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Spinal sagittal contour affecting falls: Cut-off value of the lumbar spine for falls

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ABSTRACT

Spinal deformities reportedly affect postural instability or falls. To prevent falls in clinical settings, the determination of a cut-off angle of spinal sagittal contour associated with increase risk for falls would be useful for screening for high-risk fallers. The purpose of this study was to calculate the spinal sagittal contour angle associated with increased risk for falls during medical checkups in community dwelling elders. The subjects comprised 213 patients (57 men, 156 women) with a mean age of 70.1 years (range, 55–85 years). The upright and flexion/extension thoracic kyphosis and lumbar lordosis angles, and the spinal inclination were evaluated with SpinalMouse®. Postural instability was evaluated by stabilometry, using the total track length (LNG), enveloped areas (ENV), and track lengths in the lateral and anteroposterior directions (X LNG and Y LNG, respectively). The back extensor strength (BES) was measured using a strain-gauge dynamometer. The relationships among the parameters were analyzed statistically. Age, lumbar lordosis, spinal inclination, LNG, X LNG, Y LNG, and BES were significantly associated with falls ($P < 0.05$). Multivariate logistic regression analyses revealed that lumbar lordosis was the most significant factor ($P < 0.01$). Univariate logistic regression analyses for falls about lumbar lordosis angles revealed that angles of 3° and less were significant for falls. The present findings suggest that increased age, spinal inclination, LNG, X LNG, Y LNG, and decreased BES and lumbar lordosis, are associated with falls. An angle of lumbar lordosis of 3° or less was associated with falls in these community-dwelling elders.

1. Introduction

Falls that result in fractures reduce quality of life. Approximately 30% of people aged 65 years and over fall each year, and about 20% of such incidents require medical attention [1–3]. Several factors such as aging, muscle weakness, home hazards, and psychotropic medication have been reported as risk factors for falls [3]. Spinal kyphosis arises from osteoporosis, weak back muscle strength, and/or degenerative spondylosis with aging. Kyphosis, which limits the activities of daily living and impairs the quality of life, is also considered to be one of the important causes of falls [4–7]. Furthermore, postural instability, which correlates with spinal deformities, is considered to be a risk factor for falls [8–11]. Regarding the relationships between postural instability and sagittal spinal contour, a loss of lumbar lordosis affects an increasing of spinal inclination (forward stooped posture) and also correlates with postural instability and the propensity to fall [12]. Furthermore, a previous study demonstrated that a loss of lumbar lordosis, an increase in spinal inclination, and postural imbalance were significantly higher in subjects with falls than in subjects without falls or fear of falls [11]. Therefore, spinal deformities may be significant risk factors for falls. However, precise data regarding the significant factors affecting falls and the extent of spinal deformities remain unclear. Moreover, a cut-off value of sagittal spinal contour for causing falls is unknown. With the aim to identify in the clinic setting any elders who are at risk for falls, a critical cut-off angle of sagittal spinal contour associated with falls would be helpful for screening fallers. Therefore, the aims of the present study were to investigate if sagittal spinal contour factors correlated with falls, and to determine if a cut-off value of sagittal spinal contour associated with falls among community-dwelling individuals.

2. Methods

2.1. Subjects

A cross sectional study was conducted each year from 2003 to 2009. The subjects comprised 213 patients (57 men, 156 women) with a mean age of 70.1 years (range 55–85 years) who participated in medical checkups for community dwellers in Akita, Japan. All the participants were able to walk alone and did not display any apparent neurological or metabolic disorders. The history of falls within the past year was recorded by a self report questionnaire.

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Table 1
Characteristics of the 213 subjects and variables affecting falls evaluated between fallers and non-fallers.

Variables	Total (n = 213)	Fallers (n = 29)	Non-fallers (n = 184)	$P^{\dagger}$
Number/percentage of women	156/73.2	24/82.8	132/71.7	
Age (years)	70.1 (7.9)	73.6 (7.7)	70.1 (9.8)	0.020*
Body weight (kg)	54.2 (8.3)	51.7 (8.7)	55.1 (9.6)	0.123
Height (cm)	153.2 (8.4)	150.6 (8.1)	153.9 (8.7)	0.197
Thoracic kyphosis (°)	34.0 (14.5)	33.3 (14.7)	34.4 (14.4)	0.396
Lumbar lordosis (°)	11.1 (15.5)	3.8 (20.5)	11.9 (14.3)	0.035*
Spinal inclination (°)	6.0 (8.4)	10.9 (12.2)	5.8 (7.9)	0.017*
Thoracic mobility (°)	22.2 (22.2)	19.2 (24.1)	22.6 (21.6)	0.421
Lumbar mobility (°)	36.9 (22.3)	35.9 (25.5)	36.4 (21.7)	0.810
Mobility of spinal inclination (°)	102.4 (33.7)	95.0 (43.2)	101.9 (32.9)	0.491
Stabilometry				
LNG (mm)	306.7 (174.8)	432.1 (282.0)	294.1 (146.0)	0.029*
ENV (mm^2)	126.9 (112.6)	188.0 (155.7)	122.0 (102.0)	0.051
X LNG (mm)	154.2 (80.1)	198.8 (116.2)	150.1 (70.5)	0.017*
Y LNG (mm)	225.7 (151.7)	336.9 (243.9)	214.5 (127.0)	0.046*
BES (kg)	14.4 (8.3)	9.0 (8.6)	14.9 (8.3)	0.001*

Notes: Values represent the mean (±SD); LNG, total track length; ENV, enveloped area; X LNG, lateral sway length; Y LNG, anteroposterior sway length; BES, back extensor strength.
* Significant difference.
† Mann–Whitney *U* test.

