Increasing the Cervical Lordosis With Chiropractic Biophysics Seated Combined Extension-Compression and Transverse Load Cervical Traction With Cervical Manipulation: Nonrandomized Clinical Control Trial

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Abstract

Background: Cervical lordosis has been shown to be an important outcome of care; however, few conservative methods of rehabilitating sagittal cervical alignment have been reported.

Objective: To study whether a seated, retracted, extended, and compressed position would cause tension in the anterior cervical ligament, anterior disk, and muscle structures, and thereby restore cervical lordosis or increase the curvature in patients with loss of the cervical lordosis.

Study Design: Nonrandomized, prospective, clinical control trial.

Methods: Thirty preselected patients, after diagnostic screening for tolerance to cervical extension with compression, were treated for the first 3 weeks of care using cervical manipulation and a new type of cervical extension-compression traction (vertical weight applied to the subject's forehead in the sitting position with a transverse load at the area of kyphosis). Pretreatment and posttreatment Visual Analogue Scale (VAS) pain ratings were compared along with pretreatment and posttreatment lateral cervical radiographs analyzed with the posterior tangent method for changes in alignment. Results are compared to a control group of 33 subjects receiving no treatment and matched for age, sex, weight, height, and pain.

Results: Control subjects reported no change in VAS pain ratings and had no statistical significant change in segmental or global cervical alignment on comparative lateral cervical radiographs (difference in all angle mean values $< 1.3°$) repeated an average of 8.5 months later. For the traction group, VAS ratings were 4.1 pretreatment and 1.1 posttreatment. On comparative lateral cervical radiographs repeated after an average of 38 visits over 14.6 weeks, 10 angles and 2 distances showed statistically significant improvements, including anterior head weight bearing (mean improvement of 11 mm), Cobb angle at C2-C7 (mean improvement of $-13.6°$), and the angle of intersection of the posterior tangents at C2-C7 (mean improvement of 17.9°). Twenty-one (70%) of the treatment group subjects were followed for an additional 14 months; improvements in cervical lordosis and anterior weight bearing were maintained.

Conclusions: Chiropractic biophysics (CBP) technique's extension-compression 2-way cervical traction combined with spinal manipulation decreased chronic neck pain intensity and improved cervical lordosis in 38 visits over 14.6 weeks, as indicated by increases in segmental and global cervical alignment. Anterior head weight-bearing was reduced by 11 mm; Cobb angles averaged an increase of 13° to 14°; and the angle of intersection of posterior tangents on C2 and C7 averaged 17.9° of improvement. (J Manipulative Physiol Ther 2003;26:139-51)

Key Indexing Terms: *Cervical Vertebrae; Lordosis; Traction; Posture; X-Ray; Kyphosis; Rehabilitation*

Introduction

Neck pain is becoming increasingly prevalent in today's society.[1,2] In a recent 10-year follow-up of 200 asymptomatic subjects, Gore[1] reported an incidence of 15% for the development of neck pain. Neck pain has multiple causes including tumor, infection, trauma, spinal degeneration, and mechanical factors. Concerning mechanical factors, the configuration of the sagittal cervical curve has been shown to be an important clinical outcome

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of health care, especially in cervical postsurgical outcomes.[3-5] Besides neck pain,[3-5] loss of cervical lordosis and/or cervical kyphosis has been found to be a factor or cause of tension and migraine headaches.[6-8] Intuitively, the relationship between neck pain symptoms and loss of cervical lordosis makes sense, because the cervical lordosis can be considered a primary curve, as it is formed at approximately 10 weeks of fetal development.[9]

Besides the fact that the cervical lordosis is formed in utero, the necessity of a normal cervical lordosis is supported by a wide array of studies. The current *Index Medicus* literature indicates that neck pain, headaches, surgical cases, rehabilitative treatments, whiplash, and incidences of degeneration all point to the relevance of the cervical curve as an important outcome of care.[3-19]

In 2 recent studies, Gore[1] and Marchiori and Henderson[20] found that cervical spinal degeneration is a risk factor for the development of neck pain, with the latter study showing increased intensity of pain with multiple-level degenerative changes. Of interest is the finding of an increased incidence of degenerative changes in the cervical spine with segmental or regional kyphotic alignment of the cervical spine.[5,13,14,18,19] Again, this information points to a relationship between loss of lordosis and neck pain.

Conservative methods to restore or improve cervical lordosis are rare, with review of the literature locating only 2 chiropractic biophysics (CBP) studies demonstrating significant improvement in lordosis following treatment with 2 different types of cervical extension traction.[21,22] Due to the scarcity of adequate methods to improve cervical lordosis with nonsurgical methods, we decided to measure global and segmental angles of lordosis after a program with a new type of seated, 3-point bending, cervical compression traction with a posterior-anterior transverse load at midneck.

It was hypothesized that this seated, retracted, extended, and compressed position would cause tension in the anterior cervical ligament, anterior disk, and muscle structures and thereby restore cervical lordosis or increase the curvature in patients with loss of the cervical lordosis.

Methods

Thirty volunteer, consecutive patients with decreased cervical lordosis, anterior head translation, and chronic cervicogenic pain were treated with a new type of 3-point bending cervical traction and short-term cervical manipulation. Cervical manipulation was discontinued approximately after 3 to 4 weeks of treatment (when cervicogenic pain and range of motion were deemed improved or when no further benefits were to be expected by continuing this treatment). The type of cervical manipulation was a bilateral diversified rotary break, a global lateral bending combined with a small amount of axial torsion of the head and neck.

For the purposes of this article, subjects were considered to have a decrease in their cervical lordosis if: (1) the magnitude of lordosis between C2 through C7 posterior body tangents measured less than 16°, which is 2 standard deviations below the average asymptomatic person reported by Harrison et al[23]; or (2) there were any segmental or regional kyphotic angles in their lateral cervical curves. Visual Analogue Scale (VAS) values (0 = no pain, excellent health to 10 = excruciating pain and bedridden) and lateral cervical radiographic measurements for the treatment group were matched and compared to a nonrandomized prospective control group of 33 volunteer subjects with chronic cervicogenic pain and decreased cervical lordosis. The control group subjects elected not to receive care but did have initial and follow-up lateral cervical radiographs.

The 30 treatment group consisted of 14 female subjects and 16 male subjects, with an average age of 36.0 years (SD = 14.2 years), mean height of 171.8 cm (SD = 10.4 cm), and mean weight of 82.3 kg (SD = 21.6 kg). The control group was composed of 14 female subjects and 19 male subjects, with an average age of 37 years (SD = 11.1 years), mean height of 174.1 cm (SD = 8.2 cm), and mean weight of 85.2 kg (SD = 19.5 kg). Subjects were patients/volunteers at a spine clinic in Elko, Nevada. Subjects gave informed consent, and all aspects of this project were approved by our internal review board.

