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Sagittal Spinal and Pelvic Alignment in Middle-Aged and Older Men and Women in the Natural and Erect Sitting Positions: A Prospective Study in a Chinese Population

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Background: This prospective study aimed to compare the sagittal spinopelvic parameters in the erect and natural sitting positions in healthy middle-aged and older men and women in a Chinese population.





Material/Methods: Ninety healthy middle-aged and older men and women underwent lateral whole spinal radiography in the natural and erect sitting positions. The radiographic sagittal spinopelvic parameters were measured. They included the sagittal vertical axis (SVA), the T1 pelvic angle (TPA), the pelvic incidence (PI), the pelvic tilt (PT), the sacral slope (SS), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), the T1 slope (T1S), cervical lordosis (CL), and lumbar lordosis (LL).

Results: In the natural sitting position, LL decreased by 14.5°, TK and TLK increased by 3.2° and 2.5°, respectively, PT increased by 10.3°, T1S increased by 6.9°, and CL increased by 3.4° compared with the erect position. In the natural sitting position, the mean forward-moving SVA was 33.4 mm, and the C2–C7 SVA was 6.1 mm. Men had a larger LL and smaller PT than the women when sitting in the erect position, and a greater TK, T1S, and C2–C7 SVA than women when sitting in the natural position.

Conclusions: In the natural sitting position, a reduction in LL was associated with TK, SVA and PT increased, and there were differences between men and women. The characteristics of spinopelvic alignment in healthy older adults should be considered when planning corrective spinal surgery.

MeSH Keywords: **Aged • Orthopedics • Spine**

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Background

Spinopelvic sagittal alignment is an important factor that should be considered in vertebral fusion surgery, as fusion procedures cause the spine to become fixed in a specific curvature. Previous studies have focused on evaluating the spine in the standing sagittal spine radiograph to identify the ideal alignment to guide corrective surgery [1–3]. However, evaluation of normal spinopelvic sagittal alignment has been challenged by recent studies which have shown that the sagittal spinopelvic alignment in the sitting position was significantly different from that in the standing position [4,5]. Modern lifestyles are associated with sitting as the usual posture in working and domestic environments, with most people sitting for more than eight hours per day [6]. Also, it has been reported that sitting can result in greater pressures within the lumbar intervertebral disc than standing [7]. These previous studies indicate that a lack of knowledge regarding the differences between standing and sitting could be responsible for the failure of corrective spinal surgery.

Therefore, studies on the normal spinopelvic sagittal alignment and the control mechanisms involved in the natural sitting position and the erect sitting position may provide information that improves current approaches to corrective surgical procedures. Previous studies have used the standing position as the reference, with changes compared with the forward-moving center of gravity of the body with the straighter spine and pelvic retroversion in the sitting position [4,8]. Hey et al. [9] compared the imposed erect sitting posture from the natural or preferred sitting posture in young adults. The findings showed that young people adopted the natural sitting position during most of their sitting time, and the erect sitting position usually acted as a transitional stage from standing to natural sitting [9]. Zhou et al. compared the sagittal alignments of Chinese volunteers under and over 40 years old and found that age could influence the sagittal alignments both in sitting and standing positions. Therefore, both the natural sitting position and the erect sitting position should be evaluated in studies on the control mechanisms involved in spinopelvic sagittal alignment to improve the approaches to corrective spinal surgery.

There have been few studies to compare the erect sitting position and the natural sitting position in the healthy older adults. However, given that older adults have different spinopelvic sagittal alignment compared with young adults in both the standing and sitting positions [10–13], it may be inappropriate to reconstruct the sagittal alignment of older adults based on the criteria derived from data of young adults [14]. Therefore, this prospective study aimed to compare the sagittal spinopelvic parameters in the erect sitting position and the natural sitting position in healthy middle-aged and older men and women in a Chinese population.

Material and Methods

Study design

A prospective cross-sectional study included a Chinese population of healthy middle-aged and older adults >40 years of age. This study was approved by the local institutional Ethics Committee and was conducted according to the requirements of the Declaration of Helsinki. All study participants volunteered for the study and were fully informed about the methods, purposes, and risks involved in the study protocol. All study participants provided signed informed consent.

