Sitting Position as an Alternative for Sagittal Balance Assessment: A Cross-Sectional Study

Danaithep Limskul
Faculty of Medicine, Chulalongkorn University and King Chulalongkorn Memorial Hospital, The Thai Red Cross Society, Bangkok
Asadapong Srinawakul
Faculty of Medicine, Chulalongkorn University and King Chulalongkorn Memorial Hospital, The Thai Red Cross Society, Bangkok
Aticha Ariyachaipanich
Faculty of Medicine, Chulalongkorn University and King Chulalongkorn Memorial Hospital, The Thai Red Cross Society, Bangkok
Kenny Yat Hong Kwan
Li Ka Shing Faculty of Medicine, The University of Hong Kong, Pokfulam
Wicharn Yingsakmongkol
Faculty of Medicine, Chulalongkorn University and King Chulalongkorn Memorial Hospital, The Thai Red Cross Society, Bangkok
Worawat Limthongkul
Faculty of Medicine, Chulalongkorn University and King Chulalongkorn Memorial Hospital, The Thai Red Cross Society, Bangkok
Weerasak Singhatanadgige (dr.weerasaks@gmail.com)
Faculty of Medicine, Chulalongkorn University and King Chulalongkorn Memorial Hospital, The Thai Red Cross Society, Bangkok

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Research Article

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Abstract

Background: The sagittal vertical axis (SVA) is used for spinal sagittal balance evaluation. Patients with sagittal imbalance are assessed by whole spine standing lateral radiography, with some patients demonstrating standing difficulty during the examination. We propose new positioning methods to facilitate SVA assessment in patients with sagittal imbalance who cannot tolerate the standing position.

Methods: Thirty healthy subjects had their SVA evaluated by whole spine lateral radiography in four positions: standard position by standing with the hands on the clavicles with elbows touching the trunk (TC), standing with the hands holding on to a front stationary railing within arm's reach (TS), sitting with the hands on the clavicles (IC), and sitting with the hands holding on to a stationary railing (IS). The SVA was evaluated for differences and correlations between the standard position (TC) and the new proposed positions.

Results: The mean difference in the SVA between the TC and TS group was 1.55 mm, with a limit of agreement of -36.62 to 39.72 mm and Lin's correlation of 0.63. The mean difference in the SVA between the TC and IC or IS positions indicated greater positive SVA difference with no correlation. The TS position had good regional spinal parameter correlation with the TC position, as well as pelvic parameter correlation. The IC and IS positions showed poor pelvic and other regional spinal parameter correlations.

Conclusions: The TS position can be used as an alternative method in measuring the SVA in patients with standing difficulty during radiography. Though measurement using the sitting position can be conveniently performed, this position does not correlate well with the standard SVA measurement.

Background

The sagittal vertical axis (SVA) is an important parameter in spinal sagittal balance evaluation pre- and postoperatively [1–3]. The SVA has also been shown to correlate directly with health-related quality of life outcomes in adult spinal deformity [4, 5]. The degenerative spine is one of the causes of sagittal imbalance, and patients usually have other associated problems such as neurogenic claudication or instability. These may result in a patient's inability to stand upright independently, rendering it difficult to obtain standardized radiographs to evaluate spinal alignment. In these circumstances, proper preoperative evaluation may not be possible.

The standardized method for measuring SVA is on a standing lateral radiograph of the whole spine. According to Kaneko et al [6], the patient should be in the fist-on-clavicle position with the elbows touching the trunk or hand-on-cheek position to have a proper SVA measurement. Occasionally, patients who cannot stand unaided require assistive devices such as a handheld bar during radiographic examination or an upright sitting position instead of a standing position. However, it is unknown whether these alternative positions will affect the accuracy of SVA measurements or not. Currently, there is no guideline for the assessment of sagittal parameters in this group of patients.

We propose three different postures that can be adopted by patients who cannot stand unaided during lateral whole spine radiography: standing with the hands holding on to a railing in front of the patient at arm's reach (TS), sitting with the hands on the clavicles (IC), and sitting with the hands holding on to a railing in front of the patient arm's reach (IS). The purpose of this study was to evaluate the SVA measured using these new proposed positioning methods in comparison with that measured using the standard posture (fist-on-clavicle position with the elbows touching the trunk).