Since during this CBP cervical traction an extended and compressed position of the neck was utilized in the seated position, inclusion criteria involved a screening protocol for tolerance to cervical compression with extension. Exclusion criteria included: (1) radicular signs and symptoms on the application of manually assisted extension combined with compression; (2) central canal stenosis; (3) compression fractures at any cervical level; (4) prior cervical spine surgery; and (5) moderate to severe degenerative changes in the intervertebral disks, vertebral bodies, and/or spinal ligaments. Eight subjects had to be excluded from participation in this study.

Prior to treatment with traction, each subject was asked to perform 20 to 30 neck extensions within their pain-free range of motion. This was done to warm up the tissues and increase the flexibility for neck extension. Fig 1*A* and *B*, depicts this warm-up extension procedure. Our new CBP cervical traction method consisted of an extended/compressed position of the cervical spine with a transverse load applied at the area of maximum loss of segmental cervical lordosis. The transverse load was applied with an additional posterior-anterior strap attached to a weight and pulley. The angle of the applied transverse load was changed relative to horizontal from 0.0° to 10.0°- 15.0° to 20.0° to 25.0° for lower, middle, and upper cervical curve decreases, respectively. Fig 2 illustrates the seated, extended, retracted, and compressed head position with the addition of the transverse load.

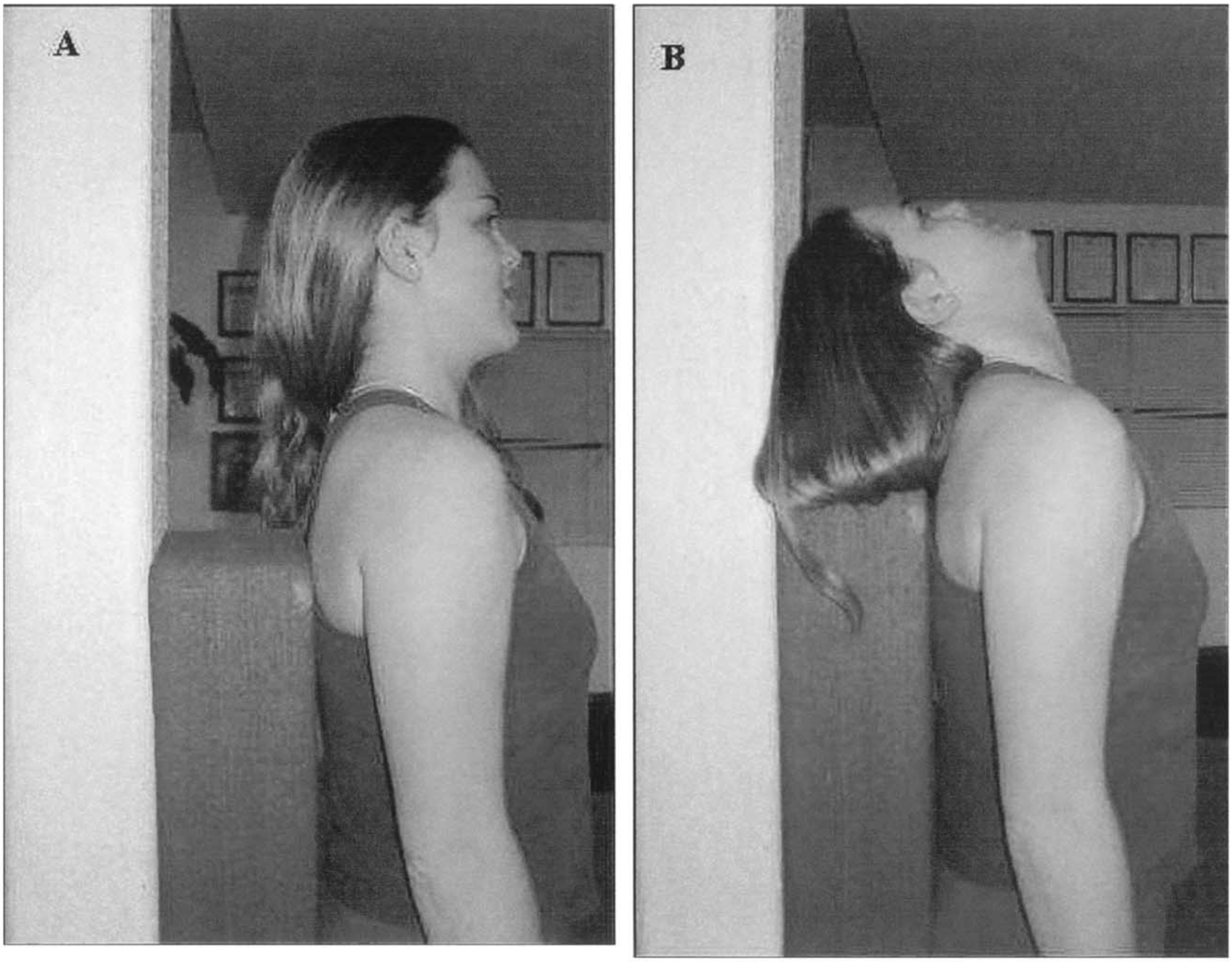

Fig 1. *Warm-up flexion/extension exercises. A 4-inch stiff foam block was placed behind the patient's thoracic spine. With the patient looking forward, they were instructed to extend their skull backward into their maximum pain-free range of motion and hold this position for 3 to 5 seconds. The patient then returned to the neutral, straight, forward position. This process was repeated between 20 and 30 times each visit.*

Initially, in order to develop tolerance for this position, 10 lb was placed over the front pulley while the subject actively (no weight added for compression) extended their head backward. This procedure was performed on consecutive visits until the subject could do this for 5 minutes. After this initial step, weight was applied to the forehead strap at a 1:2 ratio compared to the weight of the anterior strap. Most patients were able to tolerate 5 lb on the forehead compression strap and 10 lb on the transverse strap. With weight on both the forehead compression and anterior straps, traction time started at approximately 1 to 3 minutes (depending on patient tolerance) and increased 1 minute per session until the goal of 20 minutes per session was reached. Once the 20-minute goal was reached, the weight on the front and back were increased and the time was reduced to 10 minutes. Again, the patient's time was increased 1 minute per session with the new increased weight until 20 minutes was reached. This process was repeated until the patient reached (1) the goal of 20 lb on the front pull and 10 lb on the forehead for a time of 10 to 20 minutes, or (2) the patient felt that they could no longer increase the weight due to pain or discomfort. If the patient was sore in the neck after completion of their traction session, ice was applied to the posterior cervical region for 10 to 15 minutes.

