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Original Article

Analysis of factors associated with the lumbar spine and proximal femur bone mineral density of coal miners

Sijie Kuang[1*], Wei Huang[1*], Na Han[1], Shouling Wu[2], Baoguo Jiang[1], Tianbing Wang[1]

[1]Department of Trauma Orthopedics, Peking University People's Hospital, Beijing 100044, China; [2]Department of Cardiology, Affiliated Kailuan Hospital of Hebei Union University, Tangshan 063000, China. [*]Equal contributors.

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Abstract: Objective: Chinese coal miners were in a much worse occupational disease, they work underground during most of the daylight hours and are exposed to weight-bearing activity. But data concerning bone mineral density (BMD) and risk factors of BMD is lacking. We aim to identify the factors associated with low bone mineral density in coal miners. Methods: A sample of 1650 coal miners aged 30-60 years were recruited from the area of Tangshan city, located in Hebei province of China, from May to November 2011. Measurements were taken at the lumbar spine and proximal femur using DXA (OSTEOCORE-2 Vision, Medilink, France). Demographic, lifestyle, physical and occupational characteristics were collected through standardized questionnaires. Univariate, multivariate and Multiple regression were performed. Results: We found that 9.7% miners older than 50 were osteoporotic and 36.2% were osteopenia at the lumbar spine; 0.76% miners were osteoporotic and 25.4% were osteopenia at the femoral neck. Lumbar spine and femoral neck BMD correlated significantly with weight, BMI, years of work. Age was negatively correlated with femoral neck BMD. On multiple regression analysis, BMI was found to be the only independent predictor of lumbar spine BMD, whereas both BMI and years of work were found to be the independent predictors of femoral neck BMD. Conclusion: Advancing age, low BMI and longer years of work, low calcium supplements intake, less time of sun exposure, smoking and drinking history are risk factors for low BMD of coal miners in China.

Keywords: Bone mineral density, osteopenia, osteoporosis, coal miners

Introduction

In China, there are more than 15,000 coal mines and 5.5 million coal miners [1], predominantly male, who are the main labor force of family and society. They work underground during most of the daylight hours and are exposed to weight-bearing activity. The work environment is tough: hypoxia, wet, insufficient sunshine or air contaminated by organic gases or coal dust [2]. Conventional risk factors for osteoporosis include advancing age [3-5], low body mass index (BMI) [6, 7], physical inactivity [8, 9], low calcium intake [10], low vitamin D status [11] and so on. In the light of this, it might be expected that working underground will be associated with an increased risk of low bone mineral density. Thus, understanding bone mineral density (BMD), incidence of osteoporosis of the miners and what factors are associated with low BMD has important clinical and social significance.

Osteoporosis is characterized by the reduction of bone mineral density , associated with skeletal fragility, and an increased risk of fracture [12]. Dual energy X-ray absorptiometry (DXA) is the most commonly used method to measure BMD at the lumbar spine and proximal femur. BMD is the gold standard in the diagnosis of osteoporosis using DXA [13, 14]. The definition of osteoporosis has been set by World Health Organization (WHO) based on a measurement in postmenopausal women [15]: osteoporosis is defined as BMD more than 2.5 standard deviation (SD) below the mean for young adult women (T-score ≤ -2.5). Osteopenia is defined as BMD between 1.0 and 2.5 SD below the mean for young adult women (T-score > -2.5 and < -1.0). Although this guideline was estab-

lished for women, the diagnosis standard for osteoporosis has also been adapted to men [16].

This cross-sectional study was designed to examine demographic, physical and occupational characteristics and BMD of the coal miners; the association of these factors with bone mineral density (BMD) among coal miners in the Tangshan city.

Materials and methods

Design

A cross-sectional study was conducted in the Tangshan city (39.6° north latitude, 118.1° east longitude), Hebei province, from May to November, 2011.

Subjects

We investigated 1800 coal miners who attended the annual physical examination in Tangshan city of Hebei province in China. The subjects were volunteers aged between 30 and 60 years. Inclusive Criteria: (1) Male coal miners; (2) Men agreed to sign informed consent and be scanned for BMD estimation. Exclusive Criteria: (1) Men who had been diagnosed with endocrine system diseases or immune system diseases, such as hyperthyroidism or hyperparathyroidism, rheumatoid arthritis; (2) Those who had been suffered from gastrointestinal or renal diseases that affecting the absorption and regulation process of calcium and vitamin D; (3) Those who had gone through gastrectomy or intestinal resection; (4) Those who had been diagnosed with malignant tumors, for example multiple myeloma; (5) Subjects who had been using steroid hormones for more than 6 months.

