A Comparison of Methods of Evaluating Cervical Range of Motion

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Abstract

Objective: To determine whether there are differences in results when evaluating cervical range of motion (ROM) with radiographic analysis, a bubble goniometer, and a dual inclinometer and whether particular physical parameters are related to cervical ROM.

Methods: We evaluated the cervical ROM of 115 volunteers with each of the 3 clinical methods. Tape measurements of neck girth, distance from chin to sternal notch, and distances from ears to acromion were also recorded, along with sex and age. Interrater and intrarater reliabilities were determined, and the Pearson product moment correlation test and *t* test were performed on all data.

Results: Cervical ROM as determined by radiographic analysis was greater than that obtained with either a dual inclinometer or a bubble goniometer. All tape measurements were weakly correlated with all 3 means of cervical ROM evaluation, with the exception of the measurement of ear lobes to acromion, which did not correlate with radiographic analysis. There were also differences found in cervical ROM by sex and by age, with female subjects and younger subjects having a greater ROM.

Conclusion: Compared with a dual inclinometer and a bubble goniometer, radiographic analysis provides a more accurate evaluation of cervical ROM. (J Manipulative Physiol Ther 2002;25:154-60)

Key Indexing Terms: *Range of Motion (ROM); Radiography; Inclinometry; Cervical Spine*

Introduction

Chiropractors and health care providers as a whole should evaluate the range of motion (ROM) of the cervical spine as a basic physical examination parameter[1] to assign impairment ratings and discern other diagnostic information. Several methods of determining the cervical flexion-extension ROM are available to the practitioner. This investigation was undertaken to compare the results of 3 different methods of assessing the ROM of the cervical spine and to determine whether certain physical parameters, such as neck length and girth, are related to cervical ROM. Additionally, the relationship of age and sex on cervical ROM was evaluated.

Each of the 3 methods (bubble gonimeter, dual inclinometer, and radiographs) used in this study is currently used in clinical settings.[2] The dual inclinometer is the method recommended in the American Medical Association's *Guides to the Evaluation of Permanent Impairment*[3] and is often considered the clinical standard for cervical ROM.[1,4] Both interrater and intrarater reliability studies have shown the inclinometry method to be reliable.[2,4-6] Others dispute this conclusion and contend that the inclinometer method is flawed and should not be used in clinical settings.[7-9] Use of the dual inclinometer requires accurate identification of anatomic landmarks, as does the use of the bubble gonimeter, which is an inexpensive and relatively easy-to-use assessment tool. Neither the dual inclinometer nor the bubble gonimeter uses ionizing radiation exposure.

However, radiographic evaluation has long been considered the "gold standard" for studying cervical ROM.[10-12] Any other method of mensuration must measure up to radiographic methods. One of the approaches used to determine the flexion-extension ROM of the cervical spine radiographically is summation of intersegmental angles formed by motion of vertebrae. A number of techniques have been developed to do this assessment.[13-15]

Many have studied the methods of mensuration of cervical ROM and compared them to radiographic studies, and some have shown that gravity-based inclinometry with ROM devices, inclinometers, and computer-assisted devices

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Table 1. *Summary of results of background articles*

