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Slight head extension: does it change the sagittal cervical curve?

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Abstract It is commonly believed that slight flexion/extension of the head will reverse the cervical lordosis. The goal of the present study was to determine whether slight head extension could result in a cervical kyphosis changing into a lordosis. Forty consecutive volunteer subjects with a cervical kyphosis and with flexion in their resting head position had a neutral lateral cervical radiograph followed immediately by a lateral cervical view taken in an extended head position to level the bite line. Subjects were patients at a spine clinic in Elko, Nevada. All radiographs were digitized. Global and segmental angles of the cervical curve were compared for any change in angle due to slight extension of the head. The average extension of the head required to level the bite line was 13.9°. This head extension was not substantially correlated with any segmental or global angle of lordosis. Subjects were categorized into those requiring slight head extension (0°–13.9°) and those requiring a significant head extension (>13.9°). In the slight head extension group, the average change in global angle between posterior tangents on C2 and C7 was 6.9°, and 80% of this change occurred in C1–C4. In the significant head extension group, the average change in global angle between posterior tangents on C2 and C7 was 11.0°, and the major portion of this change occurred in C1–C4. Out of 40 subjects, only one subject, who was in the significant head extension group and had only a minor segmental kyphosis, changed from kyphosis to lordosis. The results show that slight extension of the head does not change a reversed cervical curve into a cervical lordosis as measured on lateral cervical radiographs. Only small extension angle changes (mean sum=4.8°) in the upper cervical segments (C2–C4) occur in head extension of 14° or less.

Keywords Kyphosis · Lordosis · Posture · Extension · Cervical spine · X-ray

Introduction

Recently, the sagittal cervical spinal curve has been shown to be an important clinical outcome of care [10, 12, 15]. Factors affecting the accuracy of measurements of cervical curvature have been shown to be reproducible, i.e., neutral resting upright posture [2, 7, 16], correct X-ray positioning [17, 18], and use of a radiographic line drawing [4, 8].

In spite of these facts, it is commonly asserted both that slight head flexion will reverse (create a kyphosis in) the lordotic sagittal cervical curve and that slight head extension will cause a cervical kyphotic configuration to change into a lordotic configuration [3, 5, 6, 11, 13, 19, 20]. However, only relatively large amounts of head flexion (15°–25°) [5, 13, 19] and neck retraction (posterior translation) [11] have been studied for their effect on the lordotic cervical curve [5, 13, 19]. To our knowledge, no investigations have been performed to see whether slight

head extension will change a cervical kyphosis back towards a lordosis. On lateral cervical radiographs, head extension to a level bite line is of interest to both surgical and rehabilitative spine specialists. Findings of any change in head position to horizontal, when comparing the before treatment radiographs with the after treatment radiographs, might negate the apparent changes in the sagittal cervical curve found following treatment.

Neutral resting lateral cervical radiographs of subjects with a cervical kyphosis at any segmental level were compared with a lateral cervical radiograph taken after the bite line was levelled by extension of the head. It was hypothesized that this slight head extension of subjects with kyphotic cervical deformities would result in a change of cervical kyphosis to lordosis.

Materials and methods

The objective was to evaluate whether small amounts of head extension can affect the cervical alignment on lateral radiographs. Forty consecutive pro-selected subjects, who had cervical kyphosis at any segmental level, volunteered to have a neutral and an additional lateral cervical radiograph. For the neutral lateral cervical radiograph, taken at 182.9 cm (72 in.), subjects assumed a comfortable resting position, which has been shown to be reproducible [14, 17]. For the second radiograph, subjects were asked to slowly extend their head until the bite line appeared visually level.

Subjects were neck pain patients at a spine clinic in Elko, Nevada. All applicable laws concerning the use of human subjects in research were followed by our internal review board. Subjects were 25 women and 15 men, who had a mean age of 36 years (SD±11.9 years), an average height of 169.7 cm (SD±10.4 cm), and an average weight of 82.75 kg (SD±17.9 kg). Subjects reported a mean score of 4.2 (SD±1.6) on a visual analog scale for pain (0=excellent health, 10=bed ridden).

