The difference of whole-body sagittal alignment in different postures in young, healthy adults

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Research article

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Abstract

Study Design

Prospective study.

Objective

To identify the differences of radiographic between standard upright position and natural and comfortable upright position.

Methods

Radiographic parameters of 50 young and healthy adults were evaluated including the global cervical angle (GCA), global thoracic angle (GTA), global lumbar angle (GLA), which were used to depict the spine profile; the distance from the cranial sagittal vertical axis (CSVA) to the posterior corner of S1(CSVA-S), the center of the hip(CSVA-H), the center of the knee(CSVA-K) and the ankle(CSVA-A), respectively in both upright positions and natural and comfortable upright position, which were employed to describe the whole-body balance.

Results

Significant differences could be observed in all the GCA(17.39 ± 6.90 vs. 10.90 ± 3.77, $p < .001$), GTA(25.63 ± 7.27 vs. 45.42 ± 8.15 $p < .001$), GLA(42.64 ± 8.05 vs. 20.21 ± 7.47 $p < .001$), CSVA-S(0.33 ± 2.76 cm vs. 8.54 ± 3.78 cm, $p < 0.001$), CSVA-H(1.53 ± 3.11 cm vs. 5.71 ± 3.26 cm, $p < 0.001$), CSVA-K(3.58 ± 2.47 cm vs. 5.22 ± 2.69 cm, $p = 0.002$) and CSVA-A(1.79 ± 1.92 cm vs. 4.79 ± 2.51 cm, $p < 0.001$) in the two different standing postures, respectively. Compared with standard upright position, natural and comfortable upright position results in a more kyphotic spine profile.

Conclusion

Significant differences in sagittal radiographic parameters were found between the standard upright position and natural and comfortable upright position, with the latter revealing a more kyphotic spinal profile more common in everyday life, which may explain the existing spinal pathologies as well as predict postoperative complications. The natural and comfortable upright position should be a factor to consider when performing a surgical plan.

Introduction

According to the Scoliosis Research Society (SRS)-Schwab classification, surgery for adult spinal deformity should achieve sagittal vertical axis (SVA) < 4 cm, a pelvic incidence (PI)-lumbar lordosis discrepancy < 10˚ and a pelvic tilt (PT) < 20˚ [1] in order to improve patient-reported scores. To assure the need for surgery especially determine the deformity correction goals, many researches focused on the radiographs which are performed with the patient being instructed to stand straight [2], which allows assessment of the patient's capacity to achieve the most upright standing posture. Several studies have already demonstrated that the improvement in sagittal balance using the C7 SVA is the strongest predictor of improved outcomes in patients with adult spinal deformity [3–6], but Kim et al. considered the cranial sagittal vertical axis (CSVA) is a better radiographic measure to predict clinical outcomes in adult spinal deformity surgery than C7 SVA [7].

After the concept of energy conservation publicized by Dubousset, where an individual could achieve balance with minimal effort [8, 9] the research of upright standing posture becomes less important in daily life. Optimal total body sagittal alignment (TBSA), from the head to the ankle joint of the human body, may be required to keep an energy-efficient erect position and horizontal gaze for ultimate clinical satisfaction, which we call natural and comfortable standing posture. But few studies concentrated on this posture commonly assumed in daily life, which may explain existing spinal pathologies [10] as well as predict postoperative complications such as proximal junctional failure (PJF) and rod breakages [11 – 14]. Few literatures have reported the dissimilarity in the sagittal radiographic parameters between the standard upright position and the natural and comfortable upright position. Therefore, our study aimed on the differences of radiographs between the two different standing postures, in order to obtain additional information beyond what is already known of the standard upright position.

Materials And Methods

Informed consent was obtained from all patients, and the study was approved by the Ethics Committee of our hospital.

This study compared radiographs of subjects in both standard upright position and natural and comfortable upright position of the whole body. Inclusion criteria of this study: 1. Aged from 21 to 30; 2. The body mass index (BMI) was with the 18–25. Exclusion criteria of the study: 1. Any spine surgery history or previous spinal conditions do not need surgery; 2. Any history of significant back or leg pain (Visual Analog Scale (VAS) score > 3); 3. Any mild axial pain or radiculopathy in the standard upright position and natural and comfortable upright position; 4. Any personal or family history of malignancy or a significant weight loss within a short period for unexplained reason; 5. Any significant trauma to the spine ever; 6. Unable to communicate or cooperate properly.