The average subject was able to reach the goal of 10 lb on the forehead and 20 lb on the anterior strap; however, 1 large muscular male subject was able to tolerate a maximum of 35 lb on the front and 17.5 lb on the forehead without any increased symptomatology. The traction treatment frequency was 2 to 5 times weekly for a total of 14.6 weeks (SD = 7 weeks). The number of visits before the second radiograph and examination were performed was 38 (SD = 12.5 visits). The second radiograph and examination were performed a minimum of 1 day after the subject's last treatment. After a

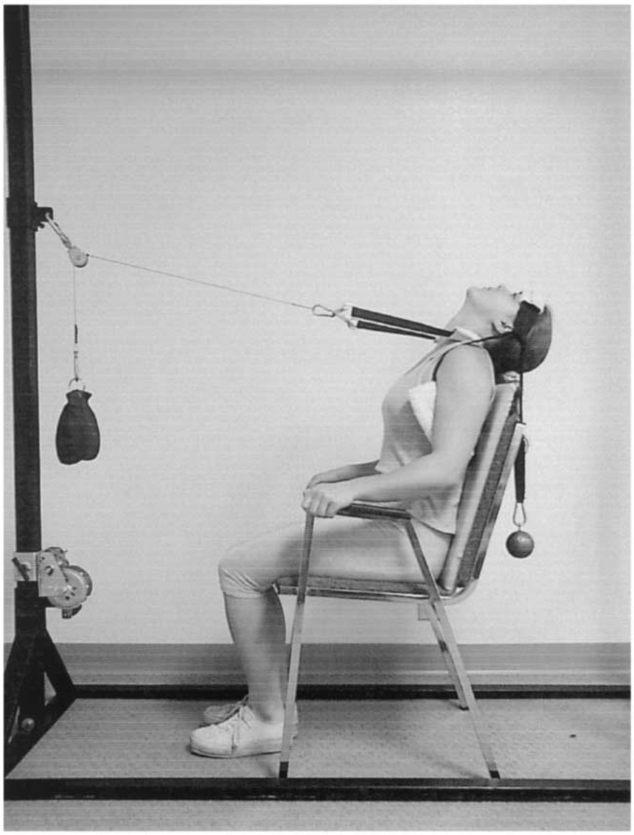

Fig 2. *Combined extension/compression and 2-way cervical traction. The head is retracted and extended with a weight strap and head harness attached to the subject's forehead and chin, while the neck is pulled posterior-anterior by a forward strap. The forward strap creates a transverse load at the level of any kyphosis. The weights were applied at a 2:1 ratio at the anterior strap compared to the head halter, starting at 10 lb:5 lb and increasing to tolerance or a maximum of 35 lb:17.5 lb. The patient is screened for tolerance to this position before commencing traction.*

subject's second radiograph and examination, they were encouraged to come in periodically throughout the year for traction to maintain their cervical curve correction.

Standard lateral cervical radiographs were obtained with the subject's right shoulder against the cabinet with a standard tube distance of 182.9 cm (72 in). Before exposure, subjects were asked to close their eyes, flex and extend their skull twice, and assume a comfortable resting position where they perceived themselves to be looking straight ahead. The eyes were then opened, and the subject was asked not to deviate from this neutral position. This neutral resting posture has been shown to be highly repeatable and stable over time.[24-26]

Lateral cervical radiographs were analyzed with the posterior tangent method, which includes global and segmental angles of lordosis. Global Cobb angles at C1-C7 and C2-C7 and a measurement of head anterior translation/protrusion were included. The posterior tangent method has been reported to have interclass and intraclass correlation coefficients in the good and high ranges with low standard errors (SE) of measurement; SE ~2° and SE ~2 mm.[27] Fig 3 illustrates this radiographic method.

Twenty-one of the 30 treatment subjects (70%) volunteered for a long-term follow-up lateral cervical radiograph and VAS pain scale. For this long-term follow-up radiograph, the average elapsed time between the first posttreatment and long-term follow-up lateral cervical radiograph was 14.0 months with a range from 4.5 months to 39 months. The average number of maintenance traction sessions was 6.1 visits (SD = 5.6 visits).

To compare between and within groups**,** 2-sided, 2-sample *t* tests and 2-sided paired *t* tests were conducted with the software Minitab (Version 12, Minitab, Inc., State College, Pa, 1998). In a few instances when situations violated the needed assumptions for the 2-sample *t* test and 2-sided paired *t* test, their respective nonparametric analogues, the Mann-Whitney test or Wilcoxon signed rank test, were utilized instead.

Results

Thirty patients were compared with 33 control subjects who did not receive treatment. Using 2-sample *t* tests, there were no statistical significant differences between the 2 groups when comparing age, height, weight, sex, and pretreatment VAS scores (Table 1). There was a statistically significant difference in the posttreatment VAS scores for these 2 groups. Paired *t* tests indicate that the pretreatment VAS (3.5 ± 2.0) and posttreatment VAS (3.4 ± 1.8) scores for the control group were not statistically different. There was, however, a statistically significant difference ($P < .0001$) for VAS scores in the traction treatment group (mean of 4.1and SD of 1.9 compared to mean of 1.1 and SD of 0.9) (Table 1).

For the control group, all differences of the means for the pretreatment and posttreatment radiographic angles were less than 1.3°. Using paired *t* tests for equality of the means derived from radiographic analysis for control subjects, there were no statistically significant differences in the 5 segmental angles from posterior tangents at C2-3 to C6-7. Also for the control group, there were no statistically significant differences in the global angle, absolute rotation angle (ARA), drawn with posterior tangents at C2-C7, in the Cobb angles at C1-C7 and C2-C7, in head flexion angle (Chamberlain's line compared to horizontal), and in the head protrusion distances measured at C1 and C2 (eg, $Tz^{C1\text{-}T1}$). (Table 2).

Using 2-sided paired *t* tests for 10 of 12 radiographic measures in the traction treatment group, all but 2 radiographic angle measurements showed statistically significant improvement to an increased lordosis at the $P < .001$ level or lower, with C5-6 being slightly higher at $P = .006$ and the C6-7 segmental angle showing marginal statistical improvement at $P = .03$. The radiographic data for the C1 angle compared to horizontal and Chamberlain's angle to horizontal violated the needed assumptions for *t* tests, and