Radiographs were digitized with a GP-9 sonic digitizer from (GTCO CalComp, Columbia, Md., USA). Digitized points were processed with our own code, developed with Trent Computer Systems of Harvest, Alabama. The following points were digitized on each radiograph:

1. Posterior hard palate and posterior margin of the foramen magnum (Chamberlain's line)
2. Angle of jaw and inferior symphysis menti
3. Mid-anterior and posterior tubercles of atlas
4. Posterior-superior, posterior-inferior, and anterior-inferior body corners of C2 through C7

Digitized points were used to create posterior body tangent lines on each vertebra (Fig. 1) and Cobb angles at C2–C7 and C1–C7. Absolute rotation angles (ARAs) were calculated as the angle of intersection of the posterior tangents on the C2 and C7 vertebral bodies. Segmental angles (RRAs) were calculated as the intersection of adjacent pairs of the posterior body tangents on C2 through C7. A segmental angle for C1–C2 was constructed as the intersection of the C2 posterior tangent and a line perpendicular to the line through the anterior and posterior arches of C1. An angle of Chamberlain's line to horizontal and a jaw angle to horizontal were also calculated (Fig. 1). A C0–C1 segmental angle for the skull to C1 was measured at the intersection of a line perpendicular to Chamberlain's line and the line through the atlas. The standard error of measurement for the posterior tangent method (1°< SEM< 2°) is lower than the reported values for the Cobb method (3°< SEM< 10°) [4, 8].

Severity of pain and/or age was investigated for an effect on our results. Segmental angles were compared for two age groups of subjects, with ages above and below the median (36.5 years) and two pain groups, with VAS scores above and below the median (4.5).

For each of the angular measurements, individual *t*-tests were used to compare the mean of patients with slight head extension to the mean of patients with significant head extension required to make their bite lines level.

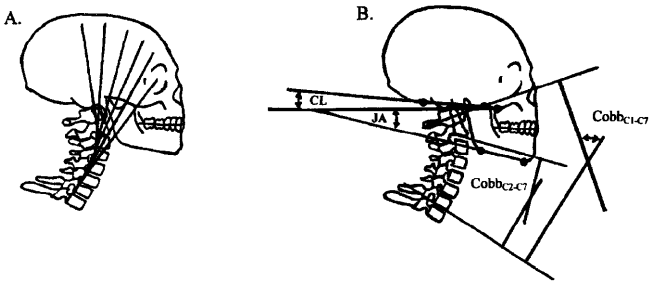

Fig. 1A, B Schematic drawing of the head and cervical vertebrae showing the measurements. **A** Posterior tangents are drawn at the posterior vertebral body margins on C2 through C7. The adjacent lines can be used to measure segmental (relative rotation) angles (RRAs), while the tangents on C2 and C7 indicate overall lordosis (the absolute rotation angle, ARA). **B** Intersected with a horizontal line, Chamberlain's line (CL) and a line on the inferior mandible angle (JA) create angles for evaluation of head flexion/extension. Cobb angles were constructed on C1 and C7, and C2 and C7

Results

Viewing extension as negative *x*-axis rotation for the 40 subjects studied, the average change in head extension, measured both as Chamberlain's line to horizontal and jaw angle to horizontal, was –13.9°. Using this mean value, we defined slight head extension as the range from 0° to –13.9° and significant head extension as ranging from –13.9° to –27.1°. None of the correlations between head extension and any global or segmental angles are substantial. Using individual *t*-tests, no significant differences were found for six of the ten angles, i.e., for all segmental angles from $RRA_{C0–C1}$ to $RRA_{C5–C6}$. A significant decrease from slight to significant head extension was detected for $ARA_{C2–C7}$ (P=0.0038), $Cobb_{C1–C7}$ (P=0.0002), and $Cobb_{C2–C7}$ (P=0.0020). The increase from slight to significant head extension for $RRA_{C6–C7}$ was not statistically significant after using the Bonferroni procedure to correct for multiplicity.

