

The Relationships among Vitamin D Level, Balance, Muscle Strength, and Quality of Life in Postmenopausal Patients with Osteoporosis

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Abstract. [Purpose] The aim of this study was to examine the relationships among vitamin D levels, balance, falls, muscular strength, and quality of life in patients with postmenopausal osteoporosis. [Subjects and Methods] Forty-six patients diagnosed with postmenopausal osteoporosis and forty-six healthy controls were included in the study. Bone mineral density was determined by DEXA, and functional balance was evaluated the Timed Up and Go (TUG) test, Chair Raising (CRT) test, Berg Balance Scale (BBS). The muscular strengths were evaluated manually. The lumbosacral region range of motion (ROM) was measured by goniometry. The QUALEFFO-41 questionnaire was used for evaluating the quality of life. [Results] No statistically significant differences in muscular strength, balance, and fall values were found between the two groups. Statistically significant differences were noted between the QUALEFFO C, E, F and G scores and the QUALEFFO total scores of the QUALEFFO-41. Dividing the patient group into two groups revealed that patients with 25(OH)D levels < 15 ng/ml had significantly higher TUG and CRT test scores compared with patients with levels ≥ 15 ng/ml. Also, binary logistic regression analysis revealed that QUALEFFO total scores were found to be the independent factors for osteoporosis. [Conclusion] In this study, we found that vitamin D is necessary to maintain back extensor muscle strength, lumbar ROM, and balance. Our results show that bone mineral density, vitamin D level, balance, lumbar ROM, and the specified muscular strengths are factors that affect the quality of life.

Key words: Postmenopausal osteoporosis, Balance, Quality of life

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INTRODUCTION

Osteoporosis is a musculoskeletal system disease characterized by an increase in bone fragility caused by a decrease in bone mass and destruction of the bone structure¹⁾. The disease is asymptomatic at the beginning but causes painful fractures as a result of insidiously progressive bone loss. The fractures related to osteoporosis occur mostly in the vertebra, hips, and forearms. While vertebral fractures cause low back and dorsal pain and deformities such as kyphosis, hip fractures may cause an increase in mortality and cause patients to be dependent on others²⁾. Many patients with vertebral fractures develop a shortening in stature together with significant pain, which decreases their ability to exercise and carry out the activities of daily life. Therefore, along with the negative effects on self-confidence, body image, and the mental status of the patient, the disease also causes a reduction in quality of life³⁾.

The flexion posture that develops frequently in the elderly changes the center of gravity and affects balance. This situation is similar in patients with osteoporosis; therefore, better posture and correction of the center of gravity can decrease postural sway. In patients with osteoporosis, balance disturbance and postural sway are two important risk factors for falling^{4, 5)}.

A low level of vitamin D in serum, which is a common public health problem, is associated with a decrease in muscle strength and physical function⁶⁾. Previous studies demonstrated that increases in muscle strength and decreases in body sway in response to vitamin D might decrease the incidence of falling. As osteoporotic fractures occur due to falling, vitamin D could decrease the risk of osteoporotic fractures through its positive effects on bones, muscles, and balance⁷⁾.

Low levels of vitamin D are a common problem⁶⁾. Therefore, the aim of this study was to demonstrate the relationship between vitamin D levels, balance, falling, muscle strength, and quality of life in postmenopausal osteoporosis (PMO) patients.

SUBJECTS AND METHODS

Forty-six PMO patients and 46 postmenopausal healthy

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controls admitted to the Physical Medicine and Rehabilitation Polyclinic of the Harran University Medical Faculty Research and Application Hospital were included in the study. The patients were informed about the content, aim, and application of the study, and informed consent was obtained (Harran University Medical Faculty Ethical Committee decision number 27, dated 21.02.2012). Patients who had psychiatric, peripheral, or central neurological diseases; lower extremity pain that prevented standing and loading; amputation and prosthesis; mental function disorders; metabolic bone disorders other than osteoporosis; diseases that might cause secondary osteoporosis; or visual impairment were not included in the study.

