

Influence of the Sagittal Vertical Axis on the Risk of Falls in Community-Dwelling Elderly People: A Retrospective Longitudinal Study

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Abstract:

Introduction: Falling is an age-related problem that increases with age. Compared with younger people, elderly people possess increased risk factors for falls, and falling among the elderly is associated with increased mortality. Risk factors for falls have been reported in elderly outpatients; however, whether sagittal spinal posture affect the risk of falls in community residents remains unclear. Therefore, we aimed to investigate the influence of sagittal spinal posture on the risk of falls in elderly community-dwelling people using spino-plevic sagittal parameters in a retrospective longitudinal study.

Methods: A total of 463 volunteers (96 men and 367 women; mean age, 72.8 years) who underwent a routine physical checkup were evaluated. Baseline whole spine and lower limb radiography, physical tests, bone mineral density (BMD), number of medications and comorbidities, patient-reported outcomes (PROs), and a history of falls in the previous four years period were examined.

Results: Univariate analysis revealed older age, lower height and weight, higher prevalence of vertebral fractures, higher number of medications, poor physical test scores including one-leg standing test and prone trunk extension, poor PROs, a higher sagittal vertical axis, and higher pelvic tilt (PT) as factors significantly associated with the risk of falls, and multivariate analysis revealed a higher sagittal vertical axis [odds ratio (OR), 1.08; 95% confidence interval (CI), 1.002-1.013; $P = 0.02$] and locomotive syndrome assessed using the 25-Question Geriatric Locomotive Function Scale score (OR, 1.028; 95% CI, 1.004-1.053; $P = 0.03$) to be associated with the risk of falls, independent of other factors in the univariate analysis.

Conclusions: The sagittal vertical axis was an independent risk factor for falls, and the prevalence of vertebral fractures and prone trunk extension correlated with the sagittal vertical axis. Prospective and intervention studies are needed to prevent future falls in elderly community volunteers with a higher sagittal vertical axis.

Keywords:

falls, elderly dwelling people, sagittal vertical axis

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Introduction

Falling is an age-related problem that increases with aging. Compared with younger people, elderly people have increased extrinsic and intrinsic risk factors for falls¹. Thus, falling is a major cause of reduced activity of daily living and quality of life among the elderly and may result in increased mortality.

There have been several reports on risk factors for falls among outpatients. Whole body sagittal balance was signifi-

cantly associated with the risk of falls among elderly patients with back pain². Elderly patients with lumbar spinal canal stenosis with C7 sagittal vertical axis >50 mm had a higher risk of falls³.

However, whether spino-pelvic sagittal parameters (SPSPs) affect the risk of falls among elderly community residents remains uncertain. Furthermore, fewer studies have been performed that included comprehensive evaluations such as physical tests and evaluations of osteoporosis and osteoarthritis in the lower extremities. Thus, the purpose of

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our study was to investigate the relationship between SPSPs and the risk of falls among middle-aged and elderly community-dwelling people in a retrospective longitudinal study.

Materials and Methods

Patients

A total of 484 consecutive volunteers aged 50 years or older who visited the Toei Hospital in the Aichi Prefecture for a medical checkup from 2012 to 2016 were enrolled. All volunteers were able to walk independently and were in a stable condition. We excluded 13 subjects who had previous and past medical histories of hemiparalysis or spastic cerebral palsy. Subjects were examined for any history of falls in the past year (Yes/No) in 2014 and 2016. Determining the history of falls in the past year is an established and powerful tool for assessing the risk of falls⁴. Volunteers who answered “Yes” to at least one parameter in the questionnaire were categorized into the fall group, whereas the others were categorized into the non-fall group. We evaluated the following baseline data in 2012: patients’ backgrounds, radiographic evaluations, and physical test scores between the two groups. This study was approved by the IRB of the authors’ affiliated institutions.

