Journal of Clinical Gerontology & Geriatrics 7 (2016) 48–52

Contents lists available at ScienceDirect

Journal of Clinical Gerontology & Geriatrics

journal homepage: www.e-jcgg.com

Original article

Beyond mobility assessment: Timed up and go test and its relationship to osteoporosis and fracture risk

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ARTICLE INFO

Article history:
Received 20 June 2015
Received in revised form
21 August 2015
Accepted 25 August 2015
Available online 10 December 2015

Keywords:
bone mineral density
fracture risk assessment tool
Garvan fracture risk calculator
osteoporotic fracture risk
timed up and go

ABSTRACT

Background: Fracture determinants are falls, bone fragility, imbalance, and decreased lower limb strength. The timed up and go (TUG) test assesses most of the fracture determinants.
Aim: To assess the relationship between mobility status using TUG test, bone mineral density (BMD), and different fracture risks predicted by different tools.
Methods: A case (TUG time > 20 seconds)–control (TUG ≤ 20 seconds) study comprised 66 patients and 72 controls. Participants were assessed for falls, fracture history, and BMD using dual energy X-ray absorptiometry; the estimated 10-year fracture risk was also calculated using both the World Health Organization fracture risk assessment tool and Garvan fracture risk calculator.
Results: Patients had a lower femoral BMD ($p = 0.009$), T score ($p = 0.003$), and Z score ($p = 0.001$). Femur neck osteoporosis had a higher number of patients ($p < 0.001$). Patients also had lower lumbar BMD ($p = 0.02$), T-score ($p = 0.02$), and Z-score ($p = 0.005$). The estimated 10-year fracture risk for hip and other osteoporotic fractures were higher among the patients using both fracture risk assessment tool and Garvan calculators.
Conclusion: Poor TUG test results are associated with lower BMD and higher estimated 10 year fracture risk.

1. Introduction

Osteoporosis is a major concern for health providers. The increased healthcare costs, morbidity, and mortality related to osteoporosis and osteoporotic fractures are major health concerns.[1] Therefore, an easy to implement, validated method for the assessment of risk of fractures is needed.[2]

The World Health Organization fracture risk assessment tool (FRAX)[3] and the Garvan fracture risk calculator[4] are both widely available tools in daily practice for individualized fracture risk prediction. These fracture risk prediction tools attempt to integrate many risk factors for osteoporotic fractures in order to produce a single estimation of the fracture risk. The risk factors for osteoporotic fractures include clinical factors such as age and history of fracture and measured parameters such as body mass index (BMI) and bone mineral density (BMD).[5] Currently, in clinical settings, BMD is the primary predictor of osteoporotic fractures.[6]

Unfortunately, less attention has been paid to the role of other risk factors for falling, such as reduced levels of physical activity, poor balance, and low physical performance. These factors have been overlooked as risks for osteoporotic fractures.[6] However, these factors, in addition to bone mass, are important determinants of the occurrence of most appendicular skeletal fractures.[7] Previous studies have suggested that poor mobility is associated with lower BMD[8] and leads to an increased fracture risk.[9] Therefore, fracture prediction models should include assessment of physical performance, along with skeletal structural risk, assessed by BMD.[7]

The timed up and go (TUG) test is a commonly used method of assessing functional mobility among older adults in geriatric clinics. The test measures speed during several functional maneuvers, including standing up, walking, turning, and sitting down. Limited training and equipment are required, so the test is convenient in clinical settings.[10] It is an integral measure of gait speed and balance in widespread clinical settings.[11]

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http://dx.doi.org/10.1016/j.jcgg.2015.08.004

The aim of this study was to assess the relationship between mobility status using TUG test, BMD, and different fracture risks predicted by different tools.

1.1. Participants

A case–control study was conducted on 138 elderly individuals aged 60 years or older who attended the Osteoporosis Detection Unit in Ain Shams University Hospital, Cairo, Egypt, from August 2012 to March 2013.