Structured interview

After the assessment of eligibility, written informed consents were collected from eligible miners regarding participation in the study, standardized questionnaires designed to document putative risk factors of osteoporosis were completed. The height and weight of subjects were measured, and the body mass index (BMI) was calculated by dividing the body weight (kg) by the height squared (m^2). Personal data were collected by individual interviews, such as age, medical history, tobacco history, alcohol use, milk intake, calcium supplements intake, vitamin D supplements intake (Yes/No) (based on 1 month prior to the interview). A smoker was defined as a current smoker regardless of amount, and a drinker was defined as one who drinks more than twice a week irrespective of the type of drink. Occupational characteristics were assessed by collecting information on years of underground work. The men were also asked about history of traumatic fractures (Yes/No). Finally, patients were categorized as high and low time of sun exposure (more than 30 min/day, below 30 min/day, respectively); high and low milk intake (more than 250 ml/day, below 250 ml/day, respectively); high and low calcium supplements intake (more than 600 mg/day, below 600 mg/day, respectively).

BMD measurement

BMD of the anteroposterior spine (L1-4) and the left hip (femoral neck, the greater trochanter, intertrochanter, total hip) was measured by DXA (OSTEOCORE-2, Vision by DXA, Medilink, France and the version of the software was V2.0.0.7 2001-10-27/H0 0 SN:C11 015M 167, France MEDILINK, France). BMD was expressed in g/cm^2. The coefficient of variation (CV) of the technique at our institution was 0.6%, we used a phantom to measure everyday during our study. The Chinese male normative database provided by the manufacturer was used for T-score calculation. Participants who were older than 50 years were categorized by the T-score of the L1-4 lumbar spine or femoral neck. Measurements were made by well trained technicians, and all scans were analyzed by a single researcher using standardized procedures as MEDILINK User Manual.

Statistical analysis

Results are presented as means (SD) and categorical variables are expressed as frequencies. Associations between continuous variables were examined by Pearson correlation. Furthermore, to illustrate the association between years of work and BMD, we used partial correlation, age and BMI as controlling factor. For categorical data, the Chi-square test was used for difference of distribution between groups. Multiple regression analyses were used to quantify the predictors of lumbar spine and femoral neck BMD. Variables which showed significance on univariate analysis were included as independent variables in the regression model, and the final regression model was

Table 1. General characteristics of the subjects (N=1650)

Characteristics	n (%)
Age: mean (SD) (years)	47.8 (4.5)
Height: mean (SD) (cm)	170.7 (5.2)
Weight: mean (SD) (kg)	73.2 (9.9)
Body mass index: mean (SD) (kg/m^2)	25.1 (3.0)
L1-4 BMD: mean (SD) (g/cm^2)	0.920 (0.13)
FN-BMD: mean (SD) (g/cm^2)	0.868 (0.11)
TH-BMD: mean (SD) (g/cm^2)	0.997 (0.12)
Years of work: mean (SD) (years)	27.6 (5.6)
Low time of sun exposure/day: n (%)	1485 (90)
Current smoking: n (%)	813 (49.3)
Current drinking: n (%)	714 (43.2)
Low milk intake: n (%)	1301 (78.9)
Low calcium supplements intake: n (%)	1530 (92.7)
Vitamin D supplements intake: n (%)	182 (11)
History of traumatic fractures	234 (14.2)
Hypertension: n (%)	777 (47.1)

BMI, body mass index; L1-4 BMD: lumbar 1-4 BMD; FN-BMD: femoral neck BMD; TH-BMD: total hip BMD.

Table 2. Correlations between bone mineral density and other characteristics

	Lumbar spine BMD		Femoral neck BMD	
	r	p	r	P
Age (years)	-0.026	0.292	-0.116	0.000
Weight (Kg)	0.155	0.000	0.194	0.000
BMI (kg/m^2)	0.108	0.000	0.177	0.000
Years of work	-0.023	0.345	-0.134	0.000

Correlation coefficients were calculated by Pearson correlation.

selected by stepwise selection. The entry of significance level (*p* value) was set to 0.10 to arrive at the most robust model. The level for significance was taken as $P \leq 0.05$. SPSS 17.0 were used for statistical analysis.