Radiographic Examination And Measurements

Based on the inclusion and exclusion criteria above, all eligible subjects underwent whole body radiographs of standard upright position and natural and comfortable upright position.

All the subjects were asked to learn how to keep the standard upright position first through pictorial charts and "stand as straight as possible and do not leaning forwards, backwards or to the sides, embracing both upper limbs in front of the chest" before taking the X-ray; and as to the natural and comfortable upright position, all the subjects were told to stand in the way which make him/her feel comfortable and relaxed and then maintain.

Radiographic measurements were performed independently by three doctors with more than two years of related experience and averaged to obtain the final measurements. Measurements performed included the C7-SVA, PT, PI, global cervical angle (GCA, the inferior end plate of C2 to inferior end plate of C7), global thoracic angle (GTA, the superior end plate of T1 and the inferior end plate of T12), global lumbar angle (GLA, the superior end plate of L1 and the inferior end plate of L5). All the three indicators above were used to describe the morphological changes of the cervical spine, thoracic spine and lumbar spine, respectively. The distance from cranial sagittal vertical axis to the posterior corner of S1 (CSVA-S), and from cranial sagittal vertical axis to the centers of the hip (CSVA-H), the knee (CSVA-K), and the ankle (CSVA-A), which were thought to be the better predictors of clinical outcomes for patients[7].

The CSVA parameters were based on anatomic landmarks showed in Fig. 1. The cranial center of mass (CCM), the posterior, superior corner of the sacrum, and the centers of the hips, knees, and ankles. The CCM was defined as the midpoint of the connecting line from rhinion to inion. On the lateral view, the center of the hips was defined as the midpoint of the line connecting the center of the two femoral heads; the center of the knees was the midpoint of the connecting line between the center of the two tibial plateaus and the center of the ankles was the midpoint of the connecting line between the apices of the talar domes [15, 16]. The distance to the sacrum, the hip center, the knee center and the ankle center from the plumb line of the CCM were define as CSVA-S, CSVA-H, CSVA-K and CSVA-A, respectively. (Fig. 2).

Data were analyzed using Statistical Product and Service Solutions software (version 19.0; SPSS, Chicago, IL). Intraclass correlation coefficient was used to assess the interobserver reliability of data measurements. Paired t tests were used for univariate analysis to compare radiographic parameters across postures. $P < 0.05$ was considered to be statistically significant.

Results

Fifty young and healthy adult subjects (25 males and 25 females) aged from 21–30 years were recruited for this study. Multiple significant radiographic differences were found between standard upright position and natural and comfortable upright position. (Table 1).

Table 1
Parameters in the directed and natural standing postures

	Directed standing (mean ± SD)	Natural standing (mean ± SD)	*P* value
C7-SVA	2.89 ± 9.07	3.67 ± 10.17	0.489
GCA	17.39 ± 6.90	10.90 ± 3.77	< 0.001
GTA	25.63 ± 7.27	45.42 ± 8.15	< 0.001
GLA	42.64 ± 8.05	20.21 ± 7.47	< 0.001
PT	11.26 ± 6.16	18.32 ± 6.53	< 0.001
PI	49.22 ± 8.67	49.47 ± 8.96	0.935
CSVA-S	0.33 ± 2.76	8.54 ± 3.78	< 0.001
CSVA-H	1.53 ± 3.11	5.71 ± 3.26	< 0.001
CSVA-K	3.58 ± 2.47	5.22 ± 2.69	0.002
CSVA-A	1.79 ± 1.92	4.79 ± 2.51	< 0.001

Compared to standard upright position, the natural and comfortable upright position showed more lordotic GCA (10.90 ± 3.77 vs. 17.39 ± 6.90, $p \leq .001$), more kyphotic GTA (25.63 ± 7.27 vs. 45.42 ± 8.15 $p \leq .001$), and less lordotic GLA (42.64 ± 8.05 vs. 20.21 ± 7.47 $p \leq .001$). The CSVA measurements were as follows for the standard upright position vs. the natural and comfort upright position: CSVA-S, 0.33 ± 2.76 cm vs. 8.54 ± 3.78 cm, $p < 0.001$; CSVA-H, 1.53 ± 3.11 cm vs. 5.71 ± 3.26 cm, $p < 0.001$; CSVA-K, 3.58 ± 2.47 cm vs. 5.22 ± 2.69 cm, $p = 0.002$; and CSVA-A was 1.79 ± 1.92 cm vs. 4.79 ± 2.51 cm, $p < 0.001$. (Table 1)