Patients were 66 elderly individuals with poor mobility (TUG times >20 seconds) and the controls were 72 elderly individuals with good mobility (TUG results ≤ 20 seconds).

According to Podsiadlo and Richardson,[10] the interpretation of their TUG test results is as follows: TUG ≤ 10 seconds = normal; 10–20 seconds = good mobility, which means they can go out alone and can move without a gait aid; and 20–30 seconds = problems because they cannot go outside alone and require a gait aid.

Shumway Cook et al[12] suggested that the TUG score of ≥ 14 seconds indicated a high risk of falls. According to Hayes and Johnson,[13] there are no normal values available for TUG performance. However, all healthy community-dwelling elderly aged 65–84 years performed the test in ≤ 20 seconds without assistance[14]; meanwhile, frail elderly participants took 10–240 seconds to perform TUG, with 45 out of 57 individuals performing the test in < 40 seconds.[10] The test results of more than 20 seconds indicated the need for assistance, which was considered as a strong indicator of poor BMD compared with fall risk alone.[14] Individuals who could not perform the TUG test were excluded from the study.

2. Materials and methods

Data regarding the history of previous fractures and falls occurring within the last year were collected.

2.1. Anthropometric measures

Weight and height were measured at the time of bone densitometry measurements and the BMI was calculated.

Functional mobility was assessed using the TUG test, which was performed using an ordinary armchair and a stopwatch. Participants were seated with their back against the chair. They were instructed to stand up, walk for 3 m (to a mark on the floor), turn around, walk back to the chair, and then sit down. The task was done at the ordinary walking speed with participants wearing their usual footwear. Timed calculation in seconds started on the word "go" and stopped as the participant sat down. One untimed trial was allowed before testing. The test was conducted three times, and a mean value was calculated for study.[10]

2.2. BMD measurement

Bone densitometry was performed on all participants using dual energy X-ray absorptiometry (DXA; Lunar DpX+_MD Pencil scanner with software version 1.3 g; Lunar Radiation, Madison, WI, USA). The scanning was done in the supine position; the examined areas were lumbar vertebrae and left femoral neck. The graph showed a total BMD in g/cm, in relation to age, its age-matched percentage (Z-score), its peak reference percentage (T-score) with consideration of patient sex, weight, and height. World Health Organization definitions were used to define osteoporosis, which is the T-score of −2.5 or less.[15]

2.3. Estimated fracture risk calculation

The baseline data were used to calculate the estimated 10-year risk of fracture using the FRAX–Palestine and Garvan calculator. FRAX–Palestine was selected because Palestine has an osteoporosis epidemiology that is close to the osteoporosis epidemiology of Egypt, which is not represented in the FRAX assessment. The age, sex, BMI, history of personal fracture, history of parental hip fracture, smoking status, glucocorticoid use, alcohol intake, presence of rheumatoid arthritis or secondary osteoporosis, and femoral neck BMD T-score were entered into the online FRAX–Palestine assessment tool.[3]

Age, sex, femoral neck BMD T-score, number of falls within the past year, and the number of fractures since the age of 50 years were also entered into the online Garvan calculator assessment tool.[4] The estimated 10-year probability of hip and osteoporotic fragility fractures were obtained for each of the individuals using both calculators.

2.4. Ethical considerations

The study methodology was reviewed and approved by the ethical committee of the Faculty of Medicine, Ain Shams University. Informed consent was obtained from all participants in this study.

2.5. Statistical methods

The collected data were coded, tabulated, revised, and statistically analyzed using SPSS version 16 (SPSS, Chicago, IL, USA). Quantitative variables were presented in the form of means and standard deviation. Qualitative variables were presented in the form of frequency tables (number and percent). Comparison of two quantitative variables was performed using the Student *t* test, while multiple variables and multiple comparisons were done by both one-way analysis of variance and *posthoc* (least significant difference) tests. The qualitative variables were compared using the χ^2 test. Linear regression analysis was performed in order to identify the variables that were independently associated with FRAX T-score estimated hip fracture. A p-value < 0.05 was considered statistically significant.

