IX. Reliability/Repeatability of Radiographic Positioning

RECOMMENDATION

Radiographic patient positioning procedures for spinal and lower extremity x-rays has been subjected to a large volume of inter and intra examiner reliability studies. The majority of these studies have found that an examiner(s) positioning of a patient is in the excellent reliability range and is not influenced by different examiners on the initial versus repeat radiographic study. However, the initial and follow-up radiographic positioning procedure should be clearly stipulated and followed. When a systematic procedure for radiographic positioning is followed, patient positioning does not cause significant errors and can be readily used for the clinical evaluation of spinal subluxation by chiropractic clinicians.

<u>Supporting Evidence</u>: Reliability Studies Class 1 and 2.

<u>PCCRP Evidence Grade</u>: Reliability Studies = a and b.

Introduction

In previous sections of this document, it was referenced that a sub-group of DACBRs and academics have made considerable assertions that x-ray analysis in clinical chiropractic practice is unreliable, invalid, and should not be routinely used to determine specific spinal treatment interventions.[1-10] In this current section, we will investigate two more such claims promulgated by these groups:[1-10]

1. Radiographic positioning is not repeatable,
2. Variations in x-ray positioning simulate subluxation or correction.

The repeatability of x-ray positioning procedures is an important topic to understand as it relates to the ability to measure the 6 types of spinal subluxations (see Section V) and their response to chiropractic treatment interventions. The debate regarding radiographic positioning procedures is not unique to chiropractic. In terms of scoliosis evaluation on the AP full spine radiograph, Capasso et al[11] discussed 4 groups of 'theoretical grounds' that may cause errors in the measurement of thoracic scoliosis:

A. Errors in taking a radiograph,
B. Errors intrinsic to the measurement method,
C. Errors due to anatomical deformity of the vertebra,
D. Observer errors in the measurement technique.

We note that B and D above were comprehensively reviewed in Section VIII. Capasso et al[11] presented some available data on full spine positioning errors and consequent scoliosis measurement effects and offered solutions to minimize these; including a precise, supervised positioning protocol. We provide a discussion of the references utilized by Cappaso et al[11] in Table 3 for thoroughness. However, the review by Cappaso et al[11] only applies to scoliosis evaluation.

In addition to reviewing the literature on x-ray positioning reliability of scoliosis deformities, the current expert panel provides an exhaustive literature review of each radiographic spinal view. Our literature search identified 57 separate studies that have evaluated the test retest reliability of radiographic positioning procedures utilizing multiple examiners, exposures, and subjects.[12-68]

The literature presented below[12-68] is in strong opposition to the opinions professed by several authors in the chiropractic literature.[1-10] In the chiropractic literature, multiple articles and/or textbooks were identified, where the opinion was presented that Chiropractic and general x-ray procedures are not reproducible to the extent needed for identification of subluxation correction.[1-10] Problematically, none of these sources[1-10] present data on the test retest reliability of x-ray positioning procedures. These sources[1-10] either offered Class V (expert opinion) evidence as support for the non reproducibility of x-ray positioning or they referenced another source which offered its' author(s) Class V evidence with no supporting data.

For an example of this Class V referencing, Peterson and Hsu[4] state, *"Patient positioning also impacts on spinal curve analysis, particularly in the cervical spine where slight alterations in flexion or extension of the head can significantly change the cervical curve.[4,5]"* Surprisingly, when one looks at Peterson and Hsu's[4] reference citations, it is found that neither of these sources present any original data on the topic of the reliability of x-ray positioning procedures.

While the topic of postural effects on the cervical curve is important to delineate, to offer generalized criticisms without data, indicates the intent of the authors is to invalidate chiropractic radiographic assessment of subluxation instead of to improve upon it or understand it. In contrast, there are two sources that have quantified the effect that slight head extension has on the cervical curvature of subjects with an initial neutral lateral cervical radiograph.[69,70] These two studies,[69,70] have found the average increased extension angle of the skull on a post-x-ray has a net increase in cervical lordosis of one half the skull extension value. In other words, a 10° skull extension on the post treatment intervention x-ray will increase the cervical lordosis by 5°.[69,70]

To compile our comprehensive review, we performed literature searches in Index Medicus, CINAHL, and Mantis locating radiographic positioning repeatability studies from different fields in healthcare. Of interest, besides MDs and DCs interest in radiographic positioning, Orthodontists, have studied head and lateral cervical radiographic positioning.

While MDs and DCs are interested in spinal alignment, segmental instability, scoliosis, thoracic kyphosis deformity, etc., Orthodontists are interested in the alignment of the skull bones and cervical vertebrae before and after (1) braces have moved teeth to new positions in the jaw and (2) the TMJ is aligned with orthotic devices inside the mouth.

