Prevalence and contributing factors of osteoporosis in the elderly over 70 years old: an epidemiological study of several community health centers in Shanghai

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Background: OP seriously affects the health status and quality of life of the elderly, even endangers life. This study aimed to investigate the prevalence and contributing factors of osteoporosis (OP) in the elderly over 70 years old of several Community Health Centers in Shanghai.

Methods: A total of 565 elderly subjects were recruited and received questionnaire survey. The general characteristics, medical history and history of OP treatment were collected. Bone mineral density (BMD) was detected, and the awareness rate, prevalence and treatment rate were determined in all of the subjects. Moreover, activity of daily living and nutritional status were also evaluated. Logistic regression analysis was performed to calculate the OR and its 95% confidence interval. Bone turnover markers (BTMs) [procollagen type 1 N-peptide (P1NP), C-terminal cross-linked telopeptides of type 1 collagen (β-CTX), molecular fragment of N-terminal osteocalcin (N-MID), and 25 hydroxyvitamin D (25OHD)] were detected and their relationship with OP was further evaluated with Pearson correlation analysis.

Results: (I) The awareness rate of OP was 89.7%, the prevalence was 39.5%, and the treatment rate was 59.5% in the elderly over 70 years old of 4 Community Health Center in Shanghai; (II) the male gender and good nutritional status were independent protective factors of OP, and aging and poor activity of daily living were independent risk factors of OP; (III) β-CTX was negatively related to BMD (r=−0.286, P=0.000), but P1NP, N-MID, and 25OHD were positively related to BMD (r=0.254, 0.349 and 0.357, P=0.000, 0.000 and 0.000).

Conclusions: Female gender, aging, malnutrition, and inability to take care of themselves are risk factors of OP in people over 70 years old of 4 Community Health Centers in Shanghai. Some BTMs are related to the BMD. BTMs together with BMD may be used to comprehensively evaluate the bone state, identify the old people with OP at early stage, and guide the clinical treatment and early monitoring of OP.

Keywords: Elderly; osteoporosis (OP); epidemiology; risk factors; bone turnover markers (BTMs)

Introduction

Osteoporosis (OP) is characterized by the decreased bone mass and destruction of the bone microstructure, which may increase the bone fragility and cause the susceptibility to fracture (1). The senile OP generally refers to the primary OP that occurs after the age of 70. The typical clinical manifestations of senile OP are the pain, shortened height, kyphosis, bone fracture and respiratory disorder. Senile OP is the main cause of bone fracture in the elderly. It seriously affects the health status and quality of life of the elderly, even endangers life, and increases the medical burden to society and families.

With the increasing emphasis on the OP in the communities in recent years, most of the elderly in Shanghai have adopted some measures to prevent OP. In the past 10 years, the life expectancy of the elderly in Shanghai increases over year. In the present study, the epidemiological characteristics of OP were investigated in the old people of community health service centers in Shanghai, aiming to understand the current knowledge, prevalence and treatment of OP in Shanghai.

Methods

General information

A total of 565 subjects no younger than 70 years were randomly recruited from four Community Health Centers (Yuyuan Community Health Center in Huangpu District, Laoximen Community Health Center in Huangpu District, Wusong Community Health Center in Baoshan District and Youyi Community Health Center in Boashan District) between Jul 2017 and Dec 2018. The inclusion criteria were as follows: (I) permanent residents of the local community; (II) no younger than 70 years; (III) normal ideation; (IV) cooperation with this study. Exclusion criteria were as follows: (I) severe heart, liver or renal dysfunction; (II) diagnosed with OP secondary to other diseases such as diabetes and hyperparathyroidism; (III) senile dementia or severe mental and neurological disease; (IV) a history of violent or pathological fractures. The project was authorized by the ethical committees of the Chinese Clinical Trial Registry, the number of the approval: ChiECRCT20190088. Informed consent was obtained from all the subjects before taking part. The general characteristics, BMD, history of treatment for OP, awareness rate of OP, prevalence of OP and treatment rate of OP were recorded.