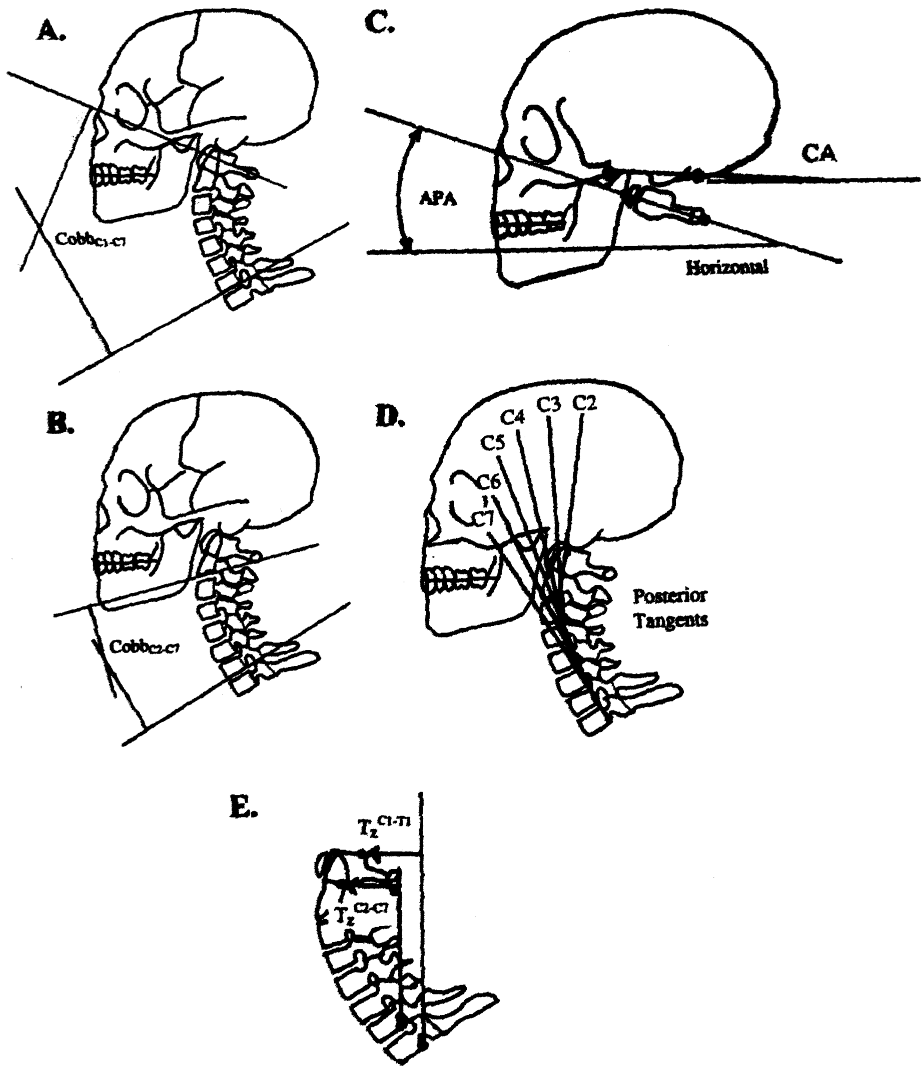

Fig 3. *Radiographic line drawing analysis utilized. The 4-line Cobb Method at C1-C7 overestimates lordosis due to the extra extension of C1-2 (***A***). In* **B***, the 4-line Cobb Method at C2-C7 underestimates lordosis due to the hooked-nose shape of the anterior-inferior body of C2. In* **C***, the atlas plane angle to horizontal (APA) and Chamberlain's angle to horizontal (CA) are depicted. In* **D***, the Harrison Posterior Tangent Method in the cervical spine at C2 through C7 creates segmental angles (RRAs), the sum of which is a global angle (ARA). In* **E***, TzC1-T1 is the displacement of C1 compared to a vertical line through posterior-inferior body of T1 and TzC2-C7 is the displacement of C2 compared to a vertical line through posterior-inferior body of C7. (Modified with permission from Lippincott Williams & Wilkins, Inc. Spine 2000;25:2072-78.)*

thus, the nonparametric Wilcoxon signed rank test was applied to these data, which showed improvement at the $P < .0001$ level (Table 3). The largest increases in lordosis were found in the mid and upper cervical spine (C2-3 = 3.3°, C3-4 = 3.5°, C4-5 = 4.2°). On average, the global angles increased between 13° and 18° (ARA_{C2-C7} = 17.9°, $Cobb_{C2-C7}$ = 13.6°, and $Cobb_{C1-C7}$ = 13.9°). The mean inclination of C1 to horizontal increased (11.7°), the head flexion angle reduced (10.5°), and head protrusion reduced by 9.5 mm to 12.2 mm between C2-C7 and C1-T1, respectively. (Table 3). Figures 4, *A* and *B*, (kyphotic cervical curve) and Figure 5, *A* through *C*, (hypolordosis) demonstrate 2 cases with increased cervical lordosis after treatment.

When separating subgroups above and below the mean age (36 years), there were no statistically significant differences in radiographic measurements for younger and older treatment group subjects for 10 angles and 2 anterior weight-bearing distances (Table 4). Also, when separating male subjects and female subjects, there were no statistically significant differences in radiographic measures (Table 5). In a few instances where data violated the assumptions for the *t* tests, the analogous nonparametric test was used in Tables 4 and 5.

Comparing the mean postradiographic angles at long-term follow-up (average 14.0 months) to values at the 3-month radiographic examination indicates no loss of C2

Table 1. *Comparison of group characteristics*

Variable	Control group* Mean	Control group* SD	Treatment group† Mean	Treatment group† SD	P‡
Age (y)	37.0	11.1	36.0	14.2	>.05
Height (cm)	174.1	8.2	171.8	10.4	>.05
Weight (kg)	85.2	19.5	82.3	21.6	>.05
VAS-pre§	3.5	2.0	4.1	1.9	>.05
VAS-post	3.4	1.8	1.1	0.9	<.0001
P‖ (VAS within groups)	>.05		<0001		

*N = 33; female/male = 14/19.
†N = 30; female/male =14/16.
‡Two-sided 2-sample *t* test.
§VAS: 0 = no symptoms, no limitations to daily living, 1, 2,. . ., 10 = severe pain and bedridden.
‖Two-sided paired *t* tests for VAS scores within groups.
§*VAS*, Visual Analogue Scale.

Table 2. *Control group average lateral cervical radiographic measurement comparisons*

Variable	Preradiographic Mean, SD	Postradiographic Mean, SD	Change	P*
$Tz^{C1\text{-}T1}$ (mm)	23.3 ± 13.5	21.4 ± 13.7	1.8	>.05
$Tz^{C2\text{-}C7}$ (mm)	23.1 ± 13.5	22.4 ± 11.6	0.8	>.05
C1-Horizontal	−15.1° ± 6.5°	−16.0° ± 7.6°	0.9°	>.05
RRA C2-C3	−4.5° ± 5.7°	−4.3° ± 4.6°	−0.2°	>.05
RRA C3-C4	−1.6° ± 4.6°	−2.0° ± 5.3°	0.4°	>.05
RRA C4-C5	−1.1° ± 5.6°	−1.5° ± 4.6°	0.5°	>.05
RRA C5-C6	−0.7° ± 4.7°	0.1° ± 4.3°	−0.8°	>.05
RRA C6-C7	−2.4° ± 5.5°	−3.3° ± 5.8°	1.0°	>.05
ARA C2-C7	−10.2° ± 10.9°	−11.1° ± 9.0°	−0.9°	>.05
Cobb C1-C7	−37.1° ± 11.1°	−36.9° ± 9.9°	−0.2°	>.05
Cobb C2-C7	−5.6° ± 13.0°	−5.8° ± 10.1°	−0.2°	>.05
Chamberlain-Horizontal	−1.6° ± 5.6°	−2.9° ± 5.7°	−1.3°	>.05

N = 33.
Tz, Horizontal distance of C1 posterior-superior body corner to posterior-inferior of T1 or horizontal distance of C2 posterior-superior body corner to posterior-inferior of C7; *RRA*, segmental angle formed by posterior vertebral body tangents; *ARA*, total curve angle from C2 to C7 formed by posterior vertebral body tangents; *Cobb angle C1-C7*, line through C1 arches to inferior endplate of C7; *Cobb angle C2-C7*, line on inferior endplate of C2 to inferior endplate of C7; *Chamberlain Horizontal*, posterior hard palate to posterior foramen magnum to horizontal.
*Two-sided paired *t*-test.

through C7 lordosis in 70% (21/30) of treatment group subjects available. Table 3 provides the comparisons of the 3-month posttreatment and 14-month follow-up lateral cervical radiographic measurements in 21 subjects available for long-term follow-up.

