
Hamza Khazzani¹,², Fadoua Allali¹²³*, Loubna Bennani¹,², Linda Ichchou¹,², Laila El Mansouri¹,², Fatima Ezzahra Abourazzak¹,², Redouane Abouqal³, Najia Hajjaj-Hassouni¹²³

¹Department of Rheumatology, El Ayachi hospital, University Hospital of Rabat-Sale, Morocco.
²Laboratory of Information and Research on Bone Diseases (LIRPOS), Faculty of Medicine and Pharmacy, Rabat, Morocco.
³Laboratory of Biostatistics, Clinical Research and Epidemiology (LBRCE), Faculty of Medicine and Pharmacy, Rabat, Morocco.
³ Labor of Biostatistics, Clinical Research and Epidemiology (LBRCE), Faculty of Medicine and Pharmacy, Rabat, Morocco

* Corresponding author

Email addresses:

    HK : hamzakhazzani@yahoo.fr
    FA : fadouaallali@yahoo.fr
    LB : loubnabennani29@yahoo.fr
    LI : ilinda19@yahoo.fr
    LE : la_mansouri1@yahoo.fr
    FZA : f.abourazzak@yahoo.fr
    RA : abouqal@invivo.edu
    NHH : n.hajjaj@medramo.ac.ma
Abstract

Background: The aim of this study was to evaluate the relationship between physical performance measures, bone mineral density, falls, and the risk of peripheral fracture in a population sample of Moroccan women.

Methods: 484 healthy women (mean age ± standard deviation, 55.1±9.6y) were included in this study. Exclusion criteria included any pathology or any treatment which can affect bone.

Main Outcome Measures: Anthropometrics and BMD of the hip and spine. Three measures to assess physical performance: timed get-up-and-go test ‘TGUGT’, five-times-sit-to-stand test ‘5 TSTS’ and 8-feet speed walk ‘8 FSW’.

Results: A highest ‘TGUGT’, ‘5 TSTS’ and ‘8 FSW’ tests were associated with a lowest BMD measured in different sites (p range from < 0.001 to 0.005). The relationship between the three tests and BMD in all measured sites remained significant after adjustment for BMI, age of menarche, total calcium intake and hours of total activity (p range from <0.001 to 0.026). In the group of post-menopausal patients, the scores of ‘TGUGT’ and ‘8 FSW’ were significantly higher in fractured patients compared with women without. After adjusting for age, BMI and total hip BMD by logistic regression, a score of ‘TGUGT’ > 14.2 sec, a score of ‘5 TSTS’ > 12.9 sec and a score of ‘8 FSW’ > 4.6 sec respectively, increased the probability of anterior peripheral fracture by 2.7, 2.2 and 2.3 (OR = 2.7; 95% confidence interval (CI) = 1.2-6.4; p = 0.019, OR = 2.2; 95% CI = 1.1-5.2; p = 0.049 and OR = 2.3; 95% CI = 1.1-5.1; p = 0.033). There was a significant positive correlation between the number of fall / year and the 3 tests. This correlation persisted after adjusting for age.

Conclusion: this study suggested that low physical performance is associated with low BMD, and a high risk of history of falls and fractures.
Background

Osteoporosis is a major public health problem. There are an estimated 1.5 million fragility fractures in the United States each year, including 700,000 spine fractures, 300,000 hip fractures, and 250,000 wrist fractures [1]. Approximately 50% of patients who sustain a hip fracture lose the ability to walk independently; up to 24% of women and 30% of men die within the first year [2,3].

In current clinical practice, most clinicians dealing with established vertebral osteoporosis focus their attentions on bone mineral density (BMD) and rarely consider fall prediction or prevention. Indeed, risk of fracture is influenced by both bone strength and falls. Measures of physical function and performance are predictors of falls, and both BMD and physical performance are independent predictors of fracture risk [4,5].

Balance deteriorates with age and constitutes a risk factor in fractures [6]. If better balance could be achieved by physical training improving muscular control, then exercise leading to improved balance might decrease the incidence of falls [7].

