterol (mmol/L); FPG, Measurements of fasting plasma glucose (mmol/L); OGTT, oral glucose tolerance test (mmol/L); HbA1c, HemoglobinA1c (%); ALT, alanine aminotransferase (U/L); Cr	Notes: BMI, Body mass index (kg/m^2); WHR, waist hip ratio; SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg); TG, triglycerides (mmol/L); TC, total cholesterol (mmol/L); LDL-C, low-density lipoprotein cholesterol (mmol/L); HDL-C, high-density lipoprotein cholesterol (mmol/L); FPG, Measurements of fasting plasma glucose (mmol/L); OGTT, oral glucose tolerance test (mmol/L); HbA1c, HemoglobinA1c (%); ALT, alanine aminotransferase (U/L); Cr

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Table 2 The association of erectile dysfunction and risk of osteoporosis
Models
Model [a] 1
Model [a] 2
Model [a] 3
Model [a] 4
Data are ORs (95%CI). Participants without osteoporosis are defined as 0 and with osteoporosis as 1. Model [a] 1 is unadjus

Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis
Models	AUC (95%CI)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	P-value (Ref: Model 1)	P-value (Ref: Model 2)
Model 1	0.70(0.65-0.75)	87.6	42.7	16.4	96.4	-	-
Model 2	0.72((0.67-0.78))	74.3	64.0	20.9	95.1	0.050	-
Model 3	0.73(0.68-0.79)	73.3	66.3	21.8	95.1	**0.017**	0.155

Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis
Model 1 including age, education, smoking, drinking, SBP, neck circumference, BMI and heart rates; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C and FPG; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C, FPG and ED; Notes: SBP, systolic blood pressure (mmHg); BMI, body mass index (kg/m^2);	Model 1 including age, education, smoking, drinking, SBP, neck circumference, BMI and heart rates; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C and FPG; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C, FPG and ED; Notes: SBP, systolic blood pressure (mmHg); BMI, body mass index (kg/m^2);	Model 1 including age, education, smoking, drinking, SBP, neck circumference, BMI and heart rates; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C and FPG; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C, FPG and ED; Notes: SBP, systolic blood pressure (mmHg); BMI, body mass index (kg/m^2);	Model 1 including age, education, smoking, drinking, SBP, neck circumference, BMI and heart rates; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C and FPG; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C, FPG and ED; Notes: SBP, systolic blood pressure (mmHg); BMI, body mass index (kg/m^2);	Model 1 including age, education, smoking, drinking, SBP, neck circumference, BMI and heart rates; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C and FPG; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C, FPG and ED; Notes: SBP, systolic blood pressure (mmHg); BMI, body mass index (kg/m^2);	Model 1 including age, education, smoking, drinking, SBP, neck circumference, BMI and heart rates; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C and FPG; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C, FPG and ED; Notes: SBP, systolic blood pressure (mmHg); BMI, body mass index (kg/m^2);	Model 1 including age, education, smoking, drinking, SBP, neck circumference, BMI and heart rates; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C and FPG; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C, FPG and ED; Notes: SBP, systolic blood pressure (mmHg); BMI, body mass index (kg/m^2);	Model 1 including age, education, smoking, drinking, SBP, neck circumference, BMI and heart rates; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C and FPG; Model 2 including age, education, smoking, drinking, SBP, neck circumference, BMI, heart rates, LDL-C, FPG and ED; Notes: SBP, systolic blood pressure (mmHg); BMI, body mass index (kg/m^2);

Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis	Table 3 Comparison of different models with or without ED for assessing osteoporosis