Study participants

The study participants underwent a detailed medical history taking and physical examination before participating in this study. The study inclusion criteria were age >40 years, no history of neck pain, back pain, or radicular pain in the previous six months, no history of chronic neck or back pain lasting more than three months, no history of spinal disease or surgery, no spinal deformity or lumbar spondylolisthesis, no history of hip or knee arthroplasty or other realignment surgery of the lower extremities, and no history of neuromuscular disorders. Women who may have been pregnant were also excluded from the study. General demographic data were recorded, including height, weight, gender, and age. Ninety healthy middle-aged and older Chinese volunteers were included in the study.

X-radiography and imaging parameters

Radiographs were taken of the study participants in the lateral standing position, the erect sitting position, and the natural sitting position, and included the whole spine and pelvis. Study participants were instructed to use the postures recommended in previous research on the erect sitting position and natural sitting position in young adults [9]. In the standing position, volunteers were requested to stand as straight as possible, with the fingers touching the collar bones. In the erect sitting position, volunteers were requested to flex their hips and knees to 90°, and sit as straight as possible, with their fingers touching their collar bones. In the natural sitting position, volunteers were instructed to sit as they usually preferred, and then put their fingers on their collarbones. A height-adjustable stool without a backrest was provided for volunteers so they could adjust the height to reach a standardized posture and put their feet flat on the ground. If their feet could not touch the ground after adjusting the seat height, a wooden step was provided.

The Picture Archiving and Communication System (PACS) (GE Healthcare, Mount Prospect, IL, USA) recorded the measured radiographic parameters, including the global parameters of the

Table 1. Measurements of the radiographic sagittal spinopelvic parameters.

Parameters	Measurements
SVA (mm)	The offset between the center of C7 and the plumb line drawn from posterosuperior corner of S1
TPA (°)	The angle between the line from the axis of the femoral head to the center of T1 and the line from the axis of the femoral head to the midpoint of the S1 endplate
CL (°)	The angle between the lower endplate of C2 and C7
C2–C7 SVA (mm)	The offset between the center of C2 and the plumb line drawn from posterosuperior corner of C7
T1S (°)	The angle between the upper endplate of T1 and horizontal line
TK (°)	The angle between the upper endplate of T4 and the lower endplate of T12
TLK (°)	The angle between the upper endplate of T11 and the lower endplate of L1
LL (°)	The angle between the upper endplate of L1 and S1
SS (°)	The angle between the sacral endplate and the horizontal line
PT (°)	The angle between the line from the middle of the sacral plate to the middle of the hip axis and the vertical line
PI (°)	The angle between the line perpendicular to the midpoint of the sacral plate and the line connecting this to the midpoint of the hip axis

The radiographic sagittal spinopelvic parameters included the sagittal vertical axis (SVA), the T1 pelvic angle (TPA), the pelvic incidence (PI), the pelvic tilt (PT), the sacral slope (SS), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), the T1 slope (T1S), cervical lordosis (CL), and lumbar lordosis (LL).

sagittal vertical axis (SVA) and T1 pelvic angle (TPA). The local curvature parameters included lumbar lordosis (LL), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), T1 slope (T1S), C2–C7 SVA, and cervical lordosis (CL). The pelvic parameters included the pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS). The parameters of the measurement are shown in Table 1, Figures 1 and 2.

Statistical analysis

Data were analyzed using SPSS version 19.0 (SPSS Inc, Chicago, IL, USA). Inter-observer and intra-observer reliability were evaluated using the intraclass correlation coefficient (ICC). Data were expressed at the mean±standard deviation (SD). The continuous radiological parameters were compared between the different positions using the paired t-test. The parameters for men were compared with those of women in different sitting positions using an independent t-test. A P-value <0.05 was considered to be statistically significant.

Results

Demographic characteristics of the study participants

Of the 90 healthy older adults recruited in the study, there were 39 men and 51 women, with a mean age of 53.2±5.7 years (range, 42–71 years). The mean height was 1.64±0.07 m

(range, 1.50–1.81 m), and the mean weight was 66.3±10.1 kg (range, 51.0–98.0 kg), with a mean body mass index (BMI) of 24.6±2.9 kg/m² (range, 19.4–32.7 kg/m²).