Patients with strong leg muscles should have better balance than those with weaker legs. This has been proven in elderly nursing home residents with a history of falls, compared with age-matched controls.

Many balance tests have been shown to predict future falls in older people. These include the following simple tests, which may be used in a busy clinical setting: the ‘timed get-up and go test’, the ‘times-sit-to-stand test’ and ‘gait speed test’.

The aim of the study was to evaluate the relationship between physical performance measures, BMD, falls, and the risk of peripheral fracture in a population sample of Moroccan women.
Subjects and Methods

Subjects

484 healthy Moroccan women volunteers were recruited from the city of Rabat, through advertisements in local hospitals. Informed consent was obtained from all patients and the study was approved by the ethics committee of our university hospital. We excluded patients with a history of (1) using medications known to influence bone metabolism within the past two years (e.g. vitamin D, calcium, corticosteroids, bisphosphonates and hormone replacement therapy); (2) musculoskeletal, thyroid, parathyroid, adrenal, hepatic, or renal disease; (3) malignancy; or (4) hysterectomy.

Data Collection and Measurements

Each patient completed a questionnaire to assess demographic characteristics and osteoporosis risk factors. We also collected data relating to the personal history of peripheral osteoporosis fractures (including proximal femoral fractures) and the self-report history of falls occurring in the last year (A fall defined as any event that led to an unplanned, unexpected contact with a supporting surface).

Anthropometric Data

Weight and height were measured without clothes or shoes at the time of bone densitometry measurements. The body mass index (BMI) was calculated as body weight (kg)/height (m2).

Physical Performance Measures
Three measures were used to assess physical and balance performance: timed get up and go test ‘TGUGT’, five-times-sit-to-stand test ‘5 TSTS’ and 8-feet speed walk ‘8 FSW’. Time was measured by stopwatch and rounded to the nearest hundredth of a second.

Timed Get Up and Go Test: In this test, the patient rises from a chair, walks 3 meters, turns around, returns to the chair, and sits down [8]. The patient was instructed to: "Sit with your back against the chair and your arms on the arm rests. On the word ‘go’, stand upright, then walk at your normal pace to the line on the floor, turn around, return to the chair, and sit down". The stopwatch was started on the word ‘go’ and stopped when the patient returned to the starting position. The Timed Get Up and Go Test was used to evaluate the functional mobility of the participants. Several studies reported high test-retest reliability [9] (ICC = 0.97) and excellent intra- and inter-reliability [8] (ICC = 0.99) for the Timed Get Up and Go test.

Five-times-sit-to-stand test: The sit-to-stand test is commonly used to assess lower extremity strength and balance [10]. The subjects began by crossing their arms on their chest and sitting with their back against the chair. Participants were asked to stand up and sit down as quickly as possible five times. The subjects were reminded to straighten their legs fully when standing. In previous studies with measurements of the same test situation, the sit-to-stand test has shown high reliability [11]. We applied the STS test five times, as Lord et al [10] had reported a high level of reliability at this frequency of the STS test.

8-feet (2.4 m) speed walk: Patients were instructed to walk as fast as possible for 8 feet (2.4 m). Patients wore the footwear they normally used. A digital stopwatch was
used to measure the time between the start of walking and when the first foot crossed the finish line. The reliability of this protocol is reported as adequate [12]. Measurement of gait speed for a short distance is used both clinically and in large epidemiological studies, such as established populations for epidemiological studies of older subjects (2.4 m [8 ft]). Gait speed has been associated with activity level [13] changes in the isometric force of lower extremity muscles [13], self-rated health, and falls [14].

**Dietary Calcium Questionnaire**

The frequential self-questionnaire of Fardellone [15] has been modified, simplified and adjusted to the food habits of Moroccans. After translation and back translation, it was administered to 62 volunteers women, aged between 30 and 60 years. To test its validity, the questionnaire was compared to the weekly docket system, chosen as a reference method. To test its reproducibility, the questionnaire was administered again after a one week interval. The coefficient of correlation was 0.91. The questionnaire correctly classified women with daily calcium intake less than 800 mg with 76.9% specificity, while its sensitivity was 86.7%.