First author	Device(s)	Results
Alaranta	Inclinometers; tape measure	Spinal flexibility study. Interobserver reliability of inclinometer and tape measure was good.
Braun	CROM; pen and paper indices	Valid indicators of cervical or stomatognathic status.
Capvano-Pucci	CROM	Acceptable intratester and intertester reliability.
Chen	3 surface inclinometers	Intraexaminer and interexaminer reliabilities varied greatly, limiting clinical usefulness.
Chibnall	Tape measure	End ROM values significantly correlated with body size.
Dimnet	Cineradiography	Reasonable basis for further evaluation of method.
Dvorak	Radiographs with computer assistance; clinical evaluations	Radiographs of clinical value for flexion/extension.
Hsieh	Tape measure	Tape measuring is a reliable means to assess neck ROM.
Kuhlman	Gravity goniometer	Younger (20-30 years) had greater motion than older (70-90 years). Women had greater ROM than men.
Lantz	Dual inclinometer; CA-6000	Good validity and reliability.
Lind	Radiographs with digitizing tablet and computer	Good reproducibility.
Mayer	Digital inclinometer; radiographs	Good correlation.
Nilsson	Strap-on goniometer	Acceptable intraexaminer reliability; less than acceptable interexaminer reliability.
Ordway	CROM; 3-Space; radiographs	For flexion/extension, no significant difference between CROM and radiographs, nor between 3-Space and radiographs. CROM and 3-Space did differ significantly.
Penning	Radiographs	Method paper.
Samo	3 surface inclinometers; radiographs	Poor validity of surface methods compared to radiographs for lumbar sagittal motion.
Sullivan	Inclinometer	Statistically significant differences in lumbar flexion, extension, and total sagittal ROM between men/women and decline in ROM with age.
Tousignant	CROM; radiographs	CROM valid for flexion/extension.
Wing	Stereophotography; standard clinical examination	Stereophotography is an accurate way to study spinal profile.
Youdas	CROM; a universal goniometer; visual examination	Good to high intraexaminer reliability with CROM or universal goniometer. CROM most reliable interexaminer. Poor to fair interexaminer reliability with visual exam and with universal goniometer.

CROM, cervical range of motion device.

has been accurate, reliable, and has correlated well with radiographic ROM studies.[1,4,5,16]

However, some studies have neglected the contribution of the occiput/atlas motion or the contribution of the thoracic spinal movement to the overall cervical ROM in the sagittal plane.[7,17] Two studies[1,4] compared cervical radiographic ROM mensuration to external inclinometry with the CROM device (Performance Attainment Associates, Roseville, Minn) and an internally referenced ROM device, the 3-Space (Polhemus, Colchester, Vt). Ordway et al[4] account for the contribution of the thoracic spinal movement to the cervical motion. They compared the CROM device to cervical ROM radiographic measurement that included the thoracic involvement and found good correlation. Similarly, they compared the internally referenced device, 3-Space, with radiographic mensuration that excluded the thoracic contribution, and the 2 methods appeared to correlate well. With the use of the CROM device method, thoracic motion was not excluded, and this contributed about 20° to the cervical ROM. Mayer et al[1] found good correlation between inclinometry measurements of the cervical spine and radiographic technique.

Physical parameters related to neck size, such as girth of neck, distances from ear lobes to acromion, and distance from chin to sternal notch may logically be related to ROM. However, little research has been done on the relationship of body size or neck size to ROM. Chibnall et al[18] states that without taking body size into account, linear measurement may underestimate or overestimate ROM. In the study by Chibnall et al,[18] cervical circumference was not accounted for. However, Pearl and Mayer[19] did study cervical ROM and compared their findings with radiographs and cineradiography but found no correlation between neck size and ROM. Several studies have determined that age,[8,10,20,21] sex,[8,20,21] degenerative changes,[11,20] and diurnal changes[22] can affect the motion of the spine. Mayer et al[1] had different findings regarding the effect of age and limited agreement regarding the effect of gender on ROM. The results of background articles are summarized in Table 1.

Methods

Students, faculty, staff and other affiliates of Texas Chiropractic College were asked to participate in this study. Those who indicated interest completed an information sheet that included their ages and a brief history of cervical trauma. No one was excluded on the basis of past trauma; those who had recent exposure to ionizing radiation often elected not to participate. All who became subjects signed informed consent forms and were provided with copies. All procedures used were in accordance with the ethical standards of the college's Human Rights in Research Committee. Evaluations of cervical ROM were performed between 4:30 PM and 6:30 PM on the campus of Texas Chiropractic College. On the day of evaluation, female subjects completed a consent form for radiography. No women who were pregnant or suspected of being pregnant participated. A total of 115 subjects, aged 21 to 64 years, were evaluated. Ten men were excluded from radiographic comparisons only because of tissue density obscuring the image of C7. No one else who wished to participate was excluded. Age and sex of subjects are presented in Table 1.