Methods

Subjects

Thirty healthy subjects (15 males, 15 females) were recruited from a population at King Chulalongkorn Memorial Hospital. The subjects were screened by history taking that consisted of previous back-related symptoms, previous surgery, underlying diseases, and physical examination of the spine to confirm that the subjects did not have any spine problems. The subjects were able to perform the proposed positions and had their SVA evaluated by whole spine lateral radiography in four positions: standard posture by standing with the hands on the clavicles with the elbows touching the trunk (TC), standing with the hands holding on to a railing in front of the patient at arm's reach (TS), sitting with the hands on the clavicles (IC), and sitting with the hands holding on to a railing in front of the patient at arm's reach (IS) (Figure 1). Sample size calculation was performed using the formula for the required samples per group [7] for the comparison of two means. With the alpha error at 0.05, the power at 0.8, a standard deviation of 2, and an expected effect size of 2, the minimum sample size required is 16. All subjects provided informed consent. The study was approved by the Institutional Review Board of the Faculty of Medicine, Chulalongkorn University (No. 669/62).

Measurement Parameters

Measurement of the SVA (Figure 1) and other spinal sagittal parameters, such as thoracic kyphosis (TK), lumbar lordosis (LL), C7-T5 angle, T2-T12 angle, and T10-L2 angle, and pelvic parameters (pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS)) (Figure 2) was performed, and the measurements were compared to evaluate whether there were any differences and correlations between the standard positioning (reference position) and the three new positioning methods.

The measurement for each spine and pelvic parameter was defined as follows:

C7–T5 kyphosis: The angle between the cranial endplate of C7 and the caudal endplate of T5.

T2–T12 kyphosis: The angle between the cranial endplate of T2 and the caudal endplate of T12.

T5–T12 kyphosis (TK): The angle between the cranial endplate of T5 and the caudal endplate of T12.

T10–L2 kyphosis: The angle between the cranial endplate of T10 and the caudal endplate of L2.

T12–S1 lordosis (LL): The angle between the cranial endplate of T12 and the cranial endplate of S1.

PI: The angle between the perpendicular line, from the middle of the sacral endplate, extending caudally, and the line extending from the middle of the sacral endplate to the center of the bicoxofemoral axis.

PT: The angle between the vertical axis and the line extending from the middle of the sacral endplate to the center of the bicoxofemoral axis.

SS: The angle between the horizontal axis and the cranial sacral endplate.

The measurement was performed twice for each parameter, with blinding, by a certified orthopedist and a radiologist. The inter-rater correlation of each measurement between the two observers were calculated for every parameter.

Statistical Analysis

The mean, SD and inter-rater measurement correlation was calculated (Table 1). The average values of the two readings were used for further calculation. The Bland-Altman [8] analysis was used to determine the limit of agreement by finding the mean difference of measurements and two standard errors of deviation above and below the mean difference determine the limit of agreement (Figure 3). The Lin's concordance correlation coefficient [9] (Rc) was used to determine the correlation between the positions, which evaluates by measuring the variation from the 45° line through the origin (the concordance line) (Figure 4). The correlation ranges from -1 to 1, with perfect agreement at 1. Statistical Package for the Social Sciences (SPSS Version 22.0) for International Business Machines (IBM) Windows (Armonk, NY) was used for statistical analysis.

Results

The mean age of the subjects was 22.3 ± 1.7 years, the mean weight was 63.4 ± 7.8 kg, and the mean height was 173 ± 4.3 cm.

The mean SVA of TC, TS, IC and IS position were -11.57 ± 23.52 mm, -10.35 ± 25.45 mm, 51.70 ± 31.81 mm, and 61.68 ± 38.03 mm respectively (Table 1). The mean spinal and pelvic parameters of each position are shown in Table 1. The mean SVA difference between the TS and TC positions was 1.55 mm with a limit of agreement of -36.62 to 39.72 mm (Table 2, Figure 3), and Rc = 0.63 (Table 2, Figure 4). Other spinal parameters of the TS position yielded good to excellent correlation with small mean difference. The TS position also had excellent pelvic parameter correlation (Table 2) with a small mean difference in every parameter.