Discussion

We hypothesized that a new type of CBP cervical extension/compression traction, with additional transverse load at midneck, would result in an increase in lordosis after a program of care due to the increased longitudinal strain on the anterior cervical ligament, anterior disk fibers, and anterior muscles. The increases in segmental angles, Cobb angles, and absolute rotation angle at C2-C7 support our hypothesis of improved lordosis with this new form of extension cervical traction. This is in contrast to no change in our control group subjects.

There has been anecdotal criticism of the hyperextension head position. Much of this criticism seems to be based on several letters to editors and case reports in the *Index Medicus* literature concerning "beauty parlor stroke."[28-32] The positions referred to were prolonged hyperextension combined with axial rotation[28-31], although Endo[32] did not discuss any rotation of the head. In 1992 and 1993, Weintraub[28-30] reported on 7 cases of "beauty parlor stroke" in which clients at beauty parlors had symptoms of nystagmus, ataxia, slurred speech, facial weakness, nausea, vomiting, vertigo, and dysarthria after having their hair shampooed. Six of

Table 3. *Treatment group average lateral cervical radiographic measurement comparisons*

Variable	Preradiographic Mean, SD	1st Postradiographic Mean, SD	Change	*P*	2nd Postradiographic Mean, SD	Change (2nd-1st)
Tz^{C1-T1} (mm)	24.2 ± 15.7	12.0 ± 12.9	12.2	<.001*	11.6 ± 15.2	−0.4
Tz^{C2-T7} (mm)	24.9 ± 12.9	15.4 ± 12.3	9.5	<.001*	15.0 ± 13.7	−0.4
C1-Horizontal	−9.7° ± 12.8°	−21.4° ± 8.1°	11.7°	<.0001†	−21.4° ± 11.0°	0.0°
RRA C2-C3	−2.7° ± 5.2°	−6.0° ± 4.9°	3.3°	<.001*	−5.0° ± 3.9°	1.0°
RRA C3-C4	−0.7° ± 5.3°	−4.2° ± 5.8°	3.5°	<.0001*	−3.9° ± 4.2°	0.3°
RRA C4-C5	−0.4° ± 4.7°	−3.8° ± 6.4°	4.2°	<.0001*	−4.8° ± 4.7°	−1.0°
RRA C5-C6	−0.2° ± 5.9°	−3.3° ± 5.9°	3.1°	=.006*	−3.6° ± 4.9°	−0.3°
RRA C6-C7	−2.6° ± 4.8°	−5.0° ± 4.5°	2.4°	=.03*	−5.2° ± 4.2°	−0.2°
ARA C2-C7	−4.2° ± 12.7°	−22.1° ± 12.4°	17.9°	<.0001*	−22.0° ± 15.8°	−0.1°
Cobb C1-C7	−31.5° ± 13.6°	−45.4° ± 10.4°	13.9°	<.0001*	−41.4° ± 21.6°	4.0°
Cobb C2-C7	−1.1° ± 12.5°	−14.7° ± 11.5°	13.6°	<.0001*	−11.5° ± 17.1°	3.2°
Chamberlain-Horizontal	1.9° ± 9.7°	−8.6° ± 10.1°	10.5°	<.0001†	−6.8° ± 8.2°	2.2°

First follow-up radiographs at a mean of 3.4 months and 38 traction sessions, second follow-up (long term) at mean of 14 months. Negative sign in RRA/ARA/Cobb means estension.

N = 30.

Tz, Horizontal distance of C1 posterior-superior body corner to posterior-inferior of T1 or horizontal distance of C2 posterior-superior body corner to posterior-inferior of C7; *RRA*, segmental angle formed by posterior vertebral body tangents; *ARA*, total curve angle from C2 to C7 formed by posterior vertebral body tangents; *Cobb angle C1-C7*, line through C1 arches to inferior endplate of C7; *Cobb angle C2-C7*, line on inferior endplate of C2 to inferior endplate of C7; *Chamberlain Horizontal*, posterior hard palate to posterior foramen magnum to horizontal.

*Two-sided 2-sample *t* test.

†Wilcoxon Signed Rank test of equality of medians.

these 7 individuals were older than 75 years and 1 was 54 years old. The 54-year old subject had been left in a position of cervical hyperextension over the edge of a shampoo bowl in excess of 2 hours. In 1995, Stratigos[31] reported on the condition of his mother after a trip to a beauty parlor. All 4 of these articles discuss in detail that the mechanism of vertebrobasilar injury is associated with cervical axial rotation while in hyperextension. In 2000, Endo[32] reported a single case of a woman aged 62 who suffered a "beauty parlor stroke." There was no mention of the duration of shampoo treatment or a detailed explanation of the position of the head.

Unlike beauty parlor employees, individuals employing this spinal traction method are trained physicians, who do screening examinations on patients for tolerance to head extension. Using our cervical traction protocol, patients are screened and then monitored while traction time periods are increased 1 minute per visit, starting at a 1 to 3 minutes, over a period of many visits. These traction methods are also not used with patients of advanced age. While any induced stroke symptoms would be unacceptable, these "beauty parlor strokes" should not be applied to our cervical extension traction methods when used by trained physicians.

In a 1999 thorough review of the literature on varying positions of the head associated with vertebral and basilar artery blood flow and dissection, Haldeman[33] concluded, "examination of the data fails to show a consistent position or movement of the neck that could be considered particularly dangerous." In addition, Thiel[34] found no occlusion of vertebral artery blood flow during various head and neck positioning tests on the patient, including head extension.

Chiropractic Studies Demonstrating Restoration of Cervical Lordosis

In a 1998 review of the literature,[35] only 5 studies from the chiropractic literature addressed the issue of restoration of the cervical curve via chiropractic treatment methods. Of these 5 studies, only 2[22,36] were considered to be of adequate quality. The study by Wallace et al[36] found a 6° improvement in cervical lordosis after 24 treatments with the Pierce method. However, they excluded 7 individuals with kyphotic cervical curves at final data evaluation due to the treatment making them significantly worse. The study by Wallace et al[36] had no control group and no long-term follow-up of their subjects. In a retrospective study, Harrison et al[22] randomly pulled 35 subjects from 200 patients treated with chiropractic biophysics adjustment technique and cervical extension compression traction. Here, a true control group and a treatment group without extension compression traction were used to compare with the results of the traction treatment group. In the traction group, after an average of 60 10-minute sessions of cervical extension traction, Harrison et al[22] found a 13.2° improvement in cervical lordosis from C2 through C7 (posterior tangent lines). Importantly, 18 (75%) of the 24 subjects with cervical kyphosis returned to a cervical lordosis following treatment. There was no long-term follow-up of this treatment group.

