CLINICAL ARTICLE

Low Grip Strength is a Strong Risk Factor of Osteoporosis in Postmenopausal Women

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Objective: To investigate the effect of grip strength on bone mineral density (BMD) in postmenopausal women. Low BMD is related to risk of fracture and falling is the strongest factor for fragility fractures. Handgrip strength is a reliable indicator of muscle strength and muscle strength is associated with falling.

Methods: For the present study 120 women were divided into two groups: those ≤65 years and those >65 years. Serum 25 hydroxyvitamin D (25OHD), BMD, and handgrip strength were measured to observe the effect of age on 25OHD, grip strength, and BMD, as well as the effect of 25OHD on grip strength and BMD. The correlation between grip strength and BMD was investigated.

Results: In the 120 patients, 25OHD was 24.31 ± 8.29 ng/mL. There were 37 cases with 25OHD <20 ng/mL and 83 cases with 25 OHD ≥20 ng/mL. The patients with 25OHD <20 ng/mL had significantly lower femoral neck BMD, most of them with a T score ≤−2.5 ($P < 0.05$). BMD measurement showed 66 patients with femoral neck T ≤−2.5, 30 cases with total hip T ≤−2.5 and 90 cases with lumbar BMD T ≤−2.5. The maximum grip strength in the group is 22.28 ± 6.17 kg. There were 38 cases with the maximum grip strength <20 kg and 82 cases with the maximum grip strength ≥20 kg. Patients >65 years had lower 25OHD, lower maximum grip strength, and lower BMD. The osteoporosis risk in postmenopausal women with a maximum grip strength <20 kg and who were >65 years was significantly elevated.

Conclusion: Handgrip strength and 25OHD decrease with aging in postmenopausal women. The patients with lower 25OHD level had significantly lower BMD of femoral neck. The patients with lower handgrip strength had significantly lower BMD of lumbar spine, femoral neck, and total hip. Grip strength measurement is the simplest muscle strength measurement method. Our study confirmed that low grip strength was correlated with low BMD and was a strong risk factor for osteoporosis in postmenopausal women.

Key words: 25 Hydroxyvitamin D; BMD; Grip strength; Postmenopausal women

Introduction

Postmenopausal women are a population vulnerable to osteoporosis, which is seriously complicated by fragility fractures. Common sites of fracture are at the spine, hip, and wrist. The incidence of these fragility fractures rises markedly with age. Hip fragility fracture is a severe complication of osteoporosis and is associated with high disability and mortality rates[1]. Osteoporosis is characterized by low bone mass and fractures. Although bone mineral density (BMD) measured by dual-energy X-ray absorptiometry (DXA) is the golden standard for the diagnosis of osteoporosis and the most widely used index for the assessment of fracture risk, the majority of patients who sustain a fracture have bone mineral density in the osteopenia range. Most patients who suffer from fragility fractures have a history of falling, and up to 95% of femoral neck factures are caused by falls[2]. BMD explains only a part of an individual's fracture risk and does not capture non-skeletal determinants of fracture risk,

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such as liability to fall. Based on the published literature on falls, Morrison *et al.* report that the annual prevalence rates of low-impact falls were 21.7%–62.5% in the elderly, and 86%–95% of fragility fractures were attributable to low-impact falls[2]. Therefore, falling is considered the most dangerous factor in fragility fractures. In addition, postmenopausal women generally suffer from vitamin D deficiency, which is detrimental to musculoskeletal health. 25 Hydroxyvitamin D (25OHD) is the best indicator of vitamin D status in humans. Lower 25OHD levels may play an important role in reduced muscle strength and increased falls. Lower 25OHD level is associated with lower BMD and a higher risk of fragility fracture. Vitamin D deficiency is one of the causes of osteoporosis and is also a risk factor for falling[3,4].

Muscle weakness, equilibrium disorder, and gait faults are the main predictors for falling. Muscle strength measurement is important for assessment of muscle function. Grip strength measurement is a simple and effective method for the assessment of muscle strength. Handgrip strength is also an effective index for the assessment of mobility and nutritional status in the elderly. Handgrip strength is inversely related to fracture risk, disability, and all-cause mortality but is positively related to bone mass and functional status in the elderly[5]. The serum 25OHD level decreases with the increase of age in postmenopausal women. Muscle strength, including handgrip strength, and BMD also decrease with the increase of age. These factors affect each; therefore, the muscle–bone relationship is worth examining. To understand the relationship between muscle and bone, and to recognize the strongest risk factor of osteoporosis among factors including age, 25OHD level, and handgrip strength, we performed a serum 25OHD test, and measured hand grip strength and BMD in postmenopausal women. We examined the effect of age on 25OHD, handgrip strength, and BMD, observed the influences of 25OHD on hand grip strength and BMD, and assessed the correlation of hand grip strength with BMD in postmenopausal women. The results are reported as follows.

