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Research article

Characteristics of sagittal spine alignment in female patients with distal radius fractures due to fall

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ABSTRACT

Objectives: Distal radius fractures occur due to reflex clasp when falling. Recently, attention has been focused on the strong relationship between sagittal spine alignment and falls. Therefore, we investigated the parameters of sagittal spinal alignment in distal radius fractures in female patients.

Patients and methods: The subjects were group D: 28 female patients with distal radius fractures aged 50 years or older (mean age: 69.3 years), and group C: 26 healthy female patients without a history of fragility fractures (mean age: 70.5 years). Height, body weight, and body mass index (BMI) were measured as physical indices. As parameters of sagittal spinal alignment, the sagittal vertical axis (SVA), pelvic tilt (PT), pelvic incidence (PI), sacral slope (SS), lumber lordosis (LL), and thoracic kyphosis (TK) were measured on lateral whole-spine plain radiographs in a standing position. The measured physical indices and sagittal spinal alignment parameters were compared between groups.

Results: Height, weight, and BMI did not differ significantly between the two groups. Among the sagittal spinal alignment parameters, PT, PI, SS, LL, and TK did not differ significantly between groups, whereas SVA was significantly higher in group D than in group C ($P < 0.05$).

Conclusion: In this study, SVA was significantly higher in group D than in group C. As SVA increased, the center of gravity of the body shifts forward, which can cause the body to lose balance and fall. This study suggested that an increase in SVA is associated with distal radius fractures.

1. Introduction

Many fractures that occur in the elderly are fragility fractures due to osteoporosis [1]. The most common sites of fragility fractures are the vertebral body, proximal femur, proximal humerus, and distal radius [2]. The incidences of vertebral fractures and proximal femur fractures increase from around the ages 60 and 70 years, respectively. The incidence of distal radius fractures also increases in women from their late 50s, but does not increase after the age of 70 years [3, 4]. Thus, it has been reported that distal radius fractures are the first fragility fractures [1]. Distal radius fractures occur due to reflex clasp when falling [1], and the fragility of the bone also affects these fractures [4, 5, 6].

It remains unclear why falls occur and result in distal radius fractures as fragility fractures in certain individuals. The risk factors for falls that have been reported thus far include muscular weakness, visual and cognitive disorders, and adverse reactions to multiple oral medications [7, 8]. On the other hand, attention has recently been paid to the strong relationship between sagittal spinal alignment and falls [7]. With aging, thoracic kyphosis (TK) increases, causing the body to lean forward. This causes compensatory changes such as an increase in posterior pelvic tilt (PT) [9]. It is known that the sagittal vertical axis (SVA), an index of the balance of the entire spine, increases in such age-related sagittal spinal alignment, and it is considered to be an index of the fall risk [10].

The purpose of this study was to investigate the characteristics of sagittal spinal alignment in distal radius fractures patients. First, we investigated parameters of sagittal spine alignment, namely SVA, PT, pelvic incidence (PI), sacral slope (SS), lumber lordosis (LL), and TK, in patients with distal radius fractures due to falls and age-matched healthy elderly persons. These parameters were compared between fracture patients and healthy elderly persons.

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2. Materials and methods

The study was approved by the ethics committee for medical research of our university (No. 19-186), and informed consent was received from all patients.

Of 75 patients with distal radius fractures who underwent surgical treatment at our hospital between April 2018 and October 2019, 28 female patients aged 50 years or older who were injured due to minor falls (mean age: 69.3 years) were enrolled (group D), and 26 healthy female patients without a history of fragility fractures (mean age: 70.5 years) who visited our outpatient department for locomotive syndrome between February 2017 and December 2018 were also enrolled (group C). Since the rate of secondary displacement by conservative treatment was 21–47 % according to Pavone's report [11], all patients with distal radius fractures were treated with volar locking plates. Men, young people under the age of 50, cases with high-energy trauma such as traffic accidents, and medical disorders were excluded. We also excluded subjects with a history of spinal surgery and compression fractures of the spine, and subjects with severe spinal deformities. None of the subjects had a history of visual impairment or dementia, or had a therapeutic intervention for osteoporosis. Height, body weight, and body mass index (BMI) were measured as physical indices in all patients.

