# The reliabilities of several measurement methods of cervical sagittal alignment in cases with cervical spine rotation using X-ray findings in cervical spine disorders

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**Structured Abstract**

**Introduction.** Several measurement methods designed to provide an understanding of cervical sagittal alignment have been reported, but few studies have compared the reliabilities of these measurement methods. The purpose of the present study was to investigate the intraexaminer and interexaminer reliabilities of several cervical sagittal alignment measurement methods and of the rotated cervical spine using plain lateral cervical spine X-rays of patients with cervical spine disorders.

**Methods.** Five different measurement methods (Borden's method; Ishihara index method (Ishihara method); C2-7 Cobb method (C2-7 Cobb); posterior tangent method: absolute rotation angle C2-7 (ARA); and classification of cervical spine alignment (CCSA)) were applied by seven examiners to plain lateral cervical spine X-rays of 20 patients (10 randomly extracted cases from a rotated cervical spine group and 10 from a nonrotated group) with cervical spine disorders. Case 1 and Case 2 intraclass correlation coefficients (ICCs) were used to analyze intraexaminer and interexaminer reliabilities. The necessary number of measurements and the necessary number of examiners were also determined. The target coefficient of correlation was set at ≥0.81 (almost perfect ICC).

**Results.** In both groups, an ICC(1, 1) ≥ 0.81 was obtained with Borden's method, the Ishihara method, C2-7 Cobb, and ARA by all examiners. The necessary number of measurements was 1. With CCSA, a kappa coefficient of at least 0.9 was obtained. In both groups, with Borden's method, the Ishihara method, C2-7 Cobb, and ARA, the ICC(2, 1) was ≥0.9, indicating that the necessary number of examiners was 1. The standard error of measurement (SEM) was lowest with Borden's method, and the Ishihara method and C2-7 Cobb had almost the same values.

**Conclusions.** Among cervical sagittal alignment measurement methods for cervical spine

disorders, regardless of cervical spine rotation, Borden's method, Ishihara method, and C2-7 Cobb offer stronger reliability in terms of the ICC and SEM.

**Key words.** cervical sagittal alignment, cervical spine disorders, rotated cervical spine, X-ray findings, intra- and interexaminer reliabilities, standard error of measurement.

## Introduction

Cervical spine X-rays are used in the auxiliary diagnosis of cervical spine disorders and can be used to measure cervical sagittal alignment in the functional evaluation of posture and other factors, as well as to obtain information on bone and joint involvement. Cervical sagittal alignment is affected by age and spinal degeneration and is reported to influence the development of cervical spine disorders.[1-3] In clinical settings, patients with neck disorders often have a forward head posture in the sagittal plane. Chiu et al.[4] reported that a forward head posture while using a computer is significantly correlated with neck symptoms. In regard to the relationship between cervical sagittal alignment and clinical symptoms, a comparison between groups with and without neck pain by McAviney et al.[5] showed more instances of neck pain in cases of cervical lordosis of 20° or less and an 18-fold greater incidence of neck pain in cases of cervical lordosis of 0° or less. Furthermore, Oktenoğlu et al.[6] reported that reducing cervical lordosis increases the risk of neck injury. For these reasons, understanding cervical sagittal alignment is considered clinically useful in the management of neck disorders. However, although several measurement methods designed to provide an understanding of cervical sagittal alignment have been reported, few studies have compared the reliabilities of measurement methods. Moreover, in clinical settings, the cervical spine is observed to be rotated because of degenerative changes or pain. In some cases, the correct neck posture may be difficult to maintain in each patient examined. However, how cervical spine rotation would influence the parameters, whether the values are acceptable, or whether the radiographs should be repeated are unknown. There has been no report investigating the reliability of cervical sagittal alignment measurement when the cervical spine was rotated.

The purpose of the present study was to investigate the intraexaminer and interexaminer

reliabilities of several cervical sagittal alignment measurement methods and cervical spine rotation using plain lateral cervical spine X-rays of patients with cervical spine disorders.

## Materials and Methods

### 1) Subjects

The subjects were 427 patients diagnosed, after visiting the facility with which the lead author is affiliated with, with a cervical spine disorder for symptoms including neck pain and shoulder girdle pain and numbness during the period from July 2013 to June 2014. Of these patients, 115 had degenerative disease confirmed from the second cervical vertebra to the seventh cervical vertebra on the plain lateral cervical spine X-rays. On the X-rays, cases in which the right and left vertebral arches (transverse process) were overlapped from the second cervical vertebra to the seventh cervical vertebra, the line connecting the posterior border of the cervical vertebra was smooth, and the shape could be clearly confirmed were classified as the nonrotated cervical spine group (61 cases). Moreover, cases in which the right and left vertebral arches were not overlapped from the second cervical vertebra to the seventh cervical vertebra, the line connecting the posterior border of the cervical vertebra was uneven, and the shape could be unclearly confirmed were classified as the rotated cervical spine group (54 cases) **(Figure 1)**. Using a random number table created in the spreadsheet software Microsoft Excel 2013, the lead author randomly extracted 10 cases from the rotated cervical spine group and 10 cases from the nonrotated group, for a total of 20 cases. The patients chosen as subjects were 13 men and 7 women with a mean age of 52.1 ± 9.8 yr. The diagnosis was cervical spondylotic radiculopathy in 10 patients, cervical disc herniation in five patients, cervical spondylosis deformans in four patients, and cervical spondylotic myelopathy in one patient. Power analysis (significance level,

$\alpha = 0.05$; power, 80%; effect size, 0.8) was performed using G*power 3 (free software, Heinrich-Heine-University, Dusseldorf, Germany). The number of subjects required for this study was calculated to be at least seven cases. Thus, it was confirmed that the number of subjects in this study exceeded the required number.