The IC and IS positions had increased positive balance compared to the TC position (mean difference of 62.63 and 72.63 mm, respectively) (Table 2), and both had poor SVA correlation. Decreased TK, LL, and T2-T12 angle were observed in both positions. In contrast, the C7-T5 and T10-L2 angles had minimal change compared to those of the TC position (Table 2).

With regard to the pelvic parameters, increased PT of about 17-18° and decreased SS of 12° were observed in both sitting positions. Nevertheless, minimal change in the PI was observed between the TC and IC positions as well as the TC and IS positions (Table 2).

Discussion

From this study, we found that the TS position had little effect on the SVA. This position also had moderate SVA correlation with a narrow agreement range (SVA within 4 cm), which will then result in low measurement variation. The position had good correlation with spinal parameters. Horton et al [10] reported that regional measures of lordosis and kyphosis were not affected by the patient's position; however, the SVA was slightly more positive with the 60° position of the arm with support provided by a pole, slightly more negative but without significance with the 90° position with a pole, and most neutral with the clavicle position. Our result showed a similar result with minimal change in the SVA in the 90° arm position, unlike that of Kaneko et al[6] that demonstrated a more negative SVA when the arms were flexed at 90°. This may be due to the stability that the position provided in addition to the position mentioned in the study from Kaneko et al. Aota et al [11] reported that hands relaxed in the front resulted in minimal SVA shift, and Vedantam et al [12] reported that arms at 30° flexion resulted in minimal SVA disturbance. These findings suggested that the SVA is not significantly affected by minimal arm flexion. This corresponded with the TC position in our study, which the position is done by keeping the elbows touching the trunk.

Marks et al [13] founded that elbows fully flexed with fists over clavicles resulted in more negative SVA when compared to standing with hands supported by modified ski pole with shoulder flexion to 30°. The study did not state the degree of arm flexion for fists over clavicles position, which could have affected the SVA. However, we propose the TS position instead of 30° shoulder flexion because the TS position provided better support for patients who are unable to stand upright independently.

The TS position also had good spinal parameter correlation compared to the TC position. These findings may be due to minimal change in posture, particularly for the pelvic parameters. Only the T10-L2 angle showed a moderate correlation of 0.69. This may be because the region is more mobile compared to other regions where measurements were taken. Horton et al [10] also examined regional measures of TK (T2-T12) and lordosis (both C2-C7 and T12-S1); the angles were not different compared to when the arms were straight out, partially flexed, or in the clavicle position (reference position).

With regard to the pelvic parameters of the TS position, we noticed that the PI increased by 2.5°, the PT by 1.17°, and the SS by 1.12° when compared to the TC position. The parameters had excellent correlation. This may also be due to minimal change in the posture. The PT and SS changes were less than those of the findings by Faro et al [14], which showed that the average PT increased by 2.7° and the SS decreased by 3.2° despite having the arm flexed at 45°. Our findings had smaller changes that may be due to the use of a standing bar, whereas the position from the study of Faro et al. only used the forward flexion of the arm.

For the other two positions (IC and IS), there was no correlation with the SVA, and there was a likelihood of overestimating the positive balance with a mean difference of about 6 mm for the IC and 7 mm for the IS position when compared to the TC position. The two positions showed low to moderate correlation with other spinal parameters. This clearly showed that the sitting position affected the angles of the spine. Hey et al [15] also conducted a study on the differences between the standing and sitting positions. The SVA of the sitting position also showed positive SVA value compared to the standing position. The study found changes in other spinal parameters similar to our study.

However, for pelvic parameters of the IC and IS positions, there was good PI correlation with a mean difference of about 4°. The PT increased and the SS decreased in the sitting position. These findings may be due to the sitting posture, which corroborated with previous reports [15–19]. Cho and colleagues [20] found that the sitting position reduced the LL, whereas the SS increased the PT when compared to the standing position. This finding supported the results of our study.