As parameters for assessing sagittal spine alignment, SVA, PT, PI, SS, LL, and TK were first measured on lateral whole-spine plain radiographs in a standing position. SVA is the distance between the sagittal C7 plumb line (which is a vertical line drawn from the vertebral body of the 7th cervical vertebra (C7) to the ground) and the posterior, superior corner of the sacrum (Figure 1A). PT is the angle between the line joining the center and the center of the femoral heads with the vertical (Figure 1B). PI is the angle between the vertical bisector of the superior end plate of S1 and the line connecting the center of the superior end plate of S1 from the midpoint of the centers of both femoral heads (Figure 1B). SS is the angle between a line perpendicular to the sagittal C7 plumb line through the center of the superior end plate of S1 and the superior end plate of S1 (Figure 1B). LL is the sagittal Cobb angle measured between the superior end plate of L1 and the superior end plate of S1 (Figure 1C). TK is the sagittal Cobb angle measured between the superior end plate of T1 and the superior end plate of L1 (Figure 1C) [12, 13, 14]. The measurement of spinal and pelvic parameters in this study was conducted by the first author (A.K), with direct guidance from the first author and corresponding author of papers already published by our university [13, 14].

The measured physical indices and parameters of sagittal spine alignment were compared between group D and group C. Data were expressed as the mean ± standard deviation (median: first quartile – third quartile). GraphPad Prism 7 (GraphPad Software, Inc., La Jolla, CA, USA) was used for statistical evaluation. The Mann–Whitney *U* test was used to calculate the age, height, weight, BMI, SVA, PT, PI, SS, LL, and TK. $P < 0.05$ was considered to indicate a significant difference.

3. Results

Measurements of height, body weight, and BMI as physical indices were 153.8 ± 5.0 (153.5: 151.9–156.5) cm, 53.9 ± 7.0 (53.8: 49.5–57.5) kg, and 22.8 ± 2.5 (22.1: 21.4–24.2) kg/m^2 in group D, and 154.7 ± 5.7 (155.0: 151.3–159.0) cm, 57.8 ± 10.4 (55.7: 51.0–61.3) kg, and 24.1 ± 3.8 (24.0: 21.1–25.8) kg/m^2 in group C, respectively. There were no significant differences between the two groups (Table 1).

SVA, PT, PI, SS, LL, and TK were measured as parameters of sagittal spine alignment. In group D, SVA was 46.8 ± 40.6 (46.5: 18.7–69.3) mm, PT was 18.0 ± 8.4 (17.5: 11.8–21.5), PI was 50.0 ± 11.0 (51.5: 45.0–56.3), SS was 32.2 ± 9.4 (33.5: 26.3–39.3), LL was 42.4 ± 12.9 (46.0: 32.8–51.5), and TK was 37.4 ± 14.2 (37.5: 30.5–46.8). In group C, SVA was 25.1 ± 28.5 (18.5: 7.0–36.8) mm, PT was 18.8 ± 8.8 (16.5: 14.3–22.0), PI was 52.3 ± 8.0 (53.0: 45.52–57.8), SS was 33.2 ± 11.0 (32.5: 25.0–40.8), LL was 44.9 ± 8.8 (45.0: 40.5–50.0), and TK was 41.2 ± 11.2 (41.0: 35.8–48.0). There were no significant differences in PT, PI, SS, LL, or TK between the two groups, whereas SVA was significantly higher in group D than in group C (Table 2).

4. Discussion

Spinal deformity due to aging begins with TK induced by vertebral fractures [12]. The center of gravity of the body shifts forward due to TK, and this results in a forward-leaning posture [15]. Accordingly, compensatory changes, such as decreased LL and retroversion of the pelvis, develop to stabilize posture [9]. This compensatory function for spinal deformity maintains sagittal spinal balance [12]. However, failure to compensate for spinal deformity leads to sagittal spinal imbalance, making falls more likely [16]. Sagittal spinal imbalance causes changes in parameters of sagittal spine alignment such as increases in SVA, TK, LL, PT, and PI, and a decrease in SS [7, 10, 15, 16, 17, 18, 19, 20]. However,

