Observational Study

Medicine

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# Does the positioning of the patient in the EOS machine affect the validity of cervical and head parameters calculated on whole-spine radiographs?

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**Abstract**

The aim was to study the validity of free-standing position using modifiers for assessing cervical spine alignment. A total of 26 asymptomatic subjects (45 ± 11years) and 13 with spinal deformities (30 ± 21years) underwent lateral radiographs using EOS®, while adopting 3 different positions, in 2 sequences, without mirror and then with mirror (m) placed in front of them: first, the neutral standing position (upper extremities positioned on the sides of the body, P1 and P1m), then free-standing (P2 and P2m) and modified free-standing (P3 and P3m) positions (shoulders flexed at 90° and fingers placed on clavicles then cheeks, respectively). Participants were asked not to move their trunk and shoulders when moving from P1 to P2 and then P3. Eighteen cervical radiographic parameters were calculated from the 6 radiographs. The effects of shoulder flexion, mirror placement, and finger positioning on cervical alignment were studied using a repeated-measures ANCOVA. Mirror placement had no effect on cervical alignment. Concerning the effect of shoulder flexion, C2–C7 and T1 slopes were significantly decreased in P2 and P2m (C2–C7 = 10° and 8°; T1 slope = 26° and 24°, respectively) and P3 and P3m (C2–C7 = 9° and 9°; T1 slope = 25° and 26°, respectively) compared to P1 and P1m (C2–C7 = 14°and 14°; T1 slope = 29°and 30°, respectively), without exceeding the uncertainty level. Assessment of cervical alignment is valid on whole-spine radiographs when the shoulders are flexed (free-standing position). Clear instructions regarding the shoulder position at 90°, without moving the trunk, neck, and head before placing the fingers on the clavicles or cheeks, can ensure a cervical alignment comparable to that obtained with the neutral position, which is considered the most physiological one.

**Abbreviations:** P1 = neutral standing position, P1m = neutral standing position, with mirror, P2 = free-standing position, P2m = free-standing position, with mirror, P3 = modified free-standing position, P3m = modified free-standing position, with mirror.

**Keywords:** cervical alignment, EOS, free-standing position, lateral radiographs, whole-spine radiographs

## 1. Introduction

The cervical spine is a mobile segment responsible for the orientation of the head relative to the pelvis. It plays an important role in maintaining a horizontal gaze during the standing position[1,2] and its alignment depends on the underlying thoracolumbar segments. Lateral cervical radiographs are generally used for cervical spine assessment. During radiographic acquisition, a neutral relaxed standing position is usually adopted and the upper limbs are positioned on the sides of the body.[3] Although this neutral relaxed position is considered the most representative and functional position,[4] as it does not alter the cervical alignment, it prohibits the visualization of the different parts of the spine during the study of the thoracic and lumbar segments.

In patients with cervical deformities, evaluation of the entire spine is recommended to assess whether other spinal segments are also affected. Radiographic assessment of global sagittal alignment is essential for establishing a treatment plan or evaluating treatment outcomes.[5] Whole-spine radiography should be performed in the most physiological and standardized positions, allowing visualization of the totality of segments, including the cervical spine.

*This study was supported by the University of Saint-Joseph (grant# FM336), institutional own funding.*

*Informed consent was obtained from the patient for publication of this case report details.*

*The authors have no conflicts of interest to disclose.*

*The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.*

*This study was approved by the ethics committee of the Saint Joseph University of Beirut, Hôtel-Dieu de France Hospital #CEHDF925 on 30th of January 2017.*

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*How to cite this article: Massaad A, Assi A, Salameh M, Bizdikian AJ, Mehanna J, Kreichati G. Does the positioning of the patient in the EOS machine affect the validity of cervical and head parameters calculated on whole-spine radiographs?. Medicine 2024;103:45(e40422).*

*Received: 22 November 2023 / Received in final form: 21 January 2024 / Accepted: 18 October 2024*

*http://dx.doi.org/10.1097/MD.0000000000040422*

Shoulder flexion allows visualization of the thoracic and lumbar segments.[6] However, this has been attributed to alterations in sagittal alignment of the spine.[7,8] One strategy proposed to counteract these changes was to place the fingers on the clavicles, thereby allowing for better assessment of the sagittal profile while providing adequate visualization of the spine.[9] Nevertheless, this free-standing position, with the shoulders flexed, has shown limited reproducibility in subjects with different angles of flexion at the level of the shoulders[10]; hence, it is difficult to define the optimal standardized position for the evaluation of the spine on whole-spine radiographs. A modified free-standing position has been proposed[11] in where the shoulders are flexed and the fingers are placed on the cheeks, to ensure the best overall visualization of the spine and to allow for the hands to be separated from the clavicles and cervicothoracic vertebrae such as C7 and T1, while simultaneously preventing the fingers from obtruding the sternum.

