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Cross-sectional Analysis of the Health-related Quality of Life and Physical Fitness Levels in Aged Japanese Women with Low Quantitative Ultrasound Values of the Os Calcaneus

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Summary. The objective of this study was to investigate the relationship between health-related quality of life (HRQOL) and physical fitness levels (PFLs) in elderly women with low bone mass and without fractures, with a further goal of developing preventive programs involving efficient exercises for osteoporotic fractures and falls. The subjects comprised 133 females over 65 years of age whose quantitative ultrasound (QUS) values were < 90% of the young adult means (YAM). Muscle strength (knee extensors, hand grip, and trunk flexors), flexibility, one-leg standing time with eyes open (one-leg stand), time required for a 10-m walk while stepping over six obstacles (10-m walk), and 6-min walking distance (6-min walk) were measured to assess PFL. The subjects' HRQOL scores were relatively high (122.5 ± 15.5; maximum, 160 points) despite their low PFLs, as compared to the Japanese standard PFL in a similar age group. An age-adjusted stepwise multiple regression analysis between PFLs and QUS or HRQOL in 115 subjects which all measurements were performed, revealed that the 10-m walk significantly contributed to the QUS (R^2 = 0.152, p = 0.001) and to the total HRQOL score (R^2 = 0.025, p = 0.039). With regard to the PFLs, the 6-min walk and one-leg stand contributed to the 10-m walk (R^2 = 0.470, p = 0.012). In conclusion, the 10-m walk was observed to be a good indicator for the estimation of HRQOL and PFLs; subsequently, balance exercise, brisk walking, and endurance walking are good exercises that can be included in preventive programs to maintain a high HRQOL.

Key words— osteoporosis; bone mass; health related quality of life; activities of daily living; walking.

INTRODUCTION

The Japanese have the highest average life expectancy in the world.[1] Maintaining a healthy life and high health-related quality of life (HRQOL) in the elderly is an important health and welfare issue. Osteoporosis and osteoporotic fractures in the elderly are some of the major causes of a decreased HRQOL. The normal aging process is characterized by a decrease in the bone mineral density (BMD) and physical fitness levels (PFLs), such as muscle strength, balance, and walking ability.[2,3,4,5] These characteristics in the elderly contribute to frailty, risk of fractures, reduction in HRQOL, and loss of independence.[2]

Some researchers have reported a significant correlation between BMD and muscle strength.[6-11] Another researches have shown that walking improves BMD in the proximal femur[3] and lumbar spine,[12,13] and decreases the risk of hip fracture in postmenopausal women.[14] Therefore, community-based or home-based exercise programs are currently required to maintain PFLs in order to prevent osteoporosis and maintain HRQOL in the elderly. Many studies have reported on HRQOL in

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Abbreviations– ADL, activities of daily living; BMD, bone mineral density; HRQOL, health-related quality of life; JOQOL, Japanese osteoporosis quality of life questionnaire; QOL, quality of life; QUS, quantitative ultrasound; YAM, young adult means.

patients with osteoporotic fractures;[15-21] however, only a few have reported on that in osteoporotic women without fractures.[18,22,23] In addition, the relationship between HRQOL and PFL in postmenopausal women with low bone mass has not been well examined.

There are considerable researches into the relationship between BMD and muscle strength by using dual X-ray absorptiometry (DXA) to measure BMD and special instruments for isometric, isotonic, or isokinetic testing to measure the muscle strength of subjects in hospitals or research facilities.[6-11] However, it is difficult to use DXA and these special instruments in a community-based setup. Quantitative ultrasound (QUS) instruments have been widely used to assess bone quantity since they have several advantages: they do not use radiation, have a reasonable cost, and are portable and easy to use.[24,25,26] Comparative studies have been revealed a significant correlation between a QUS instrument and DXA.[27,28] Few studies have investigated the relationship between QUS values and PFLs measured using simple methods or devices.

We began a preventive program for osteoporotic fractures and falls in a rural community in Japan. In this program, female inhabitants over 65 years of age were assessed in terms of the QUS values of their os calcaneus and PFLs including muscle strength, one-leg standing balance with eyes open, and walking ability. One hundred and fifty women with low QUS values were included in the study to evaluate and analyze the relationship between HRQOL and PFLs. These subjects subsequently continued to participate in the preventive program for osteoporotic fractures and falls. The objective of this study was to investigate the relationship between HRQOL and PFLs in women with low initial QUS values as well as to develop simple evaluation tools for PFLs and efficient exercises for the preventive program.