A single examiner, certified as an impairment and disability evaluator, determined cervical ROM in the sagittal plane through full active flexion and extension for all subjects, by using an electronic digital dual inclinometer. Protocol was according to the *Guides to the Evaluation of Permanent Impairment*.[3]

Each subject was seated in a chair, with the back straight and eyes looking straight ahead and parallel to the floor. The knees were flexed at 90 degrees, with feet flat on the floor. Before the mensuration took place, the subject was instructed verbally to retract the chin and flex the neck forward as far as possible and then protract the chin and extend the neck as far as possible. After the landmarks were identified and marked by a black marker on the skin, the main sensor or "master" inclinometer was placed on the vertex of the subject's head in the sagittal plane, and the "slave" inclinometer was placed at 1 inch lateral to the midline of the C7-T1 spinous process. The readings were recorded on a laptop computer with JTech software, version 4.4 (JTech Medical Industries, Heber City, Utah) at the end ROM. After each flexion and extension, the inclinometers were reset. Three trials were completed on each subject.[3]

After the mensuration by the digital inclinometers, each subject was measured by bubble goniometer. The bubble goniometer was placed on the same landmarks, and each subject was instructed to flex and extend the head in the same manner as that for measurement with the dual inclinometer. The readings were recorded manually and repeated 3 times. Again, the bubble inclinometer was reset after each flexion and extension.

Tape measurements of the cervical circumference, the distance from the inferior aspect of the earlobe to the acromion bilaterally, and the distance from the inferior aspect of the chin to the sternal notch were taken. All tape measurements were recorded in centimeters.

All of the above measurements (tape and ROM) were repeated for 30 subjects 1 week after initial measurements to determine intrarater reliability. One trained, certified practitioner took all measurements with the dual inclinometer, bubble goniometer, and tape measure.

Radiographic studies of the cervical spine included active maximum flexion and extension taken at a focal film distance of 72 inches as the subject stood in an upright posture. Each subject was instructed to keep the mouth closed during the radiographic examination. For flexion radiographs, each subject was instructed to first tuck the chin to the chest and then to flex the remainder of the cervical spine to the point of maximum flexion. For extension radiographs, each subject was instructed to first extend the chin upward and to follow by maximum extension of the remainder of the cervical spine. A Bennett HFQ-300 high-frequency 100-kHz resonant generator 15 kW/125 kVp "Hundred Series" x-ray unit was used for this project. All radiographs were taken by the same qualified, practicing diplomate of the American Chiropractic Board of Radiology.

The 2 methods of radiographic mensuration used in this project were the Penning method[15] of radiographic analysis and the Method of Bull.[23]

The Penning method requires that a smaller film with the spine in maximum extension cover a larger film with the cervical spine in maximum flexion. The C7 vertebral body and the spinous processes of both radiographs are superimposed, and a line is drawn along one edge of the smaller overlying film on the larger underlying film. The same process is repeated for C6 and each superjacent vertebral segment. The angle that is formed between the first 2 lines (eg, movement between C7 and C6) determines the ROM between the 2 contiguous vertebral segments. The summation of these angles totals the overall cervical ROM, C1-C7.

The Method of Bull incorporates 2 lines of mensuration. "Chamberlain's line" is drawn from the posterior aspect of the hard palate to the opisthion. The "atlas plane" line is drawn from the mid portion of the anterior tubercle to the mid portion of the posterior tubercle of C1. The intersection of these 2 lines forms an angle representative of the degree of flexion or extension between the occiput and C1. This angle was added to the sum of angles determined with the Penning method to discern overall cervical ROM. In the 33 instances of paradoxical motion that were observed about the occiput and C1, the angle formed during extension was subtracted from the angle formed during flexion.

Intrarater reliability was established by each of the radiographic ROM evaluators (one was the certified radiologist investigator, and the other was trained by the radiologist), each repeating the evaluation for 30 subjects. Interrater reliability was also determined for the 2 radiograph evaluators.