Detailed histories were obtained from all participants and included name-surname, age, education status, occupation, height, weight, marital status, age at menarche and menopause, style of dress, presence of a previously diagnosed disease, prescription drug use, and history of falling in the last year. Body mass index was calculated using height and weight.

The bone mineral density (BMD) of all participants was measured using a Hologic QDR 4500 ACCLAIM analyzer. The measurements were performed in two regions: the L1-L4 vertebra and femur. According to the data from WHO, values of -2.5 g/cm^2 and lower for the total lumbar, total femur, or femoral neck T-score were accepted as indicating osteoporosis, and values of -1 g/cm^2 and above were accepted as indicating that a subject was healthy.

Blood samples were taken from all participants for determination of the blood count and serum Ca, P, creatinine, ALT, AST, ALP, PTH, and vitamin 25(OH)D3 levels. The blood was taken in the morning after at least an 8-hour period of fasting. The Ca, P, ALP, AST, ALT, and creatinine levels were measured spectrophotometrically with a Roche Cobas Integra 800 biochemistry device; PTH and 25(OH)D3 vitamin levels were measured by the electrochemoluminescence method using a Roche Modular E170 hormone device. All measurements were conducted in the Biochemical Laboratory of Harran University Medical Faculty Hospital.

Balance and functional mobility were evaluated with the Timed Up and Go (TUG) and Chair Rising (CRT) tests. In the TUG test, the patients were asked to rise from a chair, walk a distance of 3 meters, turn around, walk towards the chair again, and sit down. The time to finish the test was recorded. In the CRT test, the patients were asked to fold their arms at chest level and to immediately stand up from the chair. This was repeated 5 times, and the duration was recorded in seconds^{8, 9}.

Functional balance was assessed using the Berg Balance Scale (BBS), which has been verified as valid and reliable in Turkish¹⁰. The test consists of 14 items that are frequently used in daily life activities. The patients were asked to perform the tasks for each item. Each item was scored between 0 and 4 according to the ability of the patients to carry out the task. A score of 0 points indicated that the patient could not perform the task, whereas a score of 4 points indicated that the patient could independently finish the task. The maximum score for the Berg Balance Scale is 56.

The extensor muscle strength of the back was evaluated

in the prone position; hip flexor and knee extensor muscle strengths were evaluated in a sitting position; and foot flexor and extensor muscle strengths were evaluated in the supine position. Strength was graded manually according to the Daniels' criteria between 0 (no muscle contraction) and 5 (complete movement against maximum resistance)¹¹.

The joint range of motion (ROM) in extension in the lumbar region was measured with a goniometer device.

Quality of life and physical function were assessed using the QUALEFFO-41 (Quality of Life Questionnaire of the European Foundation for Osteoporosis 41) questionnaire, which is a scale consisting of 41 questions that investigate health in five dimensions, pain, physical function, social function, general health assessment, and mental function. The answers to the QUALEFFO-41 questions are scored ranging from 1 (healthy) to 5 (unhealthy). (As a different method, questions 23–26, which have fewer possible answers, were scored from 1 to 3, and questions 27–29 were scored from 1 to 4. Questions 24, 26, and 29 were not scored when the answer “this question is not valid for me” was selected). When scoring questions 33, 34, 35, 37, 39, and 40, the order of choices was reversed, and just as in the other questions, the order was arranged from the best health status (1 point) to the worst health status (5 points). The scores of the questions related to subscales were added together, and the score for each subscale was determined by linear transformation of this sum to a scale of 100. The validity and reliability of the Turkish of the QUALEFFO-41 has been demonstrated¹²).