Ethics statement

The process and content of the study were approved by the Ethics Committee of Peking University People's Hospital. Signed informed consent was obtained from each participant prior to the interviews and scanning for BMD estimation. Each of the participants had the discretion to freely decline or with draw from this survey at any point of time. The filled-in questionnaires, written consent documents and computerized data were properly secured.

Results

The general characteristics of the participants are shown in **Table 1**. The study final population consisted of 1650 individuals, ranging from 30 to 60 years. The mean and standard deviation of age was 47.8±4.5 years. Their mean value for BMI and years of working underground was 25.1±3.0 kg/m^2 and 27.6±5.6 years. The mean BMD level for the lumbar spine was 0.920±0.13 g/cm^2, and 0.868±0.11 g/cm^2 for the femoral neck. Of all the participants, 90% were low time exposure to sunlight; 78.9% were low milk intake; 92.7% were low calcium supplements intake; 11% had vitamin D supplements intake and 14.2% had traumatic fractures history.

Frequency of osteoporosis in miners older than 50

There were 528 individuals older than 50. According to the WHO standards, based on lumbar spine BMD, 9.7% (51/528) were osteoporotic and 36.2% (191/528) were osteopenia at the lumbar spine; 0.76% (4/528) were osteoporotic and 25.4% (134/528) were osteopenia at the femoral neck.

*Correlation between bone mineral density parameters and the variables (**Table 2**)*

Associations between variables and BMD parameters were examined by Pearson correlation. As expected, age was negatively associated with BMD at femoral neck ($r=-0.116$, $P < 0.001$), however, there was no significant linear correlation between age and lumbar spine BMD ($r=-0.026$, $P=0.292$). There was a positive correlation between weight, BMI and BMD of femoral neck and lumbar spine. Also, the Pearson correlation showed significant negative correlation between years of work and FN-BMD ($r=-0.134$, $P < 0.001$). In addition, in partial correlation, age, BMI as controlling factors, there was still significant linear correlation between years of work and FN-BMD ($r=-0.07$, $P=0.004$).

*Comparison of variable values between the low BMD and normal group at lumbar spine among miners older than 50 (**Table 3**)*

There were 528 individuals older than 50. When subjects were divided according to lumbar spine BMD status, the low BMD subjects (contain osteoporosis and osteopenia) were found to have significantly lower weight and BMI than the normal subjects. And more of

Table 3. Comparison of characteristics between osteoporotic and normal subjects older than 50 years old at lumbar spine

	Lumbar spine BMD		P
	Low BMD (n=242)	Normal (n=286)	
Age (years)	52.06±1.56	52.03±1.54	0.8246
Weight	68.20±9.21	74.13±10.10	< 0.0001**
BMI (kg/m^2)	22.89±3.24	25.34±3.01	< 0.0001**
Years of work	29.52±2.98	29.12±3.57	0.1674
Low milk intake	201 (83.2%)	233 (81.4%)	0.6343
Low calcium supplements intake	230 (95.0%)	244 (85.3%)	0.0002**
Low time of sun exposure	228 (94.2%)	240 (83.9%)	0.0002**
VD supplements intake	17 (7.0%)	37 (12.9%)	0.0255*
History of traumatic fractures	40 (16.1%)	41 (14.3%)	0.4859
Working hours/week	44.20±3.0	44.2±3.3	> 0.9999
Current smoking	165 (68.2%)	114 (39.8%)	< 0.0001**
Current drinking	140 (57.9%)	91 (31.8%)	< 0.0001**

*P < 0.05; **P < 0.01. Comparisons were carried out using the t-test and the Chi-square test.

Table 4. Comparison of characteristics between low and normal BMD subjects older than 50 years old at femoral neck

	Femoral neck BMD		P
	Low BMD (n=138)	Normal (n=390)	
Age (years)	54.01±1.56	52.33±1.54	< 0.0001**
Weight	70.38±9.53	73.95±9.91	0.0003**
BMI (kg/m^2)	24.27±2.96	25.31±2.97	0.0004**
Years of work	28.77±3.81	27.37±3.33	< 0.0001**
Low milk intake	109 (78.9%)	292 (74.9%)	0.3312
Low calcium supplements intake	131 (94.9%)	339 (86.9%)	0.0098**
Low time of sun exposure	128 (92.8%)	347 (89.0%)	0.2042
VD supplements intake	15 (10.9%)	47 (12.6%)	0.7109
History of traumatic fractures	19 (13.8%)	56 (14.6%)	0.8643
Working hours/week	44.4±3.0	44.1±3.5	0.3702
Current smoking	79 (57.2%)	171 (43.8%)	0.0067**
Current drinking	56 (40.6%)	174 (44.6%)	0.4112

**P < 0.01. Comparisons were carried out using the t-test and the Chi-square test.

them smoked, drank, had low calcium supplements intake, VD supplements intake and low time of sun exposure/day.

