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Modification of the functional reach test: Analysis of lateral and anterior functional reach in community-dwelling older people

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Abstract

The purpose of this study was to evaluate the validity and reproducibility of the modified lateral functional reach (FR), and to examine the associations between a variety of functional variables and the FR in community-dwelling older people (>65 years of age). A total of 383 aged Japanese participated in this study at the rural district Kahoku, Kochi, Japan, in 2002. The average age of the subjects was 78.6 years. The activity of daily living (ADL) and mental status were measured as outcomes. FR (anterior and lateral) and timed up and go (TUG) were measured as predictors. The test–retest reliability of lateral FR between the first and second measurement was very consistent. Subjects with greater lateral FR had higher basic and instrumental ADL (IADL) scores than did those with shorter lateral FR. However, there was no significant relationship between anterior FR and ADLs. The lateral FR of participants with depression was shorter than in those without depression, while the anterior FR did not correlate with the participants' scores on the geriatric depression scale (GDS). Lateral FR should be considered as a new, alternative means of assessing geriatric social activity and mental status in the elderly.

Keywords: Lateral functional reach; Timed up and go (TUG); Activity of daily living (ADL); Depression

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1. Introduction

Elderly people that show problems in gait and balance experience difficulty in the activities of daily living (ADL). The functional reach (FR) test is a simple way to measure standing balance, that has been assessed for both validity and reliability (Duncan et al., 1990; Weiner et al., 1992). The classic FR test is inexpensive, and provides a reasonable clinical approximation of the anterior margin of stability (Duncan et al., 1990). However, the reliability of physical performance measured by the FR test has been considered to be lower than several standard self-reported measures of function (Tager et al., 1998). The anterior FR test only assesses anterior stability (Jonsson et al., 2002), and is a weak measure of the anterior stability limits. Movement of the trunk seems to influence the results of this test more than does displacement of the center of the pressure (Jonsson et al., 2002).

Elderly people frequently experience lateral falls and suffer fractures of the femoral neck. Therefore, it is important to examine the balance of the lateral side, to identify elderly people who may be at risk of falling. We improved a new procedure to measure lateral FR that involves evaluating the reach to both the right and left sides and assessing the association between the fall, many kinds of ADL, geriatric depression, and anterior FR. The purpose of this study was to assess the validity and reproducibility of the modified lateral FR test, and to document the significance of the FR in aged people.

2. Subjects and methods

2.1. Subjects

The investigated population consisted of 383 community-dwelling subjects aged 60 years and older (average age, 78.6 years) and the study was conducted in the district of Kahoku, in Kochi, Japan, in 2002. There were 234 females and 149 males ranging in age from 60 to 95 years. The subjects' average baseline characteristics are shown in Table 1.

Table 1
The baseline characteristics of the population

	Female	Male	Total
Number	234	149	383
Age (in 2002)	78.1 ± 6.2	79.3 ± 5.4	78.6 ± 5.9
Height (cm)	145.6 ± 6.7	158.5 ± 6.3	150.6 ± 9.1
Weight (kg)	57.5 ± 9.8	50.2 ± 8.9	53.0 ± 9.9
TUG (s)	12.6 ± 3.3	12.4 ± 3.1	12.5 ± 3.2
Anterior FR (cm)	24.5 ± 9.0	25.5 ± 9.8	24.9 ± 9.3
Lateral FR (cm)	17.3 ± 11.1	21.5 ± 13.6	18.9 ± 12.3
QUS (%: comparison with 20 years)	59.2 ± 14.0	68.5 ± 17.1	62.8 ± 15.9

QUS: quantitative ultrasound.

2.2. Methods

The interviews and examinations were conducted at the community plaza of Kahoku. They included a questionnaire covering physical health and functional status and a medical examination of the knee and lumbar region. Examination of functional performance such as FR and timed up and go (TUG) was also performed. The presence or absence of disease was based on the subjects' self-report of a doctor's diagnosis. Informed consent for this study was obtained from all participants.

The subjects were asked questions regarding basic ADL (BADL), such as walking, ascending and descending stairs, feeding, dressing, using the toilet, bathing, grooming, and taking medicines. The subjects were also questioned about instrumental ADL (IADL), such as using public transportation, shopping for groceries, preparing meals, paying bills, banking, writing, reading newspapers, magazines or books, taking an interest in news about health, visiting friends, giving advice to family or friends, and talking to young people) (Matsubayashi et al., 1997). We assessed the BADL and IADL scores using a 4-point scale, based on the level of assistance required for each activity: 3, completely independent; 2, some help needed; 1, much help needed; and 0, completely dependent (Matsubayashi et al., 1999).

A fall was defined as any event that led to an unplanned, unexpected contact with a supporting surface. We asked subjects to self-report the history of any falls that they had suffered in the past 6 months. The geriatric depression scale (GDS) (Gerety, 1982; Norris et al., 1987), a measure of depressive symptomatology, was assessed on a scale of 0–30 points. We assessed the items of the short form of the GDS (15 items), and a score of $\geq$6 points was considered to indicate depression.

2.2.1. The FR

FR represents the maximal distance a subject can reach forward beyond arm's length while maintaining a fixed base of support in the standing position (Duncan et al., 1990; Weiner et al., 1992; Jonsson et al., 2002). In the classic FR test, the subject is asked to reach as far as forward as possible. In the modified lateral reach test, the subject is asked to reach as far as possible to the right and left sides. The measurement of lateral FR was expressed adding the measurements of reach to the right and left side (cm). We defined the threshold of anterior FR as 30 cm (Okumiya et al., 1999). In this study, lateral FR was divided into two groups of less than 20 cm, and 21 cm and more.

2.2.2. TUG test

In the TUG test (Mathias et al., 1986; Podsiadlo and Richardson, 1991), the subjects were given oral instructions to stand up from the chair, walk 3 m as quickly and as safely as possible, cross a line marked on the floor, turn around, walk back to the chair, and sit down. We defined the threshold of TUG as 16 s.

2.2.3. Statistical analysis

The ADL and GDS data were expressed as mean ± S.D. and S.E.M. The differences between groups were evaluated using the Mann–Whitney *U*-test. The frequency of fall data

Table 2
The relation of each FR with ADLs

	Anterior FR (cm)		Lateral FR (cm)	
	Less than 30 ($N = 265$)	30 and more ($N = 101$)	Less than 20 ($N = 214$)	20 and more ($N = 146$)
BADL (points)	23.58 ± 0.99 se; 0.061	23.56 ± 1.16 se; 0.12	23.48 ± 1.11 se; 0.076	23.74 ± 0.90 se; 0.074
	$p = 0.76$		$p = 0.039$	
IADL (points)	11.58 ± 2.0 se; 0.13	11.70 ± 2.13 se; 0.21	11.34 ± 2.3 se; 0.16	12.08 ± 1.46 se; 0.12
	$p = 0.36$		$p = 0.0016$	

Mean ± S.D.; se: S.E.M.

was analyzed using the Kruskal–Wallis test. Differences were considered to be statistically significant at $p < 0.05$.

3. Results

Anterior FR and TUG were not significantly different between male and female subjects; however, lateral FR was greater in males than in females ($p = 0.0009$). The test–retest reliability of lateral FR between the first and second measurement was highly reliable (ICC = 0.90; CI: 0.89–0.96); however, the lateral FR was only weakly associated with the anterior FR (ICC = 0.32; CI: 0.22–0.41).

