The Timed Up and Go Test is Related to Quantitative Ultrasound Parameters of Bone Strength in Japanese Community-Dwelling Elderly Women

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Abstract. [Purpose] The timed up and go test (TUGT) requires no special equipment or training, and it is a simple clinical assessment tool. The aim of this study was to investigate the relationship between a quantitative ultrasound (QUS) parameter of bone strength and TUGT in Japanese community-dwelling elderly women. [Methods] Ninety-nine community-dwelling elderly women participated (mean age, 74.4 $\pm$ 5.7 years) in the present study. The speed of sound (SOS) in the right calcaneus was measured using a QUS device to assess bone strength. Physical function examinations included grip strength, single leg stance time, TUGT, and gait speed. The Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) was used to assess each subject's functioning, and each subject's age, height, and weight were also collected. [Results] In multiple linear regression analysis controlling for age, of the physical function parameters, only TUGT was significantly related to SOS in all subjects. Furthermore, the relationship between SOS and TUGT was significant for those with high TMIG-IC scores, but SOS was not associated with any physical function parameters (including TUGT) for those with low TMIG-IC scores. [Conclusion] TUGT may contribute to the development of a simple clinical assessment tool that could be used to screen for hip fracture risk.

Key words: Timed up and go test, Quantitative ultrasound, Community-dwelling elderly women

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INTRODUCTION

Decreased bone strength and physical function are known as risk factors of hip fracture in elderly women¹⁾. Hagino et al. reported that the incidence of hip fracture has been increasing in elderly women in Japan²⁾. The prevention of hip fractures is important for maintaining independence of activities of daily living (ADL) and quality of life

for elderly Japanese women, and the appropriate assessment of bone strength and physical function is necessary for the prevention of hip fracture.

To assess bone strength, measurement of bone mass using dual energy X-ray absorptiometry (DEXA) or quantitative ultrasound (QUS) is generally adopted. It has been demonstrated that the assessment of bone strength of the calcaneus using QUS is useful as a predictor of hip fracture³⁾.

It has been reported that each 1 standard deviation (SD) decrease in the speed of sound (SOS) in the calcaneus, which is one of the QUS indices, increases the risk of hip fracture 2.5 times⁴⁾.

Of the physical function measures, gait speed has been shown to be an independent predictor of hip fracture^{3,5)}. Furthermore, many previous studies have shown that gait speed is related to bone strength assessed by DEXA or QUS⁶⁻¹⁰⁾. It is also known that falls cause over 90% of hip fractures¹¹⁾, and the timed up and go test (TUGT) is a useful predictor of falls in the elderly¹²⁾. However, no previous study has investigated the relationship between bone strength and TUGT. TUGT requires no special equipment or training, and it can be easily measured as part of a clinical examination¹³⁾. Therefore, determining the relationship between bone strength and TUGT may contribute to demonstrating the usefulness of the TUGT as a predictor of hip fracture. The aim of the present cross-sectional study was to investigate the relationship between QUS parameters of bone strength and TUGT in community-dwelling elderly Japanese women.

SUBJECTS AND METHODS

Subjects

The subjects were 99 community-dwelling elderly women. They were recruited by mail or telephone from Gunma prefecture and Kanagawa prefecture, Japan: 49 women from Gunma prefecture, and 50 women from Kanagawa prefecture. The inclusion criteria were: age, 65 years or older; able to walk independently; and no restrictions of physical activities. The exclusion criteria were: known history of neuromuscular disease; myocardial infarction; chronic obstructive pulmonary disease; liver disease; kidney disease; hyperthyroidism; unstable diabetes mellitus; unstable hypertension; taking of prednisolone; or treatment for osteoporosis. Written informed consent was obtained from all the participants. This study was approved by the research ethics committee of J.F. Oberlin University.

Methods

The SOS in the right calcaneus was measured using a QUS device (CM-100; Furuno Electric Co., Ltd., Hyogo, Japan). When the SOS was measured, the subjects sat on a chair in their bare foot. All

measurements were performed using the same device after the same calibration operation, following the operation manual prepared by Furuno Electric Co., Ltd. The device had an accuracy of $\leq \pm 1\%$ in the % coefficient of variation.

Physical function examinations consisted of grip strength, single leg stance time, the timed up and go test (TUGT), and gait speed. The grip strength of the right hand was measured using a dynamometer (GRIP-D, T.K.K 5401, Takei Scientific Instruments Co., Ltd., Niigata, Japan) in the standing position. When the single leg stance time was measured, the subjects kept their eyes open, and the time that a subject could stand on her right leg without hand support or falling was measured using a stopwatch. The upper limit of measurement was set at 60 seconds. For TUGT, examiners instructed subjects to stand up from a chair without hand support, walk 3 m as quickly and safely as possible, turn around, walk back, and then sit down again, as previously reported by Shumway-Cook et al.¹²⁾. The time required to complete the task was measured using a stopwatch. For gait speed, a 9 m flat, straight walkway was marked at 2 m from both ends, for acceleration and deceleration, and gait time was measured between the two points using a stopwatch under two conditions: subjects' preferred speed; subjects' fastest speed possible. The time was divided by the distance each subject walked, and the gait speed was calculated. The Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC)¹⁴⁾ was used to assess the functioning of each subject. This index consists of 13 items, and it has been widely used to measure the extent of elderly persons' functioning. A higher score indicates higher functioning, and the maximum score on this index is 13 points. In addition, age, height, and weight were collected for each subject, and the body mass index (BMI) was calculated based on the height and weight measurements.

