A radiographic analysis of the influence of initial neck posture on cervical segmental movement at end-range extension in asymptomatic subjects

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ABSTRACT200/200

In the management of neck pain disorders, McKenzie recommends performing neck extension exercises from a fully neck retracted position in order to achieve a maximum range of lower cervical extension. However, no study has investigated the rationale for pre-positioning the neck prior to the extension exercise. This study compared end-range sagittal cervical segmental rotation and translation from three starting positions: the neck in neutral (Ex), retraction (Ret-Ex) and protraction (Pro-Ex). Twenty asymptomatic healthy volunteers were recruited. Lateral radiographs were taken in neutral and at each of the three end range positions and differences in sagittal rotation angles and translation from the neck neutral posture were calculated at each segment. The results indicated that there was a significant difference ($P<0.001$) in the pattern of the sagittal segmental rotation albeit no significant difference ($P>0.05$) in the total segmental sagittal rotation among the three conditions. Pro-Ex generated significantly ($P<0.05$) greater extension range at C1-2 than alternate conditions and Ret-Ex produced significantly ($P<0.05$) greater extension range at C6-7 than alternate conditions. In contrast, there was no significant difference ($P>0.05$) in the pattern of the segmental translation values under the three conditions. These indicate initial neck positions can influence cervical segmental movement pattern in extension.

KEYWORDS

McKenzie, Neck, Extension, Segmental movement

INTRODUCTION

Mechanical Diagnosis and Treatment (MDT) is a well-known management strategy for spinal disorders (Jackson, 2001; Gracey et al., 2002; Manca et al., 2007). For neck-related pain the MDT concept utilizes exercise predicated upon a systematic evaluation of pain location and responses to repeated cervical movements (McKenzie and May, 2006). An important aspect of the MDT concept is to identify the direction of neck movement that improves neck symptoms, which is known as the directional preference. Cervical extension is reported to be the predominant directional preference for management of such pain using MDT (Hefford, 2008). Hefford (2008) demonstrated that 12 of 15 (80%) patients with neck related upper limb pain had symptom reduction using neck extension exercises.

When prescribing neck extension exercise, emphasis has been placed on performing the extension exercise from a fully neck retracted position (McKenzie and May, 2006). Although the rationale for this is based on clinical experience, a possible biomechanical explanation is that neck extension from a neck retraction position induces greater extension in the lower segments while neck extension from a neck protraction position induces greater movement in the upper-mid cervical region. However, there have been no studies to confirm this.

Previously, Haughie et al. (1995) demonstrated that total active neck extension range increased by 10° when neck extension was commenced from erect sitting posture (mimicking a retraction posture) compared with neck extension from natural sitting posture. However, this study measured the total neck extension range with the use of an external cervical range of motion device and it was not clear which segments were influenced by altering the neck starting position. Hence, it is necessary to investigate segmental movements of the whole cervical spine during neck extension, from different neck starting postures, in order to examine which segment(s) are affected by changes of neck starting positions.

The purpose of this radiographic study was to compare the pattern of upper and lower cervical movement (sagittal cervical segmental rotation and translation) in full cervical extension when commenced from three different cervical starting positions – neutral, protraction and retraction. .

METHODS

Subject Group

Twenty asymptomatic healthy young volunteers (10 females) with a mean age of 25.3±3.4 years were recruited from advertising in the Sapporo Medical University. Exclusion criteria included pregnancy, claustrophobia, metal implants, and a history of significant cervical spine or shoulder girdle disorders. All subjects were screened with a routine physical examination of range of motion of the neck and upper limbs to ensure normal cervical movements and all subjects had a brief MRI evaluation using sagittal T2-weighted images and axial T2*-weighted images of the cervical spine to detect any evidence of cervical disc disease or congenital anomalies. An orthopedic surgeon experienced in MRI evaluation, inspected all MRI images and no subjects were rejected in this screening process.

All subjects were informed of the study design and the radiographic procedures to be used and the risks of radiation and all provided informed consent prior to data collection. Data collection was conducted in Shinoro Orthopedic, Sapporo, Japan. This study was granted ethical approval by the Research Ethics Committee of the Society of Physical Therapy Science, and was conducted in accordance with the Declaration of Helsinki.

