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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VERTICAL GROUND REACTION FORCE SHAPE IS ASSOCIATED WITH GAIT PARAMETERS, TIMED UP AND GO, AND FUNCTIONAL REACH IN ELDERLY FEMALES

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Objective: **The aim of this study was to evaluate the relationship between knee pain and various indicators of the combined performance of the lower extremity (including gait parameters, functional performance such as timed up and go, and functional reach test) and to determine whether the classification of vertical ground reaction forces correlates with gait parameters and functional performance.**

Subjects and Methods: **Simultaneous analysis of gait, time-distance parameters and vertical ground reaction force. Timed up and go, and functional reach test were examined in 130 elderly women. The vertical component of the ground reaction force was grouped into 2 categories: M-shaped and non-M-shaped.**

Results: **No significant association was found between knee pain and timed up and go, functional reach test, or gait parameters in elderly female participants. There were significant differences between subjects with M- and non-M-shaped vertical ground reaction forces with regard to timed up and go, functional reach test and Japan Orthopaedic Association score. There were also significant differences between the 2 groups (M shaped and non-M-shaped) in gait parameters.**

Conclusion: **Evaluation of the vertical ground reaction force to determine its shape may be a useful and simple tool in the analysis of gait and functional performance.**

Key words: knee pain, gait analysis, elderly females, ground reaction force, osteoarthritis.

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INTRODUCTION

Osteoarthritis of the knee is one of the most common diseases in elderly females. There are several ways of testing locomotor function of the lower extremity, including measures of muscle strength, gait analysis and some types of knee evaluation scales (1–3). However, there is limited evidence that these parameters are highly correlated with the functional state of the knee. Gait analysis is becoming recognized as an important clinical tool in orthopaedics, in pre-surgery planning, post-surgery monitoring and in a posterior evaluation of various corrective interventions (4, 5). However, it is sometimes difficult for clinicians to analyse the large amounts of data gathered in the assessment of gait time and distance parameters (5).

Objective quantitative assessment of mobility and balance is important for older people because problems with gait and balance can result in a restriction of activity. The Timed Up and Go (TUG) test correlates with gait speed, balance and movement of the lower extremities (6). The Functional Reach (FR) test is a simple measurement of standing balance that can predict falls in elderly people (7, 8).

There have been several reports concerning gait analysis in osteoarthritis of the knee (1, 9). The vertical ground reaction force (VGRF) has been shown to be a reliable and repeatable feature of gait (10–11). There have been numerous studies regarding ground reaction forces during walking (12–14). Gait speed significantly affects VGRF (12, 13, 16). The VGRF varies continually from the instant of initial contact until the foot leaves the supporting surface (17). Body mass, proportions, walking style and balance all affect VGRF (17).

There have been only a few reports regarding the relationship between VGRF and various gait parameters in elderly females with osteoarthritic knees. Analyses that include a classification of VGRF have also been limited. Thus, in this study, we focused on the vertical ground force component, classified into 2 groups: M-shaped, also known as a "dual-hump" shape (18) and non-M-shaped. The purpose of this study was to evaluate the relationship between knee pain and various indicators of the combined performance of the leg, including gait parameters, functional performance, TUG and FR and to determine whether the classification of VGRF is correlated with gait parameters and functional performance.

MATERIAL AND METHODS

Subjects

We defined the subjects with osteoarthritic knee as having knee pain and less than 100 points of Japan Orthopaedic Association (JOA) score. We have been performing annual medical checks of adults aged 65 years and

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Table I. *Japan Orthopaedic Association scores based on the osteoarthritic knee evaluation form*