There was no significant association between the anterior FR and the number of falls ($p = 0.79$) or between the lateral FR and the number of falls ($p = 0.62$). There was a tendency for TUG to be associated with the number of falls, although this association failed to achieve statistical significance ($p = 0.10$).

Subjects with greater lateral FR (≥20 cm) had higher BADL ($p = 0.039$) and IADL ($p = 0.0016$) scores than those with shorter lateral FR (<20 cm) (Table 2). However, subjects with greater anterior FR (≥30 cm) did not differ significantly from those with lesser anterior FR (<30 cm) with regard to BADL ($p = 0.76$) or IADL ($p = 0.36$). Shorter TUG values were associated with greater BADL and IADL scores than were longer TUG ($p < 0.0001$).

Table 3
The association of anterior and lateral FR with the GDS

	GDS (points)		
	Less than 6	6 and more	p value
Anterior FR (cm)	25.4 ± 8.9 se; 0.65	24.8 ± 9.8 se; 0.82	0.54
Lateral FR (cm)	21.0 ± 12.4 se; 0.91	17.7 ± 9.3 se; 0.79	0.033

se: S.E.M.

The lateral FR of participants with depression (GDS $\geq$ 6) was shorter than that of patients without depression (GDS $\leq$ 5) (p = 0.033), whereas the anterior FR was not associated with GDS scores (p = 0.54) (Table 3).

4. Discussion

The maintenance of postural control is very important for performing the daily activities of living, especially in the elderly population. Maintaining postural control is a complex process, and there is no single measure available that can assess all the aspects of this process (King et al., 1994; Wallmann, 2001). Presently, the three tools that are commonly used to measure balance impairment are the Berg balance scale (BBS), the FR test, and the TUG test. The BBS was developed to assess balance in elderly people with neurological disorders (Daubney and Culham, 1999). In this study, we measured FR and TUG in an elderly population dwelling within the Kahoku community in Kochi, Japan.

As we have indicated, FR represents the maximal distance a subject can reach forward beyond arm's length while maintaining a fixed base of support in the standing position. In the original method the subjects reached forward as far as possible, to measure anterior FR. The anterior FR test is strongly influenced by factors, such as the movement of the trunk. Limits of stability are one aspect of balance (Shumway-Cook and Woollacott, 2000). Any reduction in spinal flexibility also decreases the distance of anterior FR. Newton (2001) developed a multi-directional reach test, i.e.: forward, to the right, left and backwards, that was reliable. However, the measurements in four directions require time, and leaning backwards has the risk of falling.

We have improved a modified lateral FR test, in which the subject reaches as far as possible to the right and left sides. The test–retest reliability of lateral FR is highly consistent; however, lateral FR is not strongly associated with anterior FR.

There are many reports describing the risk factors associated with accidental falls. Davis et al. (1999) reported that having a long FR was associated with a lower risk of falling. In contrast, Eagle et al. (1999) reported that the FR test is time consuming and inconvenient and is a poor predictor of falls (Thepa et al., 1996). In an attempt to clarify these discrepancies, we examined whether anterior and lateral FR tests were associated with the frequency of falling. Our findings show that there was no relationship between these FR tests and the number of falls reported by elderly subjects. Lateral FR was correlated with BADL and IADL; but the classic anterior FR was not. Therefore, it seems that lateral FR is a useful marker for the ability to perform ADL.

Although various factors are associated with falls; impaired balance and mobility have been consistently identified as risk factors. Thus, TUG is a sensitive and specific measure for identifying community-dwelling adults who are at risk of falling (Shumway-Cook et al., 2000). The present study also indicates that TUG tends to be associated with the number of falls reported. Gait speed has also been found to be a useful indicator of ability to perform ADL (Potter et al., 1995). There was an association reported between gait time and TUG in an elderly orthopaedic rehabilitation population (Freter and Fruchter, 2000). In the present study, TUG was also related to the ADL, and our findings are consistent with the studies mentioned above.

There have been only a few reports regarding the relationship between functional performance and depression. Our study demonstrates that depressed elderly subjects have shorter lateral FR, as well as reduced balance and mobility, as compared to normal elderly subjects. In contrast, there was no relationship between anterior FR and depression. Further studies are needed to determine why lateral FR was more closely correlated with geriatric depression than anterior FR. Further studies are also needed to clarify the relationship between lateral FR and TUG, and to find out the reason why ADL is associated with lateral but not anterior FR.

In conclusion, a longer lateral FR appears to be associated with a greater ability to perform ADL and a reduced chance of suffering geriatric depression, whereas anterior FR is not associated with ADLs nor depression scores. Therefore, evaluation of lateral FR should be considered a new, alternative means of assessing geriatric social activities and mental status.

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ORIGINAL ARTICLE

Association between arterial stiffness and platelet activation

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Increased arterial stiffness is strongly associated with atherosclerosis, while platelet activation is an important trigger of thrombotic events in patients with atherosclerosis. However, little is known about the effect of arterial stiffness on platelet activation. We therefore investigated the association between arterial stiffness and platelet activation in 38 normal volunteers (20 men and 18 women) aged 23–77 years (mean = 49±15 years). Arterial stiffness was assessed by measuring brachial–ankle pulse wave velocity (ba-PWV) and heart–brachial PWV (hb-PWV). Flow cytometric analyses were performed to evaluate platelet activation by measuring surface expression of P-selectin and platelet–neutrophil complexes (PNC) before and after activation by ADP. We also calculated the difference between basal and stimulated states of P-selectin and PNC to assess platelet activation reserve. PWVs were significantly correlated with age and BP (r = 0.60–0.81). For platelet activation and activation reserve, correlations with age were less strong but remained significant (r = 0.36–0.61), with the exception of P-selectin (not significant, NS), and correlations with SBP were similar (r = 0.35–0.53). A significant correlation was found between PWVs and platelet activation (r = 0.43–0.74). Multiple regression analysis demonstrated significant correlations between platelet activation and reserve and PWVs (coefficient = 2.17–6.59), when both age and BP were adjusted for simultaneously. In conclusion, platelet activation was associated with arterial stiffness, suggesting that arterial stiffness may play an important role in thrombotic events.
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Keywords: arterial stiffness; pulse wave velocity; P-selectin; platelet–neutrophil complexes

Introduction

Platelet activation and aggregation are important triggers of thrombotic events in patients with atherosclerosis. In such patients, platelets are activated at the site of atheroma[1] due to increased shear stress in the narrowed vessels.[2,3] Increased platelet activation is observed in patients with coronary risk factors and cardiovascular events.[4–12]

Increased arterial stiffness, measured with pulse wave velocity (PWV), has been shown to be associated with atherosclerosis and risk factors of atherosclerotic cardiovascular disease,[13–21] and is an independent predictor of cardiovascular events,[22,23] Therefore, although platelets are likely to be activated in patients with atherosclerotic disease who exhibit increased arterial stiffness, little is known about the relation of arterial stiffness itself to platelet activation.

