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Balance and functional mobility predict low bone mineral density among postmenopausal women undergoing recent menopause with osteoporosis, osteopenia, and normal bone mineral density: A cross-sectional study

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ABSTRACT

The purpose of this study was to determine whether balance and functional mobility independently predict bone mineral density (BMD) in postmenopausal women. BMD at the hip and spine was measured with dual-energy x-ray absorptiometry (DEXA). Participants were assigned into groups (i.e., osteoporosis: $n=20$; osteopenia: $n=20$; normal BMD: $n=20$) according to DEXA T-scores. Participants performed the single leg stance test (SLS), timed-up-and-go (TUG), and 6-meter walking test. An ordinal logistic regression was performed to determine whether the SLS, TUG, 6MWT independently predict BMD, while accounting for age, age at menopause, and body mass index. Three factors predicted low BMD: (1) less time to hold the SLS (odds ratio (OR): 0.50); (2) longer TUG time (OR: 2.85); and (3) older Age (OR: 1.31). Women with recent menopause diagnosed with osteoporosis are at a high-risk for fracture; incorporating the SLS and TUG into risk assessments may enable prompt and targeted intervention.

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Introduction

Approximately one-third of postmenopausal women develop osteoporosis.¹ Osteoporosis has been characterized by a deterioration of bone structure, low bone mineral density (BMD), increased fragility, and a greater likelihood of fracture.^{2,3} The ability to generate new bone has also been impaired in individuals with osteoporosis, as they have shown delayed mechanical property restoration,⁴ impaired osteoprogenitor cell recruitment and differentiation,⁵ and impaired angiogenesis.⁶ Postmenopausal women with osteopenia have less severe bone loss than those with osteoporosis (T-score of -1.1 to -2.4 vs ≤ -2.5 , respectively)⁷ but they are at risk for developing osteoporosis and have a 1.8 fold increased fracture risk relative to those with normal BMD.⁸ Both osteoporosis and osteopenia can have cascading effects on the individual, such as functional

impairment, disability, pain, depression, fear of falling, increased likelihood of fractures, reduced quality of life, increased morbidity, and mortality.⁸⁻¹¹ The economic burden of osteoporosis is considerable, with annual direct medical costs estimated at 17–20 billion dollars.¹² Therefore, identifying risk factors that can detect low BMD in postmenopausal women are important for screening and prompt intervention.

The accepted standard for screening and monitoring bone loss has been dual-energy x-ray absorptiometry (DEXA).⁷ However, low BMD alone is an unreliable classifier of osteopenia and osteoporosis as the error rate has been as high as 20%,¹³ thus, other biomarkers may be necessary to more accurately identify postmenopausal women with low BMD. Impaired balance and functional mobility are modifiable risk factors that are prevalent among postmenopausal women with osteoporosis.¹⁴⁻²⁰ Balance and functional mobility have also been responsive to intervention.^{21,22} Therefore, they may serve as viable screening measures for postmenopausal women with osteoporosis and osteopenia, but further investigation is necessary.

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While demographic measures of age, age at menopause, and BMI, have predicted BMD,^{23,24} it is unclear whether clinical measures of balance and functional mobility independently predict BMD among postmenopausal women. Clinical measures of step length and gait speed during usual and brisk walking, and the single leg stance test (SLS), have predicted BMD in postmenopausal women in separate univariate regressions, but no multivariate regressions were performed due to collinearity.²⁵ Only one study has examined clinical measures of balance and functional mobility as independent predictors, and found that SLS and the ability to squat down on the floor independently predicted BMD among postmenopausal women; however, only postmenopausal women aged >65 years were included in this study.¹⁸ Thus it is unclear whether clinical measures of balance and functional mobility independently predict BMD in women undergoing recent menopause.¹⁸

More research is warranted to determine whether clinical measures of balance and functional mobility should be a routine part of medical assessment in postmenopausal women. Therefore, the purpose of this study was to determine whether clinical measures of balance and functional mobility independently predict BMD in postmenopausal women undergoing recent menopause with osteoporosis, osteopenia, and normal BMD.