More recently, Oe et al proposed placing a mirror in front of the subject while asking them to look themselves in the eyes to standardize cervical images by maintaining the same horizontal gaze and unifying the line of sight.[12]

Thus, several positions and settings can be used to assess the sagittal cervical alignment. This study aimed to evaluate the validity of different radiographic positioning methods with and without the use of a mirror when assessing cervical spine alignment. We hypothesized that the free-standing position with modifiers would be valid for assessing cervical spine alignment.

## 2. Methods

This was an IRB-approved cross-sectional study (CEHDF925) where asymptomatic subjects (group-1) were recruited according to the following criteria: no history of neck pain or orthopedic surgery and no clinical or radiographic cervical deformity with a C2–C7 sagittal vertical axis < 4 cm.[13] Adolescent patients with Idiopathic Scoliosis younger than 18 years (Cobb angle > 10°)[14] and Adults with Spinal Deformities older than 18 years (group-2, ISSG radiological criteria)[15] were enrolled. Subjects who had undergone cervical spine surgery were excluded to ensure the optimal visibility of the cervical spine. All the participants provided written informed consent.

## 3. Data acquisitions

The participants underwent lateral radiography using an EOS® system (EOS Imaging® Paris, France). Radiographs were acquired at 3 different positions: (1) neutral standing position (P1), which is a relaxed position with subjects looking ahead and the upper extremities positioned on the sides of the body[4]; (2) free-standing position (P2), where the subjects were asked to place their fingers on the clavicles[7,9,16]; and (3) modified free-standing position (P3), where the subject was asked to place their fingers on the cheeks[11] (Fig. 1). During the free-standing and modified free-standing positions, all participants were asked to first adopt a neutral relaxed position, flex their shoulders at 90°, move their fingers to the clavicles, and then to the cheeks without moving the trunk, neck, or head while keeping the shoulders in the same position. Positioning was performed by a radiology technician.

These radiographs were performed in 2 sequences, first without the use of a mirror (P1, P2, and P3) and then with a visible mirror placed in front of the subject during the neutral relaxed position, free-standing position, and modified free-standing positions (P1m, P2m, and P3m, respectively). A 10 × 120 cm mirror was positioned in the EOS® cabin at a distance of 40 cm from the subject. The position of the mirror did not change throughout the study, and when it was not required, that is, in the first set of radiographs, it was hidden by a radiolucent material.

Lateral cervical radiographs were obtained for the neutral positions (P1 and P1m); however, head-to-pelvis radiographs were obtained for the free-standing (P2 and P2m) and modified free-standing positions (P3 and P3m). All radiographs were acquired using the EOS® microdose protocol.

SterEOS® software (version 1.8, EOS® Imaging, Paris) was used to measure 18 radiographic parameters related to horizontal gaze, cervical curvatures, global cervical alignment, and