The mean value and SD were calculated for each measurement parameter. The relationships between SOS and age, height, weight, BMI, and each physical function parameter were assessed using Pearson correlation coefficients. Furthermore, stepwise multiple linear regression analysis was performed to determine the relationships between SOS and each physical function parameter. In addition, further analysis was performed to investigate the influence on the subject's functioning level. The subjects were divided into two groups by

Table1. Characteristics, speed of sound and physical function parameters in all subjects

	All subjects (n=99)	good-functioning (n=64)	poor-functioning (n=35)
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Age (years)	74.4 $\pm$ 5.7	72.7 $\pm$ 4.8	77.5 $\pm$ 6.1**
Height (cm)	148.0 $\pm$ 6.4	149.3 $\pm$ 5.4	145.3 $\pm$ 7.4**
Weight (kg)	51.7 $\pm$ 7.9	51.9 $\pm$ 7.8	51.3 $\pm$ 8.1
BMI (kg/m ²)	23.6 $\pm$ 3.2	23.3 $\pm$ 3.1	24.3 $\pm$ 3.2
TMIG-IC [†] (full marks =13 points)	12.1 $\pm$ 1.6	NA	10.3 $\pm$ 1.8
Speed of sound (m/min)	1475.8 $\pm$ 20.5	1478.9 $\pm$ 20.7	1470.1 $\pm$ 19.1*
Single leg stance time (sec)	21.7 $\pm$ 19.9	27.2 $\pm$ 20.2	11.6 $\pm$ 15.1**
Grip strength (kg)	22.0 $\pm$ 4.1	22.5 $\pm$ 3.8	21.2 $\pm$ 4.5
Timed up and go test (sec)	6.7 $\pm$ 1.9	6.1 $\pm$ 1.3	7.8 $\pm$ 2.4**
Gait speed at preferred (m/min)	79.3 $\pm$ 12.8	82.5 $\pm$ 11.5	73.4 $\pm$ 13.1**
Gait speed at fastest (m/min)	100.8 $\pm$ 18.1	107.0 $\pm$ 15.7	89.5 $\pm$ 16.8**

good-functioning: TMIG-IC score of full marks (13 points). poor-functioning: TMIG-IC score less than 13 points. TMIG-IC[†]: Tokyo Metropolitan Institute of Gerontology Index of Competence, NA = Not applicable

*: $p < 0.05$, Comparison with good-functioning elderly, **: $p < 0.01$, Comparison with good-functioning elderly

the TMIG-IC scores: those who had full-marks (13 points) on the TMIG-IC, “good-functioning”, and those who had less than 13 points, “poor-functioning”. Unpaired t-tests were used to compare the age, height, weight, BMI, SOS, and each physical function between the groups. Then, the relationships between the SOS and physical function parameters were analyzed separately for each group using Pearson correlation coefficients and stepwise multiple linear regression analysis. The statistical analyses were performed using SPSS for Windows, version 11.0J (SPSS Japan, Inc., Tokyo, Japan). The significance level was set at 5%.

RESULTS

The mean values and SDs of the subjects' characteristics, SOS, and physical function parameters are presented in Table 1. There were significant negative correlations between SOS and age ($r = -0.421$, $p < 0.01$) and TUGT ($r = -0.410$, $p < 0.01$). There were significant positive correlations between SOS and gait speed at the preferred speed ($r = 0.346$, $p < 0.01$), gait speed at the fastest speed ($r = 0.391$, $p < 0.01$), and TMIG-IC ($r = 0.198$, $p < 0.05$) (Table 2). Stepwise multiple linear regression analysis including age as a covariate was performed, because SOS and physical function were affected by age. In multiple linear regression analysis, of the physical function parameters, only TUGT was significantly related to SOS (Table 3). In other

words, a slower TUGT was associated with a decreased SOS. However, this result may have been affected by the subjects' functioning level, therefore, further analysis was performed after subjects had been divided into two groups by the TMIG-IC scores. The further analysis demonstrated that elderly subjects with poor-functioning had lower physical function and SOS than elderly subjects with good-functioning (Table 1). With respect to the relationship between SOS and physical function parameters, SOS was significantly correlated with gait speed at the preferred speed ($r = 0.375$, $p < 0.01$), gait speed at the fastest speed ($r = 0.426$, $p < 0.01$), and TUGT ($r = -0.595$, $p < 0.01$) of good-functioning elderly. Furthermore, the relationship between SOS and TUGT was significant in stepwise multiple linear regression analysis controlling for age. However, SOS was not associated with any of the physical function parameters, including TUGT, in poor-functioning elderly (Table 2).