Detection of BMD

Dual energy X-ray BMD detector (Hologc Discovery, USA) was employed to detect the BMD of the proximal femur and lumbar vertebrae at the anterior-posterior position. The BMD and T values were obtained: (I) T $\geq$–1.0, normal; (II) –2.5< T <–1.0, reduced bone mass; (III) T $\leq$–2.5, OP.

Assessment of activity of daily living

The activity of daily living (ADL) scale (2) was employed to assess the activity of daily living. The ADLs include daily self-care activities such as eating, dressing, bathing and toileting and mobility activities such as, transferring between the bed and a chair. The difficulty in performing these activities is classified into four grades (0, 5, 10 and 15): (I) >60, normal self-care activity; (II) 41–60, help requirement in the self-care activity; (III) 20–40, greatly depending on help in self-care activity; (IV) <20, functional defects) and the total score was 100.

Nutritional assessment

The mini nutritional assessment short-form (MNA-SF) (3) was used to assess the change in recent diet, the change in body weight within prior 3 months, physical performance, stress and acute disease, neuropsychiatric disease, body mass index (BMI) and calf circumference (CC), and the resultant scores were divided into favorable nutritional status ($\geq$24) and malnutrition (<24).

Detection of BTM

Fasting blood was collected from these subjects into a tube without any anticoagulant. 30 min later, the blood was centrifuged at 3,500 rpm/min for 10 min, and the serum was harvested. The contents of P1NP, β-CTX, N-MID and 25OHD in the serum were detected with an automatic electrochemiluminescence immunoassay analyzer (E601; Roche) and corresponding reagents.

Statistical analysis

Statistical analysis was done with SPSS version 21.0. Quantitative data are expressed as mean ± standard

Table 1 General characteristics of subjects in this study

Variables	Number	Percentage
Gender		
F	334	59.1
M	231	40.9
Age (yr)		
70–74	180	31.9
75–79	187	33.1
80–84	141	25.0
85–89	45	8.0
≥90	12	2.1
Therapeutic drugs*		
0	229	40.5
1	191	33.8
2	133	23.5
≥3	12	2.1
ADL		
Favorable self-care activities	409	72.4
Need help	108	19.1
Greatly need help	35	6.2
Functional defects	13	2.3
MNA-SF		
Malnutrition	58	10.3
Favorable nutritional status	507	89.7
OP		
No	342	60.5
Yes	223	39.5

*, inclusion of OP-related drugs (such as calcium, active vitamin D, bisphosphonate and calcitonin). OP, osteoporosis; ADL, activity of daily living.

Table 2 The self-care activities in the elderly with and without OP

Performance of self-care activities	OP	
	Yes	No
Favorable self-care activities (n)	127	282
Need help in self-care activities (n)	58	50
Greatly need help in self-care activities (n)	26	9
Functional defects (n)	12	1
χ^2	54.241	
P	0.000	

OP, osteoporosis.

Table 3 The nutritional status in the elderly with and without OP

Nutritional status	OP	
	Yes	No
Malnutrition (n)	42	16
Good nutritional status	181	326
χ^2	29.363	
P	0.000	

OP, osteoporosis.

Results

General characteristics

Among these 565 subjects, there were 231 males and 334 females with a mean age of 81.2±6.8 years (range, 70–95 years). The awareness rate was 89.7% (507/565). Based on the BMD, 223 subjects were diagnosed with OP and the prevalence of OP was 39.5%. In addition, 336 subjects received treatment for OP (59.5%). According to the ADL scores, serious functional defects was noted in 13 subjects (2.3%), 35 subjects greatly needed help in the self-care activities (6.2%), 108 subjects needed help in the self-care activities (19.1%) and 409 subjects had favorable self-care activities (72.4%). Favorable nutritional status was noted in 507 subjects and malnutrition was found in 58 subjects (*Table 1*).