Statistical analysis of the data obtained at the end of the study was conducted using the SPSS (Statistical Package for the Social Sciences) 11.5 software. Quantitative data (measurable data) are presented as the mean \pm standard deviation (mean \pm SD). The relevance of data to a normal distribution was evaluated with the Kolmogorov-Smirnov test. Data with a normal distribution were compared with the independent samples t-test, while data without a normal distribution were evaluated with the Mann-Whitney U Test. Qualitative data are presented as n (percentage), and comparison between groups was performed with the χ^2 test. Relationship between the variables were evaluated by Pearson's correlation analysis. In the statistical analysis, $p < 0.05$ was accepted as statistically significant. Binary logistic regression analysis was performed to find the independent predictors for osteoporosis.

RESULTS

No difference was noted between the two groups in terms of age, height, weight, body mass index, ages at menarche and menopause, marital status, education, and activity levels. The 25(OH)D levels of the patients were higher than those of the controls ($p < 0.05$; Table 1).

The mean ROM in the lumbar region was 3.5 ± 3.6 degrees in the patient group and 4.9 ± 3.4 degrees in the control group; this difference was statistically significant ($p = 0.049$). No statistically significant difference was observed between the two groups in terms of muscle strength or in the values for balance and falling. Statistically signifi-

Table 1. Demographic characteristics and laboratory findings of the patient and control groups

	Patients n=46	Controls n=46
Age (years)	61.5 ± 5.1	59.3 ± 6.2
BMI (kg/m ²)	31.6 ± 3.9	32.2 ± 3.8
Age at menarche (years)	12.8 ± 1.5	12.6 ± 1.5
Age at menopause (years)	47.9 ± 4.5	47.8 ± 4.4
Marital status (married/single/widowed)	36/0/10	38/1/7
Education (educated/not educated)	11/35	17/29
Activity levels (no sport activity/irregular/regular)	41/5/0	38/6/2
25(OH)D	14.5 ± 13.5	7.9 ± 4.9*
PTH	71.7 ± 41.2	67.6 ± 25.4
ALP	78.7 ± 23.7	78.1 ± 22.2
Ca	9.6 ± 1.1	9.5 ± 1.4
P	3.8 ± 1.1	3.5 ± 0.8

BMI: body mass index. *p<0.05

cant differences were noted in terms of the QUALEFFO C, E, F, G and total scores of the QUALEFFO-41 in the two groups (all p<0.05; Table 2).

The 25(OH)D level was <15 ng/ml in 30 patients (65%) in the patient group and in 40 individuals (87%) in the control group, and it was ≥15 ng/ml in 16 patients (35%) in the patient group and in six individuals (13%) in the control group.

The TUG and CRT balance test scores, and quality of life score QUALEFFO C were significantly higher in the group with low vitamin D levels (Table 3).

A negative correlation was detected between the vitamin D level and PTH values in the patient group ($r = -0.358$, $p = 0.015$). Positive correlation was detected between the vitamin D levels and lumbar ROM and extension muscle strength of the back. Negative correlation was detected between the TUG test score and the QUALEFFO C and E scores (Table 4).

Strong negative correlation was found between the TUG test score and the back extensor and hip flexor muscle strengths and lumbar ROM; negative correlation was found between the TUG test score and the knee extensors; strong positive correlation was detected between the TUG test score and the QUALEFFO total, C, E, F, and G scores; and positive correlation was found between the TUG test score and the QUALEFFO A, B, and D scores. Negative correlation was found between the CRT test score and the back extensor, hip flexor, knee extensor, foot extensor, and flexor muscle strengths, while positive correlation was found between the CRT test score and the QUALEFFO C score. Strong positive correlation was found between the BBS score and back extensor, hip flexor, knee extensor, foot extensor, and flexor muscle strengths and lumbar ROM; strong negative correlation was found between the BBS score and the QUALEFFO B, C, D, E, F, G and the total scores; and negative correlation was found between the BBS score and

Table 2. Muscle strength, balance tests, lumbar ROM and QUALEFFO scores in the patient and control groups