Comparison of radiographic parameters in different sitting positions

The radiographic parameters that were measured included the sagittal vertical axis (SVA), the T1 pelvic angle (TPA), the pelvic incidence (PI), the pelvic tilt (PT), the sacral slope (SS), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), the T1 slope (T1S), cervical lordosis (CL), and lumbar lordosis (LL). Using the intraclass correlation coefficient (ICC), there was good (ICC >0.8) to excellent (ICC >0.9) inter-observer and intra-observer reliability for the measured parameters (Table 2). The sagittal radiographic parameters in different sitting positions are shown in Table 3. When moving from the standing position to the sitting position, the mean SVA increased by 43.4±26.7 mm, and when the spine straightened there was a significant decrease in the mean LL (13.4±10.2°), TK (4.8±5.2°), and TLK (0.7±2.9°), followed by an increase in the mean PT (6.1±8.9°) and TPA (9.1±7.9°). The main reduction of LL occurred in lower lordosis (L4–S1, 9.3±6.8°), which accounted for 70% of the whole reduction. For cervical alignment, the CL did not increase significantly (12.7° vs. 12.9°; P=0.798), but the C2–C7 SVA increased by 2.7±7.5 mm and the T1S increased by 1.7±5.5° in the sitting position.

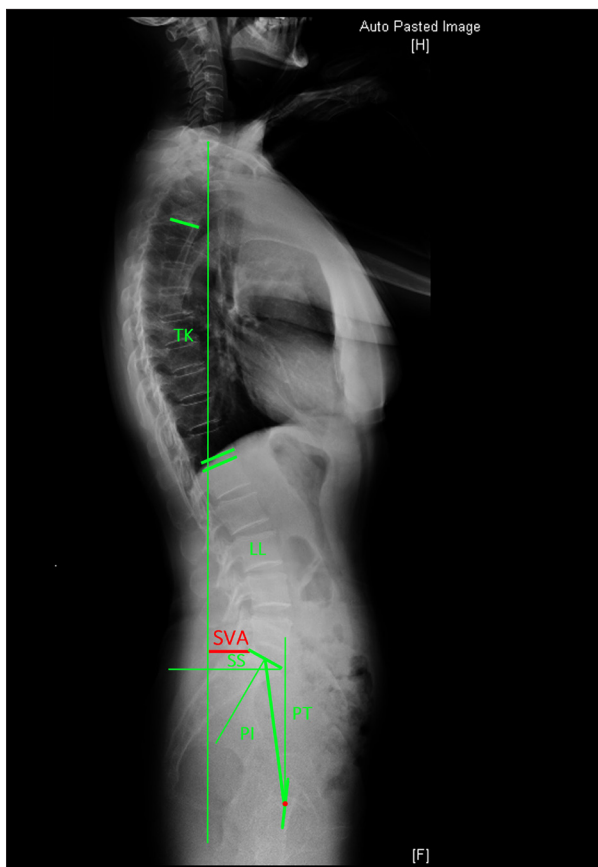


Figure 1. The measurements of the thoracolumbar and pelvic parameters. The radiographic sagittal spinopelvic parameters included the sagittal vertical axis (SVA), the T1 pelvic angle (TPA), the pelvic incidence (PI), the pelvic tilt (PT), the sacral slope (SS), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), the T1 slope (T1S), cervical lordosis (CL), and lumbar lordosis (LL).

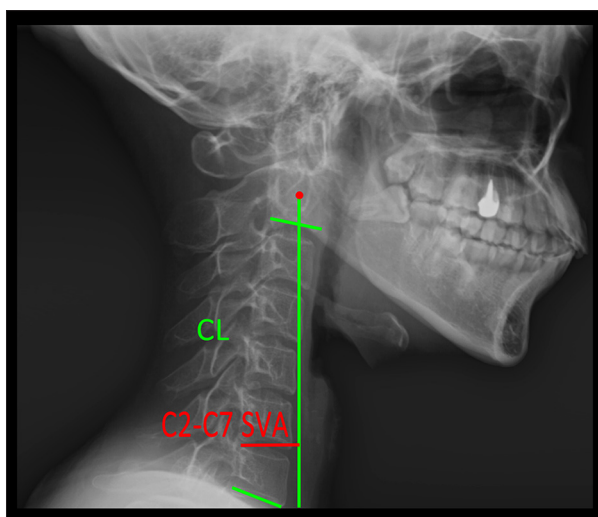


Figure 2. The measurements of the cervical parameters.

Table 2. The inter-observer and intra-observer reliability for the measured parameters evaluated using the intraclass correlation coefficient (ICC).