In this study, we used the Bland-Altman [8] analysis to determine the limit of agreement as we aimed to compare the measurement difference between the new methods and the previous one. The difference calculated can further determine, by clinical interpretation, whether to use the new methods or not. We evaluated its reproducibility using Lin's concordance correlation coefficient [9] between the new and the standard positioning methods. If other correlation coefficients such as Pearson's correlation were used, the non-reproducibility of the test may not be detected. The Pearson's correlation, which is commonly used, provides a measure of linear covariation between two sets of measurements, without specifying any correspondence degree between the groups. The Lin's concordance correlation coefficient measure reliability based on covariation and the correlation between the two measurements that fall on the 45° line passes through the origin. We have not found any other similar studies that use the same statistical analysis method as in our study.

The TS position could be applied for individuals with spinal problems who cannot tolerate an independent standing position since it showed little difference from the standard position with a narrow limit of agreement (about 4 cm positive and negative to the mean SVA). The limitation of this study is that the subjects were young and without any detectable spinal problems. However, this study aimed to determine the new posture with reproducibility for SVA measurement, which we intend to select subjects without spinal abnormalities. Therefore, the generalizability of the findings may require further study in symptomatic subjects who cannot tolerate an independent standing position.

Conclusions

When performing radiographic examination to assess the SVA, an alternative position that can be used is standing with the hands holding on to a railing in front of the patient at arm's reach. Even though the sitting position can be used conveniently, it does not correlate well with the standard SVA measurement. Additional study is needed to evaluate the application of these new positioning methods in patients with uncompensated sagittal imbalance.

Abbreviations

IC: sitting with the hands on the clavicles, IS: sitting with the hands holding on to a stationary railing, LL: lumbar lordosis, PI: pelvic incidence, PT: pelvic tilt, Rc: Lin's concordance correlation coefficient, SS: sacral slope, SVA: sagittal vertebral axis, TC: standing with the hands on the clavicles with elbows touching the trunk, TK: thoracic kyphosis, TS: standing with the hands holding on to a front stationary railing within arms' reach

Declarations

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Availability of data and materials

The datasets used and/or analyzed during the current study are not publicly available due to limitations of ethical approval involving patient data but available from the corresponding author on reasonable request.

Authors' contributions

DL analyzed collected data and written the manuscript. AS worked on process of informed consent. AA measured the x-ray parameters. KYHK reviewed and made correction to the manuscript. WY worked on research design. WL reviewed the literature relevant to the study. WS designed how to collect data and orchestrated overall flow of the research. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Informed consent to participate and procedures were approved by the Institutional Review Board, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand (No.669/62). All subjects received oral and written explanation before documentation and participation. Informed consent to participate in the study were obtained in every subject. All methods were performed in accordance with the STROBE statement guidelines and regulations.

Consent for publication

Written informed consent for publication of the images relating to the subject within the image provided was obtained.

Competing interests

The authors declare that they have no competing interests

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Tables

Table 1. Mean, SD, and inter-rater correlation of the SVA, spinal and pelvic parameters

Parameter\Position	TC	TS	IC	IS
SVA (mm.)	-10.81 ± 20.68 0.83	-9.26 ± 23.82 0.92	51.82 ± 31.38 0.99	61.82 ± 37.85 0.99
Thoracic Kyphosis	26.72°± 8.07° 0.77	29.27° ± 8.64° 0.81	19.18° ± 9.35° 0.92	18.83° ± 10.03° 0.93
Lumbar Lordosis	53.7° ± 10.18° 0.68	56.55° ± 9.97° 0.66	28.87° ± 15.56° 0.87	27.45° ± 15.40° 0.83
C7-T5	14.98°± 5.69° 0.60	16.07° ± 5.54° 0.49	12.88° ± 6.21° 0.66	14.13° ± 6.13° 0.74
T2-T12	38.43°± 8.27° 0.63	41.68° ± 9.14° 0.66	30.08° ± 10.48° 0.82	29.08° ± 12.08° 0.87
T10-L2	7.55° ± 5.82° 0.81	8.63° ± 5.79° 0.52	7.27° ± 4.72° 0.90	7.98° ± 4.41° 0.89
PI	49.95° ± 9.12° 0.74	52.45° ± 9.86° 0.79	54.83° ± 9.94° 0.76	54.83° ± 9.20° 0.82
PT	14.53° ± 6.48° 0.79	15.7°±6.78° 0.87	31.65°±12.98° 0.95	32.88° ± 12.80° 0.96
SS	35.03° ± 7.35° 0.83	36.15° ± 7.77° 0.80	22.47° ± 10.96° 0.91	22.1° ± 11.40° 0.93

(A negative value indicates negative balance of the SVA or decreased angle.)