	Patients n=46	Controls n=46
Muscle strength		
Back extensor (0–5)	3.7 ± 0.8	3.9 ± 0.8
Hip flexor (0–5)	4.1 ± 0.5	4.1 ± 0.6
Knee extensor (0–5)	4.9 ± 0.3	4.9 ± 0.3
Ankle extensor (0–5)	4.9 ± 0.2	4.9 ± 0.2
Ankle flexor (0–5)	4.9 ± 0.2	4.9 ± 0.2
Balance tests		
TUG (seconds)	15.2 ± 3.3	15.6 ± 3.8
CRT (seconds)	17.4 ± 4.7	18.2 ± 4.6
BBS	47.9 ± 6.2	49.9 ± 4.1
Lumbar ROM	3.5 ± 3.6	4.9 ± 3.4*
Falling	0.8 ± 1.1	0.8 ± 1.1
QUALEFFO		
QUALEFFO A	50.1 ± 23.3	43.1 ± 21.3
QUALEFFO B	37.1 ± 20.2	28.8 ± 21.4
QUALEFFO C	53.7 ± 23.7	42.9 ± 19.1*
QUALEFFO D	38.1 ± 15.6	31.7 ± 15.3
QUALEFFO E	63.5 ± 12.5	53.1 ± 13.6**
QUALEFFO F	54.9 ± 14.9	47.9 ± 14.3*
QUALEFFO G	54.2 ± 17.3	46.2 ± 15.6*
QUALEFFO total	48.7 ± 13.6	40.8 ± 13.9*

TUG, Timed Up and Go Test; CRT, Chair Raising Test; BBS, Berg Balance Scale; ROM, range of motion; QUALEFFO, Quality of Life Questionnaire of the European Foundation for Osteoporosis *p<0.05; **p<0.001

QUALEFFO A score (Table 5). Binary logistic regression analysis revealed that the QUALEFFO total score was the independent factor ($B = 0.046$, $SE = 0.017$, $Wald = 6.998$, $p = 0.008$) for postmenopausal osteoporosis.

DISCUSSION

A possible association has been reported between the weakening of the bone structure in osteoporosis patients and the occurrence of some muscular alterations that possibly lead to a change in center of gravity, which might result in loss of balance, falling, and fractures¹³. Some studies have reported that the dorsolumbar muscle strength decreases in females with osteoporosis and that this is related to lumbovertebral BMD^{14, 15}. A study conducted by Sylvia et al. investigated the relationship between extensor and flexor muscle strengths of the trunk and BMD in females with PMO and in healthy females and demonstrated that the extensor and flexor muscle strengths of the trunk were significantly lower in patients with osteoporosis when compared with healthy individuals. The same study reported lower lumbar ROM in females with PMO¹⁶. Sinaki et al. reported that PMO patients showed decreases in back extension muscle strength with age¹⁷. In the current study, lumbar ROM in the osteoporosis group was significantly lower than in the control group, in accordance with the lit-

Table 3. Muscle strength, balance test, lumbar ROM, falling, and quality of life in patients according

	<15 ng/ml 25 (OH)D n = 30	≥15 ng/ml 25 (OH)D n= 16
Muscle strength		
Back extensor (0–5)	3.6 ± 0.7	4.1 ± 0.9
Hip flexor (0–5)	4.1 ± 0.5	4.3 ± 0.7
Knee extensor (0–5)	4.9 ± 0.3	4.9 ± 0.3
Ankle extensor (0–5)	4.9 ± 1.9	4.9 ± 0.3
Ankle flexor (0–5)	4.9 ± 1.9	4.9 ± 0.3
Balance tests		
TUG (seconds)	16.0 ± 3.2	13.8 ± 3.2*
CRT (seconds)	18.2 ± 5.0	16.0 ± 3.8*
BBS	48.1 ± 5.1	49.7 ± 4.5
Lumbar ROM	2.8 ± 3.1	4.7 ± 4.3
Falling	0.7 ± 1.1	1.1 ± 1.1
QUALEFFO		
QUALEFFO A	52.0 ± 23.4	46.6 ± 23.6
QUALEFFO B	38.9 ± 20.8	33.6 ± 19.2
QUALEFFO C	59.3 ± 23.1	43.1 ± 21.7*
QUALEFFO D	39.9 ± 15.4	34.6 ± 15.7
QUALEFFO E	65.6 ± 11.4	59.5 ± 13.8
QUALEFFO F	57.8 ± 13.6	49.6 ± 16.3
QUALEFFO G	55.7 ± 15.7	51.2 ± 20.3
QUALEFFO total	51.1 ± 12.3	44.3 ± 14.8