3. Results

A comparison of demographic characteristics between patients and controls is shown in Table 1. There was matched demography for age and sex in patient and control groups. The most common comorbidities amongst our population were hypertension (37.7%), diabetes mellitus (26.8%), osteoarthritis (21.7%), ischemic heart disease (20.3%), and cerebrovascular stroke (2.89%) (See Supplementary Table). Patients showed a higher BMI (31.20 ± 8.56 kg/m^2), higher number of falls in the last year (1.79 ± 2.03), and a higher number of previous fractures (0.36 ± 0.65) compared with the controls (28.34 ± 7.12 kg/m^2, 1 ± 1.79, and 0.22 ± 0.45; $p = 0.03$, 0.017, and 0.004, respectively). BMD (0.78 ± 0.16 g/cm^2), femoral T-scores (−1.89 ± 1.15), and femoral Z-scores (−0.67 ± 0.098) of patients were significantly worse compared with those of controls (0.85 ± 0.13 g/cm^2, −1.33 ± 1.03, and −0.06 ± 1.05; $p = 0.009$, 0.003, and 0.001, respectively). Osteoporosis prevalence at the femoral neck was highly significant in these patients compared with the controls ($p \leq 0.001$). DXA results of the lumbar vertebrae showed significantly worse results for BMD ($p = 0.02$), T-score ($p = 0.02$), and Z-score ($p = 0.005$) for patients who had a higher prevalence of osteoporosis ($p = 0.014$; Table 1).

Table 1
Comparison between the two groups with regards to the studied variables.

Variables	Patients	Controls	*p*
Sex: Men (*n*)	33	36	0.57
Women (*n*)	33	36	
Age (y), mean ± SD	67.61 ± 5.36	66.43 ± 6.67	0.25
Weight (kg), mean ± SD	76.95 ± 20.69	71.92 ± 17.84	0.21
Height (cm), mean ± SD	157.33 ± 10.85	159.67 ± 9.02	0.26
BMI (kg/m^2), mean ± SD	31.20 ± 8.56	28.34 ± 7.12	0.03*
No. of previous falls, mean ± SD	1.79 ± 2.03	1 ± 1.79	0.01*
No. of previous fractures, mean ± SD	0.36 ± 0.65	0.22 ± 0.45	0.004*
TUG time (s), mean ± SD	32.52 ± 20.83	15.90 ± 2.43	<0.001*
Femoral neck BMD (g/cm^2), mean ± SD	0.78 ± 0.16	0.851 ± 0.13	0.009*
Femoral T-score, mean ± SD	−1.88 ± 1.15	−1.33 ± 1.032	0.003*
Femoral Z-score, mean ± SD	−0.66 ± 0.98	−0.06 ± 1.05	0.001*
Lumbar BMD (g/cm^2), mean ± SD	0.96 ± 0.19	1.041 ± 0.21	0.02*
Lumbar T-score, mean ± SD	−2.10 ± 1.59	−1.45 ± 1.71	0.02*
Lumbar Z-score, mean ± SD	−1.16 ± 1.39	−0.37 ± 1.78	0.005*
Femoral osteoporosis, *n* (%)	21 (31.81)	7 (9.72)	0.001*
Lumbar osteoporosis, *n* (%)	32 (48.48)	20 (27.7)	0.014*
Hypertension, *n* (%)	28 (42.4)	24 (33.3)	0.27
Diabetes mellitus, *n* (%)	21 (31.8)	16 (22.2)	0.2
Osteoarthritis, *n* (%)	18 (27.3)	12 (16.7)	0.13
Ischemic heart disease, *n* (%)	16 (24.2)	12 (16.7)	0.27
Cerebrovascular stroke, *n* (%)	1 (1.5)	3 (4.2)	0.34

* Statistically significant.
BMD = bone mineral density; BMI = body mass index; SD = standard deviation; TUG = timed up and go.

Table 2
Comparison between cases and controls with regards to the estimated 10 year fracture risks.