Table 2: Comparison of the SVA, spinal and pelvic parameters to those of the TC position

Parameter\Position	TS to TC	IC to TC	IS to TC
SVA (mm.)			
Mean Difference	1.55	62.63	72.63
Limit of Agreement	(-36.62 – 39.72)	(-1.07 – 126.34)	(-8.34 – 153.61)
Rc	0.63	0.07	0.03
Thoracic Kyphosis			
Mean Difference	2.55°	-7.53°	-7.88°
Limit of Agreement	(-5.24° – 10.34°)	(-19.36° – 4.30°)	(-19.90° – 4.13°)
Rc	0.85	0.56	0.57
Lumbar Lordosis			
Mean Difference	2.85°	-24.83°	-26.25°
Limit of Agreement	(-8.01° – 13.71°)	(-49.17° – -0.49°)	(-52.03° – -0.47°)
Rc	0.82	0.20	0.17
C7-T5			
Mean Difference	1.08°	-2.10°	-0.85°
Limit of Agreement	(-5.33° – 7.49°)	(-11.10° – 6.90°)	(-11.83° – 10.13°)
Rc	0.82	0.67	0.56
T2-T12			
Mean Difference	3.25°	-8.35°	-9.35°
Limit of Agreement	(-4.96° – 11.46°)	(-21.91° – 5.21°)	(-25.60° – 6.91°)
Rc	0.83	0.53	0.49
T10-L2			
Mean Difference	1.08°	-0.28°	0.43°
Limit of Agreement	(-7.80° – 9.97°)	(-13.27° – 12.67°)	(-11.35° – 12.22°)
Rc	0.69	0.25	0.34
PI			
Mean Difference	2.50°	4.88°	4.89°
Limit of Agreement	(-6.06° – 11.06°)	(-3.97° – 13.73°)	(-6.12° – 15.89°)
Rc	0.87	0.79	0.72
PT			

Mean Difference	1.17°	17.12°	18.35°
Limit of Agreement	(-3.40° – 5.74°)	(-2.45° – 36.68°)	(-1.16° – 37.86°)
Rc	0.93	0.23	0.20
SS			
Mean Difference	1.12°	-12.57°	-12.93°
Limit of Agreement	(-6.02° – 8.26°)	(-30.24° – 5.10°)	(-33.02° – 7.16°)
Rc	0.88	0.29	0.24

(A negative value indicates negative balance of the SVA or decreased angle.)