TUG, Timed Up and Go Test; CRT, Chair Raising Test; BBS, Berg Balance Scale; ROM, range of motion; QUALEFFO, Quality of Life Questionnaire of the European Foundation for Osteoporosis *p<0.05

erature. However, no significant difference was found between females with PMO and healthy females in terms of back extension muscle strengths. Thus, one can conclude that osteoporosis decreases the extension angle of the lower back region.

Balance disturbance and increased postural sway are two important risk factors in patients with osteoporosis. When compared with the healthy controls, postural sway was reported to be more frequent in patients with osteoporosis¹⁸. A study by Abreu et al., who investigated the relationship between osteoporosis and balance in the elderly, demonstrated that balance was worse in females with osteoporosis than in individuals without osteoporosis¹⁹. However, a study by Smulders et al., who investigated the effect of osteoporosis on balance, indicated no difference between healthy patients and patients with osteoporosis in terms of balance²⁰. In the current study, no significant difference was found in balance test (TUG and CRT) and BBS scores in the patient and control groups. No correlation was found between total lumbar and femur T-scores and the TUG, CRT, and BBS scores in the osteoporosis group. These results suggest that BMD does not affect balance or that factors other than osteoporosis that affect balance, such as vitamin D levels, might also have an effect on the results.

The existing literature indicates that vitamin D deficiency might have direct and indirect effects associated

Table 4. The relationship between vitamin D levels and muscle strength, balance test results, lumbar ROM, falling, and quality of life in patients

	25 (OH)D r
Muscle strength	
Back extensor	0.333*
Hip flexor	0.279
Knee extensor	0.048
Ankle extensor	-0.034
Ankle flexor	-0.034
Balance tests	
TUG	-0.343*
CRT	-0.263
BBS	0.127
Lumbar ROM	0.423*
Falling	0.115
QUALEFFO	
QUALEFFO A	-0.133
QUALEFFO B	-0.101
QUALEFFO C	-0.297*
QUALEFFO D	-0.054
QUALEFFO E	-0.299*
QUALEFFO F	-0.009
QUALEFFO G	-0.122
QUALEFFO total	-0.205

TUG, Timed Up and Go Test; CRT, Chair Raising Test; BBS, Berg Balance Scale; ROM, range of motion; QUALEFFO, Quality of Life Questionnaire of the European Foundation for Osteoporosis *p<0.05

with muscle weakness due to decreases in muscle and bone mass and quality. A study conducted by Mastaglia et al. showed that vitamin 25(OH)D levels should be ≥ 20 ng/ml to achieve optimal muscle strength and function. They found that hip abductor and knee extensor muscle strengths were significantly higher in a group with high vitamin D levels than in a group with low vitamin D levels⁷. Suzuki et al. demonstrated that a vitamin 25(OH)D level < 20 ng/ml was associated with decreased physical performance and an increased risk of falling²¹.