Recently, platelet activation has been widely evaluated by measuring soluble P-selectin; a platelet surface molecule also termed CD62P.[4,6–8,11] Although the measurement of soluble P-selectin is simple and useful, it is an indirect method of evaluating platelet activation. On the other hand, platelet activation can be detected directly by measuring surface antigen CD62P using flow cytometry.[2,3,5,9,10,12] Furthermore, detection of platelet–neutrophil complexes (PNC), which are formed as a result of interaction with CD62P provides an additional means to detect platelet activation.[24]

The purpose of this study was to investigate the association between arterial stiffness and platelet activation by measuring PWV, P-selectin, and PNC in subjects without atherosclerotic disease.

Materials and methods

Subjects

We studied 38 healthy nonsmoking volunteers (20 men and 18 women), aged 23–77 years

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(mean = 49 ± 15 years) with no evidence of heart disease on physical examination, standard 12-lead electrocardiography, chest radiography, echocardiography, or blood chemistry analysis. Subjects had no self-reported past history or current evidence of cardiovascular disease, hypertension, hypercholesterolaemia, diabetes mellitus or renal disease. Basic characteristics of subjects are shown in Table 1. None of the subjects had frequent ectopic beats or atrial fibrillation and none had taken any medication for at least 10 days. Informed consent was obtained before performing the study and the study protocol was approved by the Local Ethics Committee of Kochi Medical School.

Evaluation of arterial stiffness

Arterial stiffness was evaluated by PWV, measured using volume-plethysmographic apparatus (Colin, Komaki, Japan).[18–21] Data were acquired with subjects lying supine in a quiet and temperature-controlled room at 11 AM, at least 3 h after breakfast. Surface electrodes were attached to both wrists for ECG measurement, a microphone was positioned at the left sternal edge to detect heart sounds, and cuffs incorporating plethysmographic and oscillometric sensors were fastened around both the brachial regions and ankles to measure pulse wave forms and blood pressure. Brachial–ankle PWV (ba-PWV) and heart–brachial PWV (hb-PWV) were measured as follows. The time interval between the wave foot of the brachial waveform and that of the ankle waveform was defined as the time interval between the brachial region and ankle, while the time interval between the heart and the right brachial artery was defined as the time interval between the second heart sound and the right brachial waveform. The distance between these sampling points was calculated automatically according to the height of the subject. PWVs were calculated by dividing each distance by the respective time interval. Right brachial blood pressure (systolic and diastolic) and pulse rate were concurrently measured.

Table 1 Clinical characteristics of subjects

Parameters	*All subjects (n = 38)*
Age (years)	49 ± 15
Gender, male/female	20/18
Systolic blood pressure (mmHg)	125 ± 16
Diastolic blood pressure (mmHg)	77 ± 10
Pulse rate (bpm)	66 ± 10
Blood sugar (mg/dl)	98.5 ± 18.5
Total cholesterol (mg/dl)	192.6 ± 20.7
Blood urea nitrogen (mg/dl)	14.0 ± 18.5
Creatinine (mg/dl)	0.69 ± 0.15
PNC (%)	9.5 ± 4.9
PNC(ADP) (%)	20.2 ± 9.9
Δ-PNC	10.7 ± 6.9
P-selectin (%)	13.1 ± 1.7
P-selectin(ADP) (%)	36.6 ± 9.2
Δ-P-selectin	23.6 ± 9.1
hb-PWV (m/s)	5.3 ± 0.9
ba-PWV (m/s)	13.8 ± 3.0

Values are expressed as mean ± s.d.
PNC = platelet neutrophil complexes; ADP = adenosine diphosphate; Δ-PNC = PNC (ADP)–PNC; Δ-P-selectin = P-selectin (ADP)–P-selectin; hb-PWV = heart–brachial pulse wave velocity; ba-PWV = brachial–ankle pulse wave velocity.

Measurement of platelet activation

Sample preparation and measurement of platelet P-selectin (CD62P) and PNC levels were performed according to the method described by Peters *et al*.[24] To minimize platelet activation during blood collection, blood was drawn via a 21 G butterfly needle without the use of a tourniquet. After discarding the first 2 ml of blood, a further 2 ml was collected and immediately added to 200 μl of sodium citrate (3.13%). All antibodies were sourced as follows: Fluorescein isothiocyanate (FITC) labelled IgG1 anti-CD62P from Dainippon Pharmaceutical, Osaka, Japan, phycoerythin (PE) labelled IgG2a anti-CD42b and FITC labelled IgG1 anti-CD11b from Beckman Coulter, Fullerton, CA, USA. As negative controls, FITC-labelled IgG1 (Beckman Coulter, Fullerton, CA, USA) and double-stained (FITC/PE) IgG1 and IgG2a (Dako, High Wycombe, Bucks, UK) irrelevant antibodies were included.

Sample preparation for the measurement of platelet CD62P level: In all, 5 μl of blood was added to a round-bottomed polystyrene tube containing 50 μl of platelet buffer (10 mmol/l HEPES, 145 mmol/l NaCl, 5 mmol/l KCl, 1 mmol/l $MgSO_4$; pH 7.4), and 5 μl of anti-CD62P or control IgG1 antibody. Following gentle suspension, samples were incubated in the dark at room temperature for 20 min without stirring. Then 250 μl of fixative was added and the tubes were incubated for an additional 10 min. The samples were then diluted with 500 µl of buffer and analysed. Flow cytometric analysis was performed within 1 h of fixation.

Sample preparation for the measurement of PNC level: In all, 50 μl of blood was added to a round-bottomed polystyrene tube containing 5 μl of anti-CD42b, and 5 μl of anti-CD11b or isotype control antibodies. Following gentle mixing, samples were incubated in the dark at room temperature for 10 min without stirring. Then 500 μl of fixative was added and the tubes were incubated for additional 10 min. Flow cytometric analysis was performed within 1 h of preparation.

Flow cytometric analysis

Blood samples were analysed in a COULTER EPICS XL Profile Flow Cytometer, Miami, FL, USA, using either single or double fluorochromes. The peak emission intensity of FITC fluorescence was detected at 515 nm and that of phycoerythin fluorescence at 580 nm.

Measurement of platelet CD62P level: After forward and side scatter measurements were made with gain setting in logarithmic mode, platelet-sized events were counted. CD62P-positive platelets were defined as those with a fluorescence intensity exceeding that of 98% of the platelets staining with control antibody.

Measurement of PNC level: After forward and side scatter measurements were made with gain setting in linear mode, neutrophil-sized events were selected. Results were defined as positive when the fluorescence intensity exceeded that of 98% of the isotype-matched (IgG1 and IgG2a) control antibodies staining. Events positive for both CD11b and CD42b were considered to represent PNCs and were expressed as percentages of events with positive CD11b staining.

Evaluation of platelet activation reserve: We evaluated platelet activation reserve, that is, the ability of the platelets to be activated, in a separate experiment. Platelets were activated with 5 μl of adenosine diphosphate (ADP). We also calculated the difference between basal and stimulated states of P-selectin expression (Δ-P-selectin) and PNC level (Δ-PNC) to determine activation reserve.

Statistical analysis

Data are presented as mean ± s.d. Univariate linear correlation analysis and multiple regression analysis were used for statistical evaluation. The variables significantly associated with platelet activation on univariate analysis were included in a multiple regression analysis in order to adjust PWV for each variable. Gender differences were evaluated with ANOVA. *P*-values <0.05 were considered to represent statistical significance.