Data and Methods

From January 2015 to October 2016, 120 postmenopausal women were enrolled in our study. The patients met the following inclusion criteria: (i) natural postmenopausal women; (ii) no previous osteoporosis treatment or vitamin D supplementation; (iii) no nervous system disease or external humeral epicondylitis affecting handgrip strength measurement; and (iv) effective cooperation with handgrip strength measurement. The patients' age ranged from 44 to 93 years, with an average of 65.55 ± 10.95 years. The patients were divided into two groups by age: 70 cases ≤65 years old and 50 cases >65 years old. All patients underwent the serum 25OHD test, DXA BMD measurement, and handgrip strength measurement.

Hydroxyvitamin D Test

Fasting venous samples of the patients were drawn in the morning. Serum concentration of 25OHD was measured using electrochemiluminescence assay kits on ROCHE Cobas e 601 analyzers with the reagent of vitamin D total manufactured by ROCHE. 25OHD ≥ 20 ng/mL is defined as normal.

Bone mineral density Measurement

The BMD measurement was performed in standard posture for the patients by DXA bone densitometer (Hologic Discovery A) with machine precision of <1% and coefficient of variation (%CV) of 0.25%. The BMD of femoral neck, total hip, and lumbar spine were taken. Based on BMD diagnosis criteria, T ≤ −2.5 SD indicates osteoporosis, −2.5 SD < T < −1 SD indicates osteopenia, and T ≥ −1 SD indicates normal BMD[3].

Handgrip Strength Measurement

The handgrip strength was measured for the patients using Jamar's hand held grip dynamometer (manufactured by Patterson Medical) after instructions were given. Handgrip strength was measured three times on each side with patients in the sitting position and elbow in 90° flexion. The maximum grip strength on the dominant side was taken as analytical data. The grip strength ≥20 kg is defined as normal.

Statistics Method

All data are statistically analyzed by SPSS 18.0 software. Measurement data is indicated by mean ± SD and *t*-tests are used to compare intergroup data. Variance analysis is used to make comparison among many groups and the test is used to make multiple intergroup comparisons. Pearson correlation is used to analyze single factor correlation between maximum grip strength and femoral neck BMD and lumbar BMD, respectively. Binary logistic regression analysis is used for multi-factor correlation of age, 25OHD, maximum grip strength, and femoral neck T, hip T, and lumbar T, respectively.

Results

Effect of Age on 25 Hydroxyvitamin D, Grip Strength, and bone mineral density

Maximum grip strength, 25OHD, and BMD of every part in postmenopausal women >65 years old are significantly lower than those in the group ≤65 years (Table 1).

Correlation of 25 Hydroxyvitamin D with Grip Strength and Bone Mineral Density

In the group, 25OHD was 6.32–52.23 ng/mL, with an average of 24.31 ± 8.29 ng/mL. There were 37 cases with 25OHD < 20 ng/mL and 83 cases with 25OHD ≥ 20 ng/mL. Patients with 25OHD < 20 ng/mL had lower femoral neck BMD and more femoral necks and total hips with T ≤ −2.5 SD ($P < 0.05$) than those with 25OHD ≥ 20 ng/mL. However, there was no significant difference between their maximum grip strength levels (Table 2).

TABLE 1 Effect of age on 25OHD, maximum grip strength, and BMD (mean ± standard deviation)

Groups	Number of cases	25OHD (ng/mL)	Maximum grip strength (kg)	Femoral neck BMD (g/cm^2)	Femoral neck T	Total hip BMD (g/cm^2)	Total hip T	Lumbar BMD (g/cm^2)	Lumbar T
≤65 years	70	25.96 ± 7.77	25.00 ± 4.63	0.61 ± 0.08	−2.12 ± 0.71	0.75 ± 0.08	−1.54 ± 0.66	0.72 ± 0.08	−3.03 ± 0.76
>65 years	50	22.48 ± 8.53	19.26 ± 6.29	0.52 ± 0.10	−2.99 ± 0.92	0.65 ± 0.13	−2.40 ± 1.08	0.67 ± 0.14	−3.36 ± 1.31
P		0.027	<0.001	<0.001	<0.001	<0.001	<0.001	0.031	0.05

BMD, bone mineral density; 25OHD, 25 hydroxyvitamin D.