METHODS

Subjects and QUS

From December 1999 to August 2001, 620 female inhabitants over 65 years of age were physically examined and participated in a community-based healthcare program that was designed to prevent osteoporotic fractures and falls; they were inhabitants of a rural Japanese community in a mountainous area of Saitama Prefecture (immediately north of Tokyo). They underwent physical examination, QUS, anthropometric data (height and weight), and PFL. The subjects of this study comprised 150 females whose QUS values were < 90% of the young adult mean (YAM), and they agreed to the assessment of HRQOL.

The QUS instrument (AOS-100, ALOKA Co. Ltd., Tokyo) was used to measure the bone mass at the os calcaneus. This instrument measures the speed of sound (SOS) and indicates an osteosono-assessment index (OSI, OSI = TI × SOS^2, TI: transmission index), T-score (%YAM) and Z-score (%), and classifies the results as the following: the subjects with values less than 80% of YAM are labeled as "needing further examination of bone mass," and those with values ranging between 80% and 90% of YAM are labeled as "needing continuous observation of bone mass." In this study, we used the results of the analysis using the QUS instrument (AOS-100), i.e., %YAM, to analyze the bone mass and to explain the results of the bone mass test to the participants. Therefore, the inhabitants whose OSI values were less than 90% of the YAM were selected as the subjects.

The HRQOL of 150 subjects was assessed, and the complete results of 133 subjects were subjected to this analysis. PFL measurements were completely evaluated in 115 of the 133 subjects. Written informed consent was obtained from the participants prior to measurement of any parameter; after testing, medical doctors discussed the test results with each participant. This research program was approved by the Saitama Prefectural University Ethical Committee.

Measurements

Before participating in the program, the subjects were requested to answer a written questionnaire regarding their general health and number of falls last year. Public health nurses interviewed the respondents and confirmed the answers provided. Next, the body height and weight of the subjects were measured and their blood pressure was checked to rule out any problems that might occur during PFL testing. QUS, PFL, and HRQOL were then assessed.

PFL testing involved the assessment of the muscle strength (the knee extensor, hand grip, and number of sit-ups as an indicator of the trunk flexor strength), flexibility (forward reach in a long sitting position), one-leg standing time with eyes open (one-leg stand), 10-meter walking time for stepping over obstacles (10-m walk), and 6-minute walking distance for endurance (6-min walk).

The isometric strength of knee extension was measured in a sitting position by using a hand-held dynamometer (Power Track II MMT; JTECH Medical Industries, Heber City, UT, USA). The grip strength was measured in a standing position by using a hand-grip dynamometer (T.K.K. 1201; Takei Scientific Instruments Co., Ltd., Tokyo). The number of sit-ups from the supine position with the knees bent (the subjects' legs were held by an examiner) to the sitting position that could be completed

Table 1. Subjects' age, anthropometric data, quantitative ultrasound (QUS) values, and number of falls (N = 133)

	Mean	SD	Min	Max
Age (year)	73.0	5.4	65	96
Height (cm)	145.4	6.3	116.7	160.3
Weight (kg)	49.3	8.5	30.8	70.6
BMI	23.5	4.1	15.7	43.1
QUS (% YAM)	63.8	9.4	43	84
Number of falls (times/year)*	0.4	0.8	0	4

*, Frequency in the previous year; BMI, body mass index; YAM, young adult means.

Table 2. Distribution of quantitative ultrasound (QUS) values and number of falls

Distributions		Number	Rate (%)
QUS (%YAM)	80-89	6	4.5
	70-79	33	24.8
	60-69	52	39.1
	-59	42	31.6
	Total	133	100.0
Number of falls (times/year)*	0	107	80.5
	1	15	11.3
	2	5	3.8
	3	3	2.3
	4 or more	3	2.3
	Total	133	100.0

*, Frequency in the previous year; YAM, young adult means.

in 30s was counted.

As a test of flexibility, the forward reach distance (cm) was measured in the sitting position with the legs extended while bending the trunk forward to the greatest possible extent from the upright position. The one-leg stand for each leg (s, up to a maximum of two min) was measured using a digital stopwatch. The 10-min walk assessment involved measuring the time(s) required to walk ten meters while stepping over six soft plastic obstacles that were placed every two meters. The six-min walk, which was used to assess walking endurance, involved measuring the distance (m) that the participants walked in six min around a track.

All these measurement methods, except the isometric strength test of knee extension, were standardized for individuals over 65 years of age by the Sports and Youth Department of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan.[29] Each measured value was graded using a standardized 1 -10 point system.[29] Knee extensor strength, hand-grip, and one-leg stand were measured for both sides, and the greater value between those of either side was used to analyze PFL. For the assessment of the one-leg stand with eyes open, both the longer time (one-leg stand) and the total time for both sides (total one-leg stand) were analyzed.

