Is the Sagittal Configuration of the Cervical Spine Changed in Women With Chronic Whiplash Syndrome? A Comparative Computer-Assisted Radiographic Assessment

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Abstract

Objective: To reveal whether women with chronic whiplash-associated disorder (WAD) symptoms, grade I-II, demonstrate regional and/or segmental radiographic signs of altered cervical lordosis.

Design: Case-control study.

Setting: Radiography department at a university hospital.

Participants: Three age-balanced groups comprising 120 women. The case group included women with chronic whiplash syndrome (n = 41), and the control group included women with chronic insidious onset neck pain (n = 39) and an asymptomatic group (n = 40), who were given baseline data. The sample was referred from informed doctors and physiotherapists.

Intervention: The women sat in a standardized sitting position and radiographs were taken in a lateral position with fluoroscopic control for alignment.

Outcome Measures: Two distinct measurements were taken; 1 of the angles of the upper and lower cervical curvatures, respectively, and 1 of the angles between the inferior borders of each pair of vertebrae in the lower cervical spine. The 3 groups were compared on the ratio of the lower to upper cervical spine angles and on the mean angular values for each segment in the cervical spine.

Results: The whiplash group showed a decreased ratio between the lower versus upper cervical spine but comparisons between groups were not statistically significant. The whiplash group was in a significantly more flexed position at the C4-C5 level compared with the asymptomatic group ($P = .007$). The reliability measures have to be strengthened to render these results definitely conclusive.

Conclusion: The whiplash group exhibited a different configuration of cervical lordosis. This is clinically important and needs to be studied more closely. (J Manipulative Physiol Ther 2002;25:550-5)

Key Indexing Terms: *Cervical Vertebrae; Lordosis; Whiplash Injury; Neck Pain; Radiographs*

Introduction

Conflicting views exist about the clinical significance of variations in the sagittal configuration of the cervical spine in general[1,2] and in patients with whiplash-associated disorders (WAD) in particular.[3-6] Some researchers suggest that a straight cervical curve and angular kyphosis in patients with WAD indicate protective muscle spasm and/or disco-ligamentous injury with poor prognosis.[5,6] The great variations in the configuration of the cervical curve in asymptomatic and symptomatic subjects have led to many different opinions regarding the clinical significance of different configurations.[1-13] It is commonly believed that diminished or reversed cervical lordosis even with gross kyphotic angulations may represent a normal variant.[2,3,4,7-11,14,15] However, this opinion has been opposed recently in an extensive literature review.[1]

When measuring cervical lordosis, most studies have been concerned with the lower cervical spine[2-13] but have ignored the upper cervical spine perhaps because regional attenuation of the lordosis is the most often manifested protective posture in the lower cervical spine.[16,17] However,

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because the upper and lower cervical spine are capable of moving independently of each other,[18,19] each part has the potential to compensate for misalignment in the other part. Therefore, we hypothesize that decreased lordosis in the lower cervical spine may lead to increased lordosis in the upper part as a compensating mechanism, or vice versa, to keep the eyes level with the earth-horizontal. Similarly, decreased lordosis in the upper cervical spine and increased lordosis in the lower part may be interrelated. Measuring the lower and upper cervical curvatures independently and ascertaining their relation may, therefore, be a better indicator of overall changes in the cervical curvature.

Intersegmental angulations are a measure of each individual vertebral position in the sagittal plane. Local alteration in the sagittal configuration of 2 adjacent vertebral segments may indicate traumatic or long-term consequences of a traumatic event.[20,21] Curvatures of the spine are commonly measured by angular measurements, with landmarks at the bottom and top of the curve.[22,23] However, these measurements do not take into account what happens at segmental levels between these landmarks.[24]

The purpose of this study was to reveal whether women with persistent symptoms and musculoskeletal signs after motor vehicle crashes (WAD, grades I-II) demonstrated regional and/or segmental radiographic signs of altered configuration of the cervical lordosis compared with 2 control groups, a group with chronic insidious onset neck pain and an asymptomatic group.