	Score
Pain on walking (maximum 30 points)	
No pain, walking unlimited	30
Pain, walking unlimited	25
Pain, walking distance of 0.5–1 km	20
Pain, walking less than 0.5 km	15
Pain, walking only indoors	10
Cannot walk	5
Cannot stand	0
Pain on ascending or descending stairs (maximum 25 points)	
No pain	25
Pain, relieved by using handrails	20
Pain, with handrails, but no pain with each step	15
Pain, with each step, pain relieved by using handrails	10
Pain, with each step even with handrail use	5
Cannot ascend or descend	0
Range of motion (maximum 35 points)	
Kneeling	35
Sideways or cross-legged sitting	30
More than 110°	25
75°–109°	20
35°–74°	10
Less than 35°	0
Joint effusion (maximum 10 points)	
No effusion	10
Occasional puncture required	5
Frequent puncture required	0
Maximum total points	100

over who live in the community in Kahoku of Kochi prefecture since 1994. We then examined the locomotor ability of the subjects.

The mean age of the 130 participants was 80 years (range 65–94 years), with a mean height of 143.0 cm. Knee pain while walking was classified into 3 groups: no pain (45%), unilateral pain (28%) or bilateral pain (26%).

Average maximum flexion for all subjects was 140.9 ± 13.4 degrees. Average maximum extension was 5.2 ± 6.1 degrees. JOA scores determined from the osteoarthritic knee evaluation form (Table I) were used for the evaluation of knee function (19). JOA (0–100 points) scores averaged 90.1 ± 12.9 points. The distance between the medial chondyles was evaluated, and averaged 2.5 ± 1.4 fingers breadth.

Co-morbidities of the subjects included hypertension (31.6%), cardiac arrhythmia (6.1%), coronary artery disease (3.2%) and diabetes mellitus (5.7%). Eighteen subjects with the following conditions were excluded from this study: knee disorders after total knee arthroplasty (5 patients), high tibial osteotomy (2 patients), miscellaneous knee operations (2 patients), osteosynthesis (1 patient), multiple cerebral infarctions (7 patients) and Parkinson's disease (1 patient).

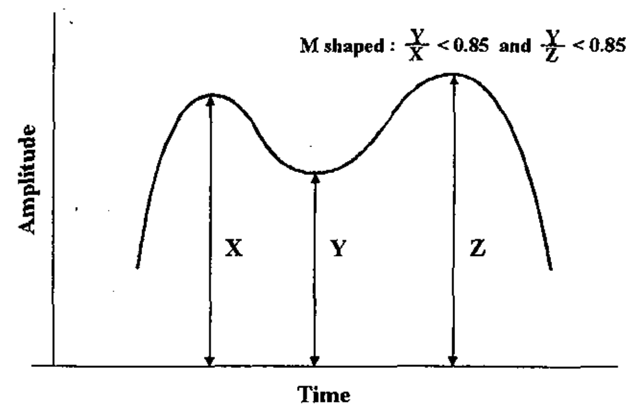

Fig. 1. Calculation of M-wave shape of vertical ground reaction force. M-shaped was defined as Y/X and Y/Z less than 0.85. All others were defined as non-M-shaped.

Gait analysis

The interviewer asked to record the gait parameters of subjects who were able to walk a distance of 10 metres. Subjects were allowed to wear their usual clothes and use their preferred (normal) speed while walking a 7-metre-long course. The first and last 2–3 metres on the walkway were not considered for measurement.

A Gait Scan® 8000 (Nitta Co. Ltd, Osaka, Japan) of gait-pattern measurement system consisting of a thin-film sensor walkway, a computer for automatic recording of the data was used in this study. This gait analysis device consists of a sensor seat (264 × 52 cm), a connector unit which fixes the sensor seat, and an interface board with a personal computer and software for data analysis.

Gait parameters, temporal distance and time factors, and ground reaction forces were measured simultaneously. Ground reaction force data for both legs was collected at a self-selected walking speed. The peak force was measured as the highest VGRF that occurred anytime during the stance phase, while the lowest VGRF occurred during the mid-stance phase.

Patients were classified into 2 groups based on the VGRF: M-shaped and non-M-shaped (Fig. 1). We defined M-shaped as lowest/highest × 100 (%) of less than 85. We assessed the shape of the VGRF for every step and classified individuals based on the result that was obtained for the greater number of steps. The mean gait variables measured in this study were walking speed (metres/sec), stride length, step width (cm), time of stride, time of single stance and time of double stance (sec). The distance parameters of stride length and step width were normalized for the height of the subject (15).