HRQOL questionnaire

In this study, the Japanese Osteoporosis Quality of Life Questionnaire (JOQOL) was used to assess HRQOL. JOQOL is an osteoporosis-targeted and disease-specific

Table 3. Physical fitness levels of the subjects and graded points according to the MEXT standard

Physical fitness levels	N	Mean	SD	Min	Max
Knee extension (N)	127	166.9	38.3	74	266
		—		—	—
Hand-grip (N)	133	154.6	63.0	0	284
		3		1	9
Sit-ups (times)	115	2.9	4.1	0	15
		2		1	9
Flexibility (cm)	127	31.6	7.8	7	51
		4		1	9
One-leg stand (sec)*	130	30.6	36.0	0	120.0
		7		1	10
Total one-leg stand (sec)*	130	48.1	63.5	0	240.0
		—		—	—
10-m walk time (sec)	127	11.6	3.8	6.8	27.3
		3		7	1
6-min walk distance (m)	118	395.9	82.9	193	741
		2		1	10

*, One-leg stand with eyes open; Upper line, measured value; lower line, graded points of the MEXT standard (1-10 points); MEXT, Ministry of Education, Culture, Sports, Science and Technology of Japan.

HRQOL questionnaire that was developed by the Committee for Development of Quality of Life (QOL) Measures of Postmenopausal Women of the Japanese Society for Bone and Mineral Research (JSBMR).[30,31]

The JOQOL consists of seven domains; namely, pain (five questions), activities of daily living (ADL, 16 questions), leisure and social activities (five questions), general health perception (three questions), posture and body image (four questions), fear of falling (four questions), and family support and summary (three questions); it has a total of 40 questions.[31] ADL consists of three subdomains; namely, self-care tasks (four questions), housework (five questions), and transfer (seven questions). The questionnaire consists of generic, disease-targeted, and cross-cultural questions.[31] Each question is graded on a 0-4 point scale, and the total score can range between a minimum of 0 and a maximum of 160 points.[31] The total score can be converted to a 0-100 scale: the higher the score, the better the QOL.[31]

The internal consistency of the total score has a Cronbach's alpha value of 0.808.[31] To assess its reliability and validity, the JSBMR Committee tested the JOQOL and the 36-item form of the Medical Outcome Survey instrument (SF-36) in 545 women with postmenopausal osteoporosis.[30] The correlation coefficients for each subscale of the JOQOL and the corresponding subscales of the SF-36 had a significance level of 0.05.[30] Test-retest reliability was assessed in 83 patients at an interval of four weeks, and the correlation coefficient was 0.920.[31]

Statistical analysis

The descriptive statistics of all variables were described in terms of mean ± SD and the distribution of QUS and falls. Simple correlation coefficients were analyzed between two variables from the total JOQOL scores and age, QUS values, and PFL as well as the coefficients between the score of each domain and the previously mentioned independent variables. The Pearson correlation coefficients were used between parametric variables, and the Kendall rank correlation coefficients were analyzed between each PFL variable or JOQOL score and nonparametric variables such as the number of falls and sit-ups. In case of the 115 subjects for whom all PFL measurements were completed, an age-adjusted

Table 4. Japanese Osteoporosis Quality of Life Questionnarire (JOQOL) scores for each domain and the totals (N = 133)

Domains		Mean	SD	Min	Max
I. Pain	(20 Point)	17.0	4.1	2	20
	(%)	85.1	20.7	10	100
II. Activities of daily living (ADL)	(64 Point)	57.5	6.6	18	64
	(%)	89.9	10.3	28	100
A. Self-care tasks	(16 Point)	14.2	1.4	5	16
	(%)	89.0	8.7	31	100
B. Housework	(20 Point)	18.6	2.4	1	20
	(%)	93.2	12.2	5	100
C. Transfer	(28 Point)	24.7	3.9	5	28
	(%)	88.1	14.1	18	100
III. Leisure and social activities	(20 Point)	11.2	3.9	3	20
	(%)	56.1	19.6	15	100
IV. General health perception	(12 Point)	6.1	1.8	0	12
	(%)	50.9	15.2	0	100
V. Posture and body image	(16 Point)	10.1	3.5	2	16
	(%)	63.2	21.6	13	100
VI. Fear of fall	(16 Point)	11.1	3.1	2	16
	(%)	69.5	19.3	13	100
VII. Family support and summary	(12 Point)	9.4	2.2	4	12
	(%)	78.3	18.5	33	100
Total JOQOL score	(160 Point)	122.5	15.0	70	153
0-100 Point	(100%)	76.6	9.4	43.8	95.6

Upper line, points for each domain; lower line, percentage of the maximum points for each domain.