Results

Both ba-PWV and hb-PWV exhibited significant positive correlations with age, systolic, and diastolic blood pressure (r = 0.60–0.81, P < 0.05 or < 0.01), and pulse rate (r = 0.44, P < 0.05, r = 0.65, < 0.01, respectively) (Table 2). For platelet activation and activation reserve, correlations with age were less strong but remained significant (r = 0.36–0.61, P < 0.05 or < 0.01) with the exception of Δ-P-selectin (not significant, NS), and correlations with systolic and diastolic blood pressure were similar (r = 0.35–0.53, P < 0.05 or < 0.01) with the exception of P-selectin (NS) (Table 3). However, platelet activation and activation reserve exhibited no significant correlation with pulse rate, blood glucose, total cholesterol, blood urea nitrogen or creatinine. No significant gender-related differences were observed in any of these correlations (Tables 2 and 3).

Table 2 Correlation between PWV and clinical indices

	hb-PWV	*ba-PWV*
Age	0.74**	0.80**
Systolic blood pressure	0.61**	0.81**
Diastolic blood pressure	0.60**	0.74**
Pulse rate	0.44*	0.65**
Blood sugar	−0.05	−0.17
Total cholesterol	−0.03	−0.30
Blood urea nitrogen	−0.32	0.32
Creatinine	0.04	−0.14
Gender		
Male	5.5 ± 1.0	14.1 ± 3.0
Female	5.2 ± 0.8	13.6 ± 3.1

PNC = platelet neutrophil complexes; ADP = adenosine diphosphate; Δ-PNC = PNC (ADP)–PNC; Δ-P-selectin = P-selectin (ADP)–P-selectin; hb-PWV = heart–brachial pulse wave velocity; ba-PWV = brachial–ankle pulse wave velocity.
For parameters from age to creatinine, values are correlation coefficients.
*P<0.05.
**P<0.01.
For gender, values are mean ± s.d., with differences evaluated with ANOVA.

PWVs exhibited significant positive correlations (r = 0.43–0.74, P < 0.05 or < 0.01) to all indices of platelet activation and reserve (Table 4, Figure 1). When age or blood pressures were adjusted for on multivariate analysis, some indices of platelet activation and reserve were significantly related to PWVs (r = 0.34–7.67, P < 0.05 or < 0.01). When both age and blood pressures were simultaneously adjusted for, significant correlations remained between platelet activation and reserve and PWVs (r = 2.17–6.59, P < 0.05 or < 0.01) (Table 4). In other words, although the relationship between PWVs and the indices of platelet activation was strongly affected by age and blood pressure, a significant association remained when these factors were adjusted for.

Discussion

The main finding of this study was that platelet activation and activation reserve were associated with arterial stiffness when analyses were adjusted for age and blood pressure. This suggests that increased arterial stiffness might play an important role in thrombotic events.

Patients with hypertension, cerebrovascular disease, coronary heart disease, diabetes mellitus, and renal failure are recognized to have less arterial compliance than normal subjects.[13–15,17–19] Increased PWV has also been reported to be an independent predictor of cardiovascular events in patients with hypertension or renal failure, and in elderly subjects.[22,23] The association between increased arterial stiffness and high incidence of cardiovascular events may be explained by the existence of atherosclerosis. Hirai *et al*[25] have demonstrated strong associations between abdominal aortic and

Table 3 Correlation between platelet activation and clinical indices

	PNC	*PNC (ADP)*	*Δ-PNC*	*P-selectin*	*P-selectin (ADP)*	*Δ-P-selectin*
Age	0.51**	0.61**	0.52**	0.36*	0.38*	0.32
Systolic blood pressure	0.41*	0.53**	0.48**	0.41*	0.43*	0.35*
Diastolic blood pressure	0.43*	0.49**	0.40*	0.25	0.40*	0.36*
Pulse rate	0.28	0.25	0.16	0.04	0.15	0.15
Blood sugar	0.09	−0.18	−0.31	−0.17	0.13	0.16
Total cholesterol	−0.14	−0.07	0.001	−0.10	−0.13	−0.11
Blood urea nitrogen	−0.01	0.12	0.18	−0.05	0.05	0.06
Creatinine	0.05	−0.13	−0.22	0.04	−0.17	−0.18
Gender						
Male	10.3±5.9	19.7±8.7	9.4±6.9	13.1±1.8	35.5±9.3	22.4±9.0
Female	8.8±3.8	20.7±11.4	11.9±6.8	13.0±1.7	37.7±9.2	24.7±9.3

PNC = platelet neutrophil complexes; ADP = adenosine diphosphate; Δ-PNC = PNC (ADP)−PNC; Δ-P-selectin = P-selectin (ADP)−P-selectin; hb-PWV = heart–brachial pulse wave velocity; ba-PWV = brachial–ankle pulse wave velocity.
For parameters from age to creatinine, values are correlation coefficients.
*$P<0.05$.
**$P<0.01$.
For gender, values are mean ± s.d., with differences evaluated with ANOVA.

Table 4 Relation between platelet activations and PWV

	PNC	*PNC (ADP)*	*Δ-PNC*	*P-selectin*	*P-selectin (ADP)*	*Δ-P-selectin*
Not adjusted						
hb-PWV	0.62**	0.74**	0.63**	0.45**	0.57**	0.50**
ba-PWV	0.59**	0.71**	0.61**	0.47**	0.51**	0.43*
Adjusted for age						
hb-PWV	2.86**	6.95**	4.09*	0.75	6.55**	5.80*
ba-PWV	0.79	2.01**	1.22*	0.28	1.75*	1.47
Adjusted for systolic blood pressure						
hb-PWV	3.20**	7.23**	4.04**	0.59	5.09*	4.50*
ba-PWV	1.21**	2.64**	1.44*	0.23	1.48	1.25
Adjusted for diastolic blood pressure						
hb-PWV	3.08**	7.67**	4.59**	0.87*	5.32**	4.46*
ba-PWV	0.97**	2.50**	1.54**	0.34*	1.45*	1.10
Adjusted for age and systolic blood pressure						
hb-PWV	2.80*	6.43**	3.63*	0.58	5.93*	5.35*
ba-PWV	1.08	2.32*	1.24	0.24	1.72	1.48
Adjusted for age and diastolic blood pressure						
hb-PWV	2.63*	6.59**	3.97**	0.78	6.06*	5.28*
ba-PWV	0.76	2.17*	1.40	0.40	1.66	1.26

PNC = platelet neutrophil complexes; ADP = adenosine diphosphate; Δ-PNC = PNC (ADP)−PNC; Δ-P-selectin = P-selectin (ADP)−P-selectin; hb-PWV = heart–brachial pulse wave velocity; ba-PWV = brachial–ankle pulse wave velocity.
'Not adjusted' — values are correlation coefficients between PWVs and indices of platelet activation before adjustment.
*$P<0.05$.
**$P<0.01$.
Other values are regression coefficients between PWVs and indices of platelet activation adjusted for age and/or blood pressures as indicated.
*$P<0.05$.
**$P<0.01$.

carotid arterial stiffness and the degree of coronary artery disease. Popele *et al*[26] recently reported that aortic stiffness as measured by PWV is strongly associated with common carotid intima-media thickness, carotid arterial plaques, and the presence of peripheral arterial disease. Moreover, some population-based studies have demonstrated higher blood pressure, increased age, and male gender to be associated with increased PWV.[16,20,21] Pulse pressure may also relate to arterial stiffness and cardiovascular events, with higher pulse pressure reflecting elevated systolic pressure and reduced diastolic pressure due to increased arterial stiffness. In the present study, significant relationships were observed between PWVs and age, blood pressure, and pulse rate, in accordance with previous studies.