Figures

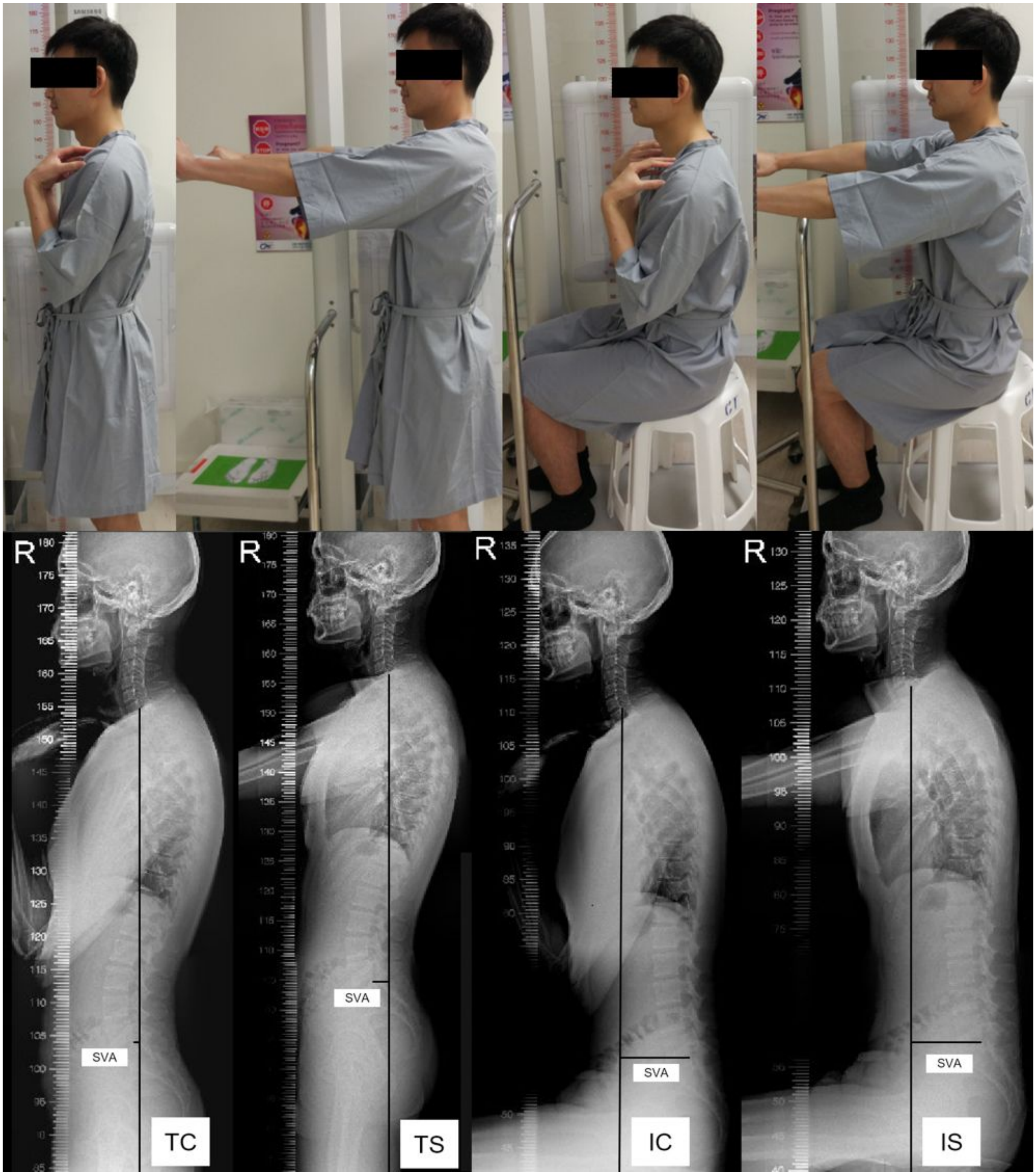

Figure 1

Measurement of the SVA in different positions. Standing with the hands on the clavicles with the elbows touching the trunk (TC, reference position), standing with the hands holding on to a railing in front of the patient at arm’s reach (TS), sitting with the hands on the clavicles (IC), and sitting with the hands holding on to a railing in front of the patient arm’s reach (IS). The SVA measured in each different position.