stepwise multiple regression analysis was performed between the QUS or JOQOL scores (total or each JOQOL domain) and the PFL variables. Subsequently, an age-adjusted stepwise multiple regression analysis between the PFL variable with significant contributions and the other PFL variables was also performed for the same 115 subjects. All data were analyzed using a SPSS version 11.5 for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS

The subjects' age, anthropometric data, QUS values, and number of falls during in the last year are described in Table 1. The QUS value was 63.8% ± 9.4% (% YAM) (Table 1), and out of the 133 subjects, six (4.5%) were classified as normal, 33 (24.8%) were classified as osteopenic, and 94 (70.7%) were classified as osteoporotic by the diagnostic criteria of primary osteoporosis (2000 version)[32] (Table 2). The average number of falls was 0.4 ± 0.8 (times/year) (Table 1); 107 subjects (80.5%) had not fallen, while 15 (11.3%) had fallen once in the last year (Table 2). PFLs are listed in Table 3, and their graded points, except with regard to one-leg stand with eyes open (7-point), were relatively low, ranging between two and four points. The total JOQOL score and scores of each domain are listed in Table 4. The total score was 122.5 ± 15.0 points (maximum, 160; 76.6% ± 9.4%). In the seven JOQOL domains, pain (85.1% ± 20.7%), ADL (89.9% ± 10.3%), and family support and summary

Table 5. Simple correlation coefficient matrices between two variables in age, quantitative ultrasound (QUS) values, number of falls and physical fitness levels (N = 133; deficit paired results were excluded)

	Age	QUS	Number of falls †	Physical fitness levels						
				Knee extension	Hand-grip	Sit-ups	Flexibility	Total one-leg	10-m walk time	6-min walk distance
	r	*r*	τ	*r*	*r*	τ	*r*	*r*	*r*	*r*
Age (year)	—	-0.31 ***	0.05	-0.48 ***	-0.22 *	-0.15 *	-0.29 **	-0.42 ***	0.44 ***	-0.47 ***
QUS (% YAM)	-0.31 ***	—	-0.04	0.29 **	0.04	0.03	0.10	0.23 **	-0.36 ***	0.40 ***
Number of falls (times/year) †	0.05	-0.04	—	-0.09	-0.06	-0.11	-0.04	-0.05	0.10	-0.09
Knee extension (N)	-0.48 ***	0.29 **	-0.09	—	0.33 ***	0.10	0.39 ***	0.14	-0.43 ***	0.43 ***
Hand-grip (N)	-0.22 *	0.04	-0.06	0.33 ***	—	0.03	0.09	0.07	-0.20 *	0.14
Sit-ups (times)	-0.15 *	0.03	-0.11	0.10	0.03	—	0.09	0.18 **	-0.19 **	0.11
Flexibility (cm)	-0.29 **	0.10	-0.04	0.39 ***	0.09	0.09	—	0.09	-0.30 **	0.30 **
Total one-leg stand (sec) ‡	-0.42 ***	0.23 **	-0.05	0.14	0.07	0.18 **	0.09	—	-0.38 ***	0.29 **
10-m walk time (sec)	0.44 ***	-0.36 ***	0.10	-0.43 ***	-0.20 *	-0.19 **	-0.30 **	-0.38 ***	—	-0.68 ***
6-min walk distance (m)	-0.47 ***	0.40 ***	-0.09	0.43 ***	0.14	0.11	0.30 **	0.29 **	-0.68 ***	—

†, Frequency in the previous year; ‡ , One leg-stand with eyes open; p values (Two-sided test); * , $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$;
r, Pearson correlation coefficient; τ, Kendall correlation coefficient; YAM, young adult means.

Table 6. Simple correlation coefficient between Japanese Osteoporosis Quality of Life Questionnaire (JOQOL) scores and age, quantitative ultrasound (QUS) values, number of falls, or physical fitness levels (N=133; deficit paired results were excluded)