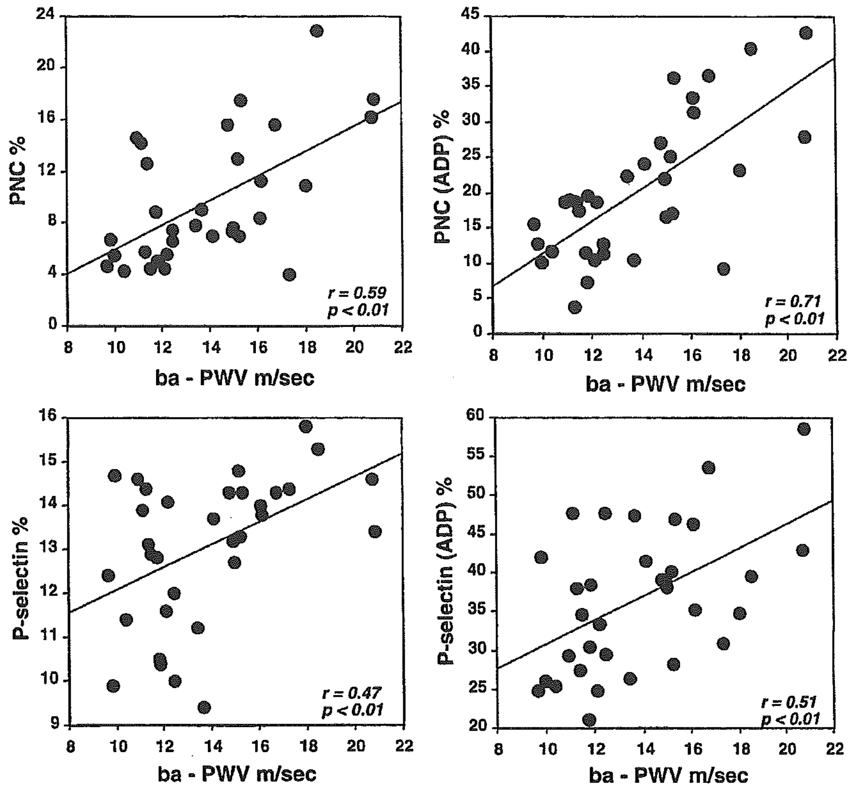

Figure 1 Correlation between ba-PWV and PNC (upper two panels). PNC = platelet neutrophil complexes; ADP = adenosine diphosphate; Δ-PNC = PNC (ADP)–PNC; Δ-P-selectin = P-selectin (ADP)–P-selectin; hb-PWV = heart–brachial pulse wave velocity; ba-PWV = brachial–ankle pulse wave velocity.

P-selectin is a component of α-granules that is expressed on the platelet surface membrane and released into the plasma upon platelet activation. Although the bulk of circulating soluble P-selectin appears to be platelet derived,[27] the substance is also found in the Weibel–Palade bodies of endothelial cells.[28] Direct measurement of platelet membrane P-selectin is therefore a more sensitive method of assessing platelet activation. In the present study, we evaluated platelet activation by measuring membrane activation markers using flow cytometry with activation-dependent monoclonal antibodies. PNC levels were also measured using the same method. P-selectin levels in our normal subjects aged 49±15 years were 13.1±1.7%; this was higher than that in quoted by other studies, possibly due to the differences in monoclonal antibodies or in sample manipulation.

P-selectin expressed on activated platelets causes formation of PNC. Moreover, platelets and platelet-derived P-selectin play an important role in thrombus growth at the site of atherosclerosis.[2] *In vivo* and *in vitro* studies have shown that shear stress and exposure to atherogenic stimuli, such as oxidization by low-density lipoprotein or cigarette smoking, induce rapid P-selectin-dependent aggregation and accumulation of leukocytes and platelets.[4,5,11] Activated platelets accumulating in thrombi at the site of ruptured atherosclerotic plaques will express CD62P. In clinical studies, P-selectin has been shown to be a marker of platelet activation related to adverse cardiovascular events such as hypertension, coronary artery disease, cerebrovascular disease, and peripheral arterial disease,[6,7,10–12] and also to be a predictor of cardiovascular events.[8,12] PNC, forming as a result of the interaction of platelet P-selectin and neutrophils also promotes platelet activation.[24] This is the first study to demonstrate that P-selectin and PNC were significantly correlated with arterial stiffness evaluated by PWV in normal subjects. In an analysis of four randomized trials, Hebert *et al*[29] showed that aspirin therapy was beneficial in the primary prevention of vascular disease. Higher levels of other membrane markers such as von Willebrand factor receptor are observed in activated platelets, which are affected by aspirin or ticlopidine.[30] Therefore, our results indicate that, in the normal population, antiplatelet agents may play a role in preventing cardiovascular events through factors other than P-selectin.

Although the exact mechanism accounting for the relationship between platelet activation and arterial stiffness is unknown, it is possible to make the following speculations. When arterial stiffness is raised, shear stress might play an important role in platelet activation. Using cone-plate viscometry,[3] Goto *et al* showed that platelet activation (measured by P-selectin surface expression, von Willebrand factor-mediated platelet aggregation and translocation of GP Ibα) was induced by high shear rate of $10\,800\,s^{-1}$. Higher arterial stiffness increases blood flow velocity and produces a steep systolic pressure waveform,[31] and it is possible that the resulting increased shear stress could promote platelet activation. Another possible mechanism is that endothelial dysfunction may interact with arterial stiffness and platelet hyperactivity. Kobayashi *et al*[32] showed significant correlation between endothelial dysfunction measured by flow-mediated dilatation and ba-PWV. Platelets are also activated by endothelial dysfunction. On the other hand, activated platelets themselves may cause arterial stiffness via vascular smooth muscle cell growth factors and extracellular matrix modulator released from platelets, that is, PDGF.[33] However, this response also occurs at the site of endothelial injury. Further study is therefore required to clarify whether arterial stiffness causes platelet activation or alternatively whether platelet activation might result in arterial stiffness.

Limitations

Despite the small sample size, it is possible that the broad age range (23–77 years) of our subjects caused outliers in PWV and platelet activation. However, significant correlations were found when age and blood pressure were adjusted for, suggesting that the influence of age did not entirely explain the correlation between PWV and platelet activation. In the present study, ba-PWV was 14.1 ± 3.0 m/s in men and 13.6 ± 3.1 m/s in women; values higher than those reported by Yamashina *et al*.[20] Furthermore, it is not known whether such a relationship between arterial stiffness and platelet activation is found in patients with conditions such as hypertension, diabetes mellitus, coronary heart disease, and stroke. Further studies should be therefore performed in such patients, using larger sample sizes.