**Physical Activity**

For the evaluation of physical activity, we used the short form of the International Physical Activity Questionnaire (IPAQ) [16]. The items of IPAQ were structured to provide separate scores on walking, moderate-intensity and vigorous-intensity activity. Computation of the total score requires summation of the duration (in minutes) and frequency (days) of walking, moderate-intensity and vigorous-intensity activities.
**Bone mineral density (BMD) measurements**

Lumbar spine, trochanter, femoral neck and total hip BMD were measured by DXA (Lunar Prodigy densitometer). Daily quality control was performed using Lunar Phantom measurements, which showed stable results during the study. The Lunar Phantom showed a precision of 0.08 expressed as the coefficient of variation (CV) in percent. Both T and Z scores were obtained. T-scores were calculated using the manufacturer's European reference population range because no Moroccan reference ranges were available.

**Statistical Analysis**

All analyses were performed using SPSS, version 10.0 for Windows. Results with \( p \) values less than 0.05 were considered statistically significant.

The relationships between BMD and physical performance measures were analyzed with Pearson correlation coefficients (r) for preliminary analyses. Using the receiver operating characteristic (ROC) curve, we determined the best cut-off point for each physical performance measure: 14.2 sec for ‘TGUGT’, 12.9 sec for ‘5 TSTS’ and 4.6 sec for ‘8 FSW’. The subjects were separated into 2 groups (group 1 was below and group 2 was above the best cut-off point) to conclude whether subjects who displayed better physical performance also had higher BMD. Student t-test was used to determine which of groups 1 and 2 had higher BMD. Using multiple regression models adjusted for Body Mass Index (BMI), age of menarche, total calcium intake, and current hours of total physical activity, we examined whether each physical performance measure had a relationship to BMD at various skeletal sites. We compared the scores of the tests between the fractured patients and non-fractured patients with Student t-test. Multiple logistic regression analysis was used to
investigate the association between the history of peripheral fracture (dependent variable) and physical performance (independent variable) after adjusting for age, BMI and total hip BMD.

In addition, we evaluated the relationship between falls and physical performance scores (Student t-test). Poisson regression was used to explore the association between the number of falls / year (dependent variable) and three tests (independent variable), after adjusting for age.

Results

Clinical Characteristics

The characteristics of subjects are shown in table 1. The mean age of the patients was 55.1 ± 9.6 years and the mean BMI was 28.2 ± 4.7 kg/m². Of the 484 participants, 175 (31.2 %) reported a history of falling. Among menopausal women (n= 360), 31 % were osteoporotic at any of the measured sites (spine, hip). (We used the WHO classification of osteoporosis which defined Osteoporosis: BMD 2.5 SD or more below the young adult mean (T-score at or below -2.5) and 11.9 % had a personal medical history of peripheral fractures (including proximal femoral fractures). The mean daily dietary calcium intake was 694 ± 231 (range 190 to 1800) mg and the median total physical activity was 2346 minutes/week (interquartile range, 929-4918).

The Relationship between Physical Performance Tests and BMD.

In univariate analysis, a highest ‘TGUG’, ‘5 TSTS’ and ‘8 FSW’ tests were associated with a lowest BMD measured in different sites (r range from -0.20 to -0.13; p range from < 0.001 to 0.005) (Figure 1).
When subjects were divided into below the best cut-off (group 1) and above the best cut-off (group 2) for ‘5 TSTS’, ‘8 FSW’ and ‘TGUGT’ (Figure 2), those in group 1 had significantly higher BMD in all measured sites.

The relationship between the three tests and BMD in all measured sites remained significant after adjustment for BMI, age of menarche, total calcium intake and hours of total activity (p range from <0.001 to 0.026) (table2).