It is the PCCRP panels position that these 57 reliability studies,[12-68] with data on radiographic positioning, supersedes the popular Class V evidence provided by the sub-group of DACBRs and academics on this topic.[1-10]

The organization of this section will be presented into tables of different regions. Tables 1-6 separate these 57 radiographic repeatability studies into 1) radiographic repeatability of the head and AP cervical views, (2) radiographic repeatability of the lateral cervical view, (3) radiographic repeatability of the thoracic spine, (4) radiographic repeatability of the lumbar spine, (5) radiographic repeatability of the pelvic region, and (6) radiographic repeatability of full spine views.

Besides being systematic, the arrangement of this data into tables of different regions will enable the interested reader to find studies for his/her specific interest. Especially, the ease of locating certain studies will save time and effort for clinicians and researchers.

Table 1. X-Ray Positioning of the Head Region (n=15).

Author, Year	Radiographic View	Findings
Cooke & Wei, 1988	217 laterals of 12 yr olds	Reproducibility: same-day repeat radiographs recorded with ear posts & with a mirror (after 4-10 minutes and 1-2 hours) = 1.9°.
Cooke 1990	Lateral: 30 lateral cervical with 5 year study	Method error: 1.9° after 1-2 hours, 2.3° after 3-6 months, & 3° after 5 years. SD (SN/vertical angulation) was 2.6° after 1-2 hours, 3.2° after 3-6 months, & 4.2° after 5 years.
Cooke & Wei, 1991	Lateral: 32 re-measured & re-digitized	Measures with most landmarks in the mid-sagittal plane showed the least increase in percentage error. error % was found to be doubled, on measurements on the retaken radiographs.
Foster et al, 1981	9 lateral x-rays, minimum 2-weeks apart.	Mean Differences: 3°-4.8° for angular measurements. X-ray positioning errors were smaller the mean error of the measurement method used.
Houston et al, 1986	24 subjects 2 lateral x-rays each on same occasion	Analysis of variance showed small, inconsistent, non-statistically significant differences in several distances and angles on repeat lateral skull-cervical spine radiographs.
Huggare 1989	AP Cervical (2) & Photos, 1 week delay	Reproducibility: craniovertical angle was 1.2°, craniocervical angle 0.9°, & cervicohorizontal angle 1.5°
Kantor et al, 1993	54 pairs of cephalometric x-rays	No statistically significant changes in 2 cranial & 4 maxillary landmarks; results suggest that patient positioning is not a major contributor to the error of cephalometric methods.
Luyk et al, 1986	lateral cephalometric: 3 and 6 films were taken for each patient	Neutral Head Posture (NHP) was not as reproducible as has been suggested by others. Reasons were examined, & new proposals made concerning a rational approach to cephalometric radiographs.
Peng & Cooke, 1999	Lateral: 20 Chinese at 12 yrs & 27 yrs	Reproducibility: after 15 years = 2.2°, after 5-year = 3.0° & 5-10 minutes reproducibility = 1.9°. After 15 years variance of NHP (4.8°) remains significantly less than variance of intracranial reference planes to vertical (25°-36°). Cephalometric analyses based on natural head posture therefore remain valid over time.
Siersbaek-Nielsen & Solow, 1982	30 orthodontic patients, 2 occasions 1-35 days apart, 3 examiners	Error: whole group was 2.3° for head position in relation to true vertical (NSL/VER), 3.1° for cervical inclination (OPT/HOR), and 3.4° for craniocervical angulation (NSL/OPT).
Solow & Siersbaek-Nielsen, 1986	43 NHP Cephalometric films on two occasions; 2.7 years apart	Changes in the conventional measures of head posture—the craniovertical angles--during the observation period showed no associations with growth changes in craniofacial morphology and was stable over time.
Spolyar 1987	20 subjects, 2 laterals & PA Skull by different examiners	Error: 1.7mm mean error (0.5mm-6.2mm) for distances, 1.59° mean error (0°-5.23°) for angles, and 3/20 had no measurable change.
Tsang & Cooke, 1999	2 replicated sets of lateral cephalograms of 30 skulls	15 angular & 1 linear measurements were obtained from both methods; All, except one, cephalometric measurement showed significant differences between the two methods ($P < 0.0001$). Error: DigiGraph Workstation ranged from 7 to 70 per cent, while that of radiographic tracings was less than 2 per cent.
Tng et al, 1994	30 skulls, 2 films each	SD of Errors: skeletal angles 0.9-1.8°, except ANB was only 0.4° & dental angles ranged from 3.2-5.8°.
Zappa et al, 1993	2 sets of 30 radiographs	Difference in the measuring error of the system & in the angular errors at time points 0, 6, & 12 months could not be detected.