Correlation between ADL and OP

The prevalence of OP was significantly different among

deviation ($\overline{x}$±s), and qualitative data as number or percentage. Comparisons between two groups were done with independent sample *t* test or Chi square test. A value of P<0.05 was considered statistically significant. Multivariable analysis was done with Logistic regression analysis, and Pearson analysis was employed to assess the relationship between BTMs and BMD.

Table 4 Factors related to OP (multivariable Logistic regression analysis)

Variables	β	S.E.	Wald	P	Exp (β)	95% CI
Male	−0.539	0.195	7.629	0.006	0.584	0.398–0.855
Age (yr)			14.095	0.007		–
75–79	0.510	0.239	4.566	0.033	1.666	1.043–2.660
80–84	0.811	0.266	9.275	0.002	2.250	1.335–3.792
85–89	1.165	0.414	7.913	0.005	3.205	1.424–7.215
≥90	2.264	1.128	4.032	0.045	9.624	1.056–87.738
ADL			11.507	0.009		–
Need help	0.578	0.244	5.628	0.018	1.783	1.106–2.875
Greatly need help	1.005	0.463	4.713	0.030	2.732	1.103–6.771
Functional defects	2.250	1.083	4.319	0.038	9.491	1.137–79.251
MNA-SF						–
Good nutritional status	−1.169	0.334	12.223	0.000	0.311	0.161–0.598
Constant	0.094	0.370	0.065	0.799	1.099	–

OP, osteoporosis; ADL, activity of daily living.

Table 5 BTM in the elderly with and without OP ($\bar{x}$±s)

Group	P1NP (ng/mL)	β-CTX (ng/mL)	N-MID (ng/mL)	250HD (ng/mL)
OP	46.33±37.76	0.66±0.24	8.51±3.21	6.66±1.67
Non-OP	77.03±51.02	0.46±0.18	22.24±16.20	12.31±7.14
t	−5.21	6.81	−9.64	−8.90
P	0.000	0.000	0.000	0.000

BTM, bone turnover marker; OP, osteoporosis; P1NP, procollagen type 1 N-peptide.

the elderly with different self-care activities (χ^2=54.241, P=0.000) (*Table 2*).

Correlation between MNA-SF and OP

The prevalence of OP was markedly different between the malnutrition people and the people with good nutritional status (*Table 3*).

Risk factors of OP

OP was used as a dependent variable, and gender, age, ADL score, and MNA-SF as independent variables for Logistic regression analysis of risk factors of OP with α=0.05. Results showed male gender and good nutritional status were independent protective factors of OP and advancing age

and poor self-care activities were independent risk factors of OP (*Table 4*).

BTM in the elderly with and without OP

The β-CTX level in OP group was significantly higher than in non-OP group (t=6.81, P<0.05). The levels of P1NP, N-MID and 25OHD in the OP group were significantly lower than in the non-OP group (t=−5.21, −9.64 and −8.90; P<0.05) (*Table 5*).

Correlation between BTM and BMD

Pearson analysis showed β-CTX level was negatively related to the BMD (r=−0.286, P=0.000) and the levels of P1NP, N-MID and 25OHD were positively related to the BMD

Table 6 Correlation between BTM and BMD

BTMs	r	P
P1NP	0.254	0.000
β-CTX	−0.286	0.000
N-MID	0.349	0.000
250HD	0.357	0.000

BTM, bone turnover marker; BMD, bone mineral density; PP1NP, procollagen type 1 N-peptide.

(r=0.254, 0.349 and 0.357, P<0.05) (*Table 6*).

Discussion

Our results showed the awareness rate of OP was 89.7% in the elderly aged 70 or older, which was significantly higher than previously reported (50.9%) (4); the prevalence of OP was 39.5%, which was similar to previously reported (4). In addition, the treatment rate of OP was 59.5%, which was significantly higher than 20% reported by Bian *et al.* (5). These may be ascribed to the routine and regular health education in the communities of Shanghai and the increased education level.