Parameters	Intra-observer ICC	Inter-observer ICC
SVA	0.98	0.99
PI	0.93	0.88
PT	0.96	0.95
SS	0.92	0.89
LL	0.86	0.83
TK	0.90	0.90
TLK	0.98	0.97
CL	0.98	0.98
TPA	0.98	0.97
C2–C7 SVA	0.97	0.95
T1S	0.94	0.90

Inter-observer and intra-observer reliability were evaluated using the intraclass correlation coefficient (ICC). The radiographic sagittal spinopelvic parameters included the sagittal vertical axis (SVA), the T1 pelvic angle (TPA), the pelvic incidence (PI), the pelvic tilt (PT), the sacral slope (SS), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), the T1 slope (T1S), cervical lordosis (CL), and lumbar lordosis (LL).

When moving from the erect sitting position to the natural sitting position, the SVA continued to increase (mean, 33.4 ± 30.5 mm), and the LL continued to decrease (mean, $14.5 \pm 12.6^\circ$), with an increase in PT (mean, $10.3 \pm 10.8^\circ$). The main reduction of LL occurred in upper lordosis (L1–L3, $8.9 \pm 7.9^\circ$), which accounted for 60% of the whole reduction. However, TK and TLK significantly increased with a mean of $3.2 \pm 6.8^\circ$ and $2.5 \pm 3.2^\circ$, respectively. For the cervical vertebral alignment, T1S significantly increased by $6.9 \pm 6.2^\circ$, corresponding to the significant increase of CL of $3.4 \pm 7.6^\circ$, and C2–C7 SVA of 6.1 ± 9.5 mm in the natural sitting position. Since T1 was the foundation of the cervical vertebrae, increased T1S required a larger CL to maintain horizontal vision (Figure 3).

In the erect sitting position, the lumbar apical vertebra was L4 (n=40) or L3 (n=32) in 80% of the volunteers in the study. The thoracolumbar end vertebra was L1 (n=33) or T12 (n=29) in 70% of the volunteers. The apical vertebra of thoracic kyphosis was T6 (n=25) or T7 (n=25) in 55% of the volunteers. In the natural sitting position, the lumbar apical vertebra moved to L5 (n=29) or L4 (n=23) in 60% of the volunteers, the thoracolumbar end vertebra moved to L1 (n=27) and L2 (n=24) in 57% of the volunteers, but the apical vertebra of thoracic kyphosis moved from T5 to L3 (Table 4).

Table 3. The sagittal parameters in different sitting positions.

Parameter	Standing	Differences	Erect sitting	Differences	Natural sitting
SVA (mm)	-9.9±25.4	43.4±26.7	33.4±21.2*	33.4±30.5	66.8±37.7*
TPA (°)	8.1±6.4	9.1±7.9	17.1±8.9*	11.8±9.6	28.9±11.5*
CL (°)	-12.7±11.0	-0.2±8.4	-12.9±12.4	-3.4±7.6	-16.3±12.5*
C2–C7 SVA (mm)	20.0±10.1	2.7±7.5	22.7±11.8*	6.1±9.5	28.9±12.4*
T1S (°)	22.3±7.5	1.7±5.5	24.0±7.5*	6.9±6.2	30.9±8.4*
TK (°)	33.9±9.8	-4.8±5.2	29.1±10.3*	3.2±6.8	32.3±11.7*
TLK (°)	9.2±6.2	-0.7±2.9	8.4±6.4*	2.5±3.2	10.9±6.8*
LL (°)	-51.6±10.7	13.4±10.2	-38.2±11.7*	14.5±12.6	-23.7±16.0*
L4–S1 (°)	-36.0±8.0	9.3±6.8	-26.7±8.8*	5.6±6.9	-21.1±9.6*
SS (°)	34.3±9.0	-6.2±9.0	28.1±9.4*	-9.9±10.8	18.1±11.9*
PT (°)	14.2±7.0	6.1±8.9	20.3±10.2*	10.3±10.8	30.6±12.8*
PI (°)	48.5±9.7	–	48.6±9.7	–	48.8±9.6

The radiographic sagittal spinopelvic parameters included the sagittal vertical axis (SVA), the T1 pelvic angle (TPA), the pelvic incidence (PI), the pelvic tilt (PT), the sacral slope (SS), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), the T1 slope (T1S), cervical lordosis (CL), and lumbar lordosis (LL). * The mean compared with the former position, $P < 0.05$.