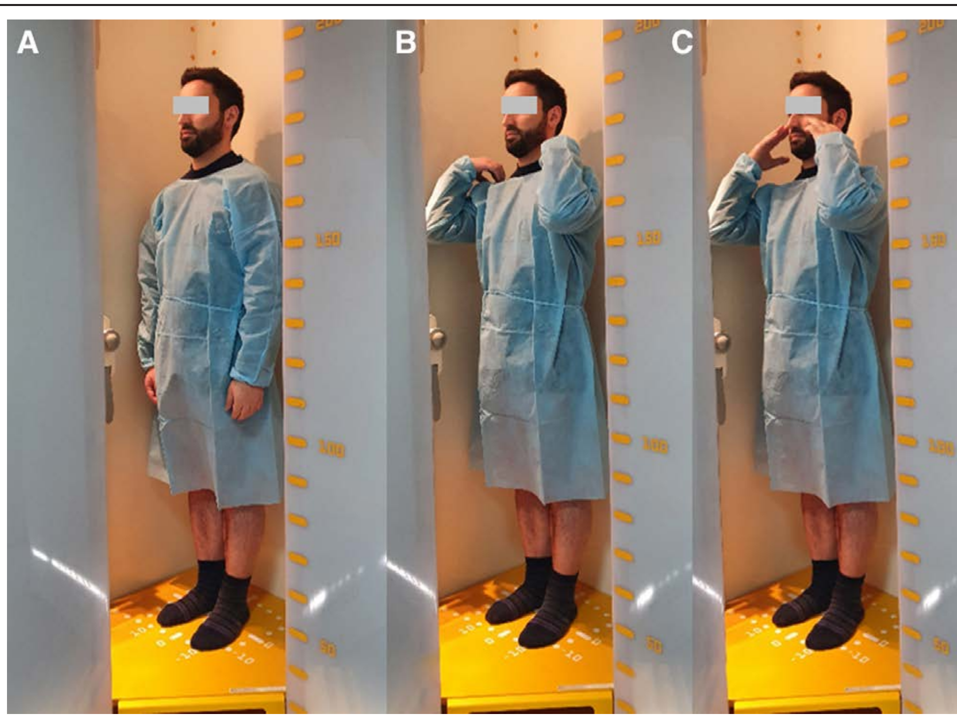


**Figure 1.** Radiograph acquisitions performed in 3 different positions: (A) Neutral relaxed position, (B) Free-standing position, and (C) Modified free-standing position.

the upper cervical, thoraco-cervical, and cervico-pelvic segments (Fig. 2). C2 tilt, T1 tilt, and CTPA were not measured in the neutral standing position (P1 and P1m) because their measurement required visibility of the femoral heads. The reliability of the cervical parameters has been reported in a previous study.[17]

## 4. Statistical analysis

Demographic data were compared between group-1 and group-2 using either Student *t* test or a Mann–Whitney *U* test, depending on the normality of the distribution of the measured parameters (Shapiro–Wilk test). Comparisons between the 6 radiographic positions for the 18 calculated parameters of the cervical spine were performed by controlling for possible confounding factors among the demographic data (age, group: asymptomatic/subjects with spinal deformities) using a repeated measures analysis of covariance.

The following conditions were investigated: (1) the effect of shoulder flexion with the free-standing position (P2) and the modified one (P3) compared to the gold standard relaxed position (P1); (2) the effect of the presence of a mirror in front of the subject; and (3) the effect of positioning the fingers on the cheeks (P3) compared to the original free-standing position with fingers on the clavicles (P2).

Statistical analyses were performed using the Xlstat® (Addinsoft, Paris, France; version 2020). The significance level was set at 0.05, and the Bonferroni correction was applied.

## 5. Results

### 5.1. Demographic data

In total, 26 subjects were enrolled in group-1 (mean age ± SD: 45 ± 11 years), and 13 subjects with spinal deformities were enrolled in group-2 (mean age ± SD: 30 ± 21 years, Adolescent patients with Idiopathic Scoliosis: N = 7; Adults with Spinal Deformities: N = 6). A significant difference was noted in age, weight, and body mass index between group-1 and group-2 (all $P < .05$, Table 1) and were accounted for in the following comparisons.

### 5.2. Comparison of radiographic parameters between group-1 and group-2

When considering the 6 positions together, a significant difference was found between group-1 and group-2 for slope of line