Table 2.
X-ray Positioning of the AP and Lateral Cervical (n=15).

Author, Year	Radiographic View	Findings
Armijo-Olivo et al, 2006	Lateral head & neck: 68 subjects, 2 x-rays	Self Balance Position compared to Frankfurt position: No changes related to gender and age were found.
Gore et al, 1987	205 subjects, 2 x-rays, 15 ± 5 yrs apart	Initial X-ray: 24° ± 14° & Follow up X-ray: 23° ± 13°. No statistically significant difference in the means.
Gore 2001	Lateral: 159 subjects, 10 yr follow-up	Means & SD of Cervical lordosis were the same: Pain is more likely to develop in persons with degenerative changes at C6-C7.
Harrison et al, 1994	Lateral: 35 control subjects, x-rays at 14 weeks apart	No statistically significant changes existed between pre- and post-tests for the control group except in C6-7 relative rotation angle.
Harrison et al, 2002	Lateral: 24 controls, x-ray at 8 months	No change in the pain VAS ratings & no statistically significant change in segmental or global radiographic alignment.
Harrison et al, 2003a	Lateral C, APC:	48 out of 50 measurements: differences between initial & follow-up radiographs are less than 1.° and 2 mm. Posture, radiographic positioning, and radiographic line drawing are highly reliable.
Harrison et al, 2003b	Lateral Cervical: 33 controls, x-rayed at 8.5 months	No change in VAS pain ratings & no statistical significant change in segmental or global cervical alignment (difference in all angle mean values < 1.3°).
Harrison et al, 2004	AP Cervical: 26 control subjects, x-rays 1 yr	No significant differences were found in the control group subjects' pain scores and AP radiographic measurements.
Hellsing et al, 1987	14 lateral x-rays, 8 months apart	No statistically significant differences were found for measurements of cervical spine curvature.
Huggare 1993	Lateral: 33 subjects, 2 cephalometric radiographs each	Reproducibility: craniovertical, craniocervical & cervicohorizontal relationships comparable with previous results with mirror method. Standing to a sitting position in the cephalostat without change in craniovertical, craniocervical or cervicohorizontal relationships.
Jackson et al, 2000	AP nasium & lateral; 38 subjects, 2 sets of x-rays within 4 hrs	ICCs = 0.94-0.98, error for upper angle and lower angles less than 1°, SEM ≈ 0.7° for lower angle.
Ordway et al, 1997	Lateral: 20 subjects, concurrent validity C-ROM device, 3Space & lateral x-ray	End-range sagittal cervical flexion, extension, protrusion, and retraction measured simultaneously with 3 devices. Protrusion and retraction can be measured reliably with all three methods studied, but without measurement consistency between devices.
Rochester & Owens, 1996	AP Nasium: 20 x-rays analyzed for the amount of y-axis rotation as artifact.	Validity study: atlas laterality = 0.2º± 0.3º from an error of 0.6º in head rotation positioning.
Sandham 1988	12 lateral cervical skull films taken 1 hour apart.	Six different measures of cervical spine and head position. No statistically significant differences were noted among any of the variables between the 1^{st} and repeat lateral cervical radiograph.
Shrout et al, 1993	Lateral: 61 subjects, 19 re-x-rayed at 0, 6, 12, 18, & 24 months.	Angular alignment error was less than 2 degrees total angular error (1.3-2.4 degrees, 95% confidence intervals).

Table 3.
X-Ray Positioning of the Thoracic Region, AP Full Spine, & Lateral Thoracic (n=10).