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ORIGINAL ARTICLE

Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people

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Abstract We have evaluated the association between trunk deformities of the sagittal plane and functional impairment of daily living in community-dwelling elderly subjects. The analysis involved a detailed assessment of indoor and outdoor activities of daily living, satisfaction with life, and mental status. The participants in this study were 236 community-dwelling older adults, aged 65 years and older, living in Kahoku district of Kochi in Japan. The participants were classified based on their posture, which was assessed using photographs of the subjects, and interviewed to assess their basic activities of daily living (BADL), instrumental ADL (IADL), and cognitive well-being in the cross-sectional study. The statistical analysis was performed using the Mann-Whitney *U*-test. The lumbar kyphosis group received significantly lower BADL and IADL scores than the normal group. The trunk deformity group which were defined as kyphosis, flat back, and lumbar lordosis groups exhibited decreases in activities that included going out, shopping, depositing and withdrawing money, and visiting friends in the hospital. These activities require going outdoors; thus, this study showed that the trunk deformity group had limitations in outdoor activities. There was no significant difference between the geriatric depression score (GDS) and the pattern of posture. The abnormal trunk deformity groups tended to score lower than the normal group with regard to subjective healthiness and life satisfaction measures, including subjective health condition, everyday feeling, satisfaction with human relationships, satisfaction with economic condition, and satisfaction with present life.

Keywords Activities of daily living · Kyphosis · Life satisfaction · Trunk deformity

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Introduction

Several studies have reported on the relationship between trunk deformity and lumbago [1,2]. It is predictable that patients with abnormal posture would be at increased risk for falling, as their balance is perturbed by the posture abnormality [3,4]. Loss of distal lumbar lordosis is the main cause of sagittal imbalance in individuals who do not maintain sagittal alignment [5]. This abnormal posture could lead to the limitation of daily activities.

There have been several evaluations of posture and functional activities to date [6]; however, very few involve elderly subjects. Ettinger et al. [7] reported that kyphotic women did not have greater back pain, disability caused by back problems, or poorer health than non-kyphotic women. Another study showed a poor correlation between quality of life and abnormal findings on radiography or densitometry [8].

Vertebral body compression fractures have been shown to be associated with the severity of kyphosis [9]. Ryan et al. [10] reported that there was a significant association between scores of osteoporosis severity and limitations in functional activity. Vertebral compression fractures associated with osteoporosis can be self-limiting, causing considerable pain and disability [8].

Vertebral compression fractures are associated with significant impairments in physical, functional, and psychosocial performance in the elderly [11,12,13]. It is crucial to improve the mental status of the elderly. However, there have been few reports regarding the association between trunk deformity and psychogenic activity in elderly patients.

In this study, we have evaluated the daily activities and mental condition of community-dwelling elderly subjects with regard to the severity of trunk deformity in the sagittal plane.

Materials and methods

Subjects

Participants who applied in 1999 included 236 community-dwelling older adults, aged 65 years and older, living in Kahoku district in Kochi prefecture, who had been enrolled in one of several studies involving annual medical check-ups (beginning in 1994). The population of Kahoku rural area is 5800 people, 50% of whom are engaged in agricultural work.

Study participants were observed from July to August 1999, and then classified based on their posture, which was assessed using photographs taken by researchers. In total, there were 145 females (mean; 79.0 years) and 91 males (mean; 80.3 years) with a mean age of 80 years (range, 65–94 years), and a mean height of 149.1 cm. Functional status of the lumbar spine [14] and knee [15] were measured using the assessment of the Japanese Orthopaedic Association (JOA). In this study, JOA scores for assessing treatment of low back pain was calculated without incorporating urinary bladder function. Comorbidities were hypertension (31.6%), cardiac arrhythmia (6.1%), diabetes mellitus (5.7%), cerebrovascular disorder (4.2%), coronary artery disease (3.2%), senile dementia (2.1%), and Parkinson's disease (0.4%).

Methods

Interviews and examinations, conducted at the community plaza of Kahoku, consisted of a questionnaire covering physical health, functional status, and mental status. The analysis of trunk deformity was examined by photography. The presence or absence of disease was based on the subjects' self-report of a doctor's diagnosis. Informed consent was obtained from all participants.

Postural analysis

In order to protect the participants' privacy when undergoing the community health check-ups, we constructed a device with which to assess trunk posture without requiring that the subjects disrobe. Participants wore clothes typical of the summer season, and the device was equipped with a band that, when twisted, would reveal the alignment of the body. Each participant had reflective surface markers attached at various locations, including C7, T6 (xyphoid process level), L4 (Jacob line level), the left greater trochanter, the left lateral chondyle of the femur, and the left lateral malleous, as shown in Fig. 1. For the photograph, participants were positioned carefully and asked to remain relaxed while standing up straight. Posture in the sagittal plane was classified into one of the following five types: I normal, II thoracic

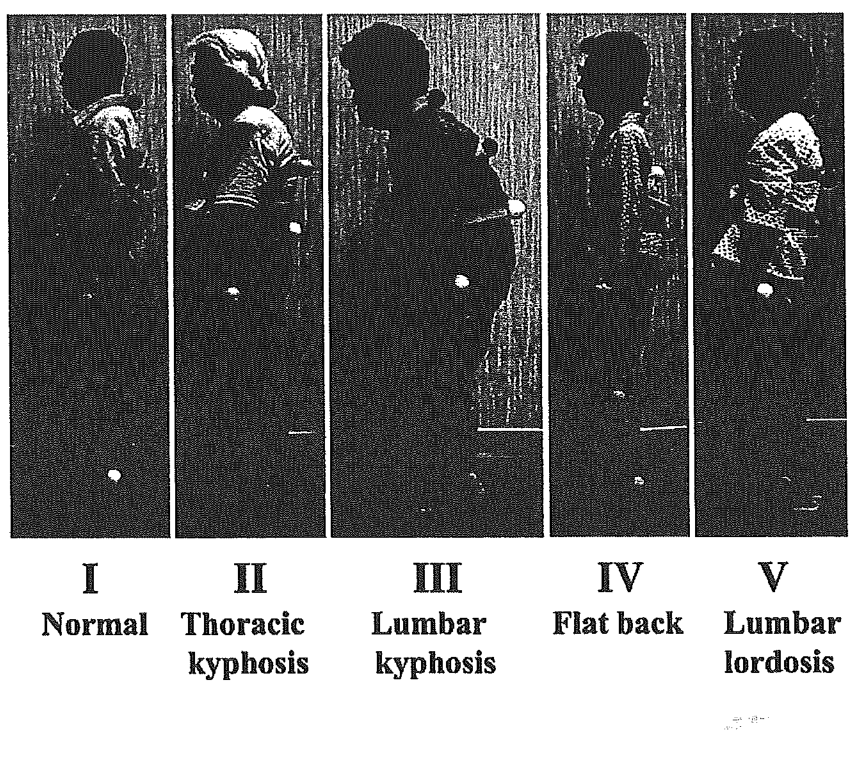

Fig. 1 Classification of trunk deformity from photographs

kyphosis, III lumbar kyphosis, IV flat back, and V lumbar lordosis, as described by Ando et al. [16,17,18]. Three orthopaedic doctors independently determined the classification, and we adopted the classification given by at least two doctors. In cases in which none of the doctors' classifications agreed, we discussed the case and jointly decided on the classification. The classification system is shown in Fig. 1, which includes photographs of patients representing each of the posture groups.