The Relationship between Physical Performance Tests and Peripheral Fracture.

In the sub-group of post-menopausal patients, the scores of the tests ‘TGUGT’, and ‘8 FSW’ were significantly higher in fractured patients compared with women with no previous fractures (14.5 sec ± 8.2 sec vs 11.4 sec ± 4.8 sec ; p< 0.001 and 5.4 sec ± 2.6 sec vs 3.9 sec ± 2.0 sec ; p< 0.001 respectively); while test ‘5 TSTS’ scores were approaching significance (14.8 sec ± 6.4 sec vs 13.3 sec ± 5.1 sec ; p = 0.08) (Figure 3).

After adjusting for age, BMI and total hip BMD by logistic regression, a score of ‘TGUGT’ > 14.2 sec, a score of ‘5 TSTS’ > 12.9 sec and a score of ‘8 FSW’ > 4.6 sec respectively, increased the probability of anterior peripheral fracture by 2.7, 2.2 and 2.3 (OR = 2.7; 95% confidence interval (CI) = 1.2-6.4; p = 0.019 OR = 2.2; 95% confidence interval (CI) = 1.1-5.1; p = 0.049 and OR = 2.3; 95% CI = 1.1-5.1; p = 0.033).

The Relationship between Physical Performance Tests and Falls

The results of the three tests were highest in the group with a history of falls, as compared with the group without (data not shown). Furthermore, there was a
significant positive correlation between the number of falls / year and the 3 tests. This correlation persisted after adjusting for age (table 3).

Discussion

In this population-based study, we showed that low physical performance is associated with reduced BMD at both the spine and hip in women. All of the measures, showed consistent significant associations with hip and lumbar spine BMD in simple correlations and multiple regression models, that were controlled for confounders already known to influence BMD. Our results are consistent with the majority of previous studies among women, showing an association between physical performance and BMD at the spine and the hip [17,18,19].

Taaaffe et al [20] found that physical capacity assessed by repeated chair stands, gait speed, walking endurance, and standing balance was only modestly related to BMD at the hip. In another study, Lindsey et al [19] showed that physical performance was associated with hip, spine and whole body BMD, using normal and brisk gait speeds, normal and brisk step length and one leg stance time. Several studies validate repeated sit to stand time as a measure of lower-extremity strength and power [10, 21], and quadriceps strength has been associated with femoral neck BMD in similar samples [22].

Physical performance is reflected in lower extremity strength and gait speed. Activity produces a mechanical load on the bone through muscle contraction and surface impact, which contributes to bone formation and remodeling. It is considered that a lack of physical activity reduces mechanical load on bones, which can then lead to a decrease in bone density. The positive effect of walking speed on hip and lumbar
spine BMD is in line with interventional exercise studies showing that regular weight bearing and/or resistance exercise over extended time periods [19] could maintain or slightly increase hip and lumbar spine BMD in older women. In light of evidence that even the force of walking can cause a femoral neck fracture when BMD is very low, it stands to reason that increased force generated by walking would stimulate bone formation at that site [19]. It is thought that a decrease in physical exercise, which would result in insufficient sun exposure due to a reduction in outdoor activity, may lead to a vitamin D deficiency, thus producing a reduction in bone density. Therefore, it appears that a lack of physical performance affects bone density reduction both directly and indirectly, and this may increase the risk of fracture [23].

In post-menopausal patients, we have found that women with self-reported prior fractures have inferior performance scores for ‘TGUGT’, ‘5 TSTS’ and ‘8 FSW’ compared with women with no previous fractures. Thus, women with earlier fractures have a poorer balance performance than women with no previous fractures. This result agrees with Gerdhem, [24] who found that previous fractures are associated with inferior physical performance (Romberg test and gait speed test) in elderly women. This is also consistent with the prospective study on the effect of fracture on physical performance. In a longitudinal case-cohort, Greendale et al [25] reported that individuals with a hip, arm, or clinical spinal fracture show global declines in physical performance compared with individuals without fractures. Stel et al found, in a prospective study, that low performance test scores were significantly associated with self-reported fractures [26]. A recent cohort study by Mannen Cawthon et al reported that poor physical function was independently associated with an increased risk of hip fracture in older men [27]. In retrospective studies there is always the question of
what comes first: impaired balance leading to a fracture? Or fracture leading to impaired balance?