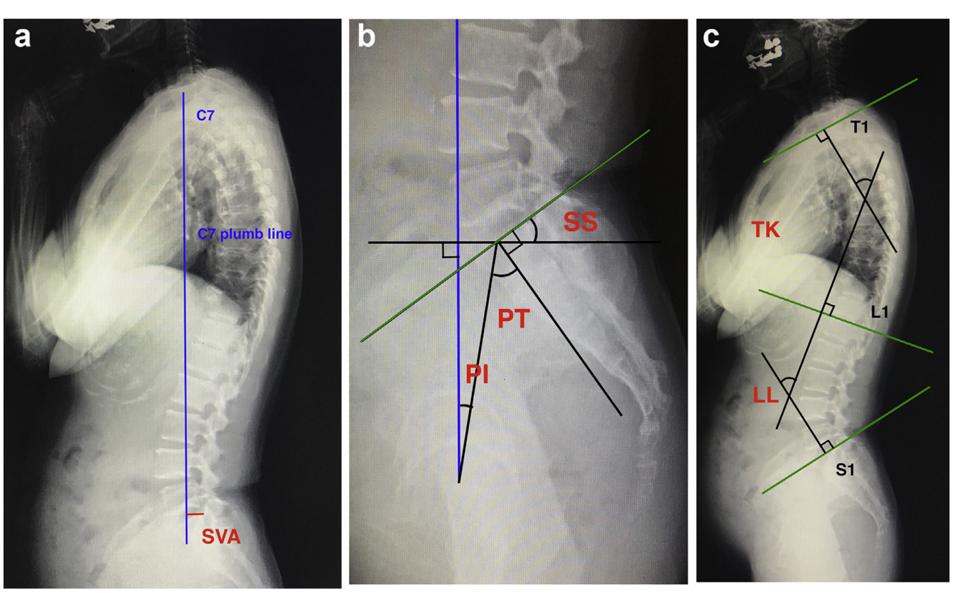

Figure 1. The parameters of sagittal spinal alignment on lateral whole-spine plain radiographs in a standing position. A: Sagittal vertical axis (SVA). SVA is the distance between the sagittal C7 plumb line (which is a vertical line drawn from the vertebral body of the 7th cervical vertebra (C7) to the ground) and the posterior, superior corner of the sacrum. B: Pelvic alignmentPelvic tilt (PT) is the angle between the line joining the center and the center of the femoral heads with the vertical. Pelvic incidence (PI) is the angle between the vertical bisector of the superior end plate of S1 and the line connecting the center of the superior end plate of S1 from the midpoint of the centers of both femoral heads. Sacral slope (SS) is the angle between a line perpendicular to the sagittal C7 plumb line through the center of the superior end plate of S1 and the superior end plate of S1. C: Thoracolumbar alignment. Lumber lordosis (LL) is the sagittal Cobb angle measured between the superior end plate of L1 and the superior end plate of S1. Thoracic kyphosis (TK) is the sagittal Cobb angle measured between the superior end plate of T1 and the superior end plate of L1.

Table 1. Physical indices in the distal radius fractures group (D group) and control group (C group).

	D group (n = 28)	C group (n = 26)	P-value
Height (cm)	153.8 ± 5.0	154.7 ± 5.7	N.S.
Body weight (kg)	53.9 ± 7.0	57.8 ± 10.4	N.S.
BMI (kg/m^2)	22.8 ± 2.5	24.1 ± 3.8	N.S.

D: Distal radius fractures, C: Control, BMI: Body mass index, N.S.: Not significant.

Table 2. The parameters of sagittal spinal alignment in the distal radius fractures group (D group) and control group (C group).

	D group (n = 28)	C group (n = 26)	P-value
SVA (mm)	46.8 ± 40.6	25.1 ± 28.5	<0.05
PT (°)	18.0 ± 8.4	18.8 ± 8.8	N.S.
PI (°)	50.0 ± 11.0	52.3 ± 8.0	N.S.
SS (°)	32.2 ± 9.4	33.2 ± 11.0	N.S.
LL (°)	42.4 ± 12.9	44.9 ± 8.8	N.S.
TK (°)	37.4 ± 14.2	41.2 ± 11.2	N.S.

D: Distal radius fractures, C: Control, SVA: Sagittal vertical axis, PT: Pelvic tilt, PI: Pelvic incidence, SS: Sacral slope, LL: Lumbar lordosis, TK: Thoracic kyphosis, N.S.: Not significant.

a consistent association between parameters of sagittal spine alignment and falls has not been established [17].

SVA is a parameter of sagittal spine alignment that is increased by forward-tilting of the trunk [10, 20]. Schwab et al. reported an SVA of more than 40 mm was an index of sagittal spinal imbalance [20]. Imagama et al. also stated that the balance ability of the body is compromised and the fall risk is increased in individuals with an SVA of more than 40 mm [10]. An increased SVA causes a forward-leaning posture with the center of gravity of the body shifting forward, which impairs the body balance, potentially resulting in falls [10]. In the present study, SVA, one of the parameters of sagittal spine alignment, was significantly higher in group D than in group C. Thus, an increase in SVA may be associated with falls that are responsible for distal radius fractures.