Differences between men and women

The mean age of the men ($N=39$) and the women ($N=51$) were 54.1 ± 6.5 years and 52.4 ± 5.0 years, respectively. The mean body mass index (BMI) of the men and women was 24.7 ± 3.3 kg/m^2 and 24.5 ± 2.6 kg/m^2 , respectively. As shown in Table 5, men presented with significantly greater C2–C7 SVA, T1S, and TK than women when in the standing position. Other parameters were similar in both groups.

When moving from the standing position to the erect sitting position, women had a significantly greater increase in PT ($9.0 \pm 8.0^\circ$ vs. $2.5 \pm 8.7^\circ$; $P < 0.001$), TPA ($11.9 \pm 7.1^\circ$ vs. $5.5 \pm 7.4^\circ$; $P < 0.001$) and greater decrease in LL ($16.7 \pm 9.4^\circ$ vs. $9.2 \pm 9.4^\circ$; $P < 0.001$) compared with men. The increase in SVA (42.4 ± 24.7 mm vs. 44.1 ± 28.4 mm; $P = 0.774$), CL ($0.5 \pm 9.5^\circ$ vs. $0.3 \pm 7.6^\circ$; $P = 0.796$), C2–C7 SVA (2.8 ± 9.8 mm vs. 2.5 ± 5.2 mm; $P = 0.832$), T1S ($0.7 \pm 6.7^\circ$ vs. $2.3 \pm 4.3^\circ$; $P = 0.217$) and decrease in TK ($5.1 \pm 5.9^\circ$ vs. $4.4 \pm 4.8^\circ$; $P = 0.508$), TLK ($1.0 \pm 2.8^\circ$ vs. $0.5 \pm 3.0^\circ$; $P = 0.423$) were similar in both groups.

When changing to the natural sitting position, men showed a significantly greater increase in T1S ($9.0 \pm 6.9^\circ$ vs. $5.5 \pm 5.1^\circ$; $P < 0.01$) compared with the women. The increase of PT ($12.1 \pm 12.1^\circ$ vs. $8.7 \pm 9.7^\circ$; $P = 0.150$) and TK ($4.2 \pm 8.0^\circ$ vs. $2.2 \pm 5.8^\circ$; $P = 0.171$) were significantly greater in men compared with women, although the differences did not reach statistical significance. The differences in other parameters were similar for men and women. Therefore, in the natural sitting position, men had greater TK, T1S, and C2–C7 SVA than women.

Discussion

The aim of this prospective study was to compare the radiographic sagittal spinopelvic parameters in the standing position, erect sitting position, and the natural sitting position in 90 healthy middle-aged and older men and women in a Chinese population. The radiographic parameters measured included the sagittal vertical axis (SVA), the T1 pelvic angle (TPA), pelvic incidence (PI), the pelvic tilt (PT), the sacral slope (SS), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), the T1 slope (T1S), cervical lordosis (CL), and lumbar lordosis (LL). The findings from this study showed that when moving from the erect sitting position to the natural sitting position, the LL decreased by 40%, and the TK increased by 10%, with an increase in PT, SVA, and CL to rebalance the spine and maintain horizontal vision. However, the mean lumbar lordosis was 23.7° in the natural sitting position, which retained an S-shaped spinal sagittal profile. This finding was different from C-shaped curvature in young adults reported by a previous study [9]. The sagittal alignment was different between men and women in the standing position and different sitting positions.

Older adults commonly experience spinal deformity [15], which affects their health and quality of life [16]. Surgical treatment is recommended for patients when non-operative management has failed [17]. For these patients, restoring the optimal sagittal alignment is the main corrective surgical procedure. However, the optimal corrective targets remain controversial, but the sitting position and its sagittal alignment should be considered