Inferior balance capability is associated with the tendency to fall, which is one of the more important risk factors for fractures [28], and interventions for fall prevention include balance training. Additionally, a possible cause for a slower physical performance in the “fractured” group might be atrophy due to prolonged bed rest or inactivity, leading to reduced muscle strength and an impaired balance with postural sway.

Our data reported a positive correlation between fall and the scores of three tests. It has been shown in many studies that there was a relationship among the elderly between balance impairment and a history of falling [29]. Poor physical performance, such as walking speed, lower extremity performance, and balance, increases the likelihood of falling [30]. According to Shumway-Cook et al, [31] the TGUG is a sensitive and specific measure for discriminating between fallers and non-fallers in community-dwelling adults. In contrast, Aslan et al [32] did not find any difference between the scores of the timed balance tests, including the TGUG and STST, while comparing the fallers and non-fallers amongst elderly subjects. There is a possibility that, even before the fracture, reduced walking speed and balance may partly explain the results of the walking test, as well as the cause of the fracture. Another explanation for slow walking amongst subjects in general is the fear of falling. Fear of falling due to an earlier fall is common, and often results in limited mobility and slower walking speed.

This study presents a number of methodological limitations to be considered in interpreting the results. Since this was a cross-sectional survey, the results must be
interpreted carefully. Cross-sectional studies such as this one, can detect associations between variables, but cannot demonstrate causality. A longitudinal study, involving a large cohort, examining the effect of physical performance on bone density, fall and the risk of peripheral fracture, is needed in order to be able to reach generalizable conclusions confidently. Furthermore, one has to be aware of the drawbacks of retrospective fracture and fall registration. However, this study had a number of strengths. Firstly, the study consisted of a large sample size. Secondly, we evaluated three criteria in the same study: bone mineral density; the risk of peripheral fracture; and fall. Another strength was the use of a variety of validated physical performance measures.

Conclusion

Our data showed that low physical performance is associated with low BMD, and a high risk of falls and fractures. Poorer physical performance was associated with the risk of peripheral fractures in postmenopausal women, independently of bone mineral density. Accordingly, it is recommended that intervention strategies to reduce the incidence of fracture should be targeted at improving both physical performance and bone density by doing regular exercise.
Competing interests

The authors declare that they have no competing interests for this study.

Authors’ contributions

We declare that we participated at the study as following:

FA, NHH and RA conceived the study and supervised its design, execution, and analysis and participated in the drafting and critical review of the manuscript. FA and RA did data management and statistical analyses. All other authors enrolled patients, participated in data acquisition and critical revision of the manuscript. HK wrote the paper with input from all investigators.

Acknowledgments

This work was supported by grants from the University Mohammed V, Souissi, Rabat-Morocco.

The University Hospital Center of Rabat- Morocco supported the bone mineral density measures.
References


17. Bevier WC, Wiswell RA, Pyka G, Kozak KC, Newhall KM, Marcus R:


22. Blain H, Vuillemin A, Teissier A, Hanesse B, Guillemin F, Jeandel C:

   Influence of muscle strength and body weight and composition on
regional bone mineral density in healthy women aged 60 years and over.