Author, Year	Radiographic View	Findings
Bunnel et al, 1988	Review article on AP Full spine scoliosis deformities.	Class V (opinion) evidence that radiographic positioning affects the magnitude of scoliosis curve values. No supporting data.
Capasso et al, 1992	Review article on AP Full spine scoliosis deformities. References Bunnel et al, Dawson et al, Swevastikoglou et al, Oda et al	Stated, 'Small positional changes of the patient may result in significant errors in curve evaluation. A standard AP free-standing view may show a difference of up to 17° when compared with a radiograph taken with a special device.'
Dawson et al, 1978	60 scoliosis subjects, AP full spine vs. scoliosis chariot (SC), same day. 14 subjects had 2, 5 minute repeated SC views.	Average differences in Cobb angle between the AP full spine and SC view of 3.4°-7.5° (increased as curve magnitude increased). Difference in 2 repeated SC views: All measured curves were within ± 3°. Authors concluded that SC views for scoliosis were more repeatable. However, repeated AP full spine views were not performed.
Desmet et al, 1982	78 scoliosis subjects, AP full spine vs. PA full spine views, 5-15 minutes apart.	Strong correlation between curve measures on AP vs. PA full spine films, r = .960. PA view had mean increased curves: 1.71°. In 5/128 curves a 9°-13° increase on PA, 19/128 curves 6°-8° increase on PA, in 4/128 curves a 6°-8° decrease on PA film. Difference is due to projection of endplates on PA vs. AP films.
Kohlmaier et al, 1995	AP FS: 100 subjects, 2 x-rays, neutral & positioning device	Balance-like positioning device can standardize spine X-rays when the patient is standing, providing better reproducibility, more accurate prognostic aspects and fewer ionizing hazards.
Milne & Williamson, 1983	261 repeated Lateral thoracic x-rays, 5 years apart	No statically significant differences in radiographic measurement of thoracic kyphosis at average 5 year follow-up.
Pruijs et al, 1994	PA full spine, 10 scoliosis subjects, 3 x-rays each. Cobb on each film. Note: this is one of the only studies to take repeat AP/PA full spine films in vivo in the same manner & view with no device.	Difference 1 and 2: -0.6° ± 2.6°, standard error 1.9°, correlation=.99 Difference 2 and 3: 0.0° ± 3.5°, standard error 1.2°, correlation=.98 Difference 1 and 3: 0.6° ± 3.2°, standard error 1.1°, correlation=.98 Whole group 1,2,3: standard error = 2.2°. "Apparently, subjects with established spinal deformity assume a more or less similar position each time they are subjected to x-ray examination."
Sevastikoglou et al, 1969	2 Scoliosis skeletons, 17 views: neutral, rotation up to 10° left and right and 5 cm elevation or depression of tube height. 2 examiners, Cobb & Ferguson.	Little effect of rotation up to 10° and alteration in tube height by 5 cm on curve magnitudes. Differences in curve measurements hardly surpassed the error of the measurement techniques themselves. Average error for specimen 1 had the largest values: 1.15° ± 0.98° for Ferguson's method and 2.06° ± 1.09° for Cobb's method. This was misrepresented by Capasso et al.[11]
Singer et al,	Lateral: 22 cases with films in vivo, & post-mortem films	In vivo & in vitro measurements strongly correlated (Cobb angle r = 0.95, curvature r = 0.78). Trends decreased in Cobb angle (1.3%, -2.6%) & increased slightly in curvature (10.7 mm, 4.1%).
Stagnara at al, 1982	Lateral: subjects at 5 yrs & 10 yrs	X-ray measurements of kyphosis and lordosis are constant to within a few degrees provided the position is clearly stipulated.

Table 4.
X-Ray Positioning of the Lumbar Region (n=5).

Author, Year	Radiographic View	Findings
Harrison et al, 2002	Lateral: 30 controls, x-ray follow-up 9 months	Pain scales and radiographic measurements did not change in the control subjects.
Harrison et al, 2003	Lateral Lumbar & APL: 6 control groups, x-rayed at 11 months	48 out of 50 measurements: differences between initial & follow-up radiographs are less than 1.° and 2 mm. Posture, radiographic positioning, and radiographic line drawing are highly reliable.
Harrison et al, 2005	APL: 23 controls, follow-up x-ray at 37.5 weeks	No significant radiographic and NRS differences were found, except in trunk-list displacement of T12 to S1, worsened 2.4 mm.
Saraste et al, 1985	Lateral: 125 subjects, recumbent & standing x-rays	Differences between radiographs of spondylolytic patients in recumbent & standing positions were analyzed with respect to vertebral slipping and lumbo-sacral lordosis. Only minor projectional & inter-observer measurement errors in variables describing vertebral size and lumbo-sacral lordosis.
Stagnara at al, 1982	Lateral: subjects at 5 yrs & 10 yrs	X-ray measurements of kyphosis and lordosis are remarkably constant to within a few degrees provided the position is clearly stipulated.

Table 5.
X-Ray Positioning of the Pelvic Region (n=7).