The slight head extension group showed a mean change in the angle between Ruth Jackson's lines of $ARA_{C2–C7}$=–6.9°±3.8°. In this group, the mean lower cervical segmental angles changed by less than 1°, while the upper cervical segmental angles changed by between –1.7°and –3.0°. The significant head extension group showed a mean change in the angle between Ruth Jackson's lines of $ARA_{C2–C7}$=–11.0°±4.7°. In this group, the mean segmental angles changed by more than 1° at all

Table 1 Angle measurements (mean±SD, in degrees) of subjects according to the required head extension. Subjects are divided into two groups: slight extension (0° to –13.9°) and significant extension (–13.9° to –27.1°), with –13.9° being the mean required head extension from a neutral head flexed position of the whole group (*ARA* absolute rotation angle, the angle between posterior body tangents on C2 and C7; *RRA* relative rotation angle, the segmental angle between adjacent vertebrae or between skull and atlas

Angles	Slight head extension group (n=20) Mean±SD	Significant head extension group (n=20) Mean±SD	P-value[a]
Head extension	9.1°±3.0°	18.7°±3.5°	<0.0001
$Cobb_{C1–C7}$	8.4°±6.2°	15.8°±5.1°	0.0002
$Cobb_{C2–C7}$	5.4°±6.5°	11.8°±5.8°	0.0020
$ARA_{C2–C7}$	6.9°±3.8°	11.0°±4.7°	0.0038
$RRA_{C0–C1}$	1.7°±4.6°	3.1°±3.8°	>0.05
$RRA_{C1–C2}$	1.8°±2.2°	4.6°±2.8°	>0.05
$RRA_{C2–C3}$	1.8°±2.5°	2.8°±3.9°	>0.05
$RRA_{C3–C4}$	3.0°±3.1°	5.6°±5.1°	>0.05
$RRA_{C4–C5}$	0.5°±3.5°	2.4°±3.8°	>0.05
$RRA_{C5–C6}$	0.9°±3.9°	1.9°±4.2°	>0.05
$RRA_{C6–C7}$	0.8°±3.0°	1.7°±3.8°	>0.05

[a] Two-sided test of equality of mean angles for slight and significant head extension

levels. Data on mean segmental angle changes are provided in Table 1.

Only one subject (with a change in jaw angle of 17°, in the significant head extension group) changed from a very slight kyphotic configuration to a lordotic configuration. It was also noted there were no significant differences between patients with slight head extension and those with significant head extension for the segmental angles (C0–C1 through C6–C7), while there were for the global angles. The mean global angle magnitude differences between slight and significant head extension groups for $Cobb_{C1–C7}$, $Cobb_{C2–C7}$, and $ARA_{C2–C7}$ indicate that neither slight nor significant head extension changes a cervical kyphosis into a cervical lordosis (Table 1). Approximately 40% of mean head extension is located between C0 and C2, with the remaining 60% being dispersed among C2–C7, unequally. Approximately 80% of head extension occurs in the upper four cervical segments (C0–C4).

After using the Bonferroni procedure to correct for multiplicity, no significant differences were detected in any of the 22 angles using age and pain scores.

The level of cervical kyphosis in the 40 subjects is approximated by a bell-shaped curve, with highest incidence (50% of subjects) at the C4 and C5 levels.

Discussion

Using a common assumption of radiologists and clinicians alike, it was hypothesized that slight head extension would change a complete or segmental kyphosis of the cervical curve back to a lordosis on the lateral cervical radiograph. Only one of our subjects, who was in the significant head extension group with only a slight kyphosis, changed configuration to a cervical lordosis. Upon visual classification of the lateral radiographs, reported by Cote et al. [4] to be reliable, it was noted that head extension caused only the already lordotic segments to show more lordosis. In contrast, the kyphotic segments did not return to an extended, lordotic position (Fig. 2). This was true regardless of the location of the segmental kyphosis.

Fig. 2 Example of radiographs of a subject in neutral posture with head flexion and with kyphosis at C5 and C6 (*left*). A slight extension of 8° (see Chamberlain's line) to level the bite line does not change the kyphosis into lordosis (*right*)

In the present report, the amount of change in segmental or global angles was not influenced by the subjects' age nor pain intensity. Likewise, neither the severity of degenerative disc disease nor bony pathologies was related to change in segmental or global angles.