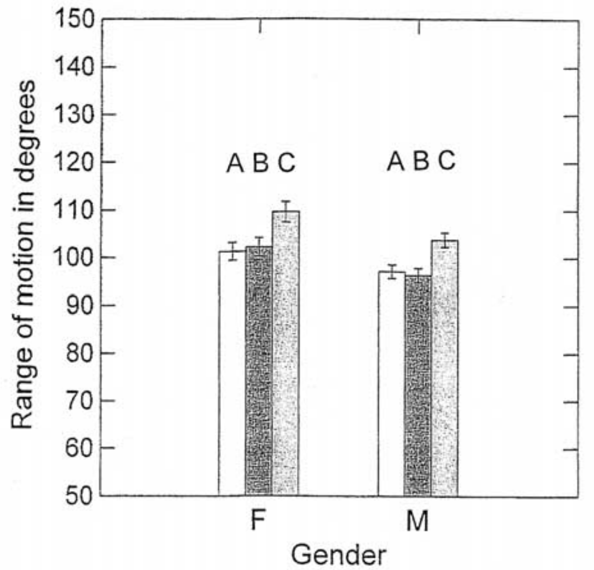

Fig 1. *ROM by sex.* A, *Dual inclinometry;* B, *bubble inclinometry;* C, *radiography.*

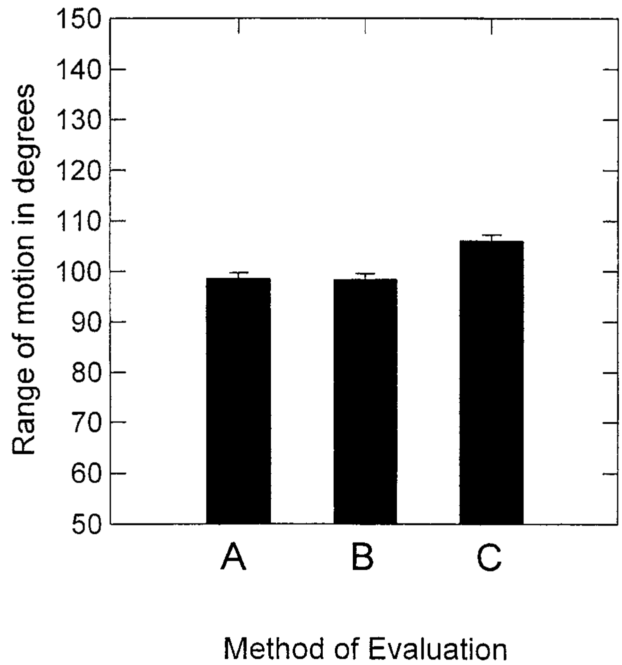

Fig 2. *ROM of all subjects.* A, *Dual inclinometry;* B, *bubble inclinometry;* C, *radiography.*

Table 2. *Subject demographics*

Age	Men	Women
20s	39*	15
30s	21	14
40s	6†	8
50s	—	1
60s	—	1
Total	66	39

*Seven subjects were not included in radiographic results because of dense tissue obscuring C7.

†Three subjects were not included in radiographic results because of dense tissue obscuring C7.

Statistical analysis was performed with Systat 8.0 (SPSS, Chicago, Ill). Analysis included the appropriate Pearson product moment correlation and *t* tests. The level of significance used throughout this study, except correlations with *P* values provided in the text, was $P = .01$.

Results

There were no significant differences in any of the intrarater or interrater reliability studies performed (Table 2), nor was any difference found for subject positional differences with inclinometry.

Considering all subjects in this study, the cervical ROM was greater for women than for men (Fig 1) with each of the 3 methods of evaluation, and ROM was greater for people in their 20s than for those >29 years of age.

Again, considering all subjects in this study, of the 3 methods of evaluating cervical ROM, there was a significant difference ($P = .01$) between the paired *t*-test results of radiographs and each of the other 2 methods. However, there was no significant difference in results between the dual inclinometer and the bubble goniometer (Fig 2 and Table 3).

The relationship between 2 variables may be described by using correlation. A correlation absolute value from 0.00 to 0.25 indicates no relationship or very little relationship between the 2 variables. A correlation value between 0.25 to 0.50 suggests a fair relationship, and values from 0.50 to 0.75 point to a good relationship between the 2 variables. A correlation absolute value of 0.75 or greater suggests a good or even excellent relationship between the 2 variables.[24]

The Pearson product moment correlations were fair (.25 to .50)[24] between each of the tape measurements taken and the ROM determined by either the dual inclinometer or the bubble goniometer (Table 4). There was no correlation (0 to .25) between the measurements from the inferior aspect of the ear lobes to acromion and the radiographic ROM results. There was fair correlation (.25 to .50) between measurements of both neck girth ($P = .399$) and inferior aspect of the chin to sternal notch ($P = .281$) and radiographic results (Table 5). All correlations of neck girth and ROM were negative values, indicating an inverse relationship ($P = -.435$ with bubble goniometer, $-.407$ with dual inclinometer and $-.399$ with radiography).