Table 1: Clinical and osteodensitometric characteristics for the studied population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>55.1 ± 9.6</td>
</tr>
<tr>
<td>Age of onset of menarche (y)</td>
<td>12.7 ± 1.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.2 ± 11.5</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>156.9 ± 8.8</td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
<td>28.2 ± 4.7</td>
</tr>
<tr>
<td>Total physical activity (min/wk)</td>
<td>2346 ± 1017</td>
</tr>
<tr>
<td>Total calcium intake (mg/d)</td>
<td>694 ± 231</td>
</tr>
<tr>
<td><strong>BMD (g/cm²)</strong></td>
<td></td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>1.011 ± 0.180</td>
</tr>
<tr>
<td>Trochanter</td>
<td>0.720 ± 0.127</td>
</tr>
<tr>
<td>Femoral neck</td>
<td>0.881 ± 0.151</td>
</tr>
<tr>
<td>Ward’s triangle</td>
<td>0.729 ± 0.161</td>
</tr>
<tr>
<td>Total hip</td>
<td>0.925 ± 0.151</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Median</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-score Lumbar</td>
<td>-1.6</td>
<td>-5.4</td>
<td>2.5</td>
</tr>
<tr>
<td>T-score Hip</td>
<td>-0.9</td>
<td>-3.5</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Abbreviations: “wk”: week; “d”: day.
Table 2: The relationship between the three tests and BMD after multiple regression models

<table>
<thead>
<tr>
<th>BMD</th>
<th>Spine</th>
<th>Femoral Neck</th>
<th>Trochanter</th>
<th>Total hip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>p</td>
<td>β</td>
<td>p</td>
</tr>
<tr>
<td>&quot;TGUGT&quot;</td>
<td>-7.33</td>
<td>&lt;0.001</td>
<td>-5.26</td>
<td>0.001</td>
</tr>
<tr>
<td>&quot;5 TSTS&quot;</td>
<td>-4.82</td>
<td>0.010</td>
<td>-3.65</td>
<td>0.026</td>
</tr>
<tr>
<td>&quot;8 FSW&quot;</td>
<td>-1.37</td>
<td>0.002</td>
<td>-1.15</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Abbreviations: “TGUGT”: Timed get-up-and-go test; “5 TSTS”: Five-times-sit-to-stand test; “8 FSW”: 8-feet speed walk; “BMD”: bone mineral density.

Each physical performance measure was entered separately into the model because of colinearity. Models were corrected for BMI, age of onset of menarche, total calcium intake, and total minutes of physical activity.
Table 3: Relation between the number of fall / year and the three tests.

<table>
<thead>
<tr>
<th></th>
<th>Risk Ratio</th>
<th>CI 95%</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TGUGT</td>
<td>1.03</td>
<td>1.01 – 1.05</td>
<td>0.021</td>
</tr>
<tr>
<td>5 TSTS</td>
<td>1.04</td>
<td>1.02 – 1.07</td>
<td>0.001</td>
</tr>
<tr>
<td>8 FSW</td>
<td>1.13</td>
<td>1.07 – 1.18</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Abbreviations: “TGUGT”: Timed get-up-and-go test; “5 TSTS”: Five-times-sit-to-stand test; “8 FSW”: 8-feet speed walk

This relation was considered after adjusting for age by poisson regression method.
Abbreviations: TGUGT, Timed get-up-and-go test; 5 TST, Five-times-sit-to-stand test; 8 FSW, 8-feet speed walk; BMD, bone mineral density.

Figure 1: Negative correlation between the three physical performances and the BMD of various skeletal sites
Abbreviations: BMD, bone mineral density.

Figure 2: Means for BMD of various skeletal sites according to the timed get-up-and-go test (TGUGT).

Group 1 was below the best cut-off (≤ 14.25 sec) and group 2 was above the best cut-off (>14.25 sec).
Figure 3: Comparison of the scores of the 3 tests between the fractured vs not fractured patients

Abbreviations: TGUGT, Timed get-up-and-go test; 5 TSTS, Five-times-sit-to-stand test;
8 FSW, 8-feet speed walk.
Additional files provided with this submission:

Additional file 1: comment 1.doc, 47K
http://www.biomedcentral.com/imedia/1218624483252179/supp1.doc
Additional file 2: comment 2.doc, 55K
http://www.biomedcentral.com/imedia/1999152152521784/supp2.doc