Many other studies have investigated the effect of vitamin D on muscle strength and balance. Some of these studies reported that vitamin D had positive effects on muscle strength and balance²², while others reported no effects²³. A meta-analysis that examined 17 studies on this topic demonstrated that vitamin D increased muscle strength and had positive, although lower, effects on balance²². In the present study, when the researchers divided the patient group into two groups based on the vitamin 25(OH)D levels, the TUG and CRT test scores were significantly higher in the group with low vitamin D levels. The osteoporosis group showed significant positive correlation between vitamin D levels and back extensor muscle strength, strong positive correlation between vitamin D levels and lumbar ROM, and

Table 5. The relationship between balance test (TUG, CRT, and BBS) results and muscle strength, lumbar ROM, and quality of life in patient groups

	TUG	CRT	BBS
	r	r	r
Muscle strength			
Back extensor	-0.560**	-0.294*	0.501**
Hip flexor	-0.412*	-0.310*	0.595**
Knee extensor	-0.320*	-0.327*	0.523**
Ankle extensor	-0.149	-0.346*	0.435*
Ankle flexor	-0.149	-0.346*	0.435*
Lumbar ROM	-0.519**	-0.239	0.417*
QUALEFFO			
QUALEFFO A	0.355*	0.042	-0.353*
QUALEFFO B	0.323*	0.072	-0.637**
QUALEFFO C	0.591**	0.345*	-0.494**
QUALEFFO D	0.343*	0.235	-0.416*
QUALEFFO E	0.425*	0.153	-0.446*
QUALEFFO F	0.416**	0.255	-0.481*
QUALEFFO G	0.443*	0.269	-0.466*
QUALEFFO total	0.539**	0.264	-0.595**

TUG, Timed Up and Go Test; CRT, Chair Raising Test; BBS, Berg Balance Scale; ROM, range of motion; QUALEFFO, Quality of Life Questionnaire of the European Foundation for Osteoporosis * $p < 0.05$; ** $p < 0.001$

significant negative correlation between vitamin D levels and the TUG test. These findings demonstrate that vitamin D has a direct effect on balance, lumbar ROM, and muscle strength.

A study by Kwan et al. that investigated the factors affecting balance by the TUG test in the elderly demonstrated that lower extremity muscle strength had an effect on balance and hence on falling²⁴. The study of Hasselgren et al., which investigated functional balance with the BBS, reported that lower extremity muscle strength affected balance²⁵. In the current study, in line with the literature, the osteoporosis group showed a significant and strong negative correlation between the TUG test score and back extensor and hip flexor muscle strengths and lumbar ROM, and significant negative correlation was found between the TUG test score and knee extensor strength. Significant negative correlation was found between the CRT test score and back extensor, hip flexor, knee extensor, foot extensor, and flexor muscle strengths. Significant strong positive correlation was found between the BBS test score and back extensor, hip flexor, knee extensor, foot extensor, and flexor muscle strengths and lumbar ROM. These results suggest that the trunk and lower extremity muscle strengths play a primary role in balance by contributing to postural stability in PMO patients.

Osteoporosis is a chronic process that has physical, social, and economic aspects; therefore, its effect on quality of life has become a subject of research in many studies. Ekström et al. investigated the relationship between quality of life and physical performance in patients with osteoporotic fractures, and physical performance was assessed with the TUG test. They demonstrated that decreases in TUG

test scores were associated with decreases in the quality of life and social life²⁶. In the present study, the QUALEFFO total and C, D, E, F and G scores were found to be significantly high in females with PMO when compared with the control group. The osteoporosis group showed significant negative correlation between the total femur T-score and QUALEFFO D score. The QUALEFFO C score was significantly higher in the individuals with low vitamin D levels. Significant negative correlation was noted between vitamin D and the QUALEFFO C and E scores in the osteoporosis group. The osteoporosis group also showed significant positive correlation between the TUG score and QUALEFFO total score, and all subgroups showed significant positive correlation between the CRT score and QUALEFFO C score, and significant strong negative correlation between the BBS score and QUALEFFO total score. The results demonstrate that balance has quite important effects on quality of life in patients with osteoporosis. Furthermore, the results also suggest that TUG and BBS tests could be used in the assessment of quality of life in females with PMO.