In contrast, TK and LL, which reflect thoracolumbar alignment, did not differ significantly between the two groups. The reference values for thoracolumbar alignment are 20–50° for TK and 20–70° for LL, and both groups satisfied these reference values in this study [21, 22]. Fon et al. reported an increased TK as a result of age-related vertebral fractures and degeneration of the intervertebral disc [23]. Sinaki et al. stated that gait instability increased with the increase in TK, leading to an increased risk of falls [15]. In addition, Ishikawa et al. reported that a reduced LL is associated with falls [16]. As individuals age, LL decreases progressively because spinal deformities and muscle weakness in the back limit the mobility of the lumbar spine [16]. Thus, imbalances in thoracolumbar alignment, such as increased TK and reduced LL, develop under the influence of age-related fragility vertebral fractures and degeneration of the intervertebral disc. Why were thoracolumbar alignments, such as TK and LL, normal in our patients? First, the mean age of group D in our study was 69.3 years, which was lower than that in previous studies. The mean ages of subjects in the studies by Sinaki et al. and Ishikawa et al. were 73.6 years and 76.5 years, respectively [15, 16]. Second, our study excluded patients with severe spinal deformities or fragility vertebral fractures. TK and LL, which are affected by age-related fragility vertebral fractures and degeneration of the intervertebral disc, are unlikely to change in group D.

There were also no significant differences in PT, PI, or SS, which are indicators of pelvic alignment, between the groups. In elderly persons, pelvic alignment is characterized by a posterior pelvic tilt via hip extension due to compensatory changes for reduced LL [9, 22]. Posterior pelvic tilt increases PT [13, 17, 22]. SS depends on the position of the pelvis relative to the hip axis and decreases inversely proportional to PT [13, 22]. PI is a patient-specific variable and does not vary with sagittal balance [13, 18, 22]. However, the greater the PI, the greater the risk of sagittal imbalance because correction of LL is necessary to maintain proper sagittal balance [18]. The reference values for pelvic parameters are <20° for PT, 55 ± 10° for PI, and 36–39 ± 9° for SS, and both groups in this study met these reference values [21, 24, 25]. As mentioned above, our patients without an imbalance in thoracolumbar alignment exhibited no changes in pelvic alignment, and the results were reflected in each parameter.

This study suggested that an increase in SVA, a parameter of sagittal spine alignment, is a risk factor for falls and ensuing distal radius fractures. Hori et al. investigated the relationship between trunk muscle strength and SVA, and suggested that lower muscle strength in the trunk was associated with a higher SVA [26]. Yurube et al. also reported two cases of improved SVA by exercise training, suggesting that strengthening of the back and lower extremity muscles, in addition to their improved flexibility, can improve sagittal spinal alignment [27]. Moreover, locomotion training has been reported to reduce fall rates and improve SVA [28]. This study suggested that it is expected that intervention with locomotion training may lead to prevention of future falls in patients with higher SVA who do not suffer from fragile fracture injury. In our study, the muscle strength of the trunk and lower extremities was not evaluated. In recent years, however, the relationship between SVA and the muscle strength of the trunk and lower extremities has been attracting attention, and exercise training can be a useful intervention to prevent falls that are responsible for distal radius fractures.

This study focused on sagittal spinal alignment and did not evaluate other risk factors for falls such as muscle weakness, visual and cognitive disorders, and adverse reactions to multiple oral medications. Measures to prevent falls resulting in distal radius fractures should be further explored based on multifaceted evaluations of the muscle strength of the trunk and lower extremities and medical conditions, in addition to sagittal spinal alignment.

5. Conclusion

In conclusion, we compared parameters of sagittal spinal alignment as a risk factor for falls between a group of patients with distal radius fractures due to falls and a control group. Among the parameters of sagittal spinal alignment, SVA was significantly higher in distal radius fracture patients than in controls. As the SVA increased, the center of gravity of the body shifted forward, and this may cause the body to lose balance and potentially result in a fall. This study suggested that an increase in SVA is associated with falls that are responsible for distal radius fractures.

Declarations

Author contribution statement

K. Naito: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

A. Kaneko: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Y. Sugiyama, Y. Iwase and K. Kaneko: Conceived and designed the experiments.

N. Nagura M. Koike:Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

H. Obata, H. Nojiri and K. Goto: Performed the experiments; Analyzed and interpreted the data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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