JOQOL domains	Age	QUS (%YAM)	Number of falls †	Physical fitness levels						
				Knee extension	Hand-grip	Sit-ups	Flexibility	Total one-leg stand ‡	10-m walk time	6-min walk distance
	r	*r*	τ	*r*	*r*	τ	*r*	*r*	*r*	*r*
I. Pain	0.19 *	-0.17 *	0.04	-0.09	-0.02	0.12	-0.01	-0.03	-0.06	-0.09
II. Total activities of daily living (ADL)	-0.45 **	0.23 **	-0.09	0.37 **	0.21 *	0.17 *	0.18 *	0.32 **	-0.57 **	0.42 **
A. Self-care tasks	-0.22 *	0.06	-0.02	0.10	0.08	-0.03	0.03	0.16	-0.12	0.04
B. Housework	-0.47 **	0.27 **	-0.05	0.35 **	0.18 *	0.20 *	0.10	0.26 **	-0.45 **	0.34 **
C. Transfer	-0.38 **	0.20 *	-0.12	0.37 **	0.22 *	0.16	0.21 *	0.32 **	-0.59 **	0.46 **
III. Leisure and social activities	-0.32 **	0.16	-0.11	0.29 **	0.15	0.17 *	0.15	0.09	-0.22 *	0.24 **
IV. General health perception	0.02	0.03	-0.17 *	0.03	0.07	0.03	-0.10	0.06	-0.09	-0.06
V. Posture and body image	-0.12	0.00	0.03	0.13	0.06	-0.02	0.19 *	0.13	-0.14	0.11
VI. Fear of fall	0.16	-0.15	-0.09	0.07	-0.06	0.10	0.01	-0.04	-0.06	-0.10
VII. Family support and summary	0.09	0.04	-0.04	0.15	0.06	0.05	-0.12	0.00	0.08	-0.06
Total JOQOL Socre	-0.21 *	0.07	-0.12	0.27 **	0.15	0.20 **	0.12	0.20 *	-0.31 **	0.18

† , Frequency in the previous year; ‡, One leg-stand with eyes open, p values (Two-sided test); *, $p < 0.05$; **, $p < 0.01$;
r, Pearson correlation coefficient; τ, Kendall correlation coefficient; YAM, young adult means.

Table 7. Age-adjusted stepwise multiple regression between the quantitative ultrasound (QUS) values or total Japanese Osteoporosis Quality of Life Questionnaire (JOQOL) score or that of each domain and physical fitness levels

Dependent variable	Selected independent variables	Adjusted R suquare	p values	Partial regression coefficients B	Partial regression coefficients SE	Standardized coefficients β	p values
QUS (%YAM)	(Invariable)			94.887	11.641		< 0.001
	10-m walk (sec)	0.152	0.001	-0.820	0.247	-0.314	0.001
Total JOQOL score	(Invariable)			130.734	18.792		< 0.001
	10-m walk (sec)	0.025	0.039	-0.835	0.400	-0.212	0.039
II. Total activity of daily living (ADL)	(Invariable)			65.995	5.297		< 0.001
	10-m walk (sec)	0.210	< 0.001	-0.578	0.113	-0.469	< 0.001
B. Housework	(Invariable)			23.750	2.214		< 0.001
	10-m walk (sec)	0.109	0.005	-0.135	0.047	-0.278	0.005
C. Transfer	(Invariable)			28.388	3.235		< 0.001
	10-m walk (sec)	0.240	< 0.001	-0.399	0.069	-0.519	< 0.001

B, partial regression coefficients adjusted for age; SE, standard error; Candidate variables for stepwise selection, Knee extension; Hand-grip; Sit-ups; Flexibility; Total one-leg stand; 10-m walk time and 6-min walk distance.

Table 8. Age-adjusted stepwise multiple regression between 10-m walk or 6-min walk or total one-leg stand and other variables of physical fitness

Dependent variable	Selected independent variables	Adjusted R suquare	p values	Partial regression coefficients B	Partial regression coefficients SE	Standardized coefficients β	p values
1. 10-m walk time (sec)	(Invariable)			17.945	4.798		< 0.001
	6-min walk (m)			-0.025	0.003	-0.573	< 0.001
	Total one-leg stand (sec) ‡	0.470	0.012	-0.010	0.004	-0.192	0.012
2. 6-min walk distance (m)	(Invariable)			662.787	101.106		< 0.001
	10-m walk (sec)			-12.441	1.735	-0.544	< 0.001
	Knee extension (N)	0.477	0.045	0.340	0.168	0.154	0.045
3. Total one-leg stand (sec) ‡	(Invariable)			389.214	80.723		< 0.001
	10-m walk (sec)	0.205	0.006	-4.811	1.716	-0.257	0.006

‡ , One-leg stand with eye open; B, partial regression coefficients adjusted for age and all selected variables each other; SE, standard error; Candidate variables for stepwise selection; 1. Knee extension; Hand-grip; Sit-ups; Flexibility; Total one-leg stand, and 6-min walk distance; 2. Knee extension; Hand-grip; Sit-ups, Flexibility; Total one-leg stand, and 10-m walk time; 3. Knee extension; Hand-grip; Sit-ups; Flexibility; 10-m walk time, and 6-min walk distance.

(78.3% ± 18.5%) showed relatively high scores, with more than 70% of the maximum points for each domain; however, leisure and social activities (56.1% ± 19.6%), general health perception (50.9% ± 15.2%), posture and body image (63.2% ± 21.6%), and fear of fall (69.5% ± 19.3%) scored less than 70% of the maximum points.