Subject setup and cervical positions

Subjects were positioned in standing with the head and neck in a relaxed, neutral resting position, looking straight ahead. The trunk was firmly supported, anteriorly and posteriorly, by a handmade wooden jig positioned at the level of the sternum. Previously it has been shown that repeated neck movements alters the resting posture of the neck, which may ultimately influence the measurement of range of motion in any given direction. (Pearson and Walmsley, 1995). To prevent this, the sagittal rotation angle of the head was set at zero for all starting positions, prior to each movement, and was checked by a specifically designed device, attached firmly to the ear (Figure 1). This device consisted of a bubble spirit level. The head was maneuvered until the bubble was centered, prior to the commencement of each test movement (sensitivity; 0.5mm/m=0.03°, accuracy; ±2.5mm/m=±0.14°, ED-KEY, EBISU, Niigata, Japan).

The subjects were instructed in how to actively move to and hold each of the three test positions; Extension (Ex) - end-range cervical extension starting from a neutral neck posture; Retraction followed by extension (Ret-Ex) - end-range cervical extension starting from a retraction posture; and Protraction followed by extension (Pro-Ex) - end-range cervical extension starting from a protraction posture. All end-range movements (extension, retraction, and protraction) were confirmed by an examiner who applied passive over pressure. Subjects were instructed to extend the neck with a standardized instruction ‘bend your head backward as far as you can to look up to the ceiling keeping your mouth open’. Subjects practiced the test positions and tasks five times in preparation for subsequent radiographs.

A lateral radiograph was taken in the neutral position and in each end range position of Ex, Ret-Ex and Pro-Ex. The order of testing of each position was randomly allocated between subjects.

Radiographic analysis

Radiographs were taken by the orthopedic surgeon (Y.I.) using standard radiographic techniques with the tube centered on the C5 vertebra. The radiographic film cassette was positioned 150 cm from the tube.

The four lateral radiographs for each subject were analyzed from digital images using ImageJ1.6 software (National Institute of Mental Health, Bethesda, USA). From each radiograph, two measurements were taken at each cervical motion segment; a sagittal rotation angle and a translation using methodology previously described (Frobin et al., 2002). Sagittal rotation angles for each segment, from Occiput-C1 to C6-7, were defined as the difference between the angles in each measurement position from those of the neutral position. The degrees of segmental extension compared with the value in the neutral position were described as negative and flexion as positive. Each translation, from C1-2 to C6-7, was measured in millimeters and was deemed negative if the projection of the cranial center point of the upper vertebra was located more posteriorly to that of the lower vertebra.

The segmental sagittal rotation angle at the Occiput-C1 segment was calculated using a modified Frobin technique (Frobin et al., 2002), where four landmarks on the C1 vertebra (superior and inferior margins of the anterior and posterior tubercles of the atlas,) were identified using an established protocol (Van Mameren et al., 1990; Dvorak et al., 1991; Ordway et al., 1999). The sagittal rotation angle was the angle between the McGregor line (hard palate to the inferior occiput) and a bisector of the four landmarks of C1 (Figure 2).

Measurements for the segmental sagittal rotation angle and translation at the C1-2 segment were based on the landmarks of C1 and the two inferior corners of C2 (Figure 2). The angle between C1 and C2 was measured between the line running through the midline of C1 and the line through inferior corners of C2. Translation was defined by the distance between the projection of the midpoint of the midline of C1 and the projection of the midpoint of the line connecting inferior corners of C2 onto the bisector between the two lines.

The sagittal rotation angles and the translation at segments from C2 to C7 were obtained by marking the two inferior corners of C2 and the corners of each vertebra from C3 to C7 as previously described (Frobin et al., 2002; Wu et al., 2007). The corner points for the C3 to C7 vertebrae were calculated mathematically by finding the midlines of each vertebra. This was defined as a line running through the midpoints between the two anterior and two posterior corners. The bisecting line between two midlines and the perpendiculars from the centers of the adjacent vertebrae were used to calculate the segmental sagittal rotation angles and range of translation (Frobin et al., 2002; Wu et al., 2007) (Figure 3).