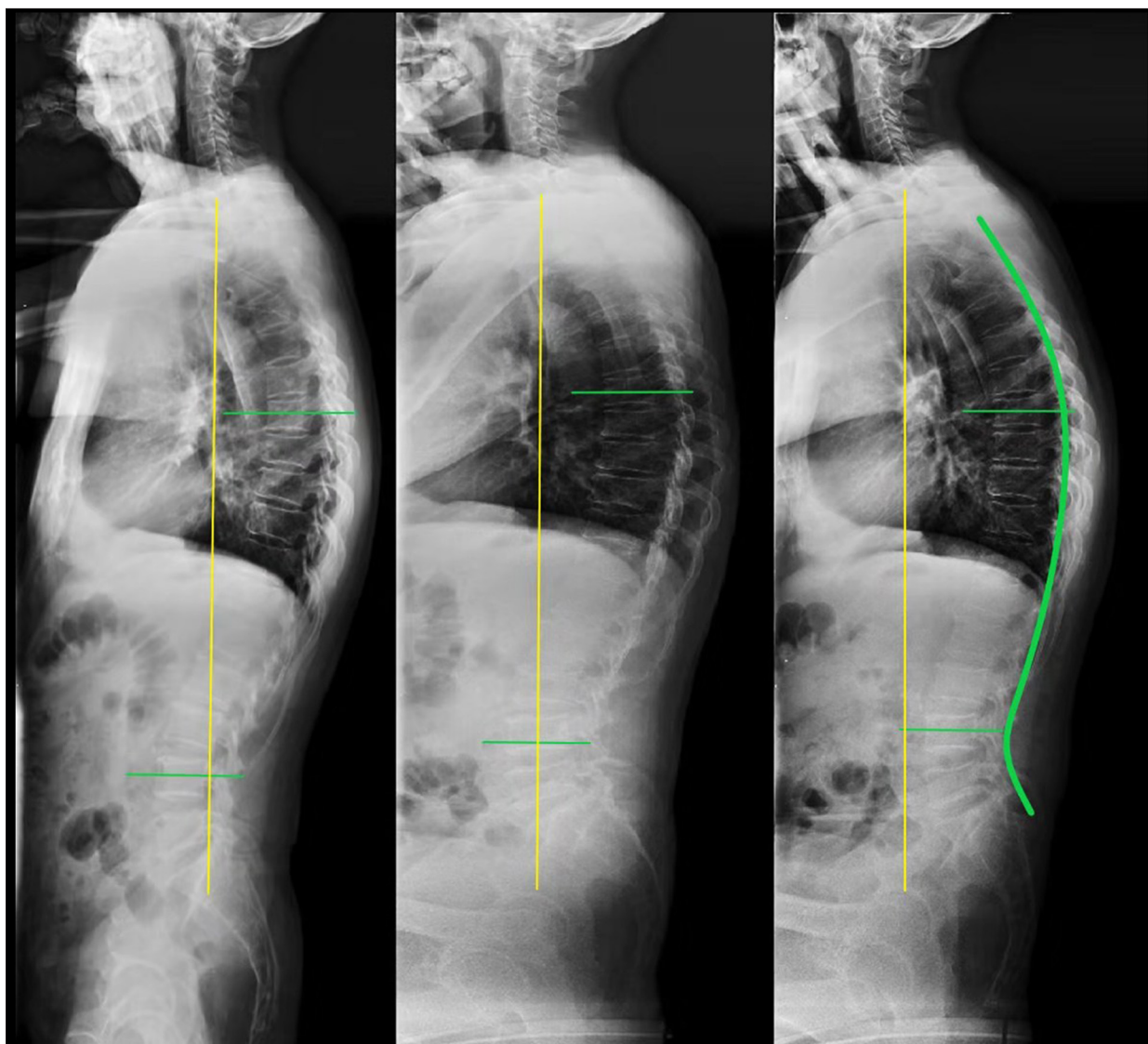


Figure 3. The image of the sagittal profile of a 61-year-old man in the standing, erect sitting, and natural sitting positions. The spine formed an S-shaped curve in the natural sitting position.

Table 4. The sagittal curve apices and end vertebrae in different positions.

	Standing	Erect sitting	Natural sitting
Lumbar lordosis			
Apical vertebra	L4 (L3–L5)	L4 (L2–L5)	L5 (L2–L5)
End vertebra	S1 (L5–S1)	S1 (L5–S2)	S1 (L5–S2)
Thoracolumbar kyphosis			
End vertebra	L1 (T10–L3)	L1 (T8–L3)	L1 (T8–L5)
Thoracic kyphosis			
Apical vertebra	T6 (T4–T9)	T7 (T5–T12)	T5–L3
End vertebra	T1 (T1–T4)	T1 (T1–T4)	T1 (T1–T3)

Table 5. The sagittal radiographic parameters in different sitting positions in men and women.