The simple correlation coefficient matrices between two variables in the age, QUS values (%YAM), number of falls, and PFL are listed in Table 5. The results indicated that QUS and all PFL variables decrease with age ($p < 0.05$ to $p < 0.001$) and that QUS was significantly correlated with knee extensor strength, total one-leg stand, 10-m walk time, and 6-min walk distance ($p < 0.01$ to $p < 0.001$). The simple correlation coefficient between the total JOQOL score or each domain and age, QUS values (%YAM), number of falls, or PFL are listed in Table 6. The results showed that the total JOQOL score was weakly but significantly correlated with age ($r = -0.21$, $p < 0.05$), knee extension ($r = 0.27$, $p < 0.01$), sip-ups ($\tau = 0.20$, $p < 0.01$), total one-leg stand ($r = 0.20$, $p < 0.05$), and 10-m walk ($r = -0.31$, $p < 0.01$). In the domains, the correlation coefficients indicated that ADL was moderately but significantly correlated with age ($r = -0.45$, $p < 0.01$), 10-m walk ($r = -0.57$, $p < 0.01$) and 6-min walk ($r = 0.42$, $p < 0.01$), and weakly but significantly correlated with QUS ($r = 0.23$, $p < 0.01$), knee extension ($r = 0.37$, $p < 0.01$), hand-grip ($r = 0.21$, $p < 0.05$), and total one-leg stand ($r = 0.32$, $p < 0.01$); leisure and social activities were weakly but significantly correlated with age ($r = -0.32$, $p < 0.01$), knee extension ($r = 0.29$, $p < 0.01$), 10-m walk ($r = -0.22$, $p < 0.05$), and 6-min walk ($r = 0.24$, $p < 0.01$). In the subdomains of ADL, self-care tasks were weakly but significantly correlated only with age ($r = -0.22$, $p < 0.05$); housework was moderately but significantly correlated with age ($r = -0.47$, $p < 0.01$) and 10-m walk ($r = -0.45$, $p < 0.01$), and weakly but significantly correlated with QUS ($r = 0.27$, $p < 0.01$), knee extension ($r = 0.35$, $p < 0.01$), sit-ups ($\tau = 0.20$, $p < 0.05$), total one-leg stand ($r = 0.26$, $p < 0.01$), and 6-min walk ($r = 0.34$, $p < 0.01$). Transfer was moderately but significantly correlated with 10-m walk ($r = -0.59$, $p < 0.01$) and 6-min walk ($r = 0.46$, $p < 0.01$), and weakly but significantly correlated with age ($r = -0.38$, $p < 0.01$), QUS ($r = 0.20$, $p < 0.05$), knee extension ($r = 0.37$, $p < 0.01$), hand-grip ($r = 0.22$, $p < 0.05$), flexibility ($r = 0.21$, $p < 0.05$), and total one-leg stand ($r = 0.32$, $p < 0.01$).

The values obtained from the age-adjusted stepwise multiple regression between the QUS or JOQOL score (total or each domain) and PFL are listed in Table 7. The multiple regression analysis demonstrated that the 10-m walk significantly contributed to the QUS ($R^2 = 0.152$, $p = 0.001$). The 10-m walk also significantly contributed to the total JOQOL score ($R^2 = 0.025$, $p = 0.039$), and significantly contributed to the ADL domain of JOQOL ($R^2 = 0.210$, $p < 0.001$) as well as housework ($R^2 = 0.109$, $p = 0.005$) and transfer ($R^2 = 0.240$, $p < 0.001$) in the subdomains of ADL. However, PFL did not contribute to other domains such as pain, leisure and social activities, general health perception, posture and body image, fear of fall, and family support and summary as well as self-care tasks in the subdomains of ADL.

The age-adjusted stepwise multiple regression analyses between the 10-m walk, 6-min walk, or total one-leg stand with eyes open and the other PFL variables are listed in Table 8. They indicated that the 6-min walk and total one-leg stand contributed significantly to the 10-m walk ($R^2 = 0.470$, $p = 0.012$). The multiple regression analyses also indicated that the 10-m walk and knee extension contributed significantly to the 6-min walk ($R^2 = 0.447$, $p = 0.045$), and that the 10-m walk contributed significantly to the total one-leg stand ($R^2 = 0.205$, $p = 0.006$) (Table 8).

DISCUSSION

The QUS value of the subjects was less than 84% of YAM, and its mean ± SD was 63.8% ± 9.4%. The diagnostic criteria of primary osteoporosis[32] indicated that, 133 subjects of these, 33 (24.8%) were classified as osteopenic and 94 (70.7%) were classified as osteoporotic. Therefore, the present QUS results indicate that the subjects have a low bone mass.