2.2. Measurements of spinal sagittal contour and mobility

The parameters of sagittal spinal contour were evaluated using SpinalMouse® (Idiag, Volkerswill, Switzerland), which is a computer-assisted and non-invasive device for measuring spinal shape and mobility using surface-based techniques, and therefore reflects the shape of the dorsal trunk in appearance [13]. Measurements were accomplished by sliding this device along the spinal processes from the cephalad end of the thoracic spine to the sacrum at posterior superior iliac spine level while the subject stood with legs together. The angles of thoracic kyphosis (angle between T1 and T12), lumbar lordosis (angle between T12 and S1), and spinal inclination (angle between a straight line from T1 to S1 and the true vertical line) were evaluated. The spinal inclination reflected a forward stooped posture. All the parameters were measured in neutral standing, trunk flexion, and trunk extension positions without any support to investigate the influence of spinal mobility on the postural instability. Repetition of the measurement with the subject in trunk flexion and extension of the spine allowed measurements of spinal mobility. The mobility range of spinal inclination, which reflects the anteroposterior range of motion by the trunk, comprising the thoracic, lumbar, and sacral mobility, was also measured at maximum trunk flexion/extension. All the spinal data were measured and then calculated automatically, requiring only a short amount of time to complete the measurements. The intra-class correlation coefficients for the measurements with SpinalMouse® were 0.92–0.95 [14].

2.3. Measurement of postural instability

Stabilometry was performed using a JK-101® force platform (Unimec, Tokyo, Japan) with construction based on the strain-gauge principle. Each patient stood on the platform in a naturally upright posture with their upper limbs aligned with the sides of the body, their legs together, and their eyes open. Measurements were performed by sampling signals of the center of pressure (COP) for 20 s at a frequency of 20 Hz using a microcomputer. The following parameters indicating postural sway (imbalance) were extracted from the COP time series: total track length (LNG) indicating the sway length, enveloped area (ENV) indicating the spatial spread of the swaying, track length in the lateral direction (X LNG) indicating the lateral sway length, and track length in the anteroposterior direction (Y LNG) indicating the anteroposterior sway length. These parameters were also described and used in previous studies [12,15]. The intra-class correlation coefficients for the postural sway measurements with the stabilometer were 0.71–0.95 [16,17].

2.4. Measurement of back extensor strength

Isometric back extensor strength (BES) in the prone position was measured using a DPU-1000N Digital Force Gauge® strain-gauge dynamometer (Imada, Toyohashi, Japan). The measurements were performed twice, and the mean force was calculated. Regarding the precision of the measurements, the coefficient of variation was 2.3% [14].

2.5. Statistical analysis

All the data were analyzed using StatView® statistical software (SAS Institute, Cary, NC). To evaluate factors associated with falls, the relationships among age, body weight, height, sagittal spinal contour, spinal mobility, postural instability, and BES were analyzed using the Mann–Whitney *U* test. Since spinal posture, postural instability, and falls differ by age and sex, multivariate logistic regression analyses after adjusting for age and sex were performed for the significant variables to reveal the most significant parameters of sagittal spinal contour. Thereafter, the subjects were divided into two subgroups based on each one degree of significant sagittal spinal angle to evaluate the cut-off values. The relationships between these subgroups and falls were analyzed using univariate logistic regression analyses after adjustment for age and sex. Taking lumbar lordosis at 5° as an example of the subgroups, the subjects were divided into a 6° or more group and a 5° or less group, and analyzed as described above. The same method was applied for angles from −2° to 11°. The correlations between the variables were estimated to be absent ($r \leq 0.2$), weak ($0.2 < r \leq 0.4$), moderate ($0.4 < r \leq 0.7$), or strong ($r > 0.7$) according to the correlation coefficients. Values of $P < 0.05$ were considered statistically significant.

3. Results

The mean values for the age, body weight, height, angles of thoracic kyphosis, lumbar lordosis, and spinal inclination, thoracic and lumbar mobility, mobility of spinal inclination, parameters of postural instability, and BES are shown in Table 1. The fallers group comprised 29 subjects and the non-fallers group comprised 184 subjects.

The fallers were lighter and shorter than the non-fallers but this was not significant. The number and percentage of women were higher in the fallers group. Mann–Whitney *U* tests revealed that age, angle of lumbar lordosis, spinal inclination, LNG, X LNG, Y LNG, and BES were significantly associated with the history of falls ($P < 0.05$).

Multivariate logistic regression analyses for falls after adjustment for age and sex among the significant parameters, including angles of lumbar lordosis and spinal inclination, LNG, X LNG, Y LNG, and BES, revealed that the angle of lumbar lordosis was the only and most significant factor (Table 2). Therefore, lumbar lordosis was selected as the most significant factor among the spinal parameters. Univariate logistic regression analyses after adjustment for age and sex to evaluate the cut-off value for falls revealed

Table 2
Multivariate logistic regression analyses after adjustment for age and sex.

	Coefficient	SE	χ^2-value	*P*-value
Lumbar lordosis angle (°)	−0.049	0.022	5.167	0.023*
Spinal inclination (°)	−0.018	0.036	0.253	0.615
LNG (mm)	0.009	0.013	0.457	0.499
X LNG (mm)	−0.007	0.009	0.669	0.413
Y LNG (mm)	−0.005	0.012	0.149	0.699
BES (kg)	−0.032	0.053	0.361	0.548

Notes: SE, standard error; LNG, total track length; X LNG, lateral sway length; Y LNG, anteroposterior sway length; BES, back extensor strength.
* Statistical significance.