Li *et al.* (6) found the prevalence of OP was comparable between males and females, but Zhang *et al.* (7) reported that the prevalence of OP in females was higher than in males of the same age group. It is indicated that the controversy about the influence of gender on prevalence of OP. In the present study, multivariate logistic regression analysis showed the prevalence of OP in females increased as compared to males (P=0.006, OR =0.584), suggesting that female gender is an independent risk factor of OP in the elderly. This may be related to the reduction of estrogen after menopause in females. In addition, the risk for OP in the elderly aged 75–79 years (P=0.033, OR =1.666), 80–84 years (P=0.002, OR =2.250), 85–89 years (P=0.005, OR =3.205) and ≥90 years (P=0.045, OR =9.624) increased as compared to the elderly aged 70–74 years, suggesting that the advancing age is also a risk factor of OP, which was consistent with the results of Mathieu *et al.* (8), who reported that the decreases in sex hormone and bone formation over age were associated with OP (9). At the same time, our study also showed the risk of OP in the elderly who need help, greatly need help or have functional defects, was 1.783, 2.732 and 9.491 times of that in the elderly with favorable self-care activities, which was consistent with the result reported by Chen *et al.* (10).

Studies have shown that the time and intensity of exercise will decrease with the decline of ADL in the elderly, and the appropriate weight-bearing and resistance exercise is beneficial to promote bone formation, reduce bone loss and avoid fragility fractures, and exercise is positively related to BMD (11,12). The BMD reduces with the reductions in the time and intensity of exercise, resulting in OP. The reduction in the ADL may decline the time and intensity of exercise, and therefore reduces the BMD. The elderly with good nutritional status had lower risk of OP than those with malnutrition (P=0.000, OR =0.311), indicating that the better the nutritional status, the less likely the OP is, which is similar to the results reported by Heaney *et al.* (13). The prevalence of OP in the elderly increases with the decrease in the nutritional status, which may be ascribed to the decreased protein intake, vitamin D reduction and calcium deficiency (14). In the present study, participants were confined to the outpatients in the Community Health Service Centers, and thus there might be bias in the composition of subjects recruited; the intake of protein, vitamin D and calcium was not determined and thus we could not determine the relationship of them with the risk for OP. Further studies are needed to classify the role of different nutrients in the pathogenesis of OP.

The organic components of the bone are mainly composed of type I collagen (about 90%), bone binding protein (about 10%) and other trace proteins (15). After adulthood, the bone growth stops, but cellular activity (bone reconstruction) continues; there are still bone formation and resorption, which remains at a dynamic equilibrium. However, menopause and certain pathological processes may increase the bone resorption, leading to OP. BTMs reflect the functions of osteoblasts and osteoclasts. It has been confirmed that the compromised bone formation is the main cause of OP in the elderly (16). The bone metabolism in the elderly shows low-turnover, the bone formation and resorption are low, and the bone formation is significantly lower than the bone resorption.

At present, the BMD measured by the dual-energy X-ray absorptiometry is recognized by the international academic community as the gold standard for diagnosis of OP (17). However, X-ray bone absorptiometry has some disadvantages, such as radioactivity; the BMD values detected are affected by the instruments used for the measurement; the cost is relatively high; change in BMD is relatively lagging, and increase of bone density will be observed at about 2 years after anti-OP treatment. Clinically, the increase in fracture risk is not always

associated with the reduction in BMD, and BTMs have a good correlation with fracture risk (18), which can compensate for the disadvantages of BMD detection. The detection of BTMs has following advantages: the changes in BTMs after anti-absorption therapy can predict the risk for fracture (19); the changes in BTMs precede the change in BMD (20); BTMs can provide information about the therapeutic efficacy at about 3 months after anti-OP treatment (21); the detection is simple, easy, and acceptable.

In the organic components of bone matrix, type I collagen is synthesized by the osteoblasts. The N-terminal and C-terminal extensions of type I collagen are removed by special proteases, forming bone matrix. The N-terminal is P1NP. When the activity of osteoblasts is enhanced, the synthesis of procollagen increases, and the blood concentration of P1NP increases. The blood P1NP concentration may reflect the ability of osteoblasts to synthesize collagen, which is the basis for the assessment of osteoblast activity and bone formation (22,23). Our study showed that P1NP was significantly lower in the OP group than in the non-OP group, suggesting that elderly patients with OP had lower bone formation than the elderly without OP. In addition, BMD was positive related to P1NP, indicating that the reduction of BMD in the elderly is related to the reduction of bone formation.