Method

Study design

This was a cross-sectional study. All methods and experimental procedures of this study were approved by the Shiraz University of Medical Sciences Ethics Committee. All participants signed the informed consent form. Postmenopausal women were recruited from the Bone Density Testing Center in Shahid Motehari Specialist Medical Clinic in Shiraz, Iran, as well as from newspapers, flyers, and posters.

Sample size

Longer backwards tandem walking time has been observed in postmenopausal women with low BMD (10.04 ± 3.65 s) relative to normal BMD (8.76 ± 3.89 s) when walking a 2.44 m line (Cohen's d : 0.94).¹⁴ Therefore, the minimum sample size required was 19 participants per group (i.e., total sample size of 57 participants across the osteoporosis, osteopenia and normal BMD groups) to achieve a power of 80% and a level of significance of 5% (two sided).

Eligibility criteria

The inclusion criteria were women aged 50–60 years, at least one-year post menopause. We selected this age range because we were interested in studying women with recent menopause. The exclusion criteria consisted of individuals: (1) with diabetes; (2) with thyroid problem; (3) with chronic musculoskeletal pain; (4) with neurological and/or musculoskeletal disease; (5) with a previous hip fracture; (6) with a previous hip, knee or spinal replacement; (7) who were taking drugs that affect BMD (e.g., steroids, calcium plus vitamin D); and (8) who were taking medications that affect balance (e.g., sedatives or hypnotics).

Procedure

The testing took place at the Bone Densitometry Center in Shahid Motehari Specialist Medical Clinic in Shiraz, Iran. Participants completed a health questionnaire, including age, age at menopause, and medical information (e.g., neurological and/or musculoskeletal diseases, illness, medications, previous surgeries, smoking status, and drinking status). Height and weight were measured. Participants also completed a DEXA scan, the timed-up-and-go test (TUG), the 6-meter walking test (6MWT), and the timed SLS, as described below.

DEXA (Hologic Discovery A, Hologic Inc, Bedford, MA, USA) is a valid and reliable tool to measure BMD.²⁶ During the DEXA scan, participants lied on their back in the supine position on the open x-ray table. Participants were asked to keep still during the scan as the large scanning arm passed over their body. A trained technologist scanned each participant at the total hip and spine regions only for approximately 20 min. Using the information from the DEXA scans, participants were classified into the osteoporosis, osteopenia, and normal BMD groups with T-scores of < -2.5, -1.0 and -2.5, and > -1.0 in the total hip or spine, respectively.⁷ We also extracted the Z-score, which provides a comparison of obtained bone density to the age-matched normal average bone, and is usually useful in cases of severe osteoporosis.^{1,27}

The valid and reliable SLS is a measure of balance and involved participants standing on their dominant leg as long as possible.²⁸ Leg dominance was determined by asking participants which leg they would kick a ball with. The test was stopped when participants: (1) touched the dominant leg with their non-dominant leg; (2) hopped; (3) touched the floor with the non-dominant foot; and (4) used any support surface, including touching the investigator. Participants completed 3 trials, and the time to completion was recorded in seconds.

The TUG is a measure of functional mobility, and includes a number of components, including balance, walking, standing up, sitting down, and also turning during walking.²⁹ The TUG involved getting up from a 40 cm chair, walking 3 m, turning around, walking back, and sitting down.²⁹ The time to completion was reported in seconds. Participants performed one familiarization trial, and the average of 2 experimental trials were used in the analysis. The test has shown inter-rater reliability (ICC=0.99) and intra-rater reliability (ICC=0.99) in a sample of community-dwelling older adults.³⁰

The 6-Meter Walk Test (6MWT) is a measure of functional mobility.³¹ Participants were asked to walk 8 meters at a comfortable pace; the time to complete the middle 6 meters was recorded, and the average of the two trials was included in the analysis.³¹ The 6MWT has shown excellent test-retest reliability (ICC=0.88) in older adults.³¹

Statistical analysis

We conducted an ordinal logistic regression to determine whether measures of balance and functional mobility independently predict BMD in postmenopausal women with osteoporosis, osteopenia, and normal BMD. Age, age at menopause, and BMI, have been identified as factors influencing BMD.^{23,24} Therefore, group (i.e., osteoporosis=3, osteopenia=2, and normal BMD=1) was used as the dependent variable, and SLS, TUG, 6MWT, age, age at menopause, and BMI were used as independent variables. The assumptions of multicollinearity and tests of proportional odds were checked. Significance was set to $p < 0.05$.