Backgrounds

We measured the bone mineral density (BMD) in the femoral neck, prevalence of vertebral fracture, and number of medications and comorbidities. We defined vertebral fracture as grade 2 and above as per the semiquantitative assessment method proposed by Genant⁵. Patient-reported outcomes (PROs), the Oswestry disability index, visual analogue scale (VAS) scores, and the 25-Question Geriatric Locomotive Function Scale (GLFS-25) scores were evaluated in 2012^{6,7}, and pain VAS scores in the subjects’ hip or knee joint were measured.

Radiographic evaluations

The sagittal vertebral axis (SVA) and pelvic tilt (PT) were proposed as measures of SPSPs. The SVA is defined as the horizontal offset from the posterosuperior corner of S1 to the vertebral body of C7. PT is defined as the angle subtended by a vertical reference line originating from the center of the femoral head and midpoint of the sacral end plate. Lower limb radiography was used for the diagnosis of osteoarthritis according to the Kellgren-Lawrence (KL) grade⁸. Digitized radiographs were transferred to an imaging software (Surgimap Spine; Nemaris Inc., New York City, NY), and each parameter was measured.

Physical tests

We measured the duration of the one-leg standing test, prone trunk extension, and grip strength. The duration of the one-leg standing test that could be performed in the limited

space of the outpatient office was assessed as the duration for which the volunteers, with their eyes open, could balance on one leg. We measured this duration in both the right and left legs, and the leg for which a longer duration of the test was obtained was used for statistical analysis⁹. In the prone back extension, we measured the height from the floor to the volunteer’s chin. We performed this evaluation two times, and the measurement for which a longer height was obtained was used for statistical analysis. Grip strength was tested for both hands with volunteers in a standing position, and the average value of two trials was recorded and used for analysis¹⁰.

Statistical analysis

Statistical analyses were performed using the SPSS version 23 statistical software (IBM-SPSS, Inc., Chicago, IL, USA). A paired *t*-test, Spearman’s correlation, and chi-squared test were used to compare the mean value and correlation between the two groups. To identify independent risk factors, we used multivariate analysis. Binomial logistic analysis was applied in a stepwise manner to the significant factors in the univariate analysis. A *P* value <0.05 was considered statistically significant.

Results

The number of volunteers who experienced falls during the study period was 96 (20%). Characteristics of all subjects are shown in Table 1. Univariate analysis revealed age, height, weight, number of medications, physical test scores, PROs, and SPSPs to be significantly associated with a history of falls in the past years. Age, the number of medications, PROs, SVA, PT, and the prevalence of vertebral fractures were significantly higher, whereas height, weight, and physical test scores were significantly lower in the fall group than in the no-fall group. The percentage of female was likely to be higher in the fall group. Similarly, the number of comorbidities and knee and hip KL grade scores were higher in the fall group. Furthermore, BMD of the femoral neck was lower in the fall group. However, these factors did not show significant difference between the groups.

Multivariate analysis revealed that the SVA [OR, 1.08; 95% CI, 1.002-1.013; *P* = 0.004] and GLFS-25 score (OR, 1.028; 95% CI, 1.004-1.053; *P* = 0.003) were significantly associated with the risk of falls (Table 2). The receiver operating characteristic (ROC) curve analysis was used to define the cutoff value of the SVA for the risk of falls. In the ROC analysis, an SVA of 56.5 mm had a sensitivity of 55% and a specificity of 77% for predicting the risk of falls (Fig. 1). Subanalysis conducted in the fall group showed that prone trunk extension was significantly negatively correlated with the SVA (Fig. 2).

Discussion

The purpose of the present study was to investigate risk

Table 1. Background and Sagittal Vertical Axis of Both Groups.