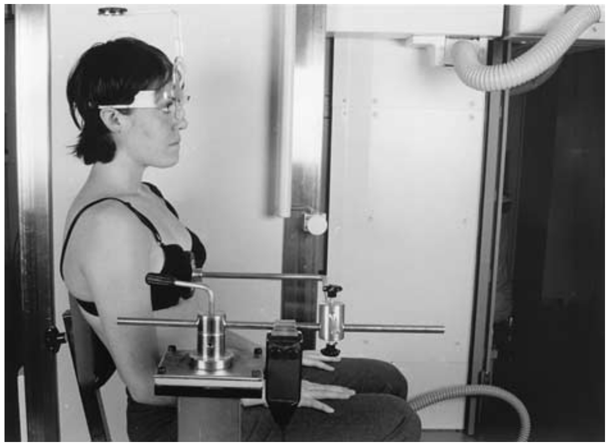

Fig 1. *Experimental set-up. The women sat in a specially constructed chair in which the chair back was reclined 10 degrees. The thorax was fixed by a pellet at the height of the lower sternum and the xyphoid process. The height of the chair was electronically adjustable, which enabled the subjects to sit with their feet positioned flat on the support with their hips and knees in 90 degrees of flexion. Their arms rested freely in their laps. The subjects were instructed to find the self-balanced natural position of the head looking straight ahead.*

Methods

Population

A total of 120 women participated. They were divided into 3 groups: a group with whiplash (n = 41), a group with insidious onset neck pain (n = 39), and an asymptomatic group (n = 40). The symptomatic subjects were recruited from informed doctors and physiotherapists. To be included in either symptomatic group, a subject's symptoms must have lasted between 6 and 48 months, and the subject could not have a history of neck pain attending medical care (the group with whiplash) or injury (the group with insidious onset neck pain). Symptom characteristics of the 2 symptomatic groups will be published elsewhere. The asymptomatic group consisted of staff at the University Hospital in Reykjavík, Iceland and students from the Physiotherapy Unit at the University of Iceland. The subjects were randomly assigned to the study. All eligible participants answered a modified form of the standardized Nordic questionnaires for the analysis of musculoskeletal symptoms.[25,26] The questionnaires ask specifically about injury-related symptoms.[25] The Icelandic Radiation Protection Institute and the Medical Ethics Committee at the University Hospital in Reykjavík provided ethical clearance for the study.

Radiographic Examination

Digital radiography (Siemens, AG 1990 Flurospot H./Digital Fluro Radiography; Software: VD 11) was used. All radiographs were taken in a lateral position, and the women sat in a standardized sitting position (Fig 1), with fluoroscopic control for alignment. The left side of the body was closer to the film and the film-tube distance was 135 cm. The beam was centered at the C4 vertebral body. The subjects wore a CROM instrument (Performance Attainment, Roseville, Minn.) during the procedure, and an independent examiner (AK) corrected the position of the head in the transverse plane when it deviated from 0. The examiner also instructed the women to actively relax in the head-neck-shoulder girdle area during the assessment. The seated position was chosen to also obtain flexion/extension radiograms. The results of the flexion/extension study will be reported elsewhere.

Measurement Technique

The radiographs were scanned into a computer and burned onto CD-ROM discs. A software program, NUDD (Kine Co, Reykjavík, Iceland), was used to mark the desired points on the radiographs. This software program made it possible to change the size and contrast of each radiograph, making it easier to make fiducials on the radiograms. The fiducials were downloaded to Microsoft Excel (Microsoft Corp, Redmond Wash) sheets in the form of *x* and *y* coordinates for each point. Two points were marked on each vertebra, starting anteriorly on C6 and finishing posteriorly on the occipital bone, with 14 points total (Fig 2). For C3-C6, the most caudal anterior and caudal posterior points