TABLE 2 Effect of 25OHD on maximum grip strength and BMD (mean ± standard deviation)

Groups	*n*	25OHD (ng/mL)	Grip strength (kg)	Femoral neck BMD (g/cm^2)	Total hip BMD (g/cm^2)	Lumbar BMD (g/cm^2)	T ≤ −2.5 (femoral neck, *n*)	T ≤ −2.5 (total hip, *n*)	T ≤ −2.5 (lumbar, *n*)
25OHD < 20 ng/mL	37	14.91 ± 3.98	20.84 ± 7.55	0.5362 ± 0.1107	0.6781 ± 0.1362	0.6952 ± 0.1232	26	14	25
25OHD ≥ 20 ng/mL	83	28.50 ± 5.94	22.92 ± 5.38	0.5823 ± 0.0960	0.7158 ± 0.1102	0.6951 ± 0.1126	40	16	65
P			0.136	0.022	0.111	0.997	0.030	0.040	0.255

BMD, bone mineral density; 25OHD, 25 hydroxyvitamin D.

Bone Mineral Density Measurement

At femoral neck, BMD was 0.299–0.755 g/cm^2, with an average of 0.568 ± 0.103 g/cm^2, and T-score was −0.8 to −5.0, with an average of −2.54 ± 0.92. Fifty-four patients had a T-score > −2.5 SD and 66 patients had a T-score ≤ −2.5 SD. At total hip, BMD was 0.324–0.909 g/cm^2, with an average of 0.704 ± 0.120 g/cm^2 and T-score was −0.3 to −5.1, with an average of −1.95 ± 0.98. Ninety patients had a T-score > −2.5 SD and 30 patients had a T-score ≤ −2.5 SD. At the lumbar spine, BMD was 0.431–0.982 g/cm^2, with an average of 0.695 ± 0.115 g/cm^2, and T-score was −0.6 to −5.9, with an average of −3.18 ± 1.06. Thirty patients had a T-score > −2.5 SD and 90 patients had a T-score ≤ −2.5 SD.

Handgrip Strength Measurement

The maximum grip strength in the group was 6–34 kg, with an average of 22.28 ± 6.17 kg. There were 38 cases with a maximum grip strength <20 kg, and 82 cases with a maximum grip strength ≥20 kg. The results demonstrated by single factor Pearson correlation analysis that lower maximum grip strength was significantly correlated with lower BMD of femoral neck, total hip, and lumbar spine ($P < 0.001$). Multifactor binary logistic analysis demonstrated that the maximum grip strength <20 kg and age > 65 years old were risk factors for suffering from osteoporosis in postmenopausal women (Table 3).

TABLE 3 Multiple factor binary logistic analysis for age, maximum grip strength, 25OHD, and femoral neck, total hip, and lumbar T ≤ −2.5, respectively

Indexes		Number of cases	Total hip T		Femoral neck T		Lumbar T	
			P	*OR* (95% *CI*)	*P*	*OR* (95% *CI*)	*P*	*OR* (95% *CI*)
Age (years)	≤65	70	0.003	0.161(0.049–0.530)	0.048	0.386 (0.150–0.993)	0.062	2.644 (0.952–7.346)
	>65	50						
Maximum grip strength (kg)	<20	38	0.010	4.138 (1.406–12.180)	0.003	5.744 (1.837–17.959)	0.037	3.481 (1.081–11.209)
	≥20	82						
25OHD (ng/mL)	≥20	83	0.344	1.650 (0.585–4.650)	0.148	1.984 (0.784–5.025)	0.205	0.556 (0.224–1.379)
	<20	37						

25OHD, 25 hydroxyvitamin D.

Discussion

The study confirmed that 25OHD, maximum grip strength, and BMD of femoral neck, total hip, and lumbar spine in postmenopausal women aged >65 years were significantly lower than those in the group ≤65 years. The patients with 25OHD < 20 ng/mL had lower femoral neck BMD and more femoral necks and total hips with T ≤ −2.5 SD, and the maximum grip strength had significant positive correlation with the BMD of the femoral neck, total hip, and lumbar spine. Multiple factor binary logistic analysis showed that being <65 years old and having maximum grip strength <20 kg were risk factors of osteoporosis in postmenopausal women, especially for patients with grip strength <20 kg.

Correlation of Low Bone Mineral Density and Falls with Fracture in Postmenopausal Women

Increasing age is an important factor leading to the reduction of BMD and muscle strength in postmenopausal women. The present study demonstrated that BMD and grip strength in the group aged >65 years were significantly less than those in the group aged ≤65 years. Berger *et al.* report that the BMD of lumbar spine, femoral neck, and total hip started to decrease at 45 years old, decreased fastest from 50–54 years old, with lumbar BMD decreasing by 4.4% and total hip BMD decreasing by 6.8% during those 5 years, and BMD declined more slowly after 55 years old[6]. BMD is used as the index for the assessment of osteoporotic fracture risk. Kanis *et al.* report that the risk of hip fracture increases 2.6 times when femoral neck BMD decreases by 1 standard

deviation, while BMD decline increases hip fracture risk by four times[7]. In reality, risk fracture increases 30 times. This shows that BMD fails to fully reflect facture risk with age. Hip bone structure deterioration should be a factor that leads to the increase of fracture risk[8–10]. However, many patients with fragility fractures have a history of falling. Among the elderly who have femoral neck fractures, 95% have a history of falling[2]. According to Kannus *et al.*, the increase in low energy traumatic fracture risk in the elderly might be caused by the increased falling risk[11].