ADL analysis

The subjects were asked questions regarding basic activities of daily living (BADL) (walking, ascending and descending stairs, feeding, dressing, using the toilet, bathing, grooming, and taking medicine) and instrumental ADL (IADL) (using public transportation, shopping for groceries, preparing meals, paying bills, depositing and withdrawing money, writing, reading newspapers, reading magazines or books, taking an interest in news of health, visiting friends, giving advice to family or friends, visiting friends in the hospital, and talking to young people) [19]. We assessed the ADL score using a 4-point scale, based on the help required for each activity: 3 completely independent; 2 some help needed; 1 much help needed; and 0 completely dependent.

Mental state analysis

Geriatric Depression Scale

The Geriatric Depression Scale (GDS) [20,21], a measure of depressive symptomatology assessed on scale of 0–30, was administrated. We assessed the short form of 15 items, it is interpreted that a score >5 points is suggestive of depression, a score >10 points is almost always depression.

Visual analog scale (VAS)

Each year, we conducted an assessment of subjective quality of life (QOL), especially subjective healthiness and life satisfaction, using a validated self-reported visual analogue scale (VAS) [22]. The components of questions were subjective health condition, everyday feeling, satisfaction with human relationship to others, satisfaction with human relationship to family, satisfaction with economic condition, satisfaction with present life, and subjective happiness. The VAS questionnaire ended with a summing-up graph in the form of a 100 mm bar, graded with the subjectively worst condition on the left and the best one on the right. The subject was asked to place a mark on the 100 mm bar based on his or her condition. We defined the distance (mm) from the left to the marked position as the VAS score (0–100), with high scores indicating a high QOL [23].

Statistical analysis

For the classification of posture, Cohen's kappa coefficients were used to test statistical reliability. To determine inter-observer reliability, each reviewer's responses were compared with those of the other reviewers.

Data concerning ADL, GDS and life satisfaction were expressed by mean, SD, and SEM. The differences among the pattern of trunk deformities were evaluated using Kruskal-Wallis test, between with (II–V) and without trunk deformities (I) were evaluated using Mann-Whitney test. Differences were considered significant at $P<0.05$.

Results

The classification of trunk deformity resulted in five groups: I normal group (109 subjects; 46.2%), II thoracic kyphosis group (47 subjects; 19.9%), III lumbar kyphosis group (41 subjects; 17.4%), IV flat back group (28 subjects; 11.9%), and V lumbar lordosis group (11 subjects; 4.7%). There was a mean inter-observer kappa coefficient of 0.47 for both observation times, with a mean inter-observer agreement of 60.2%. We calculated a mean intra-observer kappa coefficient of 0.55 for the two observation times, with a mean inter-observer agreement of 68.3%. Table 1 shows the baseline characteristics in each group. There was no significant difference in age, sex, and overall health status such as comorbidities among the groups.

The mean BADL score of abnormal trunk posture (II–V) was 23.1; that of the normal (I) group was 23.6. The lumbar kyphosis group had significantly lower BADL scores than the normal group ($P=0.017$) (Table 2). With regard to BADL, walking was more likely to be limited in the abnormal trunk posture group (II–V) than in normal participants (I) ($P=0.02$).

The mean IADL score of abnormal trunk posture (II–V) was 10.3, that of the normal (I) group was 11.2. There was no significant difference in IADL among these groups ($P=0.1$) (Table 3). However, the abnormal posture groups (II–V) had lower IADL scores that differed significantly from the normal group (I) ($P=0.047$) (Table 3).

The achieved ratio of transportation of IADLs was associated with trunk deformity ($P=0.04$) (Table 4). The group with trunk deformity group had significant disturbances in certain IADLs, including transportation, shopping for groceries, depositing and withdrawing money, and visiting friends in the hospital (Table 4). Subjects with lumbar lordosis did not exhibit significant differences from the normal group, because of the small size of this group.

There was no significant difference between GDS and the pattern of trunk deformity ($P=0.70$) (Table 5). Measures of subjective healthiness and life satisfaction (Table 6), assessed using a validated, self-reported, visual analogue scale (VAS), were not significantly dif-

Table 1 Baseline characteristics of participants. All data are expressed as mean (95% confidence interval). *I* normal, *II* thoracic kyphosis, *III* lumbar kyphosis, *IV* flat back, and *V* lumbar lordosis

	I	II	III	IV	V	Total
Number	109	47	41	28	11	236
Age	78.4 (68.9, 87.8)	81.3 (71.3, 91.4)	80.8 (70.0, 91.8)	80.2 (70.9, 89.5)	80.6 (71.8, 89.5)	80
Gender (Female, Male)	55, 54	30, 17	34, 7	18, 10	7, 4	144, 92
Height	152.0 (133.5, 170.6)	145.7 (128.8, 162.7)	142.8 (126.3, 159.2)	150.8 (134.8, 166.9)	151.6 (133.4, 169.8)	149.1
Weight	54.3 (33.7, 74.9)	47.3 (33.1, 61.5)	47.4 (29.3, 65.5)	48.1 (31.0, 65.3)	53.0 (28.5, 77.5)	50.9
JOA score (lumbar)	25.6 (18.2, 33)	25.2 (18, 32.4)	24.1 (14.7, 33.5)	24.4 (15.4, 33.4)	27.5 (23.5, 31.5)	25.2
JOA score (knee)	92.0 (67.03, 116.9)	88.9 (59.18, 118.65)	88.0 (58.53, 117.45)	89.6 (66.81, 112.45)	93.3 (63.11, 123.49)	90.5
Coexisting illness						
Hypertension	34	15	17	6	2	74
Cardiac arrhythmia	5	4	4	1	0	14
Diabetes mellitus	5	2	2	3	1	13
Cerebrovascular disorder	3	2	2	1	0	10
Coronary artery disease	4	1	2	0	0	7
Senile dementia	1	2	0	2	0	5
Parkinson disease	0	0	1	0	0	1

Table 2 Total BADL score (points) by the classification of trunk deformity in comparison with the normal trunk group (I). *I* normal, *II* thoracic kyphosis, *III* lumbar kyphosis, *IV* flat back, and *V* lumbar lordosis

	Mean	SD	95% confidence intervals
I	23.6	0.9	21.8; 25.4
II	23.3	1.56	20.18; 26.42
III	22.7	3.81	15.08; 30.32
IV	23.3	1.76	19.78; 26.82
V	23.7	0.65	22.4; 25.0
II–V	23.1	2.51	18.1; 28.12

Table 3 Total IADL score (points) by the classification of trunk deformity in comparison with the normal trunk group (I). *I* normal, *II* thoracic kyphosis, *III* lumbar kyphosis, *IV* flat back, and *V* lumbar lordosis

	Mean	SD	95% confidence intervals
I	11.2	3.13	4.94; 17.46
II	10.6	3.09	4.42; 16.78
III	9.8	4.09	1.62; 17.98
IV	10	4.42	1.16; 18.84
V	12	1.41	9.18; 14.82
II–V	10.3	3.68	2.94; 17.66

ferent from normal in participants with trunk deformity ($P=0.08$). However, the abnormal trunk deformity group tended to have lower scores with regard to subjective health condition ($P=0.03$), everyday feeling ($P=0.007$), satisfaction with human relationships to family ($P=0.035$), satisfaction with economic condition ($P=0.03$), and satisfaction with present life ($P=0.051$) than those of the normal group.