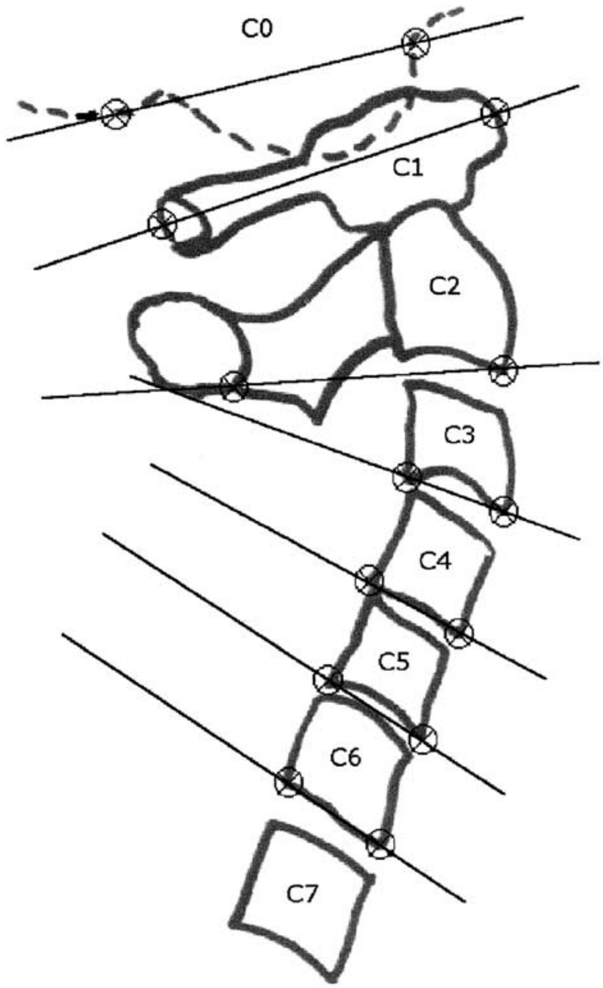

Fig 2. *Fiducials and lines used to form the measured angles. The lines on C0 and C2 measured the upper lordosis, and the lines on C2 and C6 measured the lower lordosis. The lines on 2 adjacent vertebrae measured the angle at each level.*

were marked on each vertebral body. Specific points were chosen for C2 and C1 because of their special shape and for the occipital bone. For C2, the most caudal anterior point of the vertebral body and the most caudal posterior point of the spinal canal at this level were chosen. For C1, the most prominent anterior part of the anterior tubercle and the most prominent posterior point of the posterior tubercle were chosen, forming a line bisecting the atlas. The anterior point chosen on the occipital bone was the deepest point in the groove formed by the occipital condyle and the occipital bone. Posteriorly, the most caudal point on the occipital bone aligning with the posterior surface of the spinal canal at the C1 level was chosen.

Outcome Measure

A new software program was designed to facilitate calculations of the desired angles in this study (www.kine.is.). A negative value indicated lordosis, and a positive value indicated kyphosis. Two types of measurements were made from each radiogram.

1. Measurements of the angles of the upper and lower cervical curvatures, respectively. The angle formed by lines projected parallel to the base of the skull and parallel to the inferior aspect of C2 through the marked reference points measured the upper part of the curvature. The lower part of the curve was measured by the angle formed between the aforementioned reference line for C2 and a corresponding line projected parallel to the caudal aspect of C6 (Fig 2).
2. Measurement of the angle between each pair of vertebrae to obtain segmental values. Lines projected parallel to the end plate of the cranial vertebra in relation to the end plate of the vertebra below formed this angle (Fig 2).

To assess the agreement of the measurements, the first author and an assistant (KG) evaluated 40 radiograms independently of each other after a training session. These were radiograms of the 40 subjects who first entered the study. The first author then marked all 120 radiograms, and the agreement of repeated measurements was evaluated on the same 40 radiograms. All radiograms were evaluated on a single-blind basis.

Statistical Analyses

The agreement between repeated measurements and between testers was calculated with the method outlined by Bland and Altman.[27] The main data set was described and analyzed with the 1–way analysis of variance and its equivalent, the Kruskal-Wallis test, when appropriate. The ratio of the lower to the upper cervical angle was compared across groups by using the latter test. The 1-way analysis of variance was used to compare the groups' angular values for each individual segment in the lower cervical spine. After the study, least significant difference pairwise comparisons were used to show which between-group combinations were statistically significant and which were not. The statistical significance level was set at .05 probability level for both tests.

Results

Agreement

Table 1 shows the mean difference and 2 standard deviations of the difference between repeated measurements and between the 2 testers. Values for the angles C0-C2 and C2-C6 and the angles for individual levels in the lower cervical spine are shown. The mean differences and 2 standard deviations of the differences between measurements indicate how reliable the measurements are. The differences between the first and second measurement were not statistically significant (paired Student *t* test), and plotting the data did not reveal any relation between the difference and the mean.