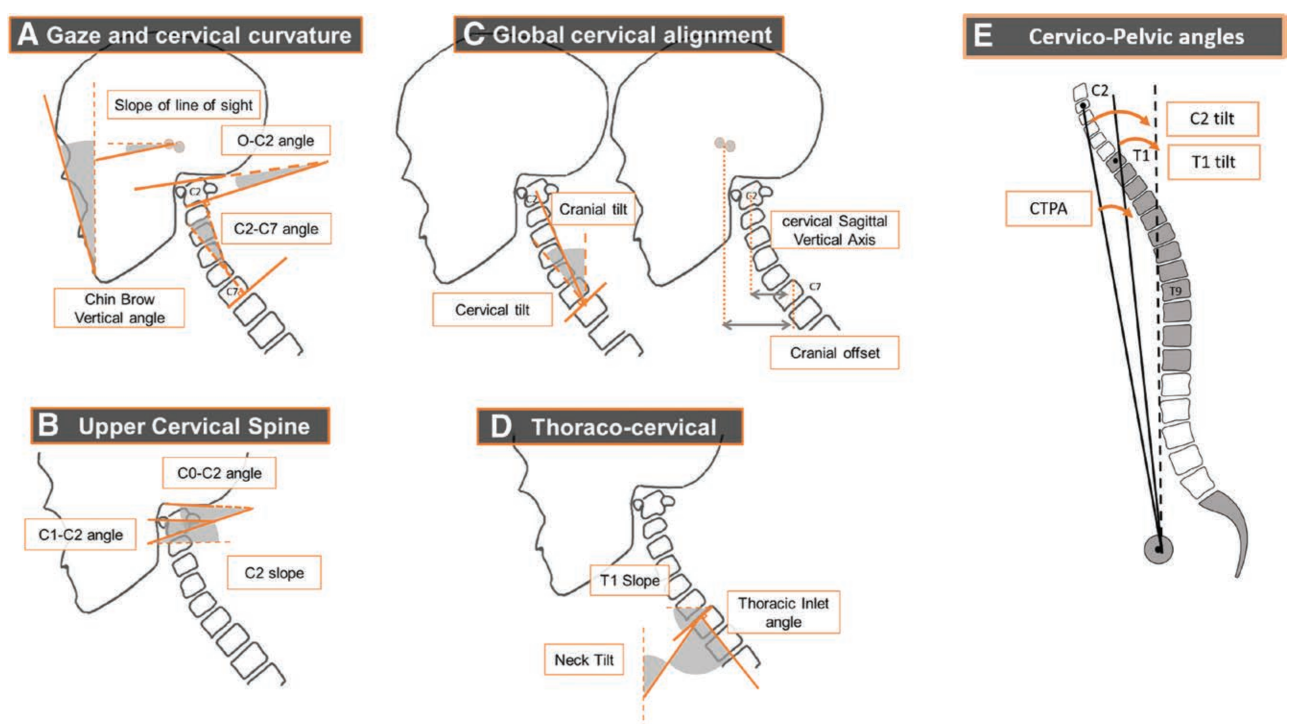


**Figure 2.** Cervical parameters measured on the sagittal radiographs: (A) Gaze and cervical curvature, (b) Upper cervical spine, (c) Global cervical alignment and (D) Thoraco-cervical parameters.

**Table 1**

**Demographic characteristics of asymptomatic subjects and subjects with spinal deformities.**

| Demographic parameter | Group-1 (Asymptomatic) (N = 26) Mean ± SD | Group-2 (Spinal deformities) N = 13 (7 AIS, 6 ASD) Mean ± SD | Group-1 vs group-2 (*P*-value) |
|---|---|---|---|
| Age (years) | 45 ± 11 | 30 ± 21 | **.01** |
| Height (cm) | 170 ± 8 | 164 ± 9 | .06 |
| Weight (kg) | 76 ± 17 | 61 ± 17 | **.01** |
| BMI (kg/m$^2$) | 26 ± 5 | 22 ± 5 | **.03** |

Statistically significant differences are in bold.

of sight (1 ± 6° vs 10 ± 10°, $P < .001$) and C0-C2 angle (35 ± 7° vs 28 ± 9°, $P = .004$).

### *5.3. Effect of shoulder flexion*

Several differences were noted in the measured parameters when the free-standing (P2 and P2m) and modified free-standing (P3 and P3m) positions were compared to the neutral relaxed positions (P1 and P1m); however, these differences did not exceed the uncertainty level (Table 2).

Cervical lordosis was decreased in the free-standing (P2: 10 ± 9°; P2m: 8 ± 9°) and modified free-standing positions (P3: 9 ± 9°; P3m: 9 ± 10°) compared to the relaxed position (P1: 14 ± 10°; P1m: 14 ± 10°, all $P < .05$), with the same pattern observed for the T1 slope.

The neck tilt was higher in the free-standing position (P2m: 50 ± 9°) and modified free-standing position (P3: 51 ± 10°, P3m: 50 ± 9°) than in the relaxed position (P1: 45 ± 11°; P1m: 42 ± 12°; all $P < .05$).

### *5.4. Effect of mirror placement*

No significant differences were noted when the mirror was placed in front of the subject during the acquisition (Table 2).

### *5.5. Effect of fingers positioning (free-standing vs modified free-standing position)*

No significant differences were noted when cervical parameters were compared when fingers were positioned on the clavicles and when those were positioned on the cheeks (Table 2).