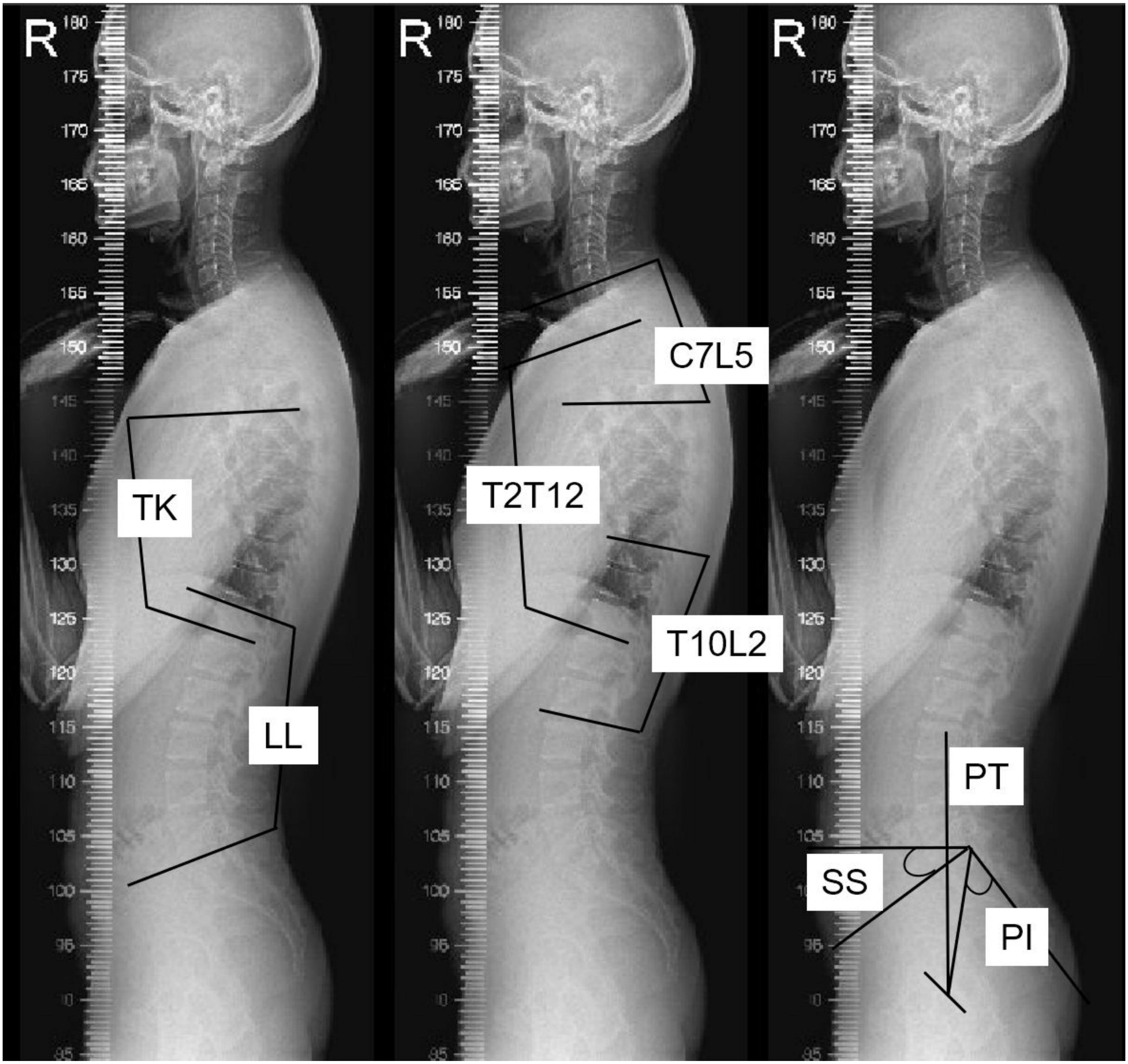

Figure 2

Measurement of spinal parameters and pelvic parameters. TK (thoracic kyphosis or T5-T12 kyphosis), LL (lumbar lordosis or T12-S1 lordosis), C7T5 (C7-T5 kyphosis), T2T12 (T2-T12 kyphosis), T10L2 (T10-L2 kyphosis), PI (pelvic incidence), PT (pelvic tilt), SS (sacral slope).