Table 1. *Agreement between repeated measurements for various levels*

Level	Intertester Mean difference ± 2 SD	Intratester Mean difference ± 2 SD
C_0-C_2	1.00 degrees ± 3.55	0.03 degrees ± 2.98
C_2-C_6	0.67 degrees ± 3.32	0.49 degrees ± 3.11
C_2-C_3	0.64 degrees ± 4.21	0.21 degrees ± 2.43
C_3-C_4	0.44 degrees ± 4.01	0.01 degrees ± 3.28
C_4-C_5	0.38 degrees ± 4.01	0.15 degrees ± 3.14
C_5-C_6	0.50 degrees ± 3.92	0.27 degrees ± 2.84

Table 2. *Mean rank for the lower cervical spine*

Group	Mean rank
Whiplash	56.08
Non-insidious onset	62.63
Asymptomatic	64.22

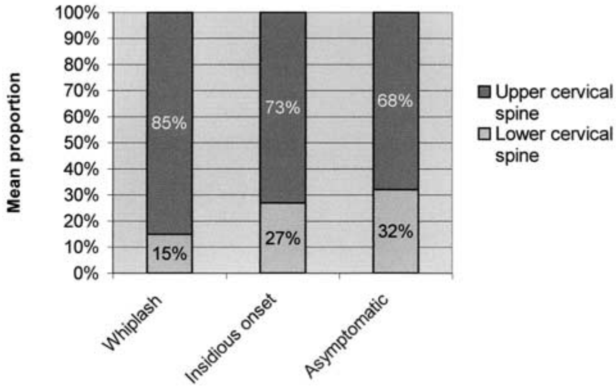

Fig 3. *The ratio of the lower to upper cervical spine lordosis in each of the 3 groups. The ratio was lowest for the whiplash group.*

Lower Versus Upper Cervical Spine

No statistical significant difference was found between groups for the ratio of the lower to upper cervical spine lordosis. The ratio was lowest for the group with whiplash but highest in the asymptomatic group, with the group with insidious onset neck pain being closer to the latter (Fig 3). The mean ranks for the values in the lower cervical spine are shown in Table 2.

Individual Segments

The results of the analysis of variance revealed a statistically significant difference for the C4-C5 level (F [2,118] = 3.8; P = .025) but not for any other levels. The analyses after the study (least significant difference pairwise comparisons) of the 3 groups for the C4-C5 level revealed that these results were caused by a significant difference between the asymptomatic group and the group with whiplash (P = .007) but not the other between-group comparisons. The mean difference for the C4-C5 level between the asymptomatic group and the group with whiplash was 3 degrees (95% confidence interval, 0.8–5.2).

Discussion

This study investigated whether women with chronic WAD of grades I-II had radiographic signs of altered configuration of the cervical lordosis compared with a group of women with insidious onset neck pain and an asymptomatic group. Figure 3 shows that in comparison with the other 2 groups, the group with whiplash exhibited a decreased ratio of lower to upper cervical lordosis. This difference was not statistically significant but may have clinical importance. The statistically significant difference for the C4-C5 segment between the whiplash group and the asymptomatic group, a mean difference of 3° (95% CI, 0.8–5.2) is considered clinically important.

According to Bland and Altman,[27] plotting the difference between 2 methods, testers, or repeated measurements against their mean reveals their agreement. The aforementioned between-group differences at the C4-C5 segment are within the 0.38° ± 4.01 limit of agreement for that level (Table 1). The statistical significance and the practically important difference at the C4-C5 segment between the group with whiplash and the asymptomatic group show that an improvement of the measurement method is needed. For the angles shown, the limits of agreement ranged from 2.84° to 4.21°. However, this method was considered better than the unit-free intraclass correlation coefficients, which have several disadvantages when documenting the reliability of clinical measurements.[27,28] To improve the agreement between measurements, assessing the whole radiographic procedure will be important.

The seated position has several limitations when documenting the sagittal alignment of the cervical spine because the cervical curvature is sensitive to the position of the pelvis, the trunk-thigh angle, and the inclination of the backrest.[29-31] There is evidence from several studies that a standing position is more reliable.[32,33] In addition, the Harrison posterior tangent method has been found to more accurately depict cervical curvature than the more commonly applied Cobb method.[34] Therefore, the standing position and the Harrison method are recommended for future studies.