## 6. Discussion

Assessment of the cervical spine is of great importance during the radiographic evaluation of patients with spinal deformities to differentiate between primary problems and compensatory mechanisms. Thus, a full-body radiograph should capture all spinal segments, including the cervical segment and head, while ensuring the natural position of the patient during radiographic acquisition. This study evaluated the effects of free-standing (shoulder flexed, fingers on clavicles) and modified free-standing positions (fingers on cheeks), and the presence of a mirror in front of the subject, on cervical spinal alignment parameters, compared to the relaxed position, which is considered to be the most physiological posture. All the studied positions seem to be valid for studying cervical alignment when the instructions related to the shoulder position at 90° while unmoving the head and trunk are respected.

### *6.1. Effect of shoulder flexion*

When the fingers were placed on the clavicles (free-standing position) or the cheeks (modified free-standing position), parameters related to the head position (chin brow vertical angle, slope of line of sight, and O–C2 angle) and global cervical alignment (cervical sagittal vertical axis) were comparable to those measured in the neutral relaxed position. Both cranial and cervical tilt tended to decrease without statistical significance (Table 2). This result could indicate a tendency for a posterior shift of the head when the arms are flexed, most likely related to postural adjustments encountered at the thoracic level. This explanation could be reinforced by the fact that thoraco-cervical parameters, specifically T1 slope, tended to decrease in the free-standing positions (P2 and P2m) as well as in the modified positions (P3 and P3m) compared to the neutral relaxed position (P1 and P1m), but did not exceed the level of uncertainty.

**Table 2**

**Comparison of radiographic parameters between the 6 different studied positions (mean ± SD).**

| | | Without mirror | | | With mirror | | | | Effect of shoulder flexion relatively to the reference position (*P*-value) | | | | Effect of mirror placement (*P*-value) | | | Effect of fingers positioning (*P*-value) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P1 | P2 | P3 | P1m | P2m | P3m | *P*-value | P1 vs P2 | P1 vs P3 | P1m vs P2m | P1m vs P3m | P1 vs P1m | P2 vs P2m | P3 vs P3m | P2 vs P3 | P2m vs P3m |
| Horizontal gaze and cervical curvature | CBVA (°) | -2 ± 11 | 2 ± 7 | 2 ± 8 | -1 ± 6 | 3 ± 7 | 4 ± 8 | | | | | | | | | | |
| | SLS (°) | 3 ± 9 | 3 ± 8 | 4 ± 8 | 3 ± 7 | 5 ± 8 | 5 ± 8 | | | | | | | | | | |
| | O–C2 (°) | 17 ± 9 | 15 ± 8 | 14 ± 8 | 16 ± 7 | 15 ± 6 | 16 ± 9 | | | | | | | | | | |
| | C2–C7 (°) | 14 ± 10 | 10 ± 9 | 9 ± 9 | 14 ± 10 | 8 ± 9 | 9 ± 10 | <.001 | <0.001* | 0.003* | <0.001* | <0.001* | | | | | |
| Global cervical alignment | cSVA (cm) | 2 ± 1 | 2 ± 1 | 3 ± 5 | 2 ± 1 | 2 ± 1 | 2 ± 1 | | | | | | | | | | |
| | Cranoff (cm) | 2 ± 1 | 1 ± 1 | 1 ± 1 | 2 ± 1 | 2 ± 1 | 2 ± 2 | | | | | | | | | | |
| | CervT (°) | 19 ± 8 | 17 ± 7 | 15 ± 8 | 18 ± 8 | 13 ± 8 | 15 ± 7 | | | | | | | | | | |
| | CranT (°) | 11 ± 4 | 9 ± 5 | 9 ± 5 | 12 ± 5 | 10 ± 5 | 11 ± 6 | | | | | | | | | | |
| Upper cervical | C0–C2 (°) | 33 ± 9 | 32 ± 8 | 32 ± 8 | 34 ± 7 | 32 ± 7 | 33 ± 10 | | | | | | | | | | |
| | C1–C2 (°) | 30 ± 8 | 28 ± 7 | 28 ± 7 | 29 ± 7 | 28 ± 6 | 29 ± 8 | | | | | | | | | | |
| | C2 slope (°) | 16 ± 7 | 15 ± 8 | 15 ± 8 | 16 ± 7 | 17 ± 7 | 17 ± 9 | | | | | | | | | | |
| Thoraco-cervical | Neck tilt (°) | 45 ± 11 | 49 ± 9 | 51 ± 10 | 42 ± 12 | 50 ± 9 | 50 ± 9 | <.001 | | <0.001* | <0.001* | <0.001* | | | | | |
| | TIA (°) | 74 ± 10 | 73 ± 10 | 74 ± 10 | 72 ± 9 | 72 ± 10 | 74 ± 10 | | | | | | | | | | |
| | T1 slope (°) | 29 ± 8 | 26 ± 7 | 25 ± 8 | 30 ± 9 | 24 ± 8 | 26 ± 7 | <.001 | 0.003* | <0.001* | <0.001* | 0.001* | | | | | |
| | T1 minus C2–C7 (°) | 16 ± 6 | 15 ± 7 | 16 ± 8 | 16 ± 8 | 15 ± 7 | 17 ± 9 | | | | | | | | | | |
| Cervico-pelvic parameters | CTPA (°) | | 3 ± 1 | 3 ± 1 | | 3 ± 1 | 3 ± 1 | | | | | | | | | | |
| | C2 tilt (°) | | 2 ± 3 | 3 ± 3 | | 3 ± 3 | 3 ± 3 | | | | | | | | | | |
| | T1 tilt (°) | | 5 ± 3 | 6 ± 3 | | 5 ± 3 | 6 ± 3 | | | | | | | | | | |