**2) Study Methods**

**I. Measurement methods**

Five different measurements were performed on patients' plain lateral cervical spine X-rays.[7] The measurements used were common measurements used in the evaluation of cervical spine alignment in orthopedic care. The medical imaging system SYNAPSE (Fujifilm Medical Systems, Tokyo, Japan) was used to take these measurements. Each of the measurements was taken three times per subject in the order assigned by the random number table. The measurement interval was arbitrary by the examiners (if all tangents for measurement were deleted before each measurement, continuous measurement was allowed). The examiners were five physical therapists, one occupational therapist, and one radiological technologist (four men and three women, mean age 32.1 ± 5.8 yr, clinical experience 10.1 ± 6.1 yr; examiners A–G) under the guidance of a board-certified spine surgeon (approved by the Board of the Japanese Society for Spine Surgery and Related Research). Photographs were taken with the patient in the upright position, the face facing forward, the outer side of the right shoulder in close contact with the film, and the median plane of the body parallel to the film plane. Moreover, in order to reproduce the anatomical landmarks of the cervical spine, the patient could not adopt an unreasonable posture, bundle the hair, or grasp the handrail only with one hand, and the radiological technologist confirmed the median position from the front and sides of the patient.

All X-rays were captured at a film-focus distance of 160 cm, with irradiation to the film surface from the left direction incident on the fourth cervical vertebra. The imaging apparatus used was a KXO-50G (Toshiba Medical Systems, Tokyo, Japan), and the image reader used was an FCR 5000 Plus (Fujifilm Medical System). The resolution was 2010 × 2520 pixels.

**II. Cervical spine alignment measurement methods**

**1. Borden's method[8] (Figure 2-a)**

This method measured the line running up to the point where the distance is greatest (C) between the line connecting the posterior border of the dens axis to the posteroinferior border of the seventh cervical vertebra (A) and the line traveling from the posterior surface of the second cervical vertebra to the posterior surface of the seventh cervical vertebra (B).

**2. Ishihara index method ("Ishihara method")[1] (Figure 2-b)**

Spinal curvature was evaluated as an index. The spinal curvature index was calculated by taking the value obtained by adding the distance between the line connecting the posteroinferior border of the second cervical vertebra (C) to the posteroinferior border of the seventh cervical vertebra (D) and each of the posteroinferior borders of the third to sixth cervical vertebrae (a3–a6), and dividing this by the distance between the posteroinferior borders of the second to seventh cervical vertebrae (spinal curvature index: [a3 + a4 + a5 + a6]/CD × 100). When each of the posteroinferior borders of the third to sixth cervical vertebrae was posterior to the line connecting the posteroinferior border of the second cervical vertebra to the posteroinferior border of the seventh cervical vertebra, the distance to each of the posteroinferior borders of the third to sixth cervical vertebrae was set as a negative value.

**3. C2-7 Cobb method ("C2-7 Cobb")[9] (Figure 2-c)**

This method measured the angle formed by the line perpendicular to the tangent of the inferior border of the second cervical vertebra and the line perpendicular to the tangent of the inferior border of the seventh cervical vertebra.

**4. Posterior tangent method: absolute rotation angle C2-7 ("ARA")[10] (Figure 2-d)**

This method measured the angle formed by the tangent of the posterior surface of the second cervical vertebra and the tangent of the posterior surface of the seventh cervical vertebra.

**5. Classification of cervical spine alignment ("CCSA")[11] (Figure 3)**

This method measured the perpendicular lines from the line connecting the posterior border of the dens axis to the posterior border of the seventh cervical vertebra (A) to the posterior borders of the third to sixth cervical vertebrae. Alignment was then classified into four categories (lordosis, straight, sigmoid, and kyphosis) on the basis of the distances to a3 to a6 (where the line perpendicular to the posterior border of the third cervical vertebra is a3). In the lordosis type, a3 to a6 were all located anterior to A, and one of the distances of the four perpendicular lines was at least 2 mm. In the straight type, a3 to a6 were all less than 2 mm. In the sigmoid type, a3 to a6 were located anterior and posterior to A, and one of the distances of the four perpendicular lines was at least 2 mm anteroposterior. In the kyphosis type, a3 to a6 were all located posterior to A, and one of the distances of the four perpendicular lines was at least 2 mm posterior.

**3) Statistical Analysis**

The measured values of each group were used to calculate Case 1 and Case 2 intraclass correlation coefficients (ICCs)[12], which were used to analyze intraexaminer and interexaminer reliabilities. These values were then inserted into the Spearman–Brown formula to find the necessary number of measurements and the necessary number of examiners. The target coefficient was set at 0.81 or higher, which is considered an almost perfect ICC[13, 14]. R-2.8.1 (CRAN, freeware) was used for the analysis.

**4) Ethical Considerations**

This study has been approved by our institution's ethics committee.

**Results**

**1) Intraexaminer Reliability (Tables 1 and 2)**

In the nonrotated cervical spine groups, an ICC(1, 1) of at least 0.9 was obtained with all measurement methods (Borden's method, Ishihara method, C2-7 Cobb, and ARA) by all examiners. The lower limit of the 95% confidence interval (95% CI) was also equivalent to or greater than the target coefficient value. In the rotated cervical spine groups, an ICC(1, 1) of at least 0.81 was obtained with all measurement methods by all examiners. However, in the Ishihara method, the lower limits of the 95% CI of two examiners were less than the target coefficient value. In both groups, with CCSA, a kappa coefficient of at least 0.9 was obtained. The necessary number of measurements was 1.

**2) Interexaminer Reliability (Tables 3 and 4)**

In both groups, in Borden's method, the Ishihara method, C2-7 Cobb, and ARA, the ICC(2, 1)

and the lower limit of the 95% CI were equivalent to or greater than the target coefficient value, indicating that the necessary number of examiners was 1. In Borden's method and ARA, the nonrotated cervical spine group had a slightly higher ICC(2, 1) than did the rotated cervical spine group. In the Ishihara method, the rotated cervical spine group had a slightly higher ICC(2, 1) than did the nonrotated cervical spine group. In both groups, the standard error of measurement (SEM)[15] was lowest with Borden's method, and the Ishihara method and C2-7 Cobb had almost the same values. The rotated cervical spine group had a higher SEM than did the nonrotated cervical spine group. With CCSA, in the nonrotated cervical spine group and the rotated group, the kappa coefficients were 0.72 and 0.63, respectively, and the necessary number of examiners was 2 and 3, respectively.