Functional performance

Timed up and go

To measure TUG, subjects were given oral instructions to stand up from

Table II. *Data (mean (SD)) for patients without pain, with unilateral and bilateral pain in elderly females*

	No pain ($n = 59$)	Unilateral pain ($n = 37$)	Bilateral pain ($n = 34$)
Body weight (kg)	45.2 (7.53)	47.2 (7.49)	52.2 (8.94)
Timed up and go (sec)	13.0 (3.0)	13.8 (4.51)	15.1 (7.28)
Functional reach (cm)	20.6 (7.2)	21.0 (7.07)	23.1 (6.89)
Stride length (cm)	63.2 (9.21)	61.1 (11.7)	61.7 (10.9)
Stride width (cm)	5.4 (2.20)	5.7 (2.14)	5.6 (1.92)
Time of stride (sec)	1.1 (0.117)	1.1 (0.179)	1.2 (0.167)
Time of single stance (sec)	0.58 (0.059)	0.59 (0.073)	0.60 (0.082)
Time of double stance (sec)	0.16 (0.037)	0.17 (0.052)	0.18 (0.069)
Gait speed (m/s)	0.6 (0.115)	0.56 (0.147)	0.54 (0.135)

Table III. *Participant characteristics given as mean (SD)*

	Height (cm)	Weight (kg)	JOA (point)	TUG (sec)	FR (cm)
Right side					
M-shaped ($n=32$)	143.8 (7.2)	46.1 (8.6)	95.2 (10.3)	11.6 (2.3)	22.5 (6.9)
Non-M-shaped ($n=47$)	142.4 (5.2)	45.9 (7.4)	86.6 (13.5)	14.6 (4.5)	18.4 (8.2)
	$p=0.187$	$p=0.96$	$p=0.0013$	$p<0.0001$	$p=0.026$
Left side					
M-shaped ($n=29$)	143.1 (8.1)	45.8 (8.1)	96.9 (6.25)	11.35 (2.25)	22.9 (7.56)
Non-M-shaped ($n=50$)	142.9 (4.7)	46.2 (7.8)	86.1 (14.1)	14.5 (4.44)	18.45 (7.74)
	$p=0.41$	$p=0.92$	$p=0.0002$	$p<0.0001$	$p=0.026$

JOA: Japan Orthopaedic Association; TUG: timed up and go; FR: functional reach

a chair, walk 3 metres as quickly and as safely as possible, cross a line marked on the floor, turn around, walk back and sit down (6).

Functional reach. 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 (7, 20).

Statistics

Data were expressed as a mean and standard deviation (SD). Differences between groups were evaluated using a Kruskal Wallis test for the analysis of knee pain (Table II) and a Mann-Whitney U test for the analysis of VGRF (Tables III and IV). Statistical significance was set at $p<0.05$.

RESULTS

Occurrence of knee pain showed a significant association with body weight; however, there was no significant difference between patients with or without pain and TUG, FR, or any gait parameters (Table II).

The shape of the VGRF was associated with certain measures of functional performance, as well as the JOA score (Table III). Patients exhibiting an M-shaped VGRF on the right and left sides had shorter TUGs and longer FRs than patients with a non-M-shaped VGRF. The total JOA score was greater for the M-shaped group than for the non-M-shaped group. Within both groups, the ground reaction forces were similar on left and right sides.

Several gait parameters varied according to the shape of the VGRF (Table IV). Stride length was longer for the M-shaped VGFR group than for the non-M-shaped VGRF group. The times of stride and single and double stance were shorter in the M-shaped VGRF group than in the non-M-shaped group. The walking speed of the M-shaped group was faster than that of the non-M-shaped group. There was no significant difference between the 2 groups in the step width on both sides.