Reduction of Muscle Strength with Increasing Age

Muscle weakness, equilibrium disorder, and gait faults are major predictors for falling. Kim *et al.* used grip strength measurement to assess muscle strength and demonstrated that age was a very important factor affecting grip strength, and muscle strength decreased after 45 years of age[12]. Decrease in muscle strength in postmenopausal women may be related to muscle mass decline after the increase of age; muscle mass declines by 3%–8% every 10 years after 30 years of age and the decline accelerates after 60 years of age[13]. Pasco *et al.* report that the positive association between muscle strength and BMD at the hip is explained by measures of lean mass[14]. Therefore, it is essential to assess the muscle strength of postmenopausal women and the elderly. Grip strength measurement is the simplest muscle strength measurement method recommended in clinical practice. Some studies have demonstrated that hand grip strength is related to lower limb muscle function, lower limb motion ability, low BMD, and fragility fractures in the elderly[12,15,16].

Effect of 25 Hydroxyvitamin D

Increasing age in postmenopausal women also results in decreasing serum 25OHD, which may be related to a decline in the absorption and synthesis abilities of vitamin D in the elderly; 25OHD in the group >65 years old is significantly lower than that in the group ≤65 years old in the study. Vitamin D is not only involved in blood calcium regulation and bone metabolism, it also affects contraction, differentiation, and proliferation of skeletal muscle cells[17]. Among the patients with 25OHD < 20 ng/mL in our study, there was lower BMD of femoral neck and there were more individuals with BMD reaching the osteoporosis threshold. The serum 25OHD level is related to osteoporotic fracture risk. It is reported that the main osteoporotic fracture risk increases by 26%–27% when serum 25OHD decreases by 1 standard deviation, and that having 25OHD < 20 ng/mL significantly increases hip fracture risk[18,19]. However, the literature regarding the effect of 25OHD on muscle strength is not consistent. Some studies demonstrate that vitamin D status has a significant positive correlation with handgrip strength, and that low 25OHD affects the balance and gait of postmenopausal women[20,21]; other studies consider vitamin D status to be irrelevant to the physical performance in the elderly[22]. In our study, we confirmed that the maximum grip strength for patients with 25OHD < 20 ng/mL showed no significant difference from that of patients with 25OHD ≥ 20 ng/mL. However, some studies have demonstrated that the maximum grip strength decreases significantly in cases where 25OHD ≤ 10 ng/mL, which indicates that 25OHD affects muscle strength only when it is lower than a certain of threshold[23]. Murad *et al.* (2011) show that vitamin D supplementation can significantly reduce the falling rate in elderly people with vitamin D deficiency[4].

Correlation of Grip Strength with Bone Mineral Density

The motor system is mainly composed of skeleton and muscle, which connect with each other. Bone is quite sensitive to mechanical stimulation, and exercise may transfer the mechanical load to the bone to promote osteogenesis. Exercise training may effectively increase bone mass and improve bone structure. A 5-year study showed that an increase in physical activity might effectively increase adolescents' peak bone mass and cortical bone thickness[24]. Exercise training also may effectively improve the BMD of the lumbar spine, femoral neck, Ward's triangle, and trochanter in postmenopausal women[25]. Muscle strength and BMD in postmenopausal women decrease with age. Dodds *et al.* found that the life course trajectory identified for grip strength was similar to the well-established life course trajectory of BMD[26]. Pasco *et al.* report that hip-flexion muscle strength and hip abduction muscle strength are positively correlated with hip BMD[14]. Kim *et al.* report that low grip strength on the dominant side was associated with low BMD of the lumbar spine, femoral neck, and total hip, and was an independent factor affecting BMD[12]. Our study showed that the maximum grip strength had a significant positive correlation with BMD of the femoral neck, total hip, and lumbar spine. The osteoporosis risk in postmenopausal women with grip strength <20 kg was very high; and the risk of osteoporosis for patients with low grip strength was higher than that of recognized factors such as age and low 25OHD level. Low grip strength is a strong risk factor of osteoporosis. Grip strength measurement is an effective method for muscle strength assessment, and vitamin D supplementation and muscle strength exercise should receive further attention for the prevention and treatment of osteoporosis.

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