		No fallen	Fallen	P values
N		375	96	
Background	Sex (male), n (%)	66 (18)	30 (31)	0.09
	Age (years)	71.8±7.4	74.2±6.8	0.007*
	Height (cm)	155±8.8	152±8.4	0.008*
	Weight (kg)	54.3±9.8	51.9±8.5	0.028*
	BMI	22.5±2.9	22.4±2.8	0.55
	BMD (%)	73.9±14.2	72.8±13.1	0.52
	Prevalence of VF, n (%)	36 (10)	19 (20)	0.02
	Number of medications	1.8±2.1	2.3±2.6	0.049*
	Number of comorbidity	0.96±0.8	1.1±0.8	0.11
Physical test	One-leg standing test (seconds)	43.1±21.4	36.8±23.3	0.011*
	Prone back extension (cm)	18.5±9.2	13.2±8.3	0.04*
	Griping power (kg)	28.5±8.5	26.1±8.0	0.027*
PROs	ODI (%)	10.8±11.2	15.0±12.3	0.001*
	VAS (mm)	2.2±2.1	2.8±2.1	0.019*
	GLFS-25	8.1±8.9	12.6±11.5	<0.001*
Spino-pelvic parameters	SVA (mm)	42.8±37.5	62.4±51.9	<0.001*
	PT (°)	17.3±9.1	20.9±10.2	<0.001*
KL grade	Hip osteoarthritis	0.15±0.5	0.05±0.3	0.06
	Knee osteoarthritis	0.97±1.1	1.1±1.1	0.22

Data are presented as the mean±standard deviation or N.

BMI: body mass index, BMD: bone mineral density, VF: vertebral fracture, ODI: Oswestry disability index, VAS: visual analog scale, GLFS-25: 25-Question Geriatric Locomotive Function Scale, SVA: sagittal vertical axis, PT: pelvic tilt, KL: Kellgren-Lawrence

*Statistically significant

Table 2. Multivariate Analysis of Association between Risk Factors and Fall.

	History of fall in a year (No=0/Yes=1) Odds ratio (95% CI)
SVA (mm)	1.008 (1.002-1.013) *
GLFS-25	1.028 (1.004-1.053) *

SVA: sagittal vertical axis, GLFS-25: 25-Question Geriatric Locomotive Function Scale.

*Statistically significant

factors for falls among elderly community residents in Japan. Indeed, we demonstrated that GLFS-25 scores and the SVA were independent risk factors for falls. In this study, the mean age of fallen group was bigger than that of no-fall group. Then, we compared mean SVA between whole 74 aged volunteers (n = 25) and same age with fallen group (n = 11) and found large SVA difference between both groups (48 mm vs. 62.4 mm). We also clarified that the SVA was significantly correlated with the height of prone trunk extension, and the prevalence of vertebral fractures was significantly increased in the fall group.

Several previous reports have described the association between the risk of falls and GLFS-25 scores. Locomotive syndrome, defined by a GLFS-25 score of 16 and above, is a condition that indicates the risk of falls requiring nursing

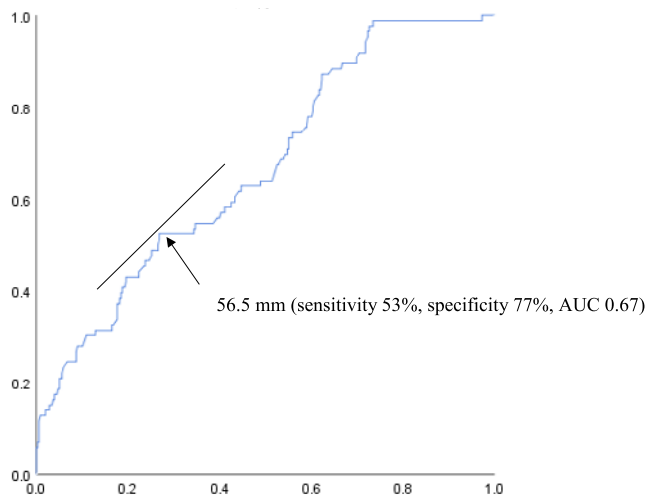


Figure 1. The receiver operating characteristic (ROC) curve for the determination of the cutoff value for the prediction of falls using sagittal vertical axis. AUC, area under the ROC curve.

care due to deteriorated musculoskeletal organs in the middle-aged and elderly people¹¹⁾. Kimura et al. also reported the usefulness of GLFS-25 to predict the risk of recurrent falls in patients with cervical myelopathy¹²⁾. In our study, we demonstrated that the GLFS-25 score was also significantly increased in the fall group and was an independent risk factor for falls.