*Statistically significant difference.

Park et al reported a decrease in the C2–C7 angle as well as a posterior translation of the cervical segments in the free-standing position compared to the neutral relaxed one,[8] the results obtained in the current study showed significant differences between the free-standing and modified free-standing positions and neutral positions for the C2–C7 angle, without exceeding the level of uncertainty; therefore, the difference remained clinically insignificant.[17]

In fact, when the shoulders are flexed, the gravity line is shifted posteriorly[4,7,10] and this could explain the tendency to increase the neck tilt. Participants tended to decrease their cervical lordosis in an attempt to maintain horizontal gaze.

The above-mentioned results indicate that global cervical alignment and curvature in the free-standing and modified free-standing positions are comparable to those in the relaxed positions; however, differences might occur at the thoracic level. A decrease in thoracic kyphosis has been previously reported when the arms were flexed during radiographic acquisition.[9,18] This might represent a compensatory mechanism to counterbalance the lever arm created by the shoulder flexion.

While limited reproducibility of the shoulder flexion might be encountered, comparable results between the relaxed position and the modified free-standing position indicate that the instructions followed in this study, have allowed to respect to a large extent the physiological curvatures of the cervical spine. Further investigations exploring segmental and global spinal alignment when a modified free-standing position is adopted are required.

### 6.2. Effect of mirror placement

The results of the current study did not show significant changes in the studied parameters when the mirror was placed in front of the subject during the radiographic acquisitions. This was not in accordance with the results obtained by Oe et al, who reported that when a mirror was placed, the subject tended to decrease their cervical lordosis and lean their head backward.[12] It should be noted that radiographs in the latter study were taken 2 years apart, and changes could be related to aging. This discrepancy might also be related to the restricted visual field imposed by the EOS cabin wall during the acquisition without the mirror in the current study. Consequently, subjects tend to naturally focus on a single point on the EOS cabin wall, resembling the acquisition with a mirror. In contrast, the use of conventional radiographic acquisition allows for a broader field of vision, potentially influencing cervical parameters, especially the horizontal gaze, as reported by Oe et al.

### 6.3. Effect of fingers positioning in the modified free-standing position

This is the first study to compare the radiographic positions of the fingers on the cheeks and clavicles. The results showed that cervical alignment was similar in both the positions. This is related to the fact that the subjects were asked to maintain their shoulders flexed at 90° while moving their fingers from the clavicles to the cheeks. These instructions are important for immobilizing the lever arm created by arm flexion in both positions; therefore, no spinal adjustments are required when the fingers are moved to the cheeks. Furthermore, the participants were asked not to move their heads, trunks, or shoulders throughout the acquisition. Therefore, clear instructions are important when positioning patients for radiographic imaging.

An example of cervical radiographs taken at 3 different positions, with and without the presence of a mirror in front of the subject, is shown in Figure 3.