Discussion

Kim et al. found that the CSVA was a more comprehensive index better than C7 SVA cause the latter one significantly correlated with the ODI, SRS total score, pain and function sub-scores, but was not significantly correlated with SRS self-image, satisfaction, and mental health scores, and compared to C7 SVA, the CSVA demonstrated a significant correlation with the ODI, SRS total score, pain, self-image, function, satisfaction and mental health sub-scores [7]. And in our study, CSVA was more sensitive when the standing position changed.

The spine provides the structural support of the body and transfer the weigh of the body to the lower extremities connecting through the pelvis. In order to maintaining the whole-body balance, enough lordosis was needed to balance the kyphosis and then the horizontal gaze could be achieved [17]. However, some postoperative complications such as PJF [11 – 13] and rod breakage [14] still remains remind us unknown biomechanical issues following surgery are still there. During the process of evaluating the postoperative results by radiographic parameters limited to the spine-pelvic area [3–6, 18, 19], such as C7 SVA and PT, the total body sagittal alignment from the skull to the ankle joint was ignored which may influence the patient-reported outcomes.

In our clinical practice, some patients showed relatively poor improvement of clinical scores although we have assessed improvement in spinal sagittal balance for them with C7 SVA after surgical correction. The C7 SVA, which means a plumb line from the 7th cervical vertebra to the sacrum, is limited to the evaluation of thoracic and lumbar spine instead of the whole spine include the cervical, and let alone the lower limbs, so it is not sufficient in evaluating global balance of the patient [20–22]. Not only the spine itself, but also the pelvis and lower limbs would be changed to compensate when spinal imbalance occurs. The spinopelvic movement at the hip joint are rotational actions about the hip center, which determined by both pelvic retroversion and backward femoral inclination. The knee flexion follows to attain full body sagittal balance after maximum hip compensation achieved, and so does the ankle joints. If the spine, hip joints, knee joints, and ankle joints are considered as a linear chain, the knee joints are the most active part of the three factors besides the spine. We speculated that the reason is the hip joints are fixed in the pelvis and the movement of the ankle joints are restricted by the ground.

Kim et al. [7] suggested that the distance from the cranial sagittal vertical axis to the ankle joint (CrSVA-A) is needed as a radiographic parameter to predict the widest range of patient-reported outcomes, cause compared to C7 SVA, which is significantly associated with the Oswestry Disability Index (ODI) and only three of the SRS sub-scores (pain, function, and total score), the CrSVA-A (Global SVA) linking the head to the ankle joint showed strong correlation with the SRS satisfaction sub-score after a retrospective radiographic and clinical analysis for 108 in adult spinal deformity(ASD) patients. Hey et al. [23] considered that the changes with age is likely produced by relaxed postural tendencies, the latter happening before the former. Based on these conclusions, we think that using just radiographic parameters from part of the body might not be enough to fully encompass clinical outcomes, so in predicting the postoperative efficacy of adult patients with spinal deformity, the use of spinal-pelvic factors alone is not enough, the head and lower limbs should also be considered. The occurrence of PJK/PJF and rod failure, evoke us a mechanical problem caused by standing posture may increase the risk of mechanical complications. Different standing postures showed different spine profile, and further affected the angle of the pedicle screws, the arc of the connecting rods and the shear force of the entire implant system. Although we are not sure by now about the impact of standing posture on postoperative complications, we believe that in the process of deformity correction, a nature and comfortable upright position should be given the equal attention as the standard upright position.

There are still weaknesses to our study. First, the ethnic applicability can be a limitation. Second, pelvic morphology is known to be different between sexes, taking the closely relationship between lumbar morphology and pelvic morphology into account, potential bias due to pelvic morphological effects between genders should be considered.

Although the findings of this current study in young, healthy adults cannot be directly applied to ASD patients until a further study showing the reproducibility of these concepts in ASD patients can be produced, standard upright position and natural and comfortable upright position are equally important and should be focused on before performing a surgical plan for ASD patients.