	Standing		Erect sitting		Natural sitting	
	Men	Women	Men	Women	Men	Women
Age (years)	54.1±6.5	52.4±5.0	54.1±6.5	52.4±5.0	54.1±6.5	52.4±5.0
Weight (kg)	71.6±11.1	62.3±7.0*	71.6±11.1	62.3±7.0*	71.6±11.1	62.3±7.0*
BMI (kg/m ²)	24.7±3.3	24.5±2.6	24.7±3.3	24.5±2.6	24.7±3.3	24.5±2.6
SVA (mm)	-10.5±24.8	-9.5±26.11	32.0±23.2	34.6±19.8	71.9±45.9	62.9±30.0
TPA (°)	8.8±5.7	7.5±6.8	14.1±6.8	19.5±9.7*	27.3±13.2	30.2±10.1
CL (°)	14.3±10.7	11.4±11.2	14.8±10.4	11.4±13.7	18.4±12.5	14.7±12.3
C2–C7 SVA (mm)	23.1±12.0	17.7±7.6*	26.1±14.8	20.1±8.0*	33.0±14.3	25.6±9.7*
T1S (°)	24.3±7.2	20.7±7.4*	25.3±7.3	23.0±7.5	33.9±7.9	28.6±8.1*
TK (°)	36.6±8.7	31.9±10.1*	31.3±9.5	27.5±10.5	35.8±9.9	29.7±12.3*
TLK (°)	10.4±6.0	8.2±6.3	9.3±6.5	7.7±6.3	12.5±7.1	9.6±6.3
LL (°)	51.1±12.2	52.0±9.6	42.0±10.7	35.3±11.7*	26.8±17.3	21.3±14.6
SS (°)	34.1±9.4	34.4±8.8	31.4±8.7	25.5±9.2*	19.5±13.5	17.1±10.6
PT (°)	13.6±6.4	14.6±7.4	16.1±8.4	23.7±10.4*	28.3±14.1	32.4±11.5
PI (°)	47.7±10.7	49.0±9.0	–	–	–	–

The radiographic sagittal spinopelvic parameters included the sagittal vertical axis (SVA), the T1 pelvic angle (TPA), the pelvic incidence (PI), the pelvic tilt (PT), the sacral slope (SS), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK), the T1 slope (T1S), cervical lordosis (CL), and lumbar lordosis (LL). BMI, body mass index. * The mean compared with the men, P<0.05.

when planning surgical correction [18], given that people spend half their waking time in the sitting position [19,20].

Some studies have demonstrated the characteristics of young adults in the standing position and different sitting positions [4,9], but no previous study has reported the normal values for older adults, including middle-aged and older people in different sitting positions. It is inappropriate to base the surgical realignment planning on the results obtained from young adults in the older population, as older people have different sagittal alignment from young adults in both standing and sitting positions, as demonstrated in our previous study and as shown in other studies [13,21,22]. Lack of knowledge of these differences when planning corrective spinal surgery in middle-aged and older adults may lead to non-matched bone alignment and might be responsible for proximal junctional failure [23]. Therefore, this study explored the normal vertebral sagittal plane of a healthy middle-aged and older population in different sitting positions, to develop a reference when planning surgery for this patient demographic.

The erect sitting position has different dynamics and curvature of the spine compared with the standing position. Nachemson [7] reported that the intradisc pressure increased by 40% during sitting compared with that in standing. Previous studies have reported that LL was reduced by 50%, and the PT

increased by 100% when moving from the standing position to the erect sitting position [4,8]. Also, Hey et al. [9] previously described the natural sitting position in healthy young adults, which was characterized by a C-shaped contour of the spine. This previous study showed that LL continued to decrease by 80% (from 26.7° to 5.4°) from the erect sitting position to the natural sitting position. However, the present study found that the decrease in LL was only 40% (from 38.2° to 23.7°) in the older adults and they showed a larger LL in both the erect sitting position (38.2° vs. 26.7°) and the natural sitting position (23.7° vs. 5.4°) compared with the young adults recruited by the previous study reported by Hey et al. [9]. Suzuki et al. [12] also reported that older people had a greater LL in the erect sitting position.