## Discussion

With respect to the ICC, Landis and Koch[14] considered an ICC of 0.81 to 1.00 to be almost perfect when the kappa coefficient is the criterion used to determine the ICC, whereas Kuwabara et al.[16] considered an ICC of at least 0.7 to indicate strong reliability. Furthermore, verification of the CI is necessary because the ICC is a point estimate. Because the ICC changes depending on individual differences in subjects, the restrictiveness of the range of reliability can become a problem.[17] It is therefore recommended to make judgments after also comparing the measured SEM.

In regard to the reliability of cervical sagittal alignment measurements, Ohara et al.[18] reported that in the measurements by two orthopedic surgeons of 120 patients without neck symptoms or with mild symptoms, five measurement methods including the Ishihara method, C2-7 Cobb, and ARA (C1-7 Cobb method, centroid measurement of cervical lordosis method) produced strong

correlations for intraexaminer and interexaminer measured values. Moreover, in the cervical lordosis group, strong relationships were seen between these measurement methods. Gwinn et al.[19] also reported excellent intraexaminer and interexaminer reliabilities in the C2-7 Cobb and ARA measurement methods in 20 cervical spondylotic myelopathy patients. With respect to SEM, Harrison et al.[20] reported that the ARA produced lower values than did the C2-7 Cobb on the basis of the results of an earlier study.

The results of the present study indicate that strong intraexaminer reliability, with ICCs, kappa coefficients, and 95% CI lower limits of at least 0.81 in almost all examiners, regardless of cervical spine rotation, can be obtained with Borden's method, Ishihara method, C2-7 Cobb, ARA, and CCSA cervical sagittal alignment measurement methods for cervical spine disorders. Furthermore, adequate results can be obtained with just one measurement, suggesting that these measurement methods are efficient and easy to use.

In terms of interexaminer reliability, regardless of cervical spine rotation, Borden's method, Ishihara method, C2-7 Cobb, and ARA produced ICCs and 95% CI lower limits of at least 0.81, indicating strong reliability. However, although adequate results were obtained with just one examiner, the reliability of the CCSA was deemed substantial in both groups. Furthermore, the SEM, which is an index of variation between examiners, suggested that Borden's method, Ishihara method, and C2-7 Cobb are measurement methods that offer stronger interexaminer reliability. On examining the Bland–Altman plot (**Figure 4A, 4B**), however, a large variation in upper and lower points representing the magnitude of error was also seen in Borden's method, Ishihara method, and C2-7 Cobb. Performing measurements in several individuals is, therefore, recommended to increase measurement accuracy.

Moreover, the rotated cervical spine group had a higher SEM, which is an indicator of data

dispersion, than did the nonrotated cervical spine group. Osteophytes and vertebral deformities caused by cervical spinal degeneration and the degrees of vertebral slippage and local curvature could also affect measured values.[19, 21] Takeshita et al.[22] reported that although a significant correlation was observed between the Ishihara method and ARA in cervical sagittal alignment measurements in patients without neck symptoms, a decreased correlation was seen in patients with a sigmoid cervical spine. This suggests that depending on the degree of cervical spinal degeneration, a measurement method in which the measurement of tangents is easier is sometimes better. Borden's method and the ARA have few tangents and are easier. Previous studies showed that Borden's method has an average value for the Japanese[7] and that the ARA has normal values for sex and age.[10] Use of the C2-7 Cobb is desirable when a posterior border deformity is present on the cervical vertebral, because the inferior border of the cervical vertebra can be used as an indicator. The Ishihara method uses several tangents. It is used to measure the cervical spinal column curvature index and for evaluation before and after cervical spine surgery. For the CCSA, kappa coefficients were considered substantial, which can affect the error of measurement criteria and result in a larger number of measurements to determine measurement indices. However, by performing evaluations by alignment type, unlike other methods, it is easier to gain a clinical understanding of the disease features, which suggests that the CCSA is an evaluation method that should be used if measurement by multiple examiners is possible to enhance reliability.

One limitation of this study was that no investigation in terms of examiner occupation or years of clinical experience was done. Furthermore, measurement became difficult when the seventh cervical vertebra was indistinct on images; in such cases, no measurement method could be used in this study. Further investigations that address these issues will be needed in the future.

## Conclusions

Among cervical sagittal alignment measurement methods for cervical spine disorders, regardless of cervical spine rotation, Borden's method, Ishihara method, and C2-7 Cobb offer stronger reliability in terms of the ICC and SEM. However, other evaluations also offer strong reliability, and they are, therefore, best used for reasons including their simplicity, applications, and evaluation features.

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## Figure legends

**Figure 1:**

**Nonrotated cervical spine and rotated cervical spine.** The right and left vertebral arches are not overlapped (A) from the second cervical vertebra to the seventh cervical vertebra; the line connecting the posterior border of the cervical vertebra is uneven (B).

**Figure 2:**

**a: Borden's method.** This method measures the line running up to the point where the distance is greatest (C) between the line connecting the posterior border of the dens axis to the posteroinferior border of the seventh cervical vertebra (A), and the line traveling from the posterior surface of the second cervical vertebra to the posterior surface of the seventh cervical vertebra (B).

**b: Ishihara method.** The spinal curvature index is calculated by taking the value obtained by adding the distance between the line connecting the posteroinferior border of the second cervical vertebra (C) to the posteroinferior border of the seventh cervical vertebra (D) and each of the posteroinferior borders of the third to sixth cervical vertebrae (a3–a6), and dividing this by the distance between the posteroinferior borders of the second to seventh cervical vertebrae (spinal curvature index: $[a3 + a4 + a5 + a6]/CD \times 100$).

**c: C2-7 Cobb.** This method measures the angle formed by the line perpendicular to the tangent of the inferior border of the second cervical vertebra and the line perpendicular to the tangent of the inferior border of the seventh cervical vertebra.