*Comparison of variable values between the low BMD and normal group at femoral neck among miners older than 50 (**Table 4**)*

Only 4 miners were osteoporotic at femoral neck. The Chi-square test was used. The low BMD subjects were found to have significantly higher age, longer years of work and lower weight and BMI than the normal subjects. And more of them smoked and had low calcium supplements intake.

*Determinants of bone mineral density of coal miners (**Table 5**)*

Multiple regression stepwise forward analysis revealed that, years of work and BMI were the independent predictor of femoral neck BMD, whereas only BMI was the independent predictor of lumbar spine BMD.

Discussion

Compared to American, Chinese coal miners were in a much worse occupational disease status [1]. According to a 2003 government report, the coal miners' death rate per one million populations was about 37 times than that of America's coal-mining death rate [17, 18]. This study is an original contribution to the study of bone mineral density of coal miners in China.

BMD has been reported to be one of the important predictor of fracture risk. At the femoral neck, we found the miners' BMD declines with increasing age as several studies showed [4, 5, 19, 20]. The study of Zhang [19] reported that significant decrease was found in the femoral neck at the rate of 0.4% per year in healthy Chinese men, which is similar to our study (0.26% per year) (not showed in table). A few studies reported that lumbar spine BMD decreased [3, 5, 20] or increased [21] with aging, but in our study, there was no linear correlation between lumbar spine BMD and age, as the study of Zhang [19] and Zhu [4] in healthy Chinese men. The loss of bone mass observed with aging is due to increased osteoclast mediated bone resorp-

Table 5. Independent determinants of lumbar spine and femoral neck BMD

	Lumbar spine BMD		Femoral neck BMD	
	β	p	B	P
Age (years)	-	NS	-	NS
BMI (kg/m^2)	0.005	P < 0.01**	0.007	P < 0.01**
Years of work	-	NS	0.003	P < 0.01**
R^2	0.073		0.094	

**P < 0.01. Statistical analysis was carried out using multiple regression models.

tion, endocortical thinning, and increased cortical porosity when all those situation----osteopenia--- is not offset by new bone formation, a net loss of bone would show up.

We confirm that BMI is positively associated with BMD and show that low BMI is an indicator of osteoporosis in Chinese male coal miners. Some studies had suggested that BMI was one of the determining factors of bone density in men [22, 23]. Morin et al suggested that high BMD was closely associated with elevated BMI. Femoral neck density was significantly lower in the normal weight than in the overweight counterparts [24]. In another study of the Taiwan population, bone density of heel showed an association with BMI by multivariate analysis [25]. In our study, we find BMI is positively associated with BMD of spine and hip. By multiple regressions stepwise forward analysis, BMI is the independent predictor of femoral neck BMD and lumbar spine BMD. Due to coal miners working environment is poor; they are vulnerable to injury or fracture, so the participants could not be too thin.

The impact of calcium supplements intake on BMD is also controversial. Some studies did not find an independent association at either BMD sites [26, 27], whereas others found a positive association with calcium intake (dietary and/or supplements) [28, 29].

In a controlled study [30], the author found the miners working underground had lower 25-hydroxyvitamin D, but had higher lumbar spine and femur BMD, underground physical working didn't seem to be a significant risk factor for low BMD values. Compared with Sarikaya S' study [30], the sample size of our study is larger and the miners are older, have worked longer underground. Conversely, we have different results. We find that working underground is a risk factor for femoral neck BMD. In the multiple linear regression analysis, Years of work is an independent predictor of BMD of femoral neck. After adjustment of age and BMI, Years of work is negatively correlated with femoral neck BMD (r=-0.07, P=0.004). We suppose that this may be related with less sunlight exposure and lower serum 25-hydroxyvitamin D. Enough sunlight and increased vitamin D intake were reasonable approaches to guarantee vitamin D sufficiency [31]. At lumbar spine, the miners who were in Low BMD had shorter sun exposure. Disappointedly, few of them took vitamin D supplements, but there was still difference between normal and low BMD of lumbar spine subjects. As recommended, RDAs of 600 IU/d vitamin D was needed for person aged 1-70 yrs [32].