Author, Year	Radiographic View	Findings
Beal 1950	AP Pelvis, 5 subjects, 3 x-rays by 3 different examiners	Femur head height differences:1-3mm Rotation of pubic symphysis relative to midline: 3mm-11mm.
Clark 1972	AP Femur/Pelvis, 1 examiner, 50 subjects, repeated x-ray with a lift in and multiple x-rays of a skeleton with 15 degrees of rotation and 5 cm of tube height changes.	AP Femur head height differences did not vary more than ± 3mm of the known short leg discrepancy of 20mm on repeated x-rays of the skeleton. Repeat femur head x-rays of the subjects with the lifts in were accurate within ± 3mm using the original determination of the short leg measurement. Thus, positioning of the subject did not result in significant error and rotation up to 15 degrees and tube elevation up to 2.5 cm does not affect the measured displacement with this x-ray technique.
Friberg et al, 1985	AP Pelvis, 20 subjects, 2 x-rays, 1-30 months apart.	Mean femur head height difference: 0.6mm with a range from 0mm-2mm.
Friberg 1987	AP Pelvis, 105 subjects, 2 x-rays, 3 weeks- 3 years apart	Mean differences: anatomical leg length 0.7mm. In 46/105 repeat films pelvic rotation about gravity was measured. Mean differences: 0.9° (range 0°-3°) ± 0.8°.
Giles & Taylor, 1981	AP Pelvis, 12 subjects, 2 x-rays same day,	On repeated pelvic x-rays with the 'correct amount of lift in place', the error between initial measures and repeated measures of leg length estimation was: 1.12mm ±.92mm.
Leppilahti et al, 1998	AP Pelvis, 15 subjects, 2 x-rays, same occasion	Leg length inequality on repeat films: 1mm (0-2mm range) ± 0.8mm. Correlation coefficient on repeat films = 0.96.
Plaugher et al, 1993	AP: 37 Subjects re x-ray: 20 at 1hr and 17at 18 days later	Subject can be reliably positioned for repeat antero-posterior pelvic radiography for both 1 hr and 18-day intervals.

Table 6.
X-Ray Positioning of the Full Spine (n=8).

Author, Year	Radiographic View	Findings
Beck & Killus 1973	Lateral full spine statistical model of healthy subjects	"…several X-rays of the same individuals furnished reproducible results, even though they were taken years apart."
Faro et al, 2004	Lateral: 50 patients in 2 different standing positions.	Fists on clavicles position has less negative shift in SVA, and in surgery patients less compensatory posterior rotation of the pelvis. This position is more representative of a patient's functional balance while still allowing adequate lateral radiographic visualization of the spine.
Horton et al, 2005	Lateral: 25 patients in 3 different standing positions	Regional measures do not differ in the three positions, but global balance is anterior with 60° arm/shoulder position. Clinically, clavicle position may result in more accurate radiographic measures & may minimize repeated radiograph exposures.
Jackson et al, 2000	Lateral: 20 volunteers & 20 patients, 2 standing lateral radiographs, 66 months and 2 weeks apart, respectively.	Small variation in the thoracic kyphosis from T1-T12 was found between the 1st and follow-up x-ray with ranked correlation coefficients of r = 0.81 for volunteers and r = 0.79 for patients. Lumbar lordosis: ranked correlation coefficients of 0.93-0.96 for both patients and volunteers.
Jackson & Hales, 2000	Lateral: 30 volunteers had 2nd radiograph 5- 6 years later.	Measurement with least change was for pelvic morphology (PR-S1 angle); then length of the pelvic radius, pelvic alignment over the hips (pelvic angle), & total lumbo-pelvic (PR-T12) & lumbosacral (T12-S1) lordosis. Other longitudinal measurements, including those for thoracic kyphosis and spinal balance by a plumb line, showed slightly greater change.
Marks et al, 2003	Lateral: 15 subjects, 4 standing positions varying shoulder & knee flexion & over ground walking	Measurement of sagittal vertical axis on shoulders flexed positions results in a sagittal vertical axis that is at least 3 to 4 cm more posterior than a sagittal vertical axis observed during a functional position. Subject repositioning resulted in an inter-trial variability of at least 0.8 cm in sagittal vertical axis, while variation as the subject held each standing posture had little contribution to overall error of measurement. Of the 4 positions, shoulder flexion (45 degrees) alone was the best position for a lateral radiograph due to minimal compromise to repeatability of sagittal vertical axis.
Van Royen et al, 1998	Lateral: one patient total ankylosis virtual SVA was constructed in 7 standing postures	X-ray with video analysis: results of the study showed that SVA translations during standing radiographic analysis in a patient with a fixed spine depend on small changes in the hip, knee, and ankle joints.
Vedantam et al, 2000	Lateral: 40 patients with & 40 without a previous spinal fusion, 2 positions	1st radiograph with patient's arms raised horizontally forward at 90° flexion, & 2nd with arms raised horizontally forward at 30° flexion at shoulder. No statistically significant difference in segmental and regional sagittal alignments. Patients had negative shift of SVA with 90° arm position.

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Head Region

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Lateral Cervical

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AP/PA Thoracic or Full Spine AP/PA View

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