**d: ARA.** This method measures the angle formed by the tangent of the posterior surface of the second cervical vertebra and the tangent of the posterior surface of the seventh cervical vertebra.

**Figure 3:**

**Classification of cervical spine alignment.** This method measures the perpendicular lines from the line connecting the posterior border of the dens axis to the posterior border of the seventh cervical vertebra (A) to the posterior borders of the third to sixth cervical vertebrae. Alignment was then classified into four categories (lordosis, straight, sigmoid, and kyphosis) on the basis of the distances to a3 to a6 (the third cervical vertebra is a3).

**Figure 4:**

**Bland–Altman plot (scatter plot of the interexaminer reliability of each measurement method). A: Nonrotated cervical spine group. B: Rotated cervical spine group.** Numbers 1–7 correspond to each examiner. For both groups, the SEM suggests that Borden's method, Ishihara method, and C2-7 Cobb are methods that offer stronger interexaminer reliability. On examining a scatter plot, however, a large variation in upper and lower points representing the magnitude of error is also seen with these methods.

Table 1. Intraexaminer reliability (ICC[1, 1] [1, 3]) of each measurement method in the nonrotated cervical spine group

| | ICC (1, 1) | 95% CI | | Coefficient by Spearman–Brown's formula | SEM | 95% CI | | ICC (1, 3) | 95% CI | | Coefficient by Spearman–Brown's formula |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lower limit | Upper limit | | | Lower limit | Upper limit | | Lower limit | Upper limit | |
| **Borden's method** | | | | | | | | | | | |
| Examiner A | 0.99 | 0.99 | 0.99 | 0.04 | 0.19 | 0.14 | 0.27 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner B | 0.99 | 0.99 | 0.99 | 0.04 | 0.24 | 0.18 | 0.35 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner C | 0.99 | 0.99 | 0.99 | 0.04 | 0.35 | 0.27 | 0.52 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner D | 0.99 | 0.99 | 0.99 | 0.04 | 0.35 | 0.27 | 0.52 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner E | 0.99 | 0.99 | 0.99 | 0.04 | 0.23 | 0.18 | 0.34 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner F | 0.99 | 0.99 | 0.99 | 0.04 | 0.38 | 0.29 | 0.56 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner G | 0.99 | 0.99 | 0.99 | 0.04 | 0.31 | 0.23 | 0.45 | 0.99 | 0.99 | 0.99 | 0.04 |
| **Ishihara method** | | | | | | | | | | | |
| Examiner A | 0.99 | 0.99 | 0.99 | 0.04 | 0.31 | 0.23 | 0.46 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner B | 0.99 | 0.98 | 0.99 | 0.04 | 1.04 | 0.79 | 1.54 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner C | 0.99 | 0.98 | 0.99 | 0.04 | 0.88 | 0.66 | 1.30 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner D | 0.98 | 0.95 | 0.99 | 0.09 | 1.52 | 1.15 | 2.24 | 0.99 | 0.98 | 0.99 | 0.04 |
| Examiner E | 0.99 | 0.99 | 0.99 | 0.04 | 0.78 | 0.59 | 1.16 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner F | 0.99 | 0.98 | 0.99 | 0.04 | 0.77 | 0.59 | 1.15 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner G | 0.99 | 0.98 | 0.99 | 0.04 | 1.02 | 0.77 | 1.51 | 0.99 | 0.99 | 0.99 | 0.04 |
| **C2-7 Cobb** | | | | | | | | | | | |
| Examiner A | 0.99 | 0.98 | 0.99 | 0.04 | 0.91 | 0.69 | 1.34 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner B | 0.99 | 0.96 | 0.99 | 0.04 | 1.34 | 1.01 | 1.99 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner C | 0.98 | 0.93 | 0.99 | 0.09 | 1.65 | 1.25 | 2.44 | 0.99 | 0.98 | 0.99 | 0.04 |
| Examiner D | 0.93 | 0.81 | 0.98 | 0.32 | 3.20 | 2.42 | 4.74 | 0.97 | 0.93 | 0.99 | 0.13 |
| Examiner E | 0.98 | 0.95 | 0.99 | 0.09 | 1.42 | 1.07 | 2.10 | 0.99 | 0.98 | 0.99 | 0.04 |
| Examiner F | 0.97 | 0.91 | 0.98 | 0.13 | 1.66 | 1.26 | 2.46 | 0.99 | 0.97 | 0.99 | 0.04 |
| Examiner G | 0.98 | 0.96 | 0.99 | 0.09 | 1.17 | 0.88 | 1.72 | 0.99 | 0.98 | 0.99 | 0.04 |
| **ARA** | | | | | | | | | | | |
| Examiner A | 0.99 | 0.98 | 0.99 | 0.04 | 1.29 | 0.97 | 1.89 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner B | 0.99 | 0.97 | 0.99 | 0.04 | 1.20 | 0.90 | 1.77 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner C | 0.98 | 0.95 | 0.99 | 0.09 | 1.97 | 1.49 | 2.92 | 0.99 | 0.98 | 0.99 | 0.04 |
| Examiner D | 0.99 | 0.97 | 0.99 | 0.09 | 1.40 | 1.06 | 2.07 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner E | 0.99 | 0.97 | 0.99 | 0.04 | 1.36 | 1.03 | 2.02 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner F | 0.98 | 0.94 | 0.99 | 0.13 | 2.30 | 1.74 | 3.40 | 0.99 | 0.98 | 0.99 | 0.04 |
| Examiner G | 0.98 | 0.95 | 0.99 | 0.09 | 1.47 | 1.11 | 2.18 | 0.99 | 0.98 | 0.99 | 0.04 |

| **CCSA** | Kappa (Cohen) | Coefficient by Spearman–Brown's formula |
|---|---|---|
| Examiner A | 1 | 0 |
| Examiner B | 1 | 0 |
| Examiner C | 1 | 0 |
| Examiner D | 1 | 0 |
| Examiner E | 1 | 0 |
| Examiner F | 0.93 | 0.32 |
| Examiner G | 1 | 0 |

Examiners A–E, physical therapists; Examiner F, occupational therapist; Examiner G, radiological technologist.