Results

Participant characteristics

Participant characteristics for the osteoporosis, osteopenia, and normal BMD are reported in Table 1. Of the 87 postmenopausal women interested in participating in this study, 27 were ineligible (i.e., diabetes ($n=2$); thyroid issues ($n=4$); chronic musculoskeletal pain ($n=10$); previous hip fracture ($n=3$); previous hip, knee or spinal replacement ($n=4$); taking drugs that affect BMD ($n=2$); and medications that affect balance and mobility ($n=2$)). Therefore, 60 postmenopausal women (20 with osteoporosis, 20 with osteopenia, and 20 with normal BMD) participated in this study. Among those with osteoporosis, 35% had osteoporosis in both the total hip and spine, 45% presented with osteoporosis at the spinal site only, and 20% had osteoporosis at the total hip site only. Among those with osteopenia, 66%

Table 1
Participant characteristics (Mean ± Standard Deviation).

Variable	Osteoporosis	Osteopenia	Normal Bone Mineral Density
Age (years)	55.80 ± 3.75	55.20 ± 3.2	53.45 ± 3.33
Age at menopause (years)	49.10 ± 1.97	49.35 ± 1.66	49.10 ± 1.44
Weight (kg)	64.51 ± 4.32	66.90 ± 5.59	69.20 ± 4.54
Height (cm)	165.25 ± 4.47	166.85 ± 4.30	166.45 ± 4.77
Body Mass Index (kg/m ²)	23.66 ± 2.01	24.04 ± 2.07	24.98 ± 1.51
Current Smoker (%)	0	0	0
Current Drinker (%)	0	0	0
T-score			
Spine	−2.92 ± 1.38	−1.34 ± 0.65	0.27 ± 0.58
Hip	−2.34 ± 0.83	−1.13 ± 0.77	0.68 ± 0.86
Z-score			
Spine	−1.84 ± 0.70	−0.30 ± 0.77	1.10 ± 0.97
Hip	−1.10 ± 0.87	−0.18 ± 0.55	1.32 ± 0.98
Single Leg Stance (s)	12.04 ± 3.18	18.66 ± 3.28	22.85 ± 3.36
Timed-Up-And-Go (s)	9.69 ± 0.85	10.05 ± 1.06	8.18 ± 1.67
6 Meter Walk Test (s)	8.48 ± 0.93	7.36 ± 1.27	7.13 ± 1.70

had osteopenia in both the total hip and spine, 21% displayed osteopenia only in the spine, and 13% displayed osteopenia only in the total hip region.

Factors that influence BMD

The ordinal logistic regression model was significant ($\chi^2(6)=80.52$, $p<0.001$). Three factors predicted low BMD: (1) shorter time to hold the SLS (OR: 0.50); (2) longer TUG time (OR: 2.85); and (3) older Age (OR: 1.31). The 6MWT, BMI and age at menopause were not significant predictors in the model (Table 2).

The assumption of multicollinearity was not violated,³² as all variables entered into the model were correlated at $r=0.007$ to $r=0.39$. The assumption of proportional odds was not violated ($\chi^2(6)=5.95$, $p=0.43$).

Discussion

This is the first study to examine whether clinical measures of balance and functional mobility independently predict BMD among postmenopausal women undergoing recent menopause with osteoporosis, osteopenia, and normal BMD. Notably, three factors independently predicted osteoporosis: (1) a shorter time to hold the SLS (OR: 0.50); (2) longer time to completion on the TUG (OR: 2.85); and (3) older Age (OR: 1.31) relative to postmenopausal women with osteopenia and normal BMD grouped together.