With regard to the subjects, the PFL measurements and the values of knee extension (166.9 ± 38.3 N), hand-grip (154.6 ± 63.0 N), and number of sit-ups (2.9 ± 4.1) were significantly lower than the Japanese standard values for 70-year-old females (knee extension: 248.9 ± 111.2 N, $p < 0.001$; hand-grip: 210.7 ± 40.2 N, $p < 0.001$; number of sit-ups: 6.3 ± 3.1 times, $p < 0.001$).[29] In addition, flexibility, 10-m walk, and 6-min walk were considered as low grade by the MEXT standard (Table 3).[33] In contrast, only the one-leg stand with eyes opened, was considered relatively high grade (7/10) by the MEXT standard (Table 3).[33]

It has been reported that muscle strength and BMD are related.[6-11,13,34] The isometric strength of knee extension significantly correlated with BMD of the total body,[6] proximal femur, and spine.[6,34] Iki et al.[10] showed that there was a positive correlation between hand-grip strength and the BMD of the spine. Huuskonen et al.[34] found that the isometric trunk flexor strength was significantly correlated with the BMD of the lumbar spine and proximal femur. Iki et al.[10] also showed that the isometric and isokinetic trunk extensor and flexor strengths had a positive effect on the annually measured change in BMD of the spine. The relationship between walking and BMD were investigated; walking improves the BMD of the proximal femur[3] and lumbar spine[12,13] and was associated with a substantially lower risk of hip fracture in postmenopausal women.[14)]

In the current study, the simple correlation coefficient between QUS and PFL variables indicated that the QUS correlated significantly with the knee extension strength, total one leg stand with eyes opened, 10-m walk, and 6-min walk ($p < 0.01$ to $p < 0.001$) (Table 5); these results were found to be similar to the results of these studies.[3,6-11,13,34)] However, the multiple regression analysis (Table 7) demonstrated that only the 10-m walk contributed significantly to the QUS ($p = 0.001$) in the subjects with low QUS values. The results of the multiple regression analysis (Table 8) also indicated that the 6-min walk and one-leg stand contributed significantly to the 10-m walk ($p = 0.012$), the 10-m walk and the knee extensor strength contributed significantly to the 6-min walk ($p = 0.045$), and the 10-m walk contributed significantly to the one-leg stand ($p = 0.006$). When performing the 10-m walk while stepping over obstacles, an individual must raise one-leg and stand on the other leg for a longer period than he/she would while walking normally; additionally, he/she should walk as fast as possible. These movements require lower leg muscle strength, trunk strength, and balance. It was assumed that the 10-m walk was related to all other PFL variables by the simple correlation coefficient analysis; hence, only the 10-m walk was found to contribute significantly to the QUS values when the multiple regression analysis was performed. In addition, the posture of the one-leg stand is similar to the posture while stepping over an obstacle during the 10-m walk. Therefore, the 10-m walk contributes to the one-leg stand and vice versa. These results demonstrated that the 10-m walk and one-leg stand with eyes open, are good valuable tools for PFLs.

The total JOQOL scores were relatively high (122.5 ± 15.0 points; 76.6% ± 9.4%) in subjects whose bone mass was less than 84% YAM (Table 4). The scores of three of the seven JOQOL domains (pain, ADL, and family support and summary) were relatively high (more than 70%); these results indicated that most of the subjects experienced less pain, maintained high ADL functions, and did not experience the need for family support. The average points of the other four domains (posture and body image, fear of fall, leisure and social activities, and general health perception) were relatively low (less than 70%). These results indicated that some subjects were concerned about postural changes and risks of fall despite the fact that more than 80% of the subjects had no history of falls in the previous year; the subjects were also socially and psychologically affected.

Many studies have reported on the HRQOL of patients with osteoporotic fractures such as those of the vertebrae,[15-22)] hip,[22,24,35)] forearm, and humerus;[21)] however, only a few studies have reported on the HRQOL of osteoporotic individuals without fractures. Tsauo et al.[23)] described how in postmenopausal osteoporotic or osteopenic women without vertebral fractures a significant negative correlation was observed between BMD and functional impairment that was evaluated by using the Oswestry Low Back Pain Disability Questionnaire as HRQOL assessment. These results suggested that the higher the BMD, the better the HRQOL in the postmenopausal women.[23)] Romagnoli et al.[18)] investigated the QOL perception in 361 asymptomatic ambulant postmenopausal women. The results of a study that used the Quality of Life Questionnaire of the European Foundation for Osteoporosis (QUALEFFO) demonstrated that the total score and physical function in the domains were impaired in patients with sub-clinical vertebral fractures or with a reduction in BMD of the femoral bone, and that the general health perception in that particular domain was also influenced by a reduction in BMD of the femoral bone.[18)] The results of these two studies are slightly controversial.