Variables	Patients	Controls	*p*
FRAX–Palestine T-score estimated hip fracture risk (%), mean ± SD	4.50 ± 6.73	1.35 ± 1.29	<0.001
FRAX–Palestine T-score estimated major osteoporotic fracture risk (%), mean ± SD	9.49 ± 9.05	4.82 ± 2.50	<0.001
Garvan hip fracture risk (%), mean ± SD	13.96 ± 21.5	4.99 ± 7.03	0.001
Garvan fragility fracture risk (%), mean ± SD	25.82 ± 21.36	16.6 ± 10.99	0.002

FRAX = fracture risk assessment tool; SD = standard deviation.

The FRAX–Palestine calculations for major osteoporotic fracture risk was 9.49 ± 9.05% for the patients versus 4.82 ± 2.50% for the controls ($p < 0.001$), a difference of 4.67%, with about 1.9-fold increase of risk among the patients. Regarding hip fractures, the risk was 4.50 ± 6.73% in patients versus 1.35 ± 1.29% in the controls ($p < 0.001$), a difference of 3.15%, with about 3.3 fold increase in risk among the patients (Table 2).

Using the Garvan fracture risk calculator, there was a significant difference between the two groups regarding the estimated 10-year fracture risk. The estimated 10-year fracture risk for hips among the patients was 13.96 ± 21.5% and 4.99 ± 7.03% among the controls; the difference was 8.97% with about 2.7-fold increase in the risk for the patients. The estimated 10-year osteoporotic/fragility fracture risk was 25.82 ± 21.36% for the patients and 16.62 ± 10.99% among the controls, a difference of 9.2%, with about 1.5-fold increased risk for the patients ($p < 0.002$; Table 2).

The effect of sex, which was assessed with regards to the difference in BMD and osteoporosis prevalence between men and women, showed that female patients were more obese BMI (34.5 ± 9.1), had slower TUG times (36.04 ± 28.05), had the least femoral neck BMD (0.74 ± 0.16), and lumbar BMD (0.91 ± 0.17). They also showed the worst femoral and lumbar T scores (−1.9 ± 1.19) and

Table 3
Sex-stratified characteristics.

	Male patients Group 1	Male controls Group 2	Female patients Group 3	Female controls Group 4	*p*				
					Groups 1 & 2	Groups 3 & 4	Groups 1 & 3	Groups 2 & 4	Between groups
BMI (kg/m^2)	27.91 ± 6.60	25.82 ± 6.94	34.50 ± 9.10	30.86 ± 6.45	0.239	0.04*	<0.001*	0.004*	<0.001*
No. of previous falls	1.67 ± 2.17	0.89 ± 1.63	1.91 ± 1.91	1.11 ± 1.95	0.09	0.08	0.609	0.62	0.104
No. of previous fractures	0.27 ± 0.51	0.08 ± 0.28	0.45 ± 0.75	0.36 ± 0.54	0.15	0.47	0.17	0.03	0.035*
TUG duration (s)	29.00 ± 8.33	15.43 ± 2.58	36.04 ± 28.0	11.17 ± 10.10	<0.001*	<0.001*	0.04*	0.77	<0.001*
Femoral BMD (g/cm^2)	0.83 ± 0.14	0.88 ± 0.15	0.73 ± 0.16	0.81 ± 0.09	0.105	0.02*	0.006*	0.02*	<0.001*
Femoral T-score	−1.86 ± 1.13	−1.31 ± 1.18	−1.90 ± 1.18	−1.34 ± 0.86	0.04*	0.03*	0.902	0.932	0.035*
Femoral Z-score	−0.55 ± 0.95	0.12 ± 1.18	−0.77 ± 1.00	−0.25 ± 0.86	0.006*	0.03*	0.37	0.121	0.002*
Lumbar BMD (g/cm^2)	1.01 ± 0.19	1.11 ± 0.23	0.91 ± 0.17	0.96 ± 0.15	0.02*	0.23	0.03*	0.002*	<0.001*
Lumbar T-score	−1.86 ± 1.62	−1.01 ± 1.94	−2.34 ± 1.55	−1.88 ± 1.34	0.03*	0.24	0.23	0.02*	0.009*
Lumbar Z-score	−1.42 ± 1.44	−0.31 ± 2.14	−0.89 ± 1.31	−0.43 ± 1.35	0.005*	0.23	0.18	0.74	0.02*

* Statistically significant.
BMD = bone mineral density; BMI = body mass index; SD = standard deviation; TUG = timed up and go.