Table 2. Intraexaminer reliability (ICC[1, 1] [1, 3]) of each measurement method in the rotated cervical spine group

| **Borden's method** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **ICC (1, 1)** | **95% CI** | | **Coefficient by Spearman–Brown's formula** | **SEM** | **95% CI** | | **ICC (1, 3)** | **95% CI** | | **Coefficient by Spearman–Brown's formula** |
| | | **Lower limit** | **Upper limit** | | | **Lower limit** | **Upper limit** | | **Lower limit** | **Upper limit** | |
| Examiner A | 0.99 | 0.99 | 0.99 | 0.04 | 0.23 | 0.18 | 0.34 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner B | 0.99 | 0.99 | 0.99 | 0.04 | 0.42 | 0.32 | 0.62 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner C | 0.99 | 0.99 | 0.99 | 0.04 | 0.29 | 0.22 | 0.43 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner D | 0.99 | 0.99 | 0.99 | 0.04 | 0.49 | 0.37 | 0.72 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner E | 0.99 | 0.99 | 0.99 | 0.04 | 0.24 | 0.18 | 0.35 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner F | 0.99 | 0.99 | 0.99 | 0.04 | 0.28 | 0.22 | 0.42 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner G | 0.99 | 0.99 | 0.99 | 0.04 | 0.31 | 0.23 | 0.45 | 0.99 | 0.99 | 0.99 | 0.04 |
| **Ishihara method** | | | | | | | | | | | |
| Examiner A | 0.89 | 0.73 | 0.97 | 0.53 | 4.66 | 3.52 | 6.89 | 0.96 | 0.89 | 0.99 | 0.18 |
| Examiner B | 0.99 | 0.99 | 0.99 | 0.04 | 0.71 | 0.53 | 1.04 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner C | 0.99 | 0.97 | 0.99 | 0.04 | 1.31 | 0.99 | 1.94 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner D | 0.99 | 0.97 | 0.99 | 0.09 | 1.40 | 1.06 | 2.07 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner E | 0.99 | 0.98 | 0.99 | 0.04 | 1.17 | 0.89 | 1.72 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner F | 0.99 | 0.96 | 0.99 | 0.04 | 1.64 | 1.24 | 2.42 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner G | 0.81 | 0.56 | 0.94 | 1.00 | 5.90 | 4.46 | 8.72 | 0.93 | 0.79 | 0.98 | 0.32 |
| **C2-7 Cobb** | | | | | | | | | | | |
| Examiner A | 0.99 | 0.99 | 0.99 | 0.04 | 0.46 | 0.34 | 0.67 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner B | 0.99 | 0.98 | 0.99 | 0.04 | 1.48 | 1.12 | 2.19 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner C | 0.98 | 0.94 | 0.99 | 0.09 | 1.98 | 1.50 | 2.93 | 0.99 | 0.98 | 0.99 | 0.04 |
| Examiner D | 0.98 | 0.95 | 0.99 | 0.09 | 3.20 | 2.42 | 4.74 | 0.99 | 0.98 | 0.99 | 0.13 |
| Examiner E | 0.99 | 0.97 | 0.99 | 0.04 | 1.72 | 1.30 | 2.54 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner F | 0.96 | 0.89 | 0.99 | 0.18 | 2.60 | 1.96 | 3.84 | 0.99 | 0.97 | 0.99 | 0.04 |
| Examiner G | 0.99 | 0.97 | 0.99 | 0.04 | 1.52 | 1.15 | 2.25 | 0.99 | 0.99 | 0.99 | 0.04 |
| **ARA** | | | | | | | | | | | |
| Examiner A | 0.99 | 0.98 | 0.99 | 0.04 | 0.94 | 0.71 | 1.39 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner B | 0.99 | 0.96 | 0.99 | 0.04 | 1.62 | 1.22 | 2.39 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner C | 0.98 | 0.94 | 0.99 | 0.09 | 1.89 | 1.43 | 2.80 | 0.99 | 0.98 | 0.99 | 0.04 |
| Examiner D | 0.97 | 0.91 | 0.99 | 0.13 | 2.00 | 1.51 | 2.96 | 0.99 | 0.97 | 0.99 | 0.04 |
| Examiner E | 0.99 | 0.96 | 0.99 | 0.04 | 1.37 | 1.04 | 2.03 | 0.99 | 0.99 | 0.99 | 0.04 |
| Examiner F | 0.97 | 0.91 | 0.99 | 0.13 | 2.41 | 1.82 | 3.57 | 0.99 | 0.97 | 0.99 | 0.04 |
| Examiner G | 0.99 | 0.97 | 0.99 | 0.04 | 1.55 | 1.17 | 2.29 | 0.99 | 0.99 | 0.99 | 0.04 |

| **CCSA** | | |
|---|---|---|
| | **Kappa (Cohen)** | **Coefficient by Spearman–Brown's formula** |
| Examiner A | 1 | 0 |
| Examiner B | 1 | 0 |
| Examiner C | 1 | 0 |
| Examiner D | 1 | 0 |
| Examiner E | 1 | 0 |
| Examiner F | 0.92 | 0.37 |
| Examiner G | 1 | 0 |