The defined vertebral landmarks were digitized twice and the mean values of these were used for subsequent analysis.

Reliability & statistic analysis

To assess repeatability of the measurements for cervical sagittal rotation angles and translations measured in extension from a neutral position, one investigator measured the images on two separate occasions. The investigator was blinded to measurements of the first occasion and the order of radiographs in different neck starting positions was changed. $ICC_{(1,2)}$ and the standard error of measurements (SEM) were calculated and Bland-Altman Plots examined for measurement error.

A repeated measures ANOVA was used to determine differences in the sagittal rotation angles and translations between Ex, Ret-Ex, and Pro-Ex positions. The Bonferroni test was employed as post-hoc test to examine the differences in segmental sagittal rotation ranges and translations at each segment from the Occiput to C7, as well as the total cervical sagittal rotation.. Statistical analysis was performed using SPSS version 18.0 (SPSS Inc., Tokyo, Japan). Statistical significance was attributed to P values less than 0.05.

RESULTS

The $ICCs_{(1,2)}$ for the measurements and SEMs taken from 80 radiographs are presented in Table 1, and can be interpreted as demonstrating good repeatability. Bland-Altman Plots for the variable showing the highest and lowest $ICC_{(1,2)}$ value are presented in Figure 4 (C3-4 Pro-Ex translation) and Figure 5 (C4-5 Ex translation), respectively. Visual inspection of these Bland-Altman Plots indicates that measurement errors can be considered random in nature.

The values for segmental rotation with standard deviations are presented in Table 2. A repeated measures ANOVA revealed an interaction between position and segment ($P<0.001$). Post-hoc analysis revealed that the extension angle of segmental rotation at C1-2 in Pro-Ex was significantly greater when compared with either Ex ($P<0.05$) or Ret-Ex ($P<0.01$). In addition, the value of extension at C6-7 in Ret-Ex was significantly greater than that of either Ex ($P<0.001$) or Pro-Ex ($P<0.05$). However, there was no significant difference ($P>0.05$) in the total cervical sagittal rotation between the three conditions.

The mean values for translation are shown in Table 3. No significant difference (P>0.05) was observed in the segmental pattern of translation between the three conditions.

DISCUSSION

This study demonstrated that there were some differences in the pattern of segmental sagittal plane rotation when commenced from different neck starting positions. Significant changes were observed at the C1-2 and C6-7 segments with no significant variations being measured at other cervical segments. The Pro-Ex movement resulted in an increased range of extension motion at C1-2 (mean 2.2°, representing 35% more extension) compared with the Ex movement. The Ret-Ex movement resulted in an additional mean 2.8° or up to 54% more extension at C6-7 when compared to the Ex movement. At a first glance, the difference of 2.2°-2.8° between the different exercise procedures may seem small, but they were statistically significantly. Furthermore these small ranges represent 35%-54% of the segmental extension range of motion at these segments. Such large percentage variation at a segmental level may be important from a clinical perspective. It must also be recognized that such small differences in range of motion may simply represent measurement error (Van Mameren et al., 1990).

Interestingly, the two different starting postures affected the C1-2 and C6-7 in an apparent inverse way, in that starting in a protracted position resulted in more extension at C1-2 and lesser at C6-7 with the reverse occurring when staring from the retraction position. This altered pattern of segmental movement coincides with the hypothesis that neck extension from neck retraction position induces greater extension in the lower segments while neck extension from a head protraction position induces greater movement in the upper-mid cervical region.

These results in this study are not unexpected as it is known that neck protrusion invokes extension in the upper cervical region and flexion in the lower cervical region whereas neck retraction invokes flexion in the upper cervical region and extension in the lower cervical region (Ordway et al., 1999). Wu et al.(Wu et al., 2010) demonstrated that generally, the lower cervical spine contributes greater extension during the initial one third of the extension motion while the middle cervical spine contributes most during the final one third of extension. Hence, when cervical extension is initiated from a protracted position, the pre-flexed lower cervical spine would not achieve maximum extension range, which normally occurs during the initial extension motion. Consequently this may explain the reduced extension range at C6-7 in the movement of Pro-Ex.