In light of the data presented here, we had to accept that it was not the case that slight head extension causes a change to lordosis of the cervical curve in patients with regions of kyphosis. Subjects with 0° to –13.9° of head extension (slight) were not associated with a change from a cervical reversal to a cervical lordosis in this study, with a mean of only 6.9° of change in the ARA between Ruth Jackson's stress lines on C2 and C7. In fact, a significant head extension, of between –14° and –27° degrees was associated with a mean of only 11° of change in the ARA at C2–C7.

We found nine references to cervical curve changes during slight head flexion/extension in the literature [3, 5, 6, 9, 11, 13, 19, 20]. In order to determine where the belief that cervical curve changes can be caused by slight head extension had arisen in the literature, secondary, tertiary, and quaternary referencing in radiology papers were traced to a few common original references. Only three studies [5, 11, 19] and one case study [13] actually addressed this issue. The remaining four studies either claimed this with no support (e.g., Clark et al. [3], Helliwell et al. [9]) or referenced the four studies that ad-

dressed the issue of curve changes caused by head flexion/extension.

More importantly, all of the previous reports utilized large degrees of head flexion (15°–25° on average) to claim that „slight“ positional changes of the skull to horizontal can cause a cervical lordosis to become military or kyphotic. In 59% of their 129 subjects, Fineman et al. [5] reported that head flexion (15°–25°) did not have an effect on the cervical configuration. While making claims about slight head flexion/extension, one report [11] did not use head flexion as the major movement, but instead used a posterior head translation position (retraction). None of these reports demonstrated the effect that extension of the head might have on the kyphotic configuration of the cervical spine.

We suggest extension of the head and the concomitant effect on reversed cervical curvatures is the more clinically relevant issue than is flexion from an already lordotic cervical spine. This is true because both surgical and conservative interventions gauge a successful outcome, in part, on the correction of abnormal anatomic alignment of the cervical spine – especially if the initial abnormal alignment is a loss of or reversal of the cervical curve [10, 12, 15]. The post-treatment radiograph is compared to the pre-treatment radiograph in order to verify anatomic alignment change or correction of cervical kyphosis to cervical lordosis. If an increased extension angle of the skull to horizontal is noted on the post-treatment radiograph, then it may be construed that the structural improvement is merely due to X-ray positioning and not to treatment intervention procedures.

However, our results for both slight and significant head extension groups demonstrate that the end point measurements of cervical curvature, – $Cobb_{C1–C7}$, $Cobb_{C2–C7}$, and the $ARA_{C2–C7}$ – show small differences compared to the change in the angle of head extension. The seven intersegmental angles (RRAs) did not show statistically significant changes when comparing small or large extension angles, while the global angles did. Thus, the use of segmental angles as outcomes for surgical and conservative methods is recommended, because large changes in these angles would then be significant. Furthermore, in only one of our 40 subjects, who had a head extension of 17.0°, did a slightly kyphotic cervical curve change to a lordosis.

It might be thought our working definition of “slight head extension” (from 0° to –13.9°) to level subjects’ bite lines, derived from the average head extension of 40 subjects, influenced our results. However, according to guidelines concerning range of motion, the upper range of our definition (14°) is almost 25% of the total range of head flexion (60°) [1]. Surely “slight head extension” should be considerably less than our average value.

Conclusion

We have shown that extension of the head by less than 14° (absolute value) to level the bite line on the lateral cervical radiograph results in small changes in the segmental and global angles comprising cervical curvature. In the majority of subjects, cervical kyphotic segments were not extended into lordosis during slight extension of the head. These results fail to support the hypothesis that correction of kyphotic cervical curve deformities visible on post-radiographic studies is the result of patient positioning errors due to increased skull extension (often referred to as head nodding). Therefore, when slightly flexed head positions are visualized on initial radiographs and not on post-treatment radiographs, surgical and conservative kyphotic alignment changes verified post-radiographically are likely due to treatment interventions. However, the subjects in the current report are not the typical surgical candidates for cervical spine surgery, and the kinematics of the operative cervical spine may therefore behave differently. This may be an area for future research into the postural changes of the lateral cervical spine.

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