The participants in this study were not clinically diagnosed with vertebral, hip, or upper limb fractures and their total JOQOL scores were relatively high; however, the scores of some domains such as leisure and social activities and general health perception were relatively low. The present results suggest that the individuals who had low bone mass without fractures maintained a high ADL with less pain; however, they were psychologically and socially affected because of their perception of low bone mass. Hence, their high ADL level with less pain was related to the relatively high total HRQOL scores despite the fact that they responded with low scores to such psychological and social domains.

Few studies have directly explained the relationship between the PFL and the HRQOL osteoporotic or osteopenic individuals though some studies have indicated the effects of exercise on HRQOL. King et al.[36)] reported that community-based endurance, strengthening, and flexibility exercises were able to improve functional levels and emotional well-being with regard to HRQOL. Chien et al.[37)] showed that the home-based trunk-strengthening exercise program could improve trunk mobility and strength and enhance QOL in osteoporotic and osteopenic postmenopausal women without vertebral fractures. Papaioannou et al.[21)] showed that home-based exercise that included stretching, strength training, and walking improved QOL in elderly women with vertebral fractures. These studies suggested that improvement in trunk mobility and strength as well as walking and balancing abilities enhanced HRQOL. However, Tsauo et al.[23)] explained that physical impairment was not always correlated with functional impairments or HRQOL.

In this study, the simple correlation coefficients (Table 6) indicated that the total JOQOL score decreased with age, and that the higher total score was related to a faster

10-m walk while stepping over obstacles. The total JOQOL score was also significantly positively correlated with knee extension, sit-ups, and total one-leg stand. With regard to the JOQOL domains, the results indicated that ADL decreases with age and increases with QUS (% YAM) and the scores of the following PFLs: knee extension and hand grip strength, total one-leg stand, and walking ability. In the ADL sub-domains, the results of all sub-domains decreased with age, and housework and transfer were similar to those of ADL, except with regard to sit-ups and flexibility. Leisure and social activities decreased with age and increased with three of the seven PFLs significantly; namely knee extension strength, 10-m walk, and 6-min walk.

It should be noted that the present results of the age-adjusted stepwise multiple regression (Table 7) indicated that the 10-m walk significantly contributed to the total JOQOL score, the ADL domain score, and to the scores of the housework and transfer in the ADL sub-domains ($p = 0.039$ to $p < 0.001$). The multiple regression analysis (Table 8) also demonstrated the relationship between the 10-m walk, the 6-min walk, total one-leg stand with eyes open, and the knee extensor strength. Therefore, it is assumed that the 10-m walk and one-leg stand with eyes opened, are also useful indicators to estimate the HRQOL level, and that balance exercise, brisk walking, and endurance walking are good exercises to be performed in a community based-program.

This study has several limitations. First, the participants were volunteers who agreed to attend the program for the prevention of osteoporosis and falls that was organized by the municipal healthcare center, and they were inhabitants of a rural community in a mountainous area. For the measurements, the bone mass, PFL, and JOQOL of 133 attendants were measured. Not all the PFL tests were carried out for some attendants because of their physical condition, such as knee and/or lumbar pain, or personal schedules. Second, the measurements were performed over two years during the winter, spring, and summer at community halls in different areas of the town. Hence, there were seasonal and environmental variances in this study. It was impossible to conduct the study within a short period of time and at the same location because this research program was designed as a part of the community-based preventive programs of the town government plan. Third, the measurements included in the HRQOL questionnaire were limited. The basic concept of JOQOL is cross-cultural;[31)] however, some questions especially those regarding the ADL and social activities domains were specific to Japanese culture. In addition, few research articles on JOQOL have been published in English.

The first conclusion is that HRQOL was relatively high in aged individuals with low bone mass and without fractures, even if their PFLs were lower than the standard Japanese values for individuals in a similar age group. However, the individuals were psychologically affected as indicated by leisure and social activities, general health perception, and fear of falling HRQOL domains. Second, the 10-m walk while stepping over six obstacles was a useful indicator of the preventive programs for osteoporosis and falls in the communities to estimate HRQOL and PFLs of the individuals with low bone mass (QUS values). In conclusion, the one-leg stand with eyes opened and 6-min walk contributed to the 10-m walk among the PFL parameters; therefore, balance exercise, brisk walking, and endurance walking exercises should be advised for a preventive program.

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