Since the 1998 review[35], at least 3 case reports have appeared in the literature that demonstrate very slight lordosis improvement following Gonstead[37,38] and Toggle[39] recoil adjustment procedures. While case reports are important in the initial evaluation of a treatment method or technique, it is generally accepted that no strong conclusions can

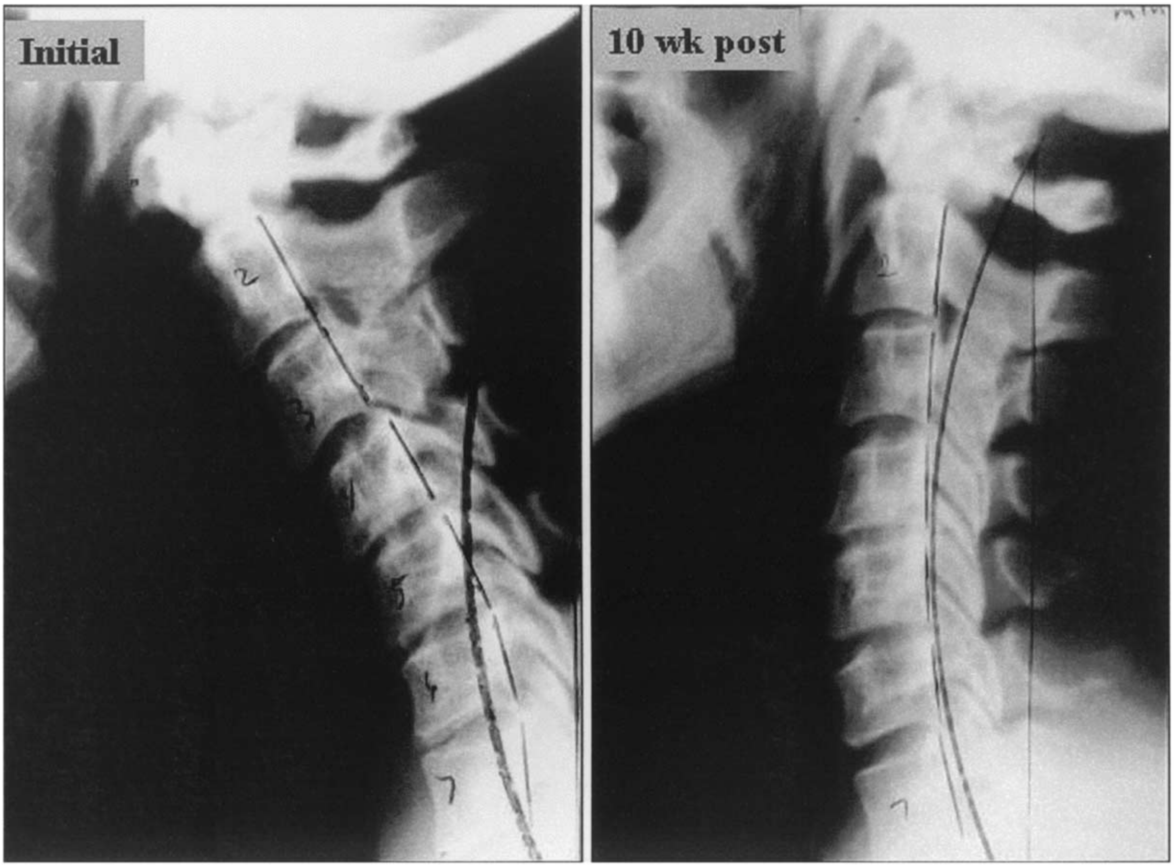

Fig 4. *Subject with initial cervical kyphosis* .

be drawn from single case reports. In fact, and in contrast to their recent case reports, in a retrospective trial following several Gonstead adjustments to the cervical spine, Plaugher et al[40] found no difference in cervical lordosis in 50 subjects.

Most recently, Harrison et al[21] published a nonrandomized clinical control trial on the ability of CBP 2-way cervical extension traction to restore the cervical lordosis. In 30 prospectively selected chronic neck pain subjects with hypolordosis, using the posterior tangent lines from C2 through C7, Harrison et al[21] reported an increase in cervical lordosis of 14.2° in an average of 35 traction sessions. In their control group, no change in cervical lordosis was found between an initial examination and an 8.3-month follow up examination. Importantly, Harrison et al[21] followed their treatment group for an additional 15.5 months and found that the improvement in cervical lordosis was mostly maintained with an average loss of only 3.7° compared to their initial posttreatment radiographs.

In the current study, we found an improvement in cervical lordosis of 17.9° between C2-C7 posterior tangents after an average of 38 treatments. At long-term follow-up of 14 months, the improvement in cervical lordosis was maintained. However, herein, we recommended maintenance traction sessions for the patient. The average number of maintenance traction sessions for our 21 follow-up subjects was 6.1 (SD ± 5.6) over 1.5 years. This equates to approximately 1 traction session every 2 to 3 months and could be a factor for our long-term follow-up cervical alignment data remaining stable with no significant loss. The effect of maintenance sessions remains to be tested, however. The current study findings are consistent with the previously discussed traction studies by Harrison et al[21,22] in the sense that large changes were found in subjects receiving different types of CBP extension traction methods compared to no change in control group subjects. The current study's findings, however, are in contrast to several studies utilizing spinal manipulative and/or adjustment procedures that have found little to no improvement in cervical lordosis following treatment.[35,40,41] We suggest that there are 2 primary reasons for this discrepancy.

First, it is a common assertion that loss of cervical lordosis and/or kyphosis is due to spasm of the anterior cervical musculature.[42-44] We have previously reviewed the literature on this topic and found that there is no actual evidence to suggest this to be true; it is mere speculation.[45] In regard to this issue, Rechtman et al[46] state, "Flattening of a cervical lordosis should be evaluated, carefully, especially in medicolegal problems, before being attributed to muscular spasm, as has been mentioned so commonly in radiologic reports. The muscular response associated with loss of cervical lordosis remains for further clarification." In fact, if the loss of cervical lordosis was