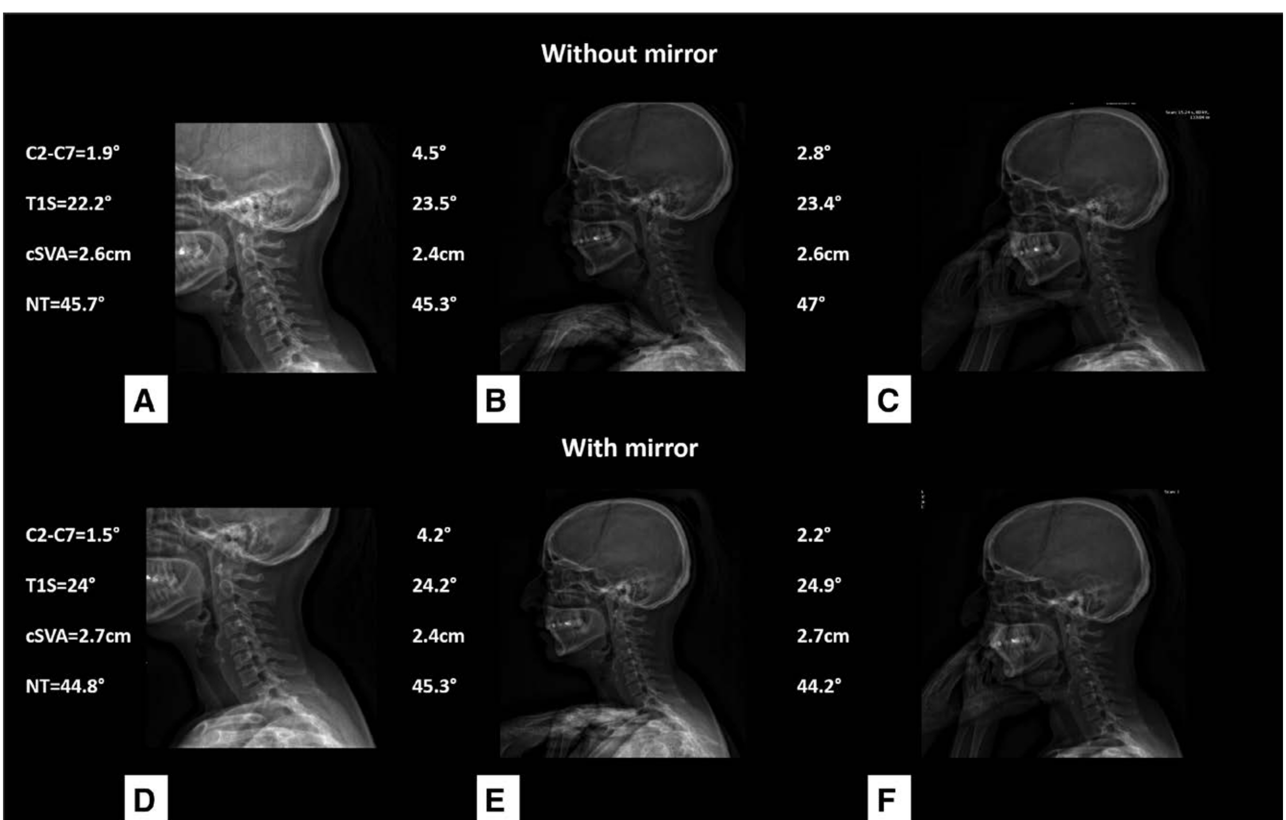


Figure 3. Cervical radiograph alignment calculated for the same subject while in neutral relaxed position (A, B), free-standing position (B–E) and modified free-standing position (C–F): C2–C7, T1 slope (T1s), cervical sagittal vertical axis (cSVA), neck tilt (NT).

To the best of our knowledge, this is the first study to compare 6 different radiographic positions to assess the validity of cervical radiographic measurements on full body radiographs. The major limitation of this study is the small number of participants, thus limiting its external validity. This is related to the difficulty in recruiting subjects who agreed to perform several radiographs, although microdose radiation was used for all acquisitions. The inclusion of subjects presenting with spinal deformities and those of different ages was of great importance in generalizing the findings to different groups.

However, expanding the sample size could be possible in the future, especially if the protocol is limited to comparing the spinal alignment during the neutral position and the modified free-standing position while considering the global sagittal alignment for the analysis.