Discussion

Trunk posture in the elderly, especially kyphosis, is known to be associated with vertebral compression fractures. Measurement of kyphosis may be useful in assessing the severity of spinal osteoporosis [9]. The high prevalence of back pain demonstrates the importance of pain management in the treatment of osteoporosis [24]. The number of recent vertebral fractures was also a significant predictor of poor performance in functional reach and walking speed tests [25]. Women with multiple vertebral deformities had significantly greater impairment of ADL function than women without such deformities [26].

Lyles et al. [12] showed that patients with vertebral compression fractures had reduced levels of functional performance, pain with activity, and difficulty in activities in comparison with patients that did not have fractures. Kyphosis is associated with qualitatively and quantitatively diminished function, especially with regard to the performance of mobility tasks [27]. Our results also showed that the walking activity of the

Table 4 The accomplished ratio (%) of IADL items compared between subjects with and without trunk deformity. Kruskal-Wallis test: among five groups, Mann-Whitney test: between with (II–V) and without trunk deformities (I). *I* normal, *II* thoracic kyphosis, *III* lumbar kyphosis, *IV* flat back, and *V* lumbar lordosis

Classification	I	II	III	IV	V	*P*-value	II–V	*P*-value
Going out using public transportation	93.1(%)	82.2(%)	75(%)	76.9(%)	77.8(%)	0.04	78.4(%)	0.003
Shopping for groceries	100	95.6	94.6	96	100	0.24	95.8	0.037
Preparing meals	98.1	93.5	91.9	92.3	100	0.37	93.3	0.09
Paying bills	99	93.3	94.6	92.3	100	0.27	94.1	0.052
Depositing and withdrawing money	98	91.3	91.9	88.5	100	0.17	91.7	0.035
Writing paper	93.2	83	86.5	80	100	0.13	85	0.053
Reading newspaper	82.4	75.6	67.6	76.9	90.9	0.32	74.8	0.17
Reading magazine or book	81	72.1	72.2	72	81.8	0.66	73	0.17
Taking an interest in news of health	97	90.7	86.5	91.7	100	0.17	90.4	0.052
Visiting friends	79	78.6	73	80	81.8	0.94	77.4	0.78
Giving advice to family or friend	85.1	75	73	80	100	0.19	77.6	0.16
Visiting friend in the hospital	98	89.1	91.9	88.5	100	0.12	90.8	0.023
Talking to young people	92.2	87	86.5	80.8	90.9	0.52	85.8	0.14

Table 5 Geriatric depression scale (GDS) by the classification of trunk deformity. *I* normal, *II* thoracic kyphosis, *III* lumbar kyphosis, *IV* flat back, and *V* lumbar lordosis

	Mean	SD	95% confidence intervals
I	5.8	3.65	−1.5; 13.1
II	5.9	3.79	−1.68; 13.48
III	6.6	3.76	−0.92; 14.12
IV	6.4	3.14	0.12; 12.68
V	5.4	3.78	−2.16; 12.96
II–V	6.2	3.62	−1.04; 13.44

abnormal trunk deformity group was more limited than that of normal participants. In contrast, kyphosis is associated with decreased bone mineral density (BMD) and loss of height, but does not cause substantial chronic back pain, disability, or poor health in older women [7]. However, previous studies have not assessed patterns of trunk deformity in the context of detailed assessments of functional impairment of daily living in the elderly.

In this study, we classified trunk deformity into five groups: I normal; II thoracic kyphosis; III lumbar kyphosis; IV flat back; and V lumbar lordosis. Previously, we reported that standing trunk posture was closely associated not only with distance and time parameters of gait, but also with functional performance measures such as functional reach and timed up and go tests in elderly subjects dwelling in a rural community [17]. In the present study, we evaluated if trunk deformity is associated with the results of a detailed assessment of indoor and outdoor activities of daily living, satisfaction with life, and mental status.

This study demonstrated that the lumbar kyphosis group had decreased activities of daily living, manifested primarily in the basic ADL of walking. Of the IADL, the trunk deformity group exhibited decreased activities of daily life such as going out, shopping, depositing and withdrawing money, and visiting friends in the hospital. These activities require going out of doors. This means the abnormal trunk deformity group experienced limited outdoor activities. The lumbar kyphosis group had greater interest in their own health, possibly because they have plenty of time to think about their own health at home, as their outdoor activities are limited.

So far, few reports have discussed the association between trunk deformity and mental status. However, vertebral deformity was shown to be associated with psychological morbidity in elderly Chinese women [28].

With regard to subjective healthiness and life satisfaction, there was no significant difference among the trunk deformity groups; however, the abnormal posture group tended to score lower than the normal group on measures of their own subjective health condition, everyday feeling, satisfaction with human relationships,

Table 6 Satisfaction-with-life score by the trunk deformity. Mann-Whitney test: between with (II–V) and without trunk deformities (I). *I* normal, *II* thoracic kyphosis, *III* lumbar kyphosis, *IV* flat back, and *V* lumbar lordosis

	Mean; SD		
	Normal (I)	Abnormal (II–V)	*P*-value
Subjective health condition	64.9; 17.85	59.3; 18.75	0.033
Everyday feeling	68.5; 18.56	61.7; 19.52	0.007
Satisfaction with human relationship to others	80.8; 16.31	77.6; 19.17	0.29
Satisfaction with human relationship to family	82.1; 14.55	77.5; 16.61	0.035
Satisfaction with economic condition	62.1; 20.91	55.6; 22.72	0.03
Satisfaction with present life	68.3; 20.55	62.5; 23.2	0.051
Subjective happiness	67.1; 20.09	64.0; 21.37	0.32
Total	457.8; 181.07	428.7; 155.95	0.08

satisfaction with economic condition, and satisfaction with present life. Therefore, the trunk deformity group experienced less subjective healthiness and satisfaction with life. This result may be explained by the limitation of outdoor activities that can lead to a limited social life and difficulty in enjoying a healthy and active life in the community.

Schreiner et al. reported that Geriatric Depression Scale was accurate and reliable in dementia among Japanese subjects [29]. Although the subjective impression of mental status in the trunk deformity group was not as favorable as that of normal group, the GDS in the trunk deformity group did not reveal significant difference in that of normal group. In another study, a significant association was found between BMD of the hip and depressive symptoms after adjustment for osteoporosis risk factors [30]. They suggested the relationship between low BMD and depression was associated with endogenous steroid. We should evaluate the GDS of the larger number of participants by the classification of trunk posture and detailed background of participants to clarify the relation of depression and spinal deformity.

In this study, we did not take X-rays of thoracic and lumbar lesions in the participants, and therefore cannot speculate on the association between spinal posture and vertebral fracture. Further examinations of the radiography of spine and bone densities, such as dual energy X-ray absorptiometry (DXA) or quantitative ultrasound, are necessary to assess the association between spinal posture and vertebral osteoporosis in the community-dwelling elderly. Further studies are also needed to evaluate the cause of the limitation in outdoor activities experienced by study participants with lumbar kyphosis, and to clarify and assess the relationship between mental status and trunk deformity through long-term follow-up.

In conclusion, patients in this study with trunk deformities exhibited decreases in activities that require going outdoors.The abnormal trunk deformity groups also tended to score lower than the normal group with regard to subjective healthiness and life satisfaction measures.

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