Smoking, particularly in current smokers, has been reported to be negatively correlated with BMD changes in men [27, 33-35], and the deleterious effect of smoking on bone health is stronger in lean smokers than in smokers with high fat mass [36]. Such mechanisms include alterations in intestinal calcium absorption, calciotropic hormone metabolism and dysregulation in sex hormone production and metabolism, alterations in adrenal cortical hormone metabolism [37]. In terms of alcohol intake, the results have been reported conflicted. Nguyen TV [38] and Eleftheriou KI [39] reported moderate alcohol consumption was associated with greater BMD. Alcohol abuse reduced bone mineral density partly, and had indirect effects on endocrine system, cytokine system, vitamin D levels [40]. The influence of alcohol drinking on BMD may depend upon age and the amount, the kind of alcohol consumed. Smoking and alcohol use were frequent and serious in coal miners. In the present study, at lumbar spine, a significant difference was observed between low BMD and normal subjects in terms of current smoking and drinking; at femoral neck, a significant difference was observed between low BMD and normal subjects in terms of current smoking.

This present study is the first large scale report on the BMD of the lumbar spine and hip of coal miners in China. We noted that the incidence of lumbar osteoporosis, osteopenia was significantly higher than that of femoral neck (9.7% VS 0.76%; 36.2% VS 25.4%) and nearly half

miners' lumbar BMD is below normal (45.8%). Further analysis, the four osteoporotic miners of femoral neck all older than 50, this phenomenon suggests that we should pay attention to older miners' bone health. Low body mass index and advancing age are risk factors of low BMD of lumbar spine and of femoral neck. In a study of healthy Shanghai men [19], between 50-59 years old, prevalence of osteoporosis and osteopenia of L1-4 was 4.2% and 21.4%, which is lower than our study (9.7% and 36.2%); prevalence of osteoporosis and osteopenia of femoral neck is 1.5% and 42.4%, which is higher than our study (0.76% and 25.4%). In another Hong Kong study of Chinese men [41], the prevalence of osteoporosis in lumbar spine in the groups of aged 40-59 years was 2%. In Korean men, between 40-60 years the prevalence of osteoporosis and osteopenia of lumbar is similar to our study, but prevalence of osteopenia of femoral neck is apparently lower than our research [42]. This variation may be caused by different DXA machines or whether a local-derived reference or a manufacturer-provided reference is used [43, 44]. Also, this variation may be caused by the miners' work. Mostly the work of miners is weight-bearing, they often work bending or squatting, the activity of hip is more; the activity of waist is relatively less.

There are some limitations to our study. The population is composed of middle-aged men, but studies suggest that in men bone loss accelerates after the age of 70 years [45]. So, the influence of underground working on bone mineral density may not fully manifest. Also, the workers didn't have dinner at same place, and the diet composition varied, we didn't accurately calculate the amount of calcium intake. The third, there was no control group of subjects who had similar demographic profile and worked above ground. However, the main purpose of the study is to examine BMD and analyze the association of anthropometric factors, lifestyles with bone mineral density of coal miners in china, those limitations can be improved in future research. In the other hand, our study is the first large sample to report BMD and risk factors of low BMD in miners, which is of great importance for the diagnosis and treatment of osteoporosis in coal miners.

In conclusion, age and years of work, BMI, calcium supplements intake, time of sun exposure, smoking, drinking history were found to be significantly correlated with the BMD values of the miners. So suggestions are as follows: Firstly, workers who are older or work longer should be rotated to work above ground, particularly osteoporosis miners. Secondly, when we are hiring workers, we can't choose the workers who are too thin. Thirdly, the workers should keep healthy life habits, avoid smoking or drinking and have enough calcium supplements intake, sun exposure.

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Disclosure of conflict of interest

None.

Address correspondence to: Drs. Tianbing Wang and Baoguo Jiang, Department of Trauma and Orthopedics, Peking University People's Hospital, Beijing 100044, China. Tel: +86-10-88326550; E-mail: wangtianbing@medmail.com.cn (TBW); Tel: +86-10-88326250; Fax: +86-10-88326252; E-mail: jiangbaoguo@vip.sina.com (BGJ)

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