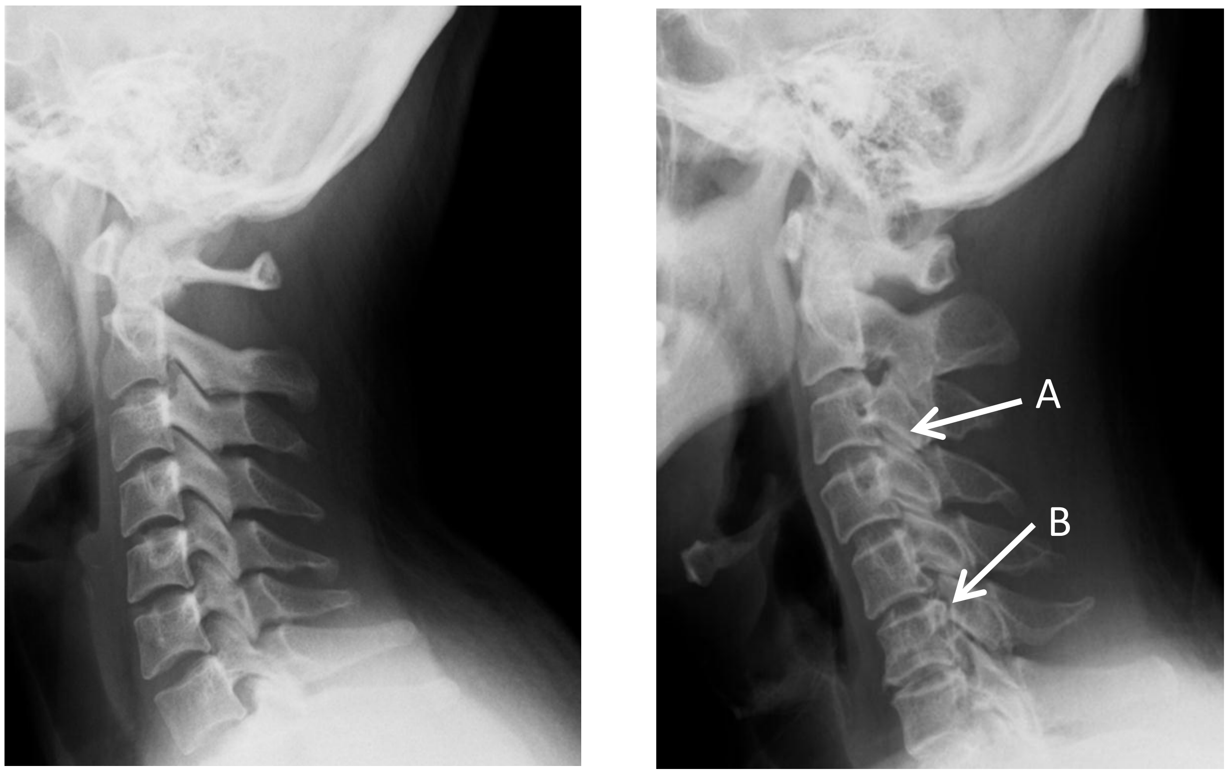
Examiners A–E, physical therapists; Examiner F, occupational therapist; Examiner G, radiological technologist.

**Table 3. Interexaminer reliability (ICC[2, 1] [2, 7]) and kappa coefficients of each measurement method in the nonrotated cervical spine group**

| | ICC (2, 1) | 95% CI | | Coefficient by Spearman–Brown's formula | SEM | 95% CI | | ICC (2, 7) | 95% CI | | Coefficient by Spearman–Brown's formula |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lower limit | Upper limit | | | Lower limit | Upper limit | | Lower limit | Upper limit | |
| Borden's method | 0.98 | 0.95 | 0.99 | 0.09 | 0.92 | 0.78 | 1.14 | 0.99 | 0.99 | 0.99 | 0.04 |
| Ishihara method | 0.95 | 0.88 | 0.99 | 0.22 | 1.73 | 1.45 | 2.13 | 0.99 | 0.98 | 0.99 | 0.04 |
| C2-7 Cobb | 0.97 | 0.93 | 0.99 | 0.13 | 1.88 | 1.58 | 2.32 | 0.99 | 0.99 | 0.99 | 0.04 |
| ARA | 0.95 | 0.89 | 0.99 | 0.22 | 2.85 | 2.40 | 3.51 | 0.99 | 0.98 | 0.99 | 0.04 |
| | **Kappa (Cohen)** | **Coefficient by Spearman–Brown's formula** | | | | | | | | | |
| CCSA | 0.72 | 1.66 | | | | | | | | | |

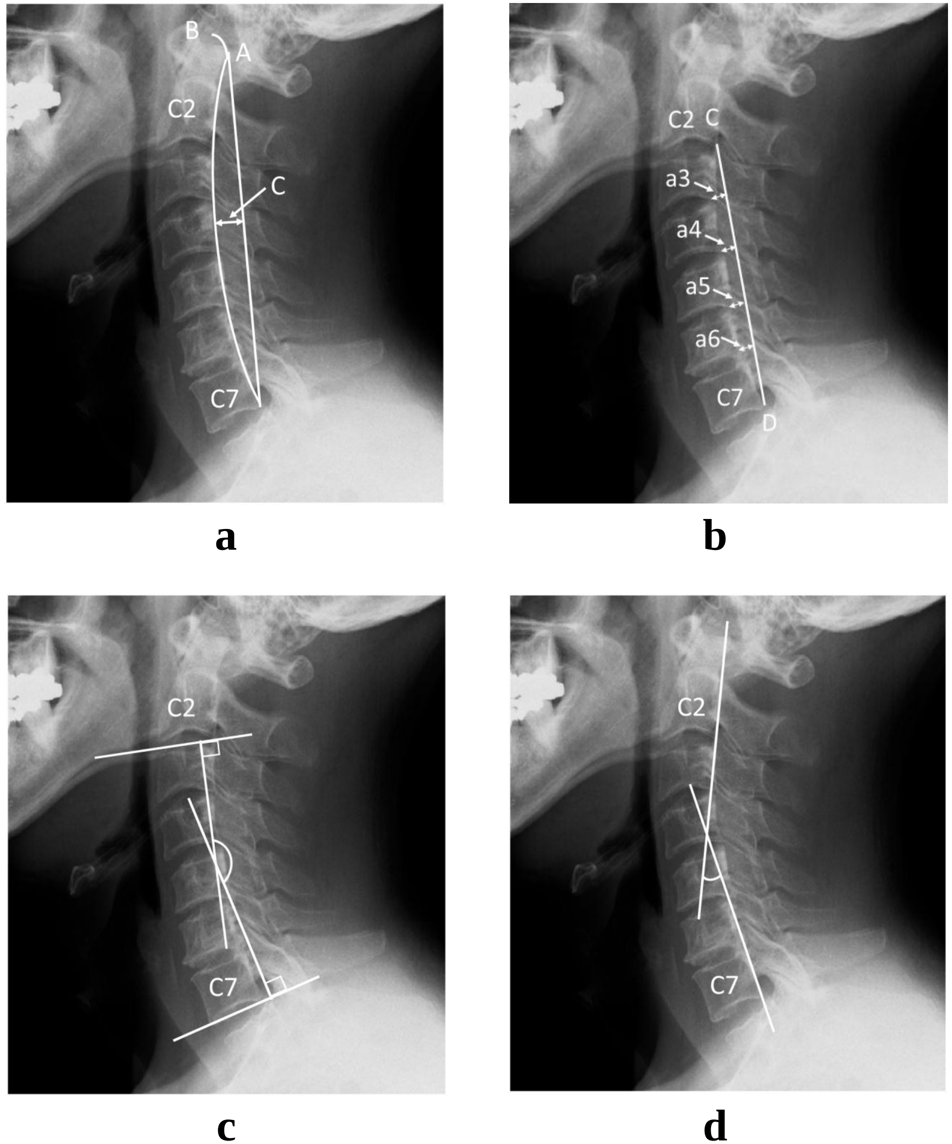
**Table 4. Interexaminer reliability (ICC[2, 1] [2, 7]) and kappa coefficients of each measurement method in the rotated cervical spine group**