In the current study, the osteoporosis group showed negative correlation between lumbar ROM and the QUALEFFO total, A, B, C, and E scores, while negative correlation was found between back extensor muscle strength and the QUALEFFO total, A, C, and E scores. Furthermore negative correlation was found between hip flexor muscle strength and the QUALEFFO total, A, B, C, E, and F scores and between the foot flexor and extensor muscle strengths and the QUALEFFO total, B, C, F, and G scores. These data indicate that, lumbar ROM and, back extensor, hip flexor, foot flexor, and extensor muscle strengths are factors that affect the quality of life in patients with PMO. Accordingly,

osteoporosis rehabilitation should include optimizing of vitamin D levels, strengthening exercises to increase the muscle strengths of the trunk and lower extremity, and education pertaining to balance and coordination exercises to increase quality of life.

In conclusion, the present study showed that vitamin D is necessary for back extensor muscle strength, lumbar ROM, and balance. Therefore, the vitamin D levels should be kept in mind for physical therapy modalities and vitamin D treatment approaches, especially in postmenopausal osteoporosis patients suffering from balance problems who receive traditional physical therapy management. The risk of falling should be assessed in postmenopausal females with osteoporosis by inexpensive and easily performed techniques such as measurement of back extensor, hip flexor, foot flexor, and extensor muscle strengths and lumbar ROM. The findings presented here also suggest that bone mineral density, vitamin D levels, balance, lumbar ROM, and muscle strengths are factors that affect quality of life.