Table 4
Sex-stratified estimated 10 year fracture risk% using FRAX–Palestine and Garvan calculators.

	Male patients Group 1	Male controls Group 2	Female patients Group 3	Female controls Group 4	*p*				
					Groups 1 & 2	Groups 3 & 4	Groups 1 & 3	Groups 2 & 4	Between groups
FRAX T-score major osteoporotic fracture	7.809 ± 7.66	3.93 ± 2.14	11.17 ± 10.10	5.72 ± 2.54	0.013*	0.001*	0.035*	0.23	<0.001*
FRAX T-score hip fracture	4.65 ± 7.41	1.54 ± 1.51	4.35 ± 6.09	1.15 ± 1.01	0.008*	0.006*	0.79	0.72	0.002*
Garvan femoral any osteoporotic/fragility fracture 10-y risk	18.4 ± 16.8	13.21 ± 9.8	33.24 ± 22.99	20.03 ± 11.12	0.17	0.001*	<0.001*	0.071	<0.001*
Garvan femoral hip fracture 10-y risk	8.19 ± 14.26	4.13 ± 7.24	19.74 ± 25.95	5.85 ± 6.80	0.27	<0.001*	0.003*	0.63	<0.001*

* Statistically significant.
FRAX = fracture risk assessment tool.

Table 5
Linear regression analysis for predictors of fracture risk assessment tool T-score hip fracture.

Variable	Standardized β coefficient	SE	*p*	95% confidence interval	
				Lower	Upper
Age	0.105	0.067	0.216	−0.052	0.225
Women	0.005	0.853	0.951	−1.771	1.665
BMI	−0.231	0.053	0.01*	−0.255	−0.036
TUG	0.254	0.044	0.002*	0.052	0.229
No. of previous fractures	0.338	0.708	<0.001*	1.601	4.468
DM	−0.036	0.981	0.678	−2.349	1.533
Hypertension	0.039	0.901	0.651	−1.375	2.192
IHD	−0.107	1.021	0.189	−3.371	0.673
CVS	−0.043	2.350	0.590	−5.920	3.383
Osteoarthritis	−0.014	0.976	0.863	−2.100	1.763
Constant		5.348	0.671	−12.864	8.304

* Statistical significance.
BMI = body mass index; CVS = cerebrovascular stroke; DM = diabetes mellitus; IHD = ischemic heart disease; SE = standard error; TUG = timed up and go.

(−2.35 ± 1.55) and the worst femoral Z scores (−0.077 ± 1.01) (Table 3).

Women also had higher estimated 10-year fracture risk by FRAX–Palestine T-score, which estimated the major osteoporotic fracture risk, Garvan femoral hip fracture risk, and Garvan femoral any fragility/osteoporotic fracture (Table 4).

Linear regression analysis revealed that TUG, BMI, and the number of previous fractures were independent predictors of FRAX T-score, which estimated hip fractures after adjustment for age, sex, and comorbidities (Table 5).