| | ICC (2, 1) | 95% CI | | Coefficient by Spearman–Brown's formula | SEM | 95% CI | | ICC (2, 7) | 95% CI | | Coefficient by Spearman–Brown's formula |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lower limit | Upper limit | | | Lower limit | Upper limit | | Lower limit | Upper limit | |
| Borden's method | 0.96 | 0.90 | 0.99 | 0.18 | 1.34 | 1.13 | 1.66 | 0.99 | 0.98 | 0.99 | 0.04 |
| Ishihara method | 0.96 | 0.91 | 0.99 | 0.18 | 2.52 | 2.12 | 3.11 | 0.99 | 0.99 | 0.99 | 0.04 |
| C2-7 Cobb | 0.97 | 0.92 | 0.99 | 0.13 | 2.64 | 2.23 | 3.26 | 0.99 | 0.99 | 0.99 | 0.04 |
| ARA | 0.93 | 0.85 | 0.98 | 0.32 | 3.31 | 2.79 | 4.08 | 0.99 | 0.98 | 0.99 | 0.04 |
| | **Kappa (Cohen)** | | **Coefficient by Spearman–Brown's formula** | | | | | | | | |
| CCSA | 0.63 | | 2.50 | | | | | | | | |




**a: Non-rotated cervical spine** **b: Rotated cervical spine**

Figure 1

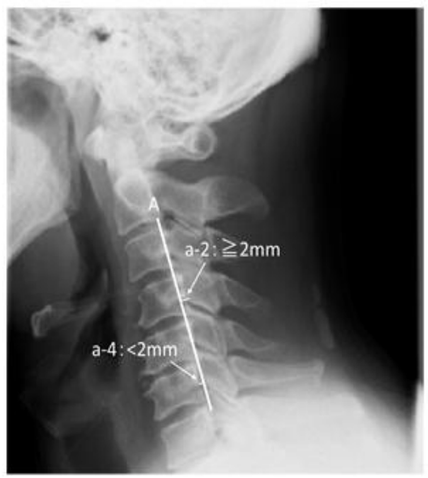



**a: Borden's Method**
**c: C2-7 Cobb**
**b: Ishihara Method**
**d: ARA**

Figure 2


**a**


**b**

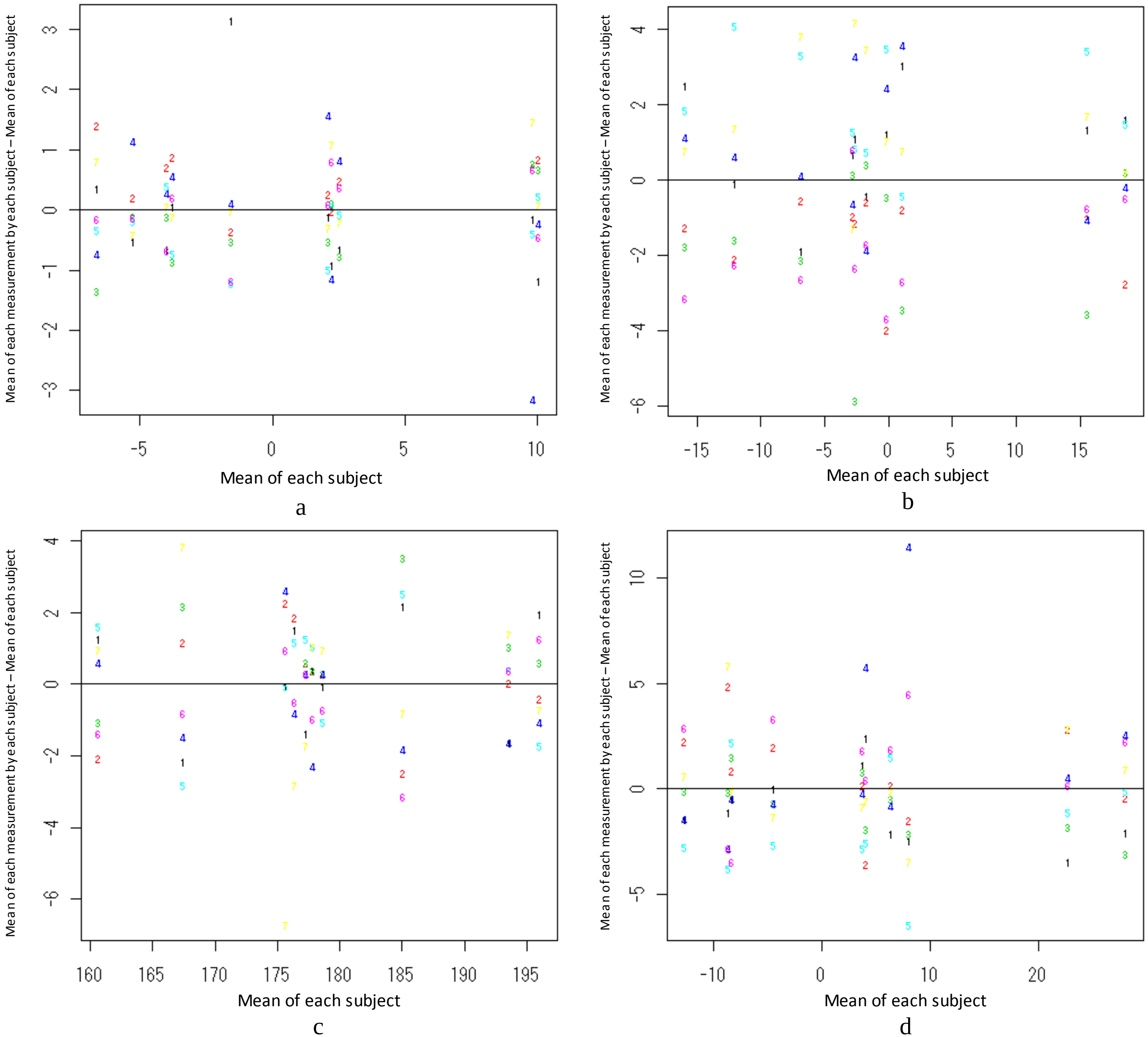



**c**


**d**

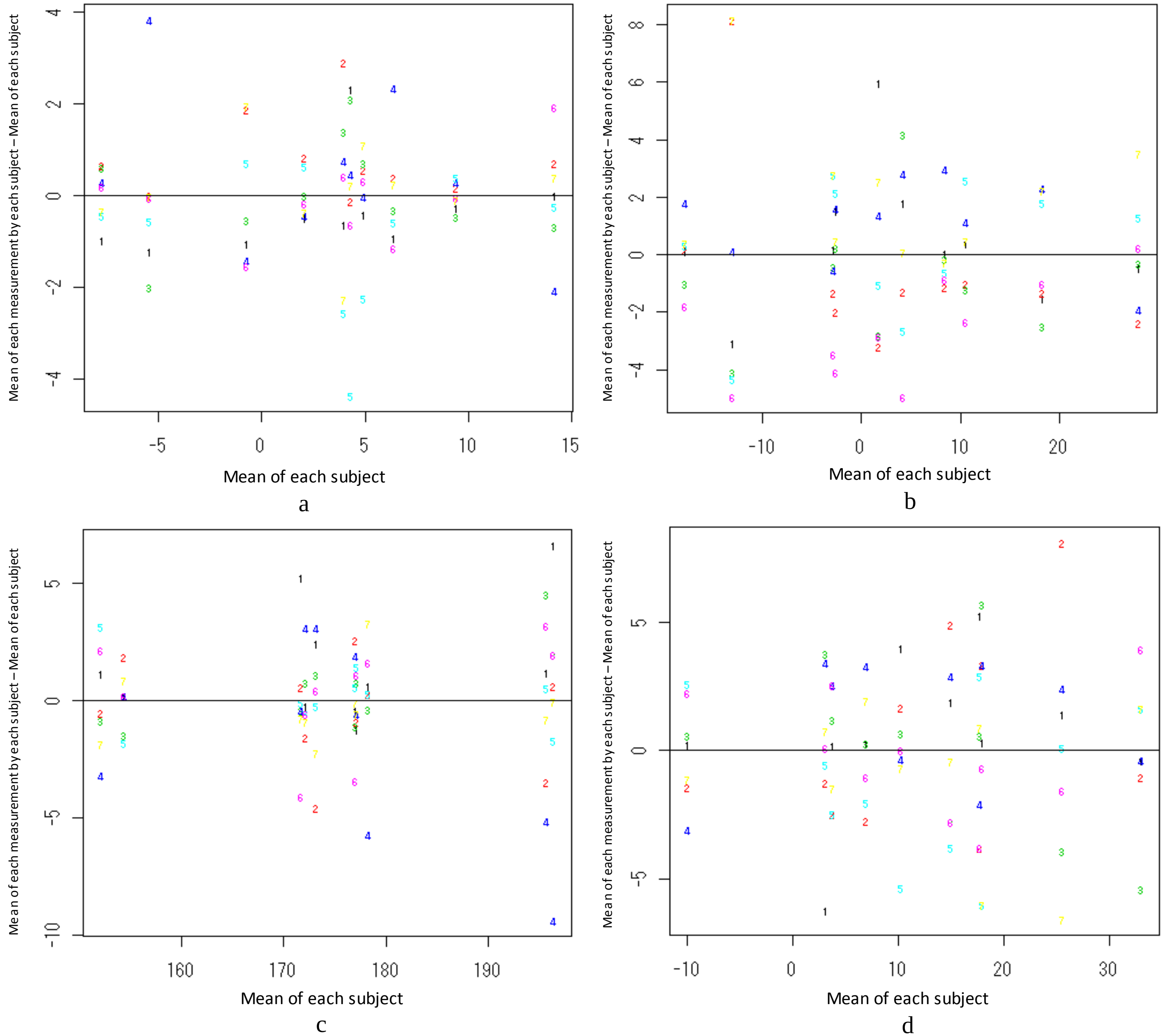
**a: Lordosis** **b: Straight**
**c: Sigmoid** **d: Kyphosis**

Figure 3




**a: Borden's Method  b: Ishihara Method  c: C2-7 Cobb  d: ARA**

# Figure 4A




**a: Borden's Method b: Ishihara Method c: C2-7 Cobb d: ARA**

# Figure 4B