The findings from the present study also showed that the differences between the erect sitting position and the natural sitting positions involved in the pelvis, thoracic spine, and cervical spine. The curvature of the upper spine in the natural sitting position tended to progress by a 10% increase of TK and a 25% increase in TLK, and T1S increased with TK, followed by an increased CL to maintain horizontal vision. With the reduction in LL by 14.5° and an increase in TK by 3.2°, respectively, the spine became more kyphotic as the SVA and C2–C7 SVA moved forward, combined with an increased PT to rebalance the spine. However, despite the similar changing

trend in parameters when transitioning from the erect sitting position to the natural sitting position, the spine of older individuals still maintained an S-shaped curve in the natural sitting position, which was different from the C-shaped curve described in young adults [9] with a larger LL (23.7° vs. 5.4°) and a smaller PT (30.6° vs. 48.0°). This finding might be due to poor lumbosacral mobility and degeneration of the posterior ligament and muscle complex in older adults.

This study also investigated whether gender influenced the sagittal alignment in different sitting positions. Men had a larger TK than women, and a larger T1S and C2–C7 SVA in the standing position. When moving from the standing position to the erect sitting position, the decrease in LL and increase in PT were greater in women than in men, which resulted in a smaller LL and larger PT for women when in the erect sitting position. However, when changing to the natural sitting position, men showed greater pelvic retroversion compared with women. Therefore, the PT was similar between the groups in the natural sitting position, but the TK, T1S, and C2–C7 SVA were greater in men. Therefore, the characteristics of spinopelvic alignment in healthy older adults should include gender differences when planning corrective spinal surgery.

Sitting is an important posture that should be considered preoperatively and postoperatively during the management of spinal deformity. Based on the present study, we recommend that standing and sitting whole spine X-rays should both be obtained from patients before surgery, and there are several reasons for this. First, sitting radiographs of the spine can help to define spinal flexibility [18], especially for the older population. This study showed that the spinal flexibility of older individuals was limited due to degeneration. Secondly, this study showed that the differences between the standing position and sitting positions were individualized, and for patients with small differences that could be identified preoperatively, sagittal alignment radiography using the standing position may be used. However, for patients with large differences, sitting position alignment radiography should be used to prevent unsuitable sagittal alignment that may result in postoperative pain when in the sitting position [24]. Thirdly, preoperative radiographs may help to identify the apical and end vertebrae of spinal curvature, which are different in the standing position and the sitting position. After surgery, posture during sitting should be considered, especially the natural sitting posture. The present study showed that the slumped posture in the natural sitting position resulted in increased spinal kyphosis, which can lead to more pressure in adjacent vertebral segments that result in symptoms [25]. Therefore, the upright sitting posture should be encouraged for patients who tend to adopt the flexed sitting posture after spinal surgery, and this should be included in postoperative patient health education.

To the best of our knowledge, this was the first study to demonstrate the characteristic sagittal alignment in different sitting positions of healthy middle-aged and older individuals. Older adults shared similar trends in the changes of sagittal radiography parameters with young adults when moving from the erect sitting position to the natural sitting position. However, the spine of older adults had a larger LL and smaller PT to maintain the S-shaped sagittal profile in the natural sitting position, which was different from the C-shaped curvature previously found in young adults [9].

With the increase in the older population and the increased functional health support and corrective spinal surgical requirements, the number of spinal surgical procedures are increasing and includes more aggressive osteotomies [14,26]. However, for these patients, the corrective surgical goal has not been to restore the spine to normal, but to restore an age-appropriate alignment that enables activities of daily life [14]. The sagittal alignment of the spine of the older population in different sitting positions shown by this study could act as a reference, as the characteristics of spinopelvic alignment in healthy older adults should be considered when planning corrective spinal surgery.

This study had several limitations. When sitting, the posture depends on the task being performed and the nature of the seats used [27]. However, the present study only included the erect sitting position and the relaxed natural sitting position in a seat without a back. Also, people from different countries and cultures might prefer different sitting positions, such as the Korean cross-legged sitting posture, and the Japanese kneeling position [28], and these factors were not considered in this study, which included a Chinese population. It would be valuable to conduct future studies on the characteristics of spinopelvic alignment in healthy older adults in different countries and cultures when planning corrective spinal surgery.

Conclusions

This prospective study aimed to compare the sagittal spinopelvic parameters in the erect and natural sitting positions in healthy middle-aged and older men and women in a Chinese population. In the natural sitting position, a reduction in LL was associated with TK, SVA and PT increased, and there were differences between men and women. The characteristics of spinopelvic alignment in healthy older adults should be considered when planning corrective spinal surgery.

Conflict of interest

None.

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