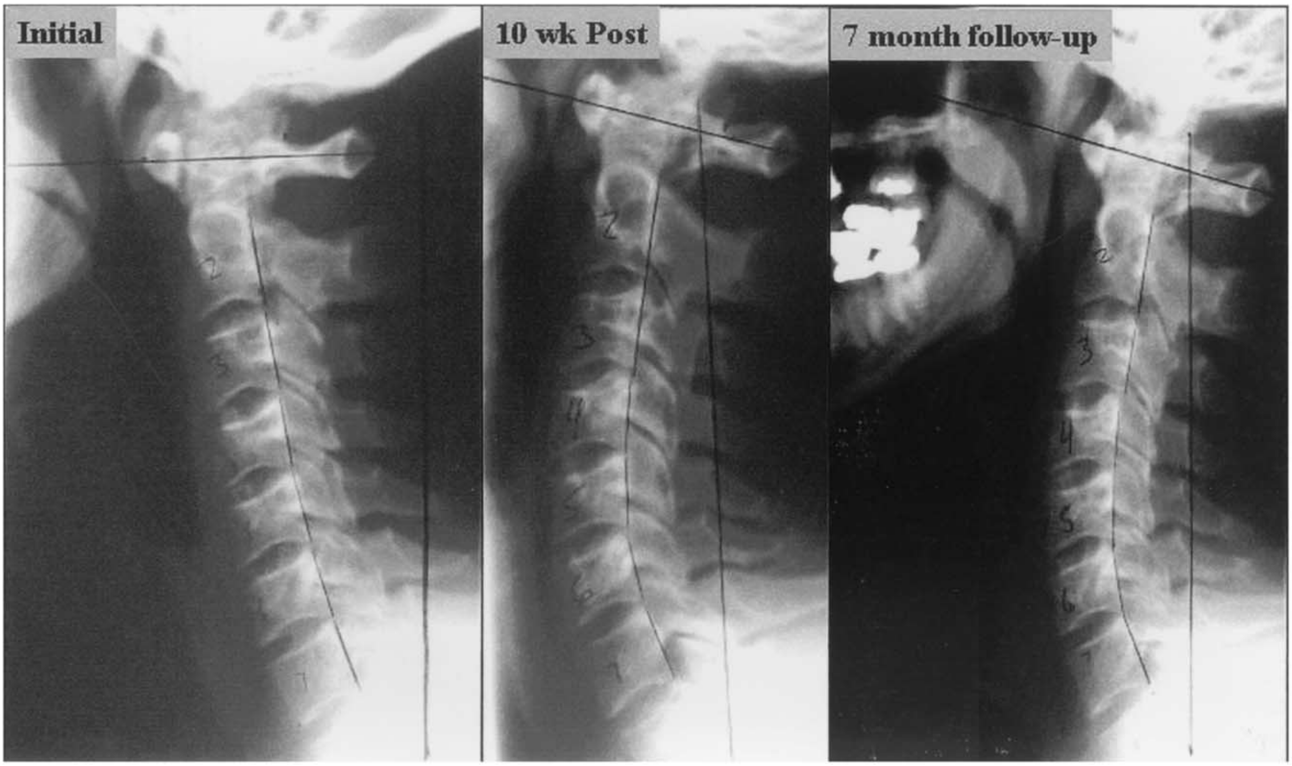

Fig 5. *Harrison Modified Riser-Ferguson Method applied to AP lumbar radiographs. Using the bisections, between points placed at the narrow-waisted lateral vertebral body margins, as centroids, best-fit lines are drawn from L5 to the scoliosis apex and from T12 to the apex. The angle of intersection (LD angle) is determined. After drawing a line on the sacral base, a lumbosacral angle (LS) can be calculated by extending the L5-apex line through the L5-S1 disk. A vertical line through the 2nd sacral tubercle (VAL is not shown) can help determine lateral displacements. The tilt of the sacral base (HB) is compared to horizontal.*

merely due muscular spasm, then spinal manipulative therapy should be able to readily demonstrate improvement in cervical lordosis following treatment. This is true because one of the suggested benefits of spinal manipulative thrusts is a reduction in muscle spasms or muscle activity; this is supported by both theoretical and experimental studies.[47,48]

Second, recent evidence suggests that loss/reversals of the cervical curve may be caused by an engineering phenomenon termed *buckling* or *snap through*.[49-51] Previously in this journal, we discussed the details of this engineering theory.[52] Mechanically, spinal buckling takes place 2 to 3 times faster than spinal muscles can react. After buckling, spinal tissues are deformed into a new resting (buckled) position that must be remodeled back into their original position. However, all spinal tissues display time-dependent, history-dependent, and force-dependent viscoelastic properties.[53-56] Deformation in spinal tissues is related to the magnitude of the applied load as well as the duration.[53-56]

In spinal ligaments under tensile loads, most of the stress relaxation process is completed in approximately 8 minutes; however, the intervertebral disk continues to deform for 20 to 60 minutes.[54] In extension loading, most of the spinal creep will be completed during a 20-minute time period of sustained loading.[55] For this reason, the duration of traction in our study was increased to a maximum of 20 minutes. The time-dependent, viscoelastic property of spinal connective tissue is why we believe that extension traction leads to consistent improvement in cervical lordosis and manipulation does not. In other words, our extension compression 3-point bending cervical traction causes longitudinal strain on the anterior cervical ligament, anterior disk fibers, and anterior cervical muscles, resulting in a change in their resting length.

Additionally, in a very comprehensive, systematic review of the literature in 1996 by Hurwitz et al,[57] no reports of positional changes in the cervical lordosis were reported following manipulation by chiropractors, physical therapists, medical doctors, or other health care providers. The authors concluded manipulation was effective and safe for neck pain and headaches but reported no outcomes in favor of structural changes brought about by manipulation. A more recent, 2001 review of the literature by physical therapists using retrieved data bases from both chiropractic and nonchiropractic sources concluded that no reported values for lordosis change following manipulation were found. The focus again was on the effectiveness for pain relief, and few, if any, investigators claimed structural changes.[58]

In the current study, the improvements in cervical lordosis and anterior head translation are, however, significantly

Table 4. *Mean radiographic changes in treatment group, age comparisons above and below the mean (36 yrs)*

Variable	<36 yrs* Mean ± SD	>36 yrs† Mean ± SD	*P*
Tz^{C1-T1} (mm)	13.1 ± 18.0	11.4 ± 11.1	>.05‡
Tz^{C2-C7} (mm)	10.1 ± 14.4	9.0 ± 10.2	>.05‡
C1-Horizontal	12.6 ± 10.7	10.8 ± 5.7	>.05§
RRA C2-C3	2.6 ± 4.5	3.9 ± 3.6	>.05‡
RRA C3-C4	5.3 ± 4.9	4.5 ± 4.2	>.05‡
RRA C4-C5	3.7 ± 4.2	4.6 ± 4.9	>.05‡
RRA C5-C6	3.5 ± 6.0	2.7 ± 5.7	>.05‡
RRA C6-C7	2.1 ± 5.6	2.8 ± 6.4	>.05‡
ARA C2-C7	17.3 ± 11.0	18.4 ± 11.5	>.05‡
Cobb C1-C7	13.5 ± 10.2	14.2 ± 9.0	>.05‡
Cobb C2-C7	12.6 ± 9.7	14.7 ± 8.8	>.05‡
Chamberlain-Horizontal	11.8 ± 13.2	9.1 ± 4.2	>.05§

Tz, Horizontal distance of C1 posterior-superior body corner to posterior-inferior of T1 or horizontal distance of C2 posterior-superior body corner to posterior-inferior of C7; *RRA*, segmental angle formed by posterior vertebral body tangents; *ARA*, total curve angle from C2 to C7 formed by posterior vertebral body tangents; *Cobb angle C1-C7*, line through C1 arches to inferior endplate of C7; *Cobb angle C2-C7*, line on inferior endplate of C2 to inferior endplate of C7; *Chamberlain Horizontal*, posterior hard palate to posterior foramen magnum to horizontal.
*N = 15.
†N = 15.
‡Two-sided 2-sample *t* test.
§Mann-Whitney test.