4. Discussion

The muscle–bone unit reflects a functional term that is important in the development of pubertal bone, as well for skeletal integrity.[16] It is known that muscle strength is a major determinant of skeletal quality.[17] Physical stress was found not only to increase bone mass but also improved bone geometry and also increased bone strength.[18] This easy and applicable tool was used regularly for performing the comprehensive geriatric TUG test to assess muscle strength, balance, and gait, together with fall risk, which are the major determents of osteoporotic fractures. The hypothesis of this study was that abnormal TUG results, which reflected reduced muscle strength, impaired gait and balance, and increased fall risk, could be strongly associated with reduced BMD and increased fracture risk. The current study included 138 elderly men and women who attended the osteoporosis detection unit in the Geriatrics Department of Ain Shams University Hospital. They were divided into a case group and a control group (matched for age and sex) based on TUG test times > 20 seconds and ≤ 20 seconds, respectively. The cutoff point of ≤ 20 seconds was selected for controls as it indicated good mobility, going out alone, and mobility without a gait aid.[10,19] The current study showed that poor mobility, as indicated by TUG time > 20 seconds, was associated with reduced lumbar spine and femur neck BMD. These results are consistent with other studies that used different physical performance tests showing an association between physical performance, BMD at the spine and the hip, and fracture risk in older persons. Taaffe et al[20] found that physical capacity, assessed by repeated chair stands, gait speed, walking endurance, and standing balance, was modestly related to BMD at the hip. However, Lindsey et al[21] showed that poor physical performance is associated with reduced hip, spine, and whole body BMD, while using normal and brisk gait speeds, normal and brisk step length, and one leg stance time. They explained that the decrease in bone density in patients with poor physical activity was due to the reduced mechanical load on bones. Similar results were obtained when the TUG test was used to assess physical performance; Khazzani et al[22] studied 484 healthy women, and three measurements were used to assess physical performance of TUG test, five-times-sit-to-stand test, and 8-feet timed walk. They found that low physical performance was associated with a reduced BMD at both the spine and hip in women. Moreover, Garber et al[23] reported that elderly women with normal BMD had better results than osteoporotic women on the TUG test. The TUG test results suggested that osteoporotic women had functional difficulties compared with those with normal BMD. The new insight in this study was correlated with the TUG test results with fracture risks assessed by FRAX–Palestine and Garvan calculators. Results showed that prolonged TUG times (> 20 seconds) were strongly related to increased 10-year fracture risk of both hip and major/fragility osteoporotic fractures. Few studies have addressed this issue; Zhu et al[7] performed a 10-year longitudinal study of the TUG test and BMD measurement to predict fractures. TUG test performance was found to be an independent risk factor for incident nonvertebral fractures independent of BMD and other risk factors in elderly women. As osteoporotic fracture has serious

consequences (i.e., high mortality, frequent hospitalization, high health care costs, functional impairment, pain, and reduced quality of life), and the existence of an easy-to-implement and valid method to assess the risk of fractures has become crucial. This is why calculators such as FRAX and Garvan were implemented; however, both of them are dependent on BMD measurements, which makes their application difficult, especially in a country such as Egypt. Therefore, with an office-based assessment tool, it will be easier to conduct studies and determine who is at a higher risk of developing fractures, which requires little equipment, such as the TUG test, a very helpful tool for selecting patients for DXA scanning. A highly significant relationship was found between prolonged TUG times (> 20 seconds) and 10-year fracture risk, and together with different DXA parameters. This highlights the importance of such a test in assessing the elderly beyond only mobility measurements. We strongly recommend the routine use of the TUG test in assessing the Egyptian elderly so as to detect the risk of falls, which is the major cause of osteoporotic fractures, and also to detect the elderly who may need further DXA assessment. Our study limitations are the small sample size and the use of a predetermined slightly long TUG test cut-off point. Our study cannot prove a causative association between abnormal TUG results, osteoporosis, and osteoporotic fractures; therefore, further longitudinal studies are strongly recommended.

Conflicts of interest

The authors declare no conflicts of interest with respect to the authorship and publication of this article.

Funding

The authors received no financial support for the research or authorship of this article.

Ethical consideration

Informed consent was received from each participant. The study methodology was reviewed and approved by the Research Review Board of the Geriatrics and Gerontology Department, Faculty of medicine, Ain Shams University.

Acknowledgments

The authors thank the participants and the Osteoporosis Detection Unit in Ain Shams University Hospital.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jcgg.2015.08.004