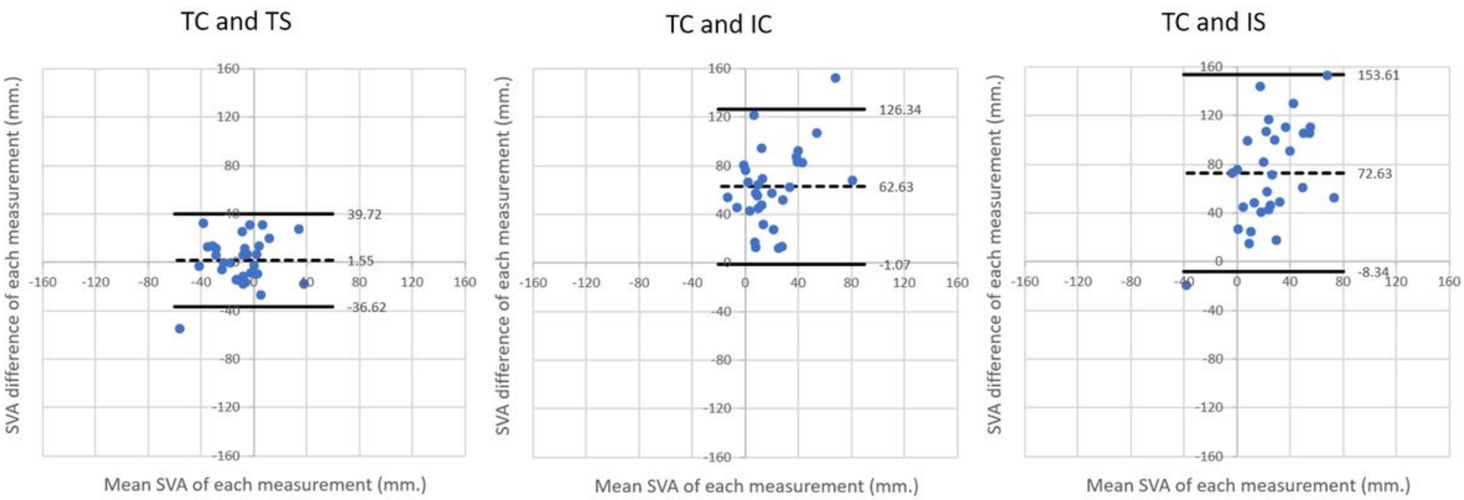

Figure 3

Mean SVA and difference of SVA from each subject between TC and TS, TC and IC, and TC and IS position, illustrated in Bland-Altman limit of agreement diagram. The dashed line represents the mean difference between the positions. The black line above and below the dashed line is the upper and lower limit of agreement, respectively.

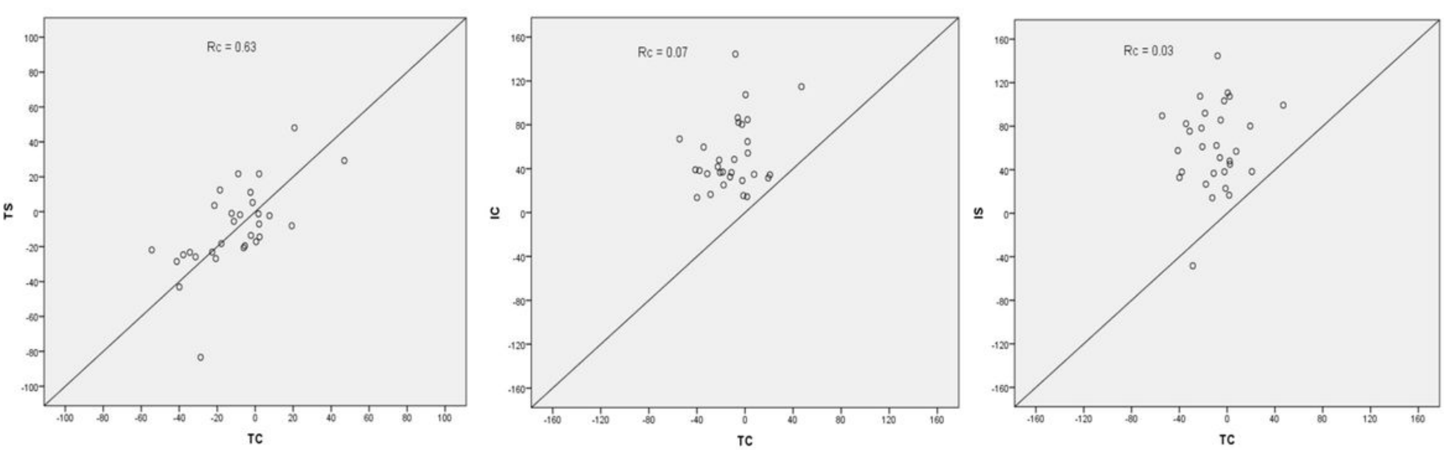

Figure 4

Lin's concordance correlation coefficient (Rc) between TC and TS, TC and IC, and TC and IS, respectively. This reproducibility index is the correlation between the two readings that fall on the 45° line through the origin. The maximum value is one, achieved when there is perfect concordance.