In conclusion, the assessment of cervical alignment is valid on whole-spine radiographs when the shoulders are flexed in asymptomatic subjects as well as in subjects with spinal deformities. Clear instructions regarding the shoulder position at 90°, without moving the trunk, neck, and head before placing the fingers on the clavicles or cheeks, can ensure a cervical alignment comparable to that obtained in the neutral position, which is considered the most physiological position.

## Author contributions

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**Writing—original draft:** Abir Massaad, Michel Salameh.
**Writing—review & editing:** Abir Massaad, Ayman Assi, Aren Joe Bizdikian, Gaby Kreichati.

## References


[1] Diebo BG, Challier V, Henry JK, et al. Predicting cervical alignment required to maintain horizontal gaze based on global spinal alignment. Spine (Phila Pa 1976). 2016;41:1795–800.
[2] Khalil N, Bizdikian AJ, Bakouny Z, et al. Cervical and postural strategies for maintaining horizontal gaze in asymptomatic adults. Eur Spine J. 2018;27:2700–9.
[3] Yukawa Y, Kato F, Suda K, Yamagata M, Ueta T. Age-related changes in osseous anatomy, alignment, and range of motion of the cervical spine. Part I: Radiographic data from over 1,200 asymptomatic subjects. Eur Spine J. 2012;21:1492–8.
[4] Marks MC, Stanford CF, Mahar AT, Newton PO. Standing lateral radiographic positioning does not represent customary standing balance. Spine (Phila Pa 1976). 2003;28:1176–82.
[5] Scheer JK, Tang JA, Smith JS, et al. Cervical spine alignment, sagittal deformity, and clinical implications: a review. J Neurosurg Spine. 2013;19:141–59.
[6] Vedantam R, Lenke LG, Bridwell KH, Linville DL, Blanke K. The effect of variation in arm position on sagittal spinal alignment. Spine. 2000;25:2204–9.
[7] Marks M, Stanford C, Newton P. Which lateral radiographic positioning technique provides the most reliable and functional representation of a patient's sagittal balance? Spine (Phila Pa 1976). 2009;34:949–54.
[8] Park S-M, Song K-S, Park S-H, Kang H, Daniel Riew K. Does whole-spine lateral radiograph with clavicle positioning reflect the correct cervical sagittal alignment? Eur Spine J. 2015;24:57–62.
[9] Faro FD, Marks MC, Pawelek J, Newton PO. Evaluation of a functional position for lateral radiograph acquisition in adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2004;29:2284–9.
[10] Kaneko K, Aota Y, Sekiya T, Yamada K, Saito T. Validation study of arm positions for evaluation of global spinal balance in EOS imaging. Eur J Orthop Surg Traumatol. 2016;26:725–33.
[11] Morvan G, Mathieu P, Vuillemin V, et al. Standardized way for imaging of the sagittal spinal balance. Eur Spine J. 2011;20:602–8.
[12] Oe S, Togawa D, Yoshida G, et al. Effects of mirror placement on sagittal alignment of the spine during acquisition of full-spine standing X-rays. Eur Spine J. 2018;27:442–7.
[13] Ames CP, Smith JS, Eastlack R, et al. Reliability assessment of a novel cervical spine deformity classification system. J Neurosurg Spine. 2015;23:673–83.
[14] Lenke LG, Betz RR, Harms J, et al. Adolescent idiopathic scoliosis: a new classification to determine extent of spinal arthrodesis. J Bone Joint Surg Am. 2001;83:1169–81.
[15] Kim HJ, Iyer S, Zebala LP, et al. Perioperative neurologic complications in adult spinal deformity surgery. Spine (Phila Pa 1976). 2017;42:420–7.
[16] Horton WC, Brown CW, Bridwell KH, Glassman SD, Suk S-I, Cha CW. Is there an optimal patient stance for obtaining a lateral 36" radiograph? A critical comparison of three techniques. Spine (Phila Pa 1976). 2005;30:427–33.
[17] Salameh M, Bizdikian AJ, Saad E, et al. Reliability assessment of cervical spine parameters measured on full-body radiographs in asymptomatic subjects and patients with spinal deformity. Orthop Traumatol Surg Res. 2021;107:103026.
[18] Aota Y, Saito T, Uesugi M, Ishida K, Shinoda K, Mizuma K. Does the fists-on-clavicles position represent a functional standing position? Spine (Phila Pa 1976). 2009;34:808–12.