Considering the sexes separately, paired *t* tests indicated there was a significant difference ($P = .01$) in the ROM results between radiography and dual inclinometry, and there was a significant difference ($P = .01$) in results between radiography and use of bubble goniometry. There

Table 3. *Intrarater reliability*

Method	Trial 1	Trial 2
Bubble goniometry* (n = 36)	99.944 ± 10.990	99.537 ± 9.488
Digital inclinometer* (n = 36)	98.352 ± 10.146	98.157 ± 8.802
Radiographs - evaluator 1* (n = 30)	109.600 ± 13.983	108.850 ± 13.655
Radiographs - evaluator 2* (n = 30)	100.683 ± 12.088	100.817 ± 12.394
Neck girth† (n = 36)	37.425 ± 3.969	37.069 ± 4.177
Chin-sternal‡ (n = 36)	12.578 ± 1.584	12.659 ± 1.589
Left ear-acromion§ (n = 36)	20.619 ± 1.791	20.681 ± 1.809
Right ear-acromion§ (n = 36)	20.428 ± 2.157	20.597 ± 2.188

*Mean ROM in degrees ± SD.
†Mean (cm) ± SD.
‡Mean notch distance ± SD.
§Distance (cm) ± SD.

Table 4. *Mean ROM for the 3 methods*

Method	Mean ROM
Bubble goniometer	98.319 ± 12.891
Dual inclinometer	98.525 ± 12.259
Radiographs	106.010 ± 12.797

Mean is expressed in degrees ± SD.

Table 5. *Pearson product moment correlations*

	Bubble goniometer	Dual inclinometer	Radiograph
Neck girth	−0.435	−0.407	−0.399
Chin to sternal notch distance	0.312	0.354	0.281
Average distance from earlobe to acromion	0.293	0.347	0.149

was no significant difference in results with the dual inclinometer versus the bubble goniometer for either men or women.

In general, when age by decades was included in the groupings for each of the 3 methods of discerning cervical ROM, results indicated that ROM was greatest for both men and women in their 20s. With the dual inclinometry, the mean for men in their 20s was 100.725 and for women in their 20s was 104.933. With the bubble goniometer, the mean for men in their 20s was 100.384 and for women was 104.711. With the use of radiography, the mean cervical ROM for men in their 20s was 108.167 and for women was 117.167.

Cervical ROM for both men and women was less in their 30s. The mean cervical ROM determined by dual inclinometry for men in their 30s was 91.651 and for women was 102.786. With the bubble goniometry, mean cervical ROM for men in their 30s was 89.921 and for women was 104.048. Radiographs indicated a mean of 98.167 for men in their 30s and 111.071 for women in their 30s. Cervical ROM was least in the 40s (the 2 subjects over 49 were included in the 40s for statistical analyses). For subjects in their 40s, the mean cervical ROM with dual inclinometry was 91.222 for men and 95.750 for women. With bubble goniometry, the mean for men in their 40s was 90.259 and for women was 98.250. With the use of radiography, the mean cervical ROM for men in their 40s was 92.000 and for women was 99.813. However, not in all instances were the differences significant.

The use of the dual inclinometer to assess ROM showed that although men in their 20s (mean = 100.725) had significantly greater ROM than all those >29 years of age (mean = 91.522), there was only a trend for women in their 20s (mean = 104.933) to have greater ROM than all those >29 years of age (mean = 99.056). Results with the bubble goniometer indicated that men in their 20s had a greater ROM (mean = 100.384) than all those >29 years of age (mean = 90.022). With the bubble goniometer, results for female subjects did not indicate a greater ROM in the 20s (mean = 104.711) than in the 30s or older (mean = 100.736). Radiographic results indicated greater ROM for men and women in their 20s (mean = 108.167 and 117.167, respectively) than for men and women >29 years of age (mean = 96.625 and 104.917, respectively). Men in their 30s showed significantly less ROM than younger men with all 3 methods of determining ROM (dual inclinometer mean = 91.651, bubble goniometer mean = 89.921, radiography mean = 98.167).