Table 5. *Mean radiographic changes in treatment group, females vs males*

Variable	Females* Mean ± SD	Males† Mean ± SD	*P*
Tz^{C1-T1} (mm)	9.0 ± 12.3	15.1 ± 16.4	>.05‡
Tz^{C2-C7} (mm)	6.7 ± 11.3	12.0 ± 12.9	>.05‡
C1-Horizontal	9.6 ± 6.8	13.6 ± 9.5	>.05‡
RRA C2-C3	3.6 ± 4.2	2.9 ± 4.0	>.05‡
RRA C3-C4	5.0 ± 4.7	4.9 ± 4.4	>.05‡
RRA C4-C5	2.6 ± 4.6	5.6 ± 4.0	>.05‡
RRA C5-C6	2.6 ± 3.7	3.5 ± 7.2	>.05‡
RRA C6-C7	3.3 ± 6.6	1.7 ± 5.4	>.05‡
ARA C2-C7	17.1 ± 12.0	18.5 ± 10.6	>.05‡
Cobb C1-C7	12.1 ± 8.7	15.4 ± 10.1	>.05‡
Cobb C2-C7	12.3 ± 9.8	14.7 ± 8.7	>.05‡
Chamberlain-Horizontal	8.1 ± 5.0	12.4 ± 12.4	>.05§

Tz, Horizontal distance of C1 posterior-superior body corner to posterior-inferior of T1 or horizontal distance of C2 posterior-superior body corner to posterior-inferior of C7; *RRA*, segmental angle formed by posterior vertebral body tangents; *ARA*, total curve angle from C2 to C7 formed by posterior vertebral body tangents; *Cobb angle C1-C7*, line through C1 arches to inferior endplate of C7; *Cobb angle C2-C7*, line on inferior endplate of C2 to inferior endplate of C7; *Chamberlain Horizontal*, posterior hard palate to posterior foramen magnum to horizontal.
*N = 14.
†N = 16.
‡Two-sided 2-sample *t* test.
§Mann-Whitney test.

larger than the 2 previous papers utilizing extension traction.[21,22] One of the reasons for increased changes might be the fact that the current study utilized traction durations of up to 20 minutes, whereas in 1 of the previous studies,[22] a maximum of 10 minutes was used. This difference in duration does not explain the increased change between the results herein and the recent study by Harrison et al,[21] as both utilized up to 20 minutes of sustained traction loads. We therefore propose that the difference in amount of correction in cervical lordosis has to do with the type of extension traction being used. Different traction methods apply different forces to the head and neck. In the first traction study by Harrison et al,[22] a combined load of extension and compression was used; in the second traction study by Harrison et al,[21] a combined load of extension with a transverse posterior to anterior load at midneck was used; and in the current study, a combined load of extension, compression, and a transverse posterior to anterior load at midneck was used.

Study Limitations

A criticism of the current study's methods, however, might be that we asked the patient to perform warm-up extension exercises. Since warm-up exercises were not performed in the 2 previous studies[21,22] on extension traction, this might be responsible for the increased cervical curve correction. However, we could not locate any manuscripts demonstrating increased cervical lordosis following the use of extension exercises. Likewise, our combined treatment of spinal manipulation and cervical traction might lead one to believe that spinal manipulation was responsible for the increases in cervical lordosis found in the current manuscript. But studies on spinal manipulation have not reported significant cervical curve improvements that are even close to the magnitude found in the current study (17.9° ARA C2 through C7). In contrast to curve increases, cervical spinal manipulation may be responsible for pain relief in many of our subjects. Currently, it is unknown what role correction of kyphotic cervical spine deformities plays in the amelioration of a patient's pain syndromes. We suggest it has a role in many chronic cervical spine conditions.[3-8,10-12]

A change in head neutral position (flexion/extension) might be thought to negate or be the cause of the cervical lordosis improvements found in our patient population. Although this is a common assertion in regard to cervical lordosis[45], there are only 2 manuscripts that address the issue of a neutral lordosis radiograph and a second radiograph taken in slight to moderate head extension to quantify any increased lordosis.[59,60] In a recent study by Harrison et al,[59] an average head extension (change in Chamberlain's line to horizontal) of 14° had only minimal increase in C2 through C7 lordosis (6.9°). Similarly, Hellsing[60] found that 20° of increased skull extension caused only a 10° change in cervical lordosis. In the current study, the average increased extension angle on the postfilm was 10°. If we assume a 1/2 to 1 ratio as found in the 2 studies above, then only a 5° increase in cervical lordosis would be expected from head flexion/extension. The magnitude of increased lordosis in our current study is 3.6 times this amount. Additionally, the study by Harrison et al[59] found statistically significant changes in only the global angle of cervical lordosis due to increased skull extension, while no statistically significant changes were found for any of the segmental angles. In direct contrast, in the current manuscript, statistically significant increases in segmental angles of lordosis were found in the traction treatment group, pointing to an effect of traction and not from increased skull extension.

The reason we did not standardize (position each subject in the horizontal skull position) the neutral lateral by artificially repositioning the patient's head posture is based on the following factors. First, we deem it important to identify a subject's perception of their neutral position. If a subject has head flexion in their neutral resting posture, then leveling the individual to a preconceived position will miss this important finding. Second, our neutral resting posture positioning procedure has been shown to be repeatable in previous studies on head posture,[24-26] in the control groups of 2 of our previous studies,[21,22] and in the current manuscript control group. Therefore, in addition to increased lordosis, our treatment group subjects had a change in their abnormal head flexion angle toward increased extension on the pretreatment to posttreatment radiograph. Additionally, Wallace et al[36] studied this head flexion claim of affecting cervical lordosis directly. Using tongue depressors between the teeth to evaluate the bite line, they obtained second lateral cervical radiographs of their subjects by artificially repositioning the bite line level. They found little change in cervical lordosis between the 2 sets of lateral cervical views.

Lastly, a criticism of all types of extension traction methods would be the taking of radiographs immediately after the patient completes a session of traction. Recovery from sustained loading requires a minimum of 8 hours of nonloaded activity.[61] This is why in all 3 of our traction studies it was explicitly required that the posttreatment radiograph be taken a minimum of 1 day after a given patient's last traction session. Additionally, our long-term follow-up data make this a moot criticism due to the fact that the correction was stable.

Conclusion

After a new CBP technique form of 3-point bending, cervical extension/compression traction in 30 cervical pain subjects, we found statistically significant changes in pain scales and lateral cervical radiographic measurements compared to no change in 33 neck pain control subjects. Average global angle improvement in the treatment group between C2 and C7 posterior tangent lines was 17.9°, in Cobb angles at C1-C7 and C2-C7, the improvements were 13.9° and 13.6°. At long-term follow-up of 14 months in 70% of the treatment group, the improvements in cervical lordosis following traction treatment remained stable. The fact that no statistically and clinically significant differences for beginning and follow-up radiographic measurements in 33 control subjects indicates the repeatability of radiographic positioning, radiographic line drawing analysis, and sagittal cervical posture. Due to the design of this nonrandomized study, it is unknown if the improvement in the patients' cervicogenic pain was caused by the improvement in sagittal plane alignment of the cervical spine. Future nonrandomized and randomized projects should address this issue.

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