β-CTX is a degradation product of type I collagen C-terminal peptide and is one of the most valuable markers for the assessment of osteoclast activity and bone resorption (24,25). Increased serum β-CTX indicates the increased bone resorption. Our study showed that β-CTX was elevated significantly in the OP group as compared to non-OP group. It is suggested that the bone resorption in elderly with OP is more evident than in those without OP. Moreover, there's a negative correlation between BMD and β-CTX, indicating that the decreased BMD in the elderly is related to the increased bone resorption. In the present study, we focused on the increased bone resorption in the OP elderly compared with non-OP elderly, and self-control was employed, which will be improved in our future studies.

Osteocalcin is a non-collagen bone matrix protein secreted by mature osteoblasts, and accounts for 25% of non-collagen components in the bone matrix and 2% of total bone protein. The serum osteocalcin is diverse in the form: about 1/3 is intact osteocalcin (i.e., full-length osteocalcin), 1/3 is N-terminal moderate molecular (N-MID) fragment of osteocalcin and 1/3 is short peptide. Due to the poor stability of the full-length osteocalcin, the temperature and time of storage will affect the experimental results. Therefore, serum N-MID is generally measured in clinical practice. Detection of N-MID is simple and rapid, and N-MID is also a specific biochemical indicator of bone formation. Our study showed N-MID level was significantly lower in the OP group than in the non-OP group, suggesting the elderly with OP have lower bone formation than the non-OP elderly. In addition, BMD is positively related to N-MID, indicating that the reduction of BMD in the elderly is related to the reduction of bone formation.

The blood levels of biochemical indicators reflecting bone formation in our study were lower in the OP group than in the non-OP group, and the biochemical indicators reflecting bone resorption were higher in the OP group than in the non-OP group. In other words, the indicators reflecting bone formation reduced gradually but those reflecting the bone absorption increased gradually with the deterioration of OP, indicating the shift of bone reconstruction balance to a negative equilibrium. With the increase of age, the bone resorption is faster than the bone formation, and the bone reconstruction is in a negative balance, resulting in a gradual decrease in the bone mass and subsequent OP (26). BMD together with biochemical indicators of bone metabolism is better to reflect the bone state, and plays an important role in clinically guiding the targeted anti-OP treatment.

In patients with primary OP, there are dysfunction of vitamin D production and metabolism, resulting in a decrease in the active vitamin D. Although vitamin D does not directly reflect the activity of osteoblasts or osteoclasts, an *in vitro* study reported that vitamin D was able to promote the differentiation and maturation of precursor cells into osteoblast, induce the synthesis of osteocalcin in the osteoblasts, enhance alkaline phosphatase activity, and promote collagen production and insulin-like growth factors (25). In the present study, the blood 25OHD was significantly reduced in the OP group compared with the non-OP group, and the BMD was positively related to blood 25OHD, indicating that the decreased BMD in the elderly is associated with decreased bone formation.

In summary, female gender, advancing age, malnutrition, and poor self-care activities in daily living are independent risk factors of OP. To strengthen the community health education, increase nutrition intake and improve the self-care activities may be employed to prevent the occurrence of OP. In addition, P1NP, β-CTX, N-MID, 25OHD and BMD are related to the BMD, and can reflect the balance between osteoblast function and osteoclast function. BMD

together with BMD can be used to comprehensively assess the state of bone health, which is important for early identification of senile OP, guiding the clinical use of anti-OP treatment and monitoring of therapeutic efficacy.

Acknowledgments

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The project was authorized by the ethical committees of the Chinese Clinical Trial Registry, the number of the approval: ChiECRCT20190088. Informed consent was obtained from all the subjects before taking part.

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