DISCUSSION

The present study investigated the relationships between a QUS index and TUGT in community-dwelling elderly Japanese women. Previous studies have reported that physical function is associated with a QUS index or BMD using DEXA. Associations of BMD with gait speed, single leg stance time, and muscle strength have been shown in middle-aged and elderly women^{6,8,15}.

Table 2. Relationship between speed of sound and characteristics and physical function parameters

Independent variable	All subjects (n=99)	good-functioning (n=64)	poor-functioning (n=35)
	r	r	r
Age	-0.421**	-0.500**	-0.192
Height (cm)	0.105	0.074	0.029
Weight (kg)	0.086	-0.011	0.265
BMI (kg/m ²)	0.044	-0.044	0.321
TMIG-IC [†] (points/13)	0.198*	NA	0.110
Single leg stance time (sec)	0.171	0.186	-0.118
Grip strength (kg)	0.169	0.164	0.111
Timed up and go test (sec)	-0.410**	-0.595**	-0.171
Gait speed at preferred (m/min)	0.346**	0.375**	0.170
Gait speed at fastest (m/min)	0.391**	0.426**	0.184

good-functioning: TMIG-IC score of full marks (13 points). poor-functioning: TMIG-IC score less than 13 points. r = Pearson correlation coefficient, NA = Not applicable, Dependent variable: speed of sound, TMIG-IC[†]: Tokyo Metropolitan Institute of Gerontology Index of Competence, *: p<0.05 **: p<0.01

Table 3. Stepwise multiple linear regression analysis (determination of related factors to SOS)

Independent variable	R ²	β	t-value	p value
(constant)			60.993	0.001
Age (fixed)	0.177	-0.276	-2.485	0.015
Timed up and go test (sec)	0.042	-0.250	-2.254	0.026
(excluded independent variable)				
Single leg stance time (sec)		-0.106	-1.001	0.320
Grip strength (kg)		0.090	0.950	0.345
Gait speed at preferred (m/min)		0.031	0.227	0.821
Gait speed at fastest (m/min)		0.054	0.333	0.740
TMIG-IC [†] (points/13)		-0.083	-0.765	0.446

Dependent variable: speed of sound, TMIG-IC[†]: Tokyo Metropolitan Institute of Gerontology Index of Competence.

Furthermore, in studies involving community-dwelling elderly women, muscle strength and gait speed were related to BMD or QUS^{7,10}). With respect to walking ability, Kwon et al. reported that a decline in gait speed was associated with decreased BMD in a longitudinal observation of community-dwelling elderly women⁹). Furthermore, Kitagawa et al. reported a relationship between the number of daily walking steps and QUS^{16,17}). The results of these previous studies demonstrate that walking ability is related to BMD and QUS, but the relationship between BMD or QUS and TUGT was not investigated in these previous studies. As in previous studies, the present study also showed that gait speed was related to QUS in univariate analysis. However, only TUGT was significantly related to QUS in multivariate

analysis.

TUGT is associated with gait speed and ADL¹³). Furthermore, TUGT is known to be useful for predicting falls in the elderly and in patients after hip fracture surgery^{12,18}). Also, Morris et al. reported that TUGT was more useful than gait speed as a predictor of falls in community-dwelling elderly women with a history of vertebral fracture¹⁹). Therefore, TUGT can be considered a comprehensive assessment tool of physical function and fall risk for the elderly. The relationship between TUGT and QUS in multivariate analysis found in the present study may be responsible for feature of TUGT that reflect physical function and fall risk of elderly women. Besides, the relationship between QUS and the TUGT found in the present study is of great interest from the standpoint of fall

causation in hip fractures.

A straight walkway of at least 10 m is required to measure gait speed. In addition, a pedometer and a certain period of time are required to examine the number of daily walking steps. Therefore, measurements of gait speed and daily walking steps are less practical than TUGT at the local community level, because TUGT requires a distance of only 3 m and no special equipment or training. Thus, TUGT is more clinically practical than gait speed or daily walking steps. The present findings concerning the relationship between QUS and TUGT may prove helpful in the development of a simple clinical assessment tool for screening for the risk of hip fracture.

In the present study, no relationship between SOS and TUGT was found for the poor-functioning elderly. The reason for this result cannot be clearly determined based on the data of the present study alone. It has been suggested that several factors are responsible for bone strength. For example, bone strength is associated with body weight, physical activity, and calcium intake in elderly women²⁰. Indeed, the present study found a weak correlation between SOS and BMI in poor-functioning elderly, though the correlation was not statistically significant (Table 2). Physique, as measured by BMI or body weight, may have more influence on bone strength than physical function in poor-functioning elderly.

The present study had several limitations. Since the present study was a cross-sectional design, the cause and effect relationship between TUGT and QUS cannot be determined. The association between fracture and the TUGT was not investigated; therefore, the usefulness of the TUGT as a predictor of fracture should be carefully interpreted. Finally, the factors (physical function, calcium intake, and BMI) associated with SOS cannot be clearly demonstrated in poor-functioning elderly, since the sample size of poor functioning elderly was small in the present study. Therefore, further data on SOS and physical function in the elderly with poor function need to be accumulated.

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