REFERENCES

- 1) Anonymous NIH Consensus Development Panel on Osteoporosis Prevention, Diagnosis, and Therapy: Osteoporosis prevention, diagnosis, and therapy. *JAMA*, 2001, 285: 785–795 [PubMed]. [Medline] [CrossRef]
- 2) Kanis JA, Burlet N, Cooper C, et al. European Society for Clinical and Economic Aspects of Osteoporosis and Osteoarthritis (ESCEO): European guidance for the diagnosis and management of osteoporosis in postmenopausal women. *Osteoporos Int*, 2008, 19: 399–428. [Medline] [CrossRef]
- 3) Mauck KF, Clarke BL: Diagnosis, screening, prevention, and treatment of osteoporosis. *Mayo Clin Proc*, 2006, 81: 662–672. [Medline] [CrossRef]
- 4) Sinaki M, Lynn SG: Reducing the risk of falls through proprioceptive dynamic posture training in osteoporotic women with kyphotic posturing: a randomized pilot study. *Am J Phys Med Rehabil*, 2002, 81: 241–246. [Medline] [CrossRef]
- 5) Sinaki M, Brey RH, Hughes CA, et al.: Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. *Osteoporos Int*, 2005, 16: 1004–1010. [Medline] [CrossRef]
- 6) Holick MF: Too little vitamin D in premenopausal women: why should we care? *Am J Clin Nutr*, 2002, 76: 3–4. [Medline]
- 7) Mastaglia SR, Seijo M, Muzio D, et al.: Effect of vitamin D nutritional status on muscle function and strength in healthy women aged over sixty-five years. *J Nutr Health Aging*, 2011, 15: 349–354. [Medline] [CrossRef]
- 8) Yelnik A, Bonan I: Clinical tools for assessing balance disorders. *Neurophysiol Clin*, 2008, 38: 439–445. [Medline] [CrossRef]
- 9) Cooper R, Kuh D, Hardy R, Mortality Review Group FALCon and HAL-Cyon Study Teams: Objectively measured physical capability levels and mortality: systematic review and meta-analysis. *BMJ*, 2010, 341: c4467. [Medline] [CrossRef]
- 10) Şahin F, Yılmaz F, Özmaden A, et al.: Reliability and validity of the Turkish version of the Berg Balance Scale. *J Geriatr Phys Ther*, 2008, 31: 32–37. [Medline] [CrossRef]
- 11) Daniels L, Worthingham C: *Muscle testing: techniques of manual examination*. Philadelphia: WB Saunders, 2007, pp 2–3.
- 12) Koçyigit H, Gülseren S, Erol A, et al.: The reliability and validity of the Turkish version of Quality of Life Questionnaire of the European Foundation for Osteoporosis (QUALEFFO). *Clin Rheumatol*, 2003, 22: 18–23. [Medline] [CrossRef]
- 13) Zhou Z, Zheng L, Wei D, et al.: Muscular strength measurements indicate bone mineral density loss in postmenopausal women. *Clin Interv Aging*, 2013, 8: 1451–1459. [Medline] [CrossRef]
- 14) Imagama S, Matsuyama Y, Hasegawa Y, et al.: Back muscle strength and spinal mobility are predictors of quality of life in middle-aged and elderly males. *Eur Spine J*, 2011, 20: 954–961. [Medline] [CrossRef]
- 15) Crepaldi G, Romanato G, Tonin P, et al.: Osteoporosis and body composition. *J Endocrinol Invest*, 2007, 30: 42–47. [Medline]
- 16) Cunha-Henriques S, Costa-Paiva L, Pinto-Neto AM, et al.: Postmenopausal women with osteoporosis and musculoskeletal status: a comparative cross-sectional study. *J Clin Med Res*, 2011, 3: 168–176. [Medline]
- 17) Sinaki M, Khosla S, Limburg PJ, et al.: Muscle strength in osteoporotic versus normal women. *Osteoporos Int*, 1993, 3: 8–12. [Medline] [CrossRef]
- 18) Lynn SG, Sinaki M, Westerlind KC: Balance characteristics of persons with osteoporosis. *Arch Phys Med Rehabil*, 1997, 78: 273–277. [Medline] [CrossRef]
- 19) Abreu DC, Trevisan DC, Costa GC, et al.: The association between osteoporosis and static balance in elderly women. *Osteoporos Int*, 2010, 21: 1487–1491. [Medline] [CrossRef]
- 20) Smulders E, van Lankveld W, Laan R, et al.: Does osteoporosis predispose falls? A study on obstacle avoidance and balance confidence. *BMC Musculoskelet Disord*, 2011, 12: 1. [Medline]
- 21) Suzuki T: [Frontiers in vitamin D; basic research and clinical application. Vitamin D and falls]. *Clin Calcium*, 2011, 21: 71–79. [Medline]
- 22) Dawson-Hughes B: Serum 25-hydroxyvitamin D and muscle atrophy in the elderly. *Proc Nutr Soc*, 2012, 71: 46–49. [Medline] [CrossRef]
- 23) Qutubuddin A, Cifu DX, Adler RA, et al.: A pilot study of vitamin D and balance characteristics in middle-aged, healthy individuals. *PM R*, 2010, 2: 23–26. [Medline] [CrossRef]
- 24) Kwan MM, Lin SI, Chen CH, et al.: Sensorimotor function, balance abilities and pain influence Timed Up and Go performance in older community-living people. *Aging Clin Exp Res*, 2011, 23: 196–201. [Medline] [CrossRef]
- 25) Hasselgren L, Olsson LL, Nyberg L: Is leg muscle strength correlated with functional balance and mobility among inpatients in geriatric rehabilitation? *Arch Gerontol Geriatr*, 2011, 52: e220–e225. [Medline] [CrossRef]
- 26) Ekström H, Dahlin-Ivanoff S, Elmståhl S: Effects of walking speed and results of timed get-up-and-go tests on quality of life and social participation in elderly individuals with a history of osteoporosis-related fractures. *J Aging Health*, 2011, 23: 1379–1399. [Medline] [CrossRef]