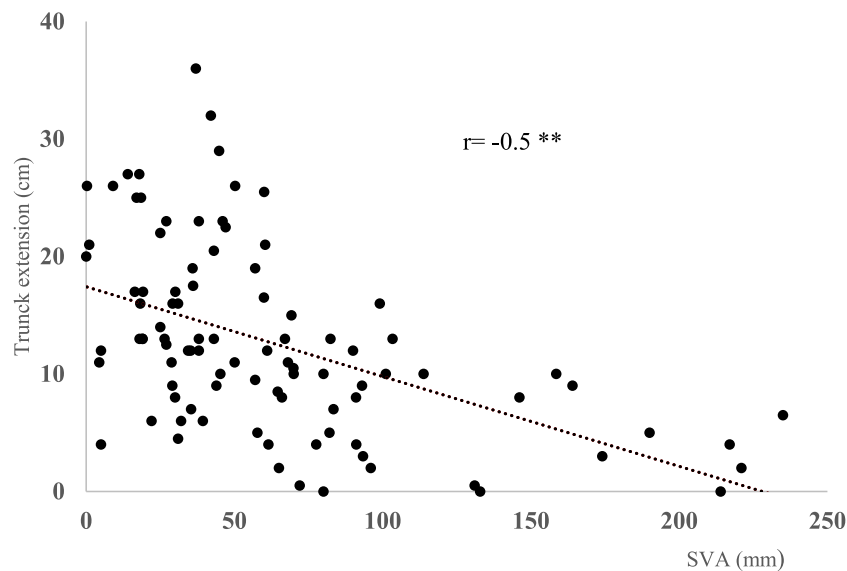


Figure 2. Correlation between sagittal vertical axis and prone trunk extension. ** indicates significant correlation between prone trunk extension and sagittal vertical axis.

The present study demonstrated that the SVA was an independent risk factor among the SPSPs. Regarding factors related to deterioration in sagittal balance in our study, the prevalence of vertebral fracture and prone trunk extension were significantly associated with the SVA (Fig. 2). Recently, investigations have examined that acute pain and morphologic change of the spine from vertebral fracture caused deterioration of SVA^{13,14} and that poor back muscle and fore posture were related to sagittal imbalance^{2,15}. However, those studies evaluated spinal alignments by Spinal Mouse and entailed on outpatients with back pain. Therefore, our study has novelty in that we conducted our research for regional dwelling volunteers with whole spinal radiograph.

There are several limitations to this study. First, we couldn't estimate exactly how many volunteers are suffering from cervical myelopathy leading to falling risk included in this study. Second, we did not investigate the dwelling environment of subjects. A previous study showed that an effective modification of the home environment reduces the risk of falls¹⁶. Furthermore, in their cross-sectional survey among community-dwelling adults in Japan, Tanaka et al. reported that living in a barrier home was a risk factor for falls¹⁷. Third, we did not survey the details of prescribed medications. Kojima et al. reported that the use of particular drugs, such as antihypertensives, aspirin, bisphosphonates, and hypnotics, was associated with a risk of falls in elderly outpatients¹⁸. They also reported that the number of prescribed medications was associated with a risk of falls in their univariate analysis, which is consistent with the finding of the present study. Further, the risk of falls would be associated with not only the number but also the type of medication. Regardless of the limitations, the strength of this study was the evaluation of SPSPs using whole spine radiography and the observation that the SVA was an independent risk factor

for falls in our retrospective longitudinal study.

In conclusion, our findings indicated that the SVA and GLFS-25 scores were significant risk factors for falls in elderly community-dwelling individuals among several other parameters. The prevalence of vertebral fractures and height of prone trunk extension correlated with an increased SVA. Therefore, the prevention of the incidence and progression of vertebral fractures, in addition to restrain the back muscle, may be important in preventing falls among the elderly people.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Author Contributions: Yu Yamato, Tomohiko Hasegawa, Go Yoshida, Tatsuya Yasuda, Tomohiro Banno, Hideyuki Arima, Shin Oe, Hiroki Ushirozako, Koichiro Ide, and Yuh Watanabe contributed to measurement of parameters. Yukihiro Matsuyama contributed to review the manuscript.

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