The use of radiographs showed significant differences between men in their 20s and women in their 20s, as well as between men in their 30s and women in their 30s, with the women in both age groups having greater cervical ROM. This difference was also demonstrated between men and women in their 30s with the use of the bubble goniometer. Radiography also showed that cervical ROM was significantly and progressively reduced for women with age; ROM was less for women in their 30s (mean = 111.071) than for those in their 20s (mean = 117.167) and less for women in their 40s (mean = 99.813) than for those in their 30s.

Although there was no significant difference in ROM between men in their 30s (dual inclinometry mean = 91.651, bubble goniometry mean = 89.921, radiography mean = 98.167) and men in their 40s (dual inclinometry mean = 91.222, bubble goniometry mean = 90.259, radiography mean = 92.000), there was significantly less ROM for men in their 30s than for men in their 20s (dual inclinometry mean = 100.725, bubble goniometry mean = 100.384, radiography mean = 108.167) according to results of all 3 methods of evaluation.

Discussion

The objective of this study was to determine whether there are differences in cervical ROM measured by 3 methods of mensuration based on different underlying mechanisms: bubble goniometry, dual inclinometry, and radiography. We also sought to determine whether certain physical parameters, including sex and age, had any relationship to cervical ROM. Many of the findings of this investigation are in agreement with those of previous investigators. Several investigators[4,15,18,19] have shown diminished ROM with age. This often-found age-related phenomenon is probably associated with the decreasing flexibility of cartilage that is attributed to the greater number of covalent cross-links in the collagen of older people[25] and the reduced tensile-strength of ligaments with age.[26]

The differences between men and women with regard to the age of development of this reduced flexibility, as indicated by radiography versus the inclinometer and the goniometer, may be explained by the greater sensitivity of the radiographic technique, with radiographs detecting changes at earlier ages. The greater ROM in women is also supported by Kuhlman,[18] Lind et al,[5] and Alaranta[19] and may be attributable to hormonal differences.

Results indicating no significant difference overall between the inclinometer and the bubble goniometer suggest they are equally reliable. Radiographic techniques providing significantly different results from either of the other 2 methods of evaluating range of motion may indicate its greater sensitivity.

Many previous studies have focused on interrater and intrarater reliability evaluations of a single method of discerning spinal ROM. Other studies, although comparing different methods or instruments, have not considered such diverse approaches as this study but have instead concentrated on comparisons of similar types of instrumentation. Of course, the identification of surface landmarks and positioning may contribute to discrepancies[1,2,4,7,12,14] between those methods (inclinometry and goniometry) that rely on such landmarks and methods that do not. However, if there is real need to accurately discern cervical ROM, then as few sources of discrepancy as possible should be incorporated into the evaluation. The use of radiography allows the practitioner to evaluate the actual extent to which the vertebrae can accommodate flexion and/or extension. However, radiography is invasive and has inherent risk factors. Therefore, the use of radiography to evaluate cervical ROM should be exercised in a judicious manner and used when very precise measurements are required.

The Pearson product moment correlations between the tape measurements and the 3 methods of evaluating ROM were fair or weak. Fair, inverse correlations between neck girth and each of the 3 methods of evaluating ROM (Table 4) may be indicative of a need for additional investigation.

The evaluations of cervical ROM by sex and age support radiography as more sensitive to differences than either the dual inclinometer or the bubble goniometer.

Conclusion

In circumstances in which there are no contraindications and in which accurate and reliable cervical ROM evaluation is needed, radiographic evaluation is the method of choice because of its greater sensitivity. In addition, women generally have greater cervical ROM than men, and younger people have a greater cervical ROM than older people. Furthermore, additional study of the relationship between tape measurements of physical parameters and cervical ROM is needed to discern the extent of the relationship(s) between them.

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