DISCUSSION

Osteoarthritis of the knee is common in elderly females and it is well-known that it is associated with gait disturbances. There have been numerous reports regarding the relationship between osteoarthritis and gait parameters. An evaluation of the relationship between gait parameters and knee pain in elderly females found no significant association between knee pain and gait parameters or functional performance. Findings such as these have suggested that numerous factors, such as the posture of the trunk, lumbar lesions, the condition of other joints (such as the hip and ankle) and mental status, all contribute to gait parameters in elderly females. Therefore, it is important to consider these factors in the analysis of people with knee pain.

An advantage of gait analysis as a diagnostic or research tool is that many factors can be assessed at one time; however, proper evaluation of the resulting data can be complex. Quantitative data of time and distance parameters of gait analysis is difficult to understand and interpret whether it is within normal or not.

One study showed no overall abnormality in the shape or amplitude of the ground reaction force measured for the natural gait of knee-pain subjects (21). The present study, which involved the evaluation of one simple aspect of the VGRF (classified as M-shaped and non-M-shaped), showed that the shape of the ground reaction force was correlated with the pain

Table IV. *Gait parameters (mean (SD)) for subjects with M-shape and non-M-shape of vertical ground reaction force*

	Stride length (cm)	Step width (cm)	Time of stride (sec)	Time of single stance (sec)	Time of double stance (sec)	Gait speed (m/s)
Right side						
M-shaped ($n=32$)	70.1 (8.7)	5.5 (2.1)	1.03 (0.09)	0.5 (0.04)	0.1 (0.02)	0.7 (0.11)
Non-M-shaped ($n=47$)	55.8 (89.9)	5.8 (2.3)	1.2 (0.15)	0.6 (0.07)	0.2 (0.047)	0.5 (0.1)
	$p<0.0001$	$p=0.712$	$p<0.0001$	$p<0.0001$	$p<0.0001$	$p<0.0001$
Left side						
M-shaped ($n=29$)	70.6 (9.2)	5.5 (2.08)	1.0 (0.087)	0.54 (0.042)	0.1 (0.02)	0.69 (0.12)
Non-M-shaped ($n=50$)	56.5 (9.9)	6.0 (2.47)	1.8 (0.15)	0.61 (0.075)	0.2 (0.046)	0.5 (0.11)
	$p<0.0001$	$p=0.146$	$p<0.0001$	$p<0.0001$	$p<0.0001$	$p<0.0001$

component of the JOA score. In another study, increased gait speed was associated with shorter force periods and larger peak forces (16).

In the present study we found that there were no differences between the right and left legs with respect to gait parameters, functional performance or the shape of the ground reaction force. Consistent with our findings, another study showed no significant differences between the right and left foot with respect to ground reaction force during walking (22).

In our study we found that both gait parameters and functional performance were significantly correlated with the shape of the VGRF. Several previous studies have examined VGRFs in normal subjects and patients with osteoarthritis; however, prior to the present study, there was little known concerning the relationship between the VGRF and gait parameters or functional performance in elderly females with knee osteoarthritis. In one study it was found that the 2 peaks in the vertical component measured for the affected side in knee-osteoarthritis patients became less apparent, with significantly lower magnitudes than in normal subjects (18). In addition, patterns of VGRFs were nearly identical during overground and treadmill walking (23) and the general waveform and its characteristic features did not seem to be affected by the sex of normal subjects (18). In the present study, we could not find a correlation between pain and the mechanism of the shape of VGRF. Further study is needed to clarify the changing mechanism of VGRF in osteoarthritic knee.

In the present study, we did not examine inter-rater reliability: future study is needed to investigate this and the validity with respect to M-shape and gait analysis.

In conclusion, our classification of VGRF is a simple and useful tool for assessment of gait function. It was correlated with many parameters of gait and functional performance, such as TUG and functional reach. Our study indicated that a change in the VGRF, from non-M-shaped to M-shaped, is crucial to the improvement of gait parameters and gait performance. Further studies are needed to seek methods for altering the shape of the ground reaction force.

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