Declarations

Ethical Statement: The study was approved by the Ethics Committee of The Third Hospital of HeBei Medical University, and all patients provided written informed consent to participate before enrollment.

Consent for Publication: All authors consent to publish this paper.

Availability of data and material: The datasets used or analyzed during the study are available from the corresponding author on reasonable request.

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Authors' contributions: Rui Xue: first author; clinical studies; manuscript preparation and editing; Dai Liu: statistical analysis; Yong Shen: corresponding author; guarantor of integrity of entire study; manuscript revision. All authors read and approved the final manuscript.

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Figures

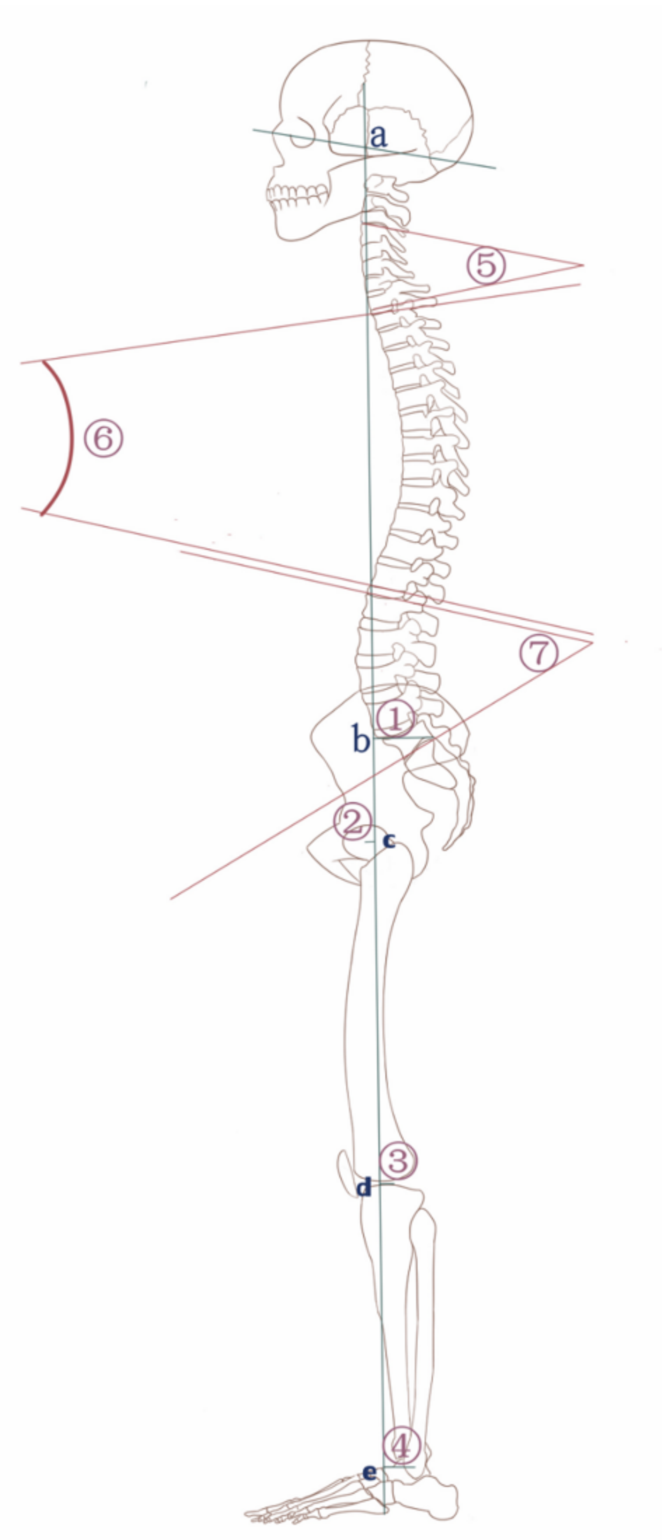

Figure 1

Schematic drawing depicting the landmarks, the parameters and angles used in the measurements: a. the cranial center of mass, b. the posterior tip of the sacrum c. the center of the femoral heads d. the center of the knees e. the center of the ankles □ CSVA-S □ CSVA-H □ CSVA-K □ CSVA-A □ GCA □ GTA □ GLA