Our results highlight that clinical measures of balance (i.e., the SLS) and mobility (i.e., the TUG) add distinct value in predicting BMD in women with recent menopause. Our results extend previous work that has shown that balance, mobility, and age independently predict BMD in older postmenopausal women.^{18,23,24} Age was likely a significant factor in predicting osteoporosis due to estrogen deficiency after menopause.²⁴ It is possible that the

6MWT as a measure of functional mobility did not add further value to the model because it only includes straight-ahead gait, while the TUG includes straight-ahead gait as well as other important functional mobility skills, such as turning and sit-to-stand transitions.²⁹ Perhaps age at menopause and BMI were not significant predictors of osteoporosis, as age at menopause was very similar among our BMD groups, and our participants did not exhibit low BMI, which has been a risk factor for osteoporosis.^{23,24} The pattern of poor balance and mobility with decreasing BMD is in line with previous work.^{14–18,20,33,34} In fact, clinical measures of balance and mobility have more accurately identified postmenopausal women with low BMD than kinematic analyses.^{16,35} Overall, our study highlights that women diagnosed with osteoporosis with recent menopause, are a high fracture risk group due to low BMD and poor balance and mobility.

Osteoporotic fracture is a major health care problem worldwide.³⁶ An increasing aging population places a large burden on the healthcare system to treat osteoporosis, fall-related fractures, and fragility fractures.³⁷ Postmenopausal women are highly susceptible to osteoporosis, and late diagnosis and treatment may lead to increased morbidity and mortality.³⁶ Pharmaceutical drugs are the first line of treatment for low BMD;²² however, they have had little effect on improving other key fracture risk factors, such as low muscle strength, power, and functional capacity, which are all independent of low BMD.²² Our study suggests that the SLS and TUG are modifiable factors that may be used as determinants of fracture risk. The SLS and TUG may be useful screening tools, as they are cost-effective, quick to deliver, and accurately identify postmenopausal women with low BMD. Including clinical measures of balance and functional mobility in routine assessments may afford prompt therapeutic intervention in postmenopausal women. Accurately identifying postmenopausal women with osteopenia may present with a window of opportunity to prescribe early intervention to prevent osteoporosis.

Table 2.

Ordinal logistic regression predictors of BMD in postmenopausal women with osteoporosis, osteopenia, and normal BMD.

Variable	Coefficient	SE	Confidence Interval		OR	SE	Confidence Interval		Z-score	p-value
			Lower	Upper			Lower	Upper		
SLS	−0.70	0.16	−1.02	−0.38	0.50	0.08	0.36	0.68	−4.30	<0.001*
TUG	0.90	0.33	0.26	1.54	2.45	0.80	1.29	4.65	2.75	0.006*
6MWT	0.26	0.28	−0.28	0.81	1.30	0.36	0.75	2.25	0.94	0.346
Age	0.27	0.13	0.02	0.52	1.31	0.17	1.02	1.69	2.13	0.033*
Age at Menopause	−0.09	0.23	−0.53	0.36	0.92	0.21	0.59	1.43	−0.38	0.71
BMI	−0.01	0.20	−0.41	0.39	0.99	0.20	0.67	1.48	−0.04	0.97

Note: SE: standard error; CI: confidence interval; OR: odds ratio; SLS: single leg stance test; TUG: timed-up-and-go; 6MWT: 6 meter walk test; BMI: body mass index; * $p<0.05$.

Limitations and future directions

This study has a few limitations. These findings are only generalizable to postmenopausal women with recent menopause with osteoporosis, osteopenia, and normal BMD. It is possible that physical activity level may have influenced the results; however, we did not collect this information. Future research should examine other potential risk factors between groups (e.g., muscle strength, lower limb proprioception), as well as include a larger and older sample.

Conclusion

The SLS and TUG independently predicted BMD among women undergoing recent menopause with osteoporosis, osteopenia, and normal BMD. Our research suggests that incorporating the SLS and TUG into risk assessments for postmenopausal women may facilitate prompt and targeted intervention.

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Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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