According to our knowledge, the relation between lower and upper cervical spine lordosis in different patient groups has not been investigated before. Measuring each segmental level's contribution to total cervical lordosis and comparing these values across different groups has also not been a common practice in most research of cervical lordosis. The results of this study show the preponderance of the angle between the C1-C2 vertebrae to the total cervical lordosis (Fig 4). Comparing the segmental angular values for the asymptomatic subjects in this study with the segmental

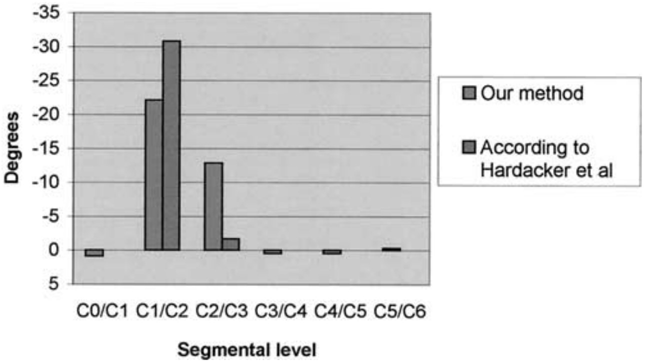

Fig 4. *Each level's contribution to total lordosis in the asymptomatic group showing the preponderance of C1. We marked the posterior point on C2 twice to show the relation between our study and the study of Hardacker et al.*[35]

angular values obtained in a study of 100 asymptomatic subjects conducted by Hardacker et al[35] is of great interest. In this latter study, higher values were obtained for the C1 level but lower values were obtained for the C2 level compared with the corresponding values in our study. These discrepancies obviously were caused by a different reference point on the posterior aspect of the C2 vertebrae between the 2 studies. The Cobb method used in our study was modified for the C2 vertebra to reflect the contribution of the C2 vertebra to the lordosis more efficiently. A tangent line between the anterior hook-shaped corner and the posterior corner on the inferior body of C2 was found to underestimate the lower cervical lordosis and overestimate the upper cervical lordosis. When we marked the caudal posterior point of the C2 vertebral body on 30 radiograms, as Hardacker et al[35] had done, instead of the caudal posterior point of the spinal canal, we obtained similar values to theirs. The results of the 2 studies are therefore comparable, despite the different radiographic assessment positions, and show that the lower cervical spine below the C2 vertebra contributes far less to total cervical lordosis (Fig 4). The fact that the atlas contributes most to cervical lordosis is consistent with its weight-bearing function.

Many symptoms in late whiplash syndrome remain obscure.[36,37] Preventing the development and persistence of these symptoms is therefore difficult. Altered cervical curvature may play a role in the symptomatology of some whiplash subjects. In a whiplash-type movement, the passive integrity of a cervical motion segment may be threatened and thereby its biomechanic[38] and/or neurophysiologic stability.[39] Correct segmental alignment of the spine depends on adequate function of the deep local muscles to provide a stable base for efficient limb and spinal movements.[40,41] The change in the ratio of lower to upper cervical spine lordosis observed in the whiplash subjects in this study may indicate dysfunction of the deep flexors in the upper cervical spine and of the deep extensors in the lower cervical spine. This hypothesis warrants further investigation.

There are much data to support the view that the function of the cervical spine is best preserved and in the least strenuous way by maintaining physiological lordosis.[42-46] Apart from intrinsic factors, the cervical curvature depends on the head on trunk position[35] and the position of the trunk under the head, including the shape of the thoracic kyphosis.[47] The inclination of the sacrum and the configuration of lumbar lordosis may also play important roles in the size of the cervical lordosis.[29] The muscles must be activated more in subjects where the head's line of gravity falls more anteriorly as in forward head posture[48] or when the thrust line through the cervical spine (cervical gravity line) falls outside the arc formed by the anterior segment (discs and vertebrae) of the column.[49] Therefore, the misalignment at the C4-C5 level observed in the whiplash group may have clinical importance because the load-bearing capacity of the cervical spine will be greatly reduced.[49]

Conclusion

This study indicates that the cervical lordosis of patients with whiplash may be differently configured. The group with whiplash showed a decreased ratio of lower to upper cervical spine lordosis. The between-group differences for this ratio were not statistically significant but may be clinically important. The whiplash group was in a significantly more flexed position at the C4-C5 level compared with the asymptomatic group. Future studies should use a standing position and the posterior tangent method to enhance reliability when measuring sagittal alignment of the cervical spine.

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