Wu et al. (2010) did not examine segmental movement at C1-2 during cervical movement, and it is therefore not possible to use their findings to identify a reason why the extension range of C1-2 increased in Pro-Ex and decreased in Ret-Ex. One explanation for this phenomenon may be that paradoxical movements occur at C1/2 during flexion and extension due to the location of the joints of the atlas with respect to the line of gravity of the head and the line of action of the neck flexor and extensor muscles (Bogduk, 2002). Whether the atlas flexes or extends during flexion-extension of the head depends on where the occiput rests on the atlas (Bogduk, 2002). For example, if the neck is first protracted, the center of gravity of the head will come to lie relatively anterior to the atlantoaxial joint. Consequently, the atlas will be tilted into flexion by the weight of the head, irrespective of any action by longus cervicis on its anterior tubercle. However, if the head is retracted, the center of gravity of the head will tend to lie more posterior than when the head is protruded, and paradoxically, the atlas will be squeezed into extension by the weight of the head. tour finding of neck extension from neck retraction position inducing greater extension in the lower cervical spine while neck extension from a head protraction position induces greater movement in the upper cervical spine concurs with this hypothesis.

We found no significant difference in the total range of cervical extension starting from each different resting posture. Haughie et al (1995) demonstrated approximately 10° difference in extension range between neck extension from an erect sitting posture and a natural sitting posture. Our results possibly indicate that the increased extension range in the previous study in neck extension commenced from erect sitting posture (mimicking a retraction posture) might have been achieved by increased extension at the cervicothoracic junction rather than cervical segments. Hence, the biomechanical basis for the therapeutic benefits of Ret-Ex may be explained by the movement being induced in the cervicothoracic junction, away from the source of neck pain (Aquino et al., 2009), by relatively fixing the upper cervical spine.

Cervical sagittal rotation accompanies posterior translations (Frobin et al., 2002; Reitman et al., 2004; Pickett et al., 2005; Wu et al., 2007) because of the orientation and shape of the zygapophyseal joints below the C2 vertebra. Hence, we expected to find altered segmental translation corresponding with an altered pattern of segmental sagittal rotation. However, we found no such difference in the pattern or value of translation between the different trials of neck extension. However, compared with the means, standard deviations were large, which might explain the lack of difference between different trials. In addition, in the lower cervical segments, posterior translation occurred to a lesser extent than in the middle cervical segments, a finding corresponding with previous studies.

The effect of exercise on segmental translation range is conceptually important in the presence of cervical instability, as it would not be appropriate for an exercise to magnify the translation range at a potentially unstable segment. In this study, it was shown that for healthy volunteers, initial neck position did not significantly change the range or direction of segmental translation. Nevertheless further investigation is required to investigate if initial neck position influences segmental translation movements in patients with neck pain disorders with potential instability because of trauma or pathology (Kristjansson et al., 2003; Centeno et al., 2007).

This study demonstrated good reliability for the assessment of sagittal rotation range and translation. To date, for the reliable measurement of translation, specialized software has been required and the assessment of translation is generally undertaken in research settings. However, we demonstrated reliable measurement of translation using general measurement software – ImageJ1.6. Hence, this study enables clinicians to measure and assess translation with confidence using this simple software.

The present study has some limitations. Measurement did not include the cervico-thoracic junction because radiographically, this region was obscured by the shadow of the shoulder. Hence, it is impossible to evaluate the impact of different neck starting positions on cervicothoracic junction kinematics during neck extension. An alternative method of investigation is required for this objective, such as vertical MRI. In addition, data were provided for end-range extension positions only and did not inform on the movement pattern through range. Different starting postures may potentially affect muscle firing patterns around the neck and upper trunk and thereby influence movement through range.

Further studies are required to evaluate real-time changes using combinations of electromyography and real-time visualization of cervical kinematics, for example video fluoroscopy. Finally, all subjects were young and healthy without cervical spinal disorders. It is not possible to directly compare these results with the kinematics of older subjects or those with neck pain disorders, particularly following trauma, who may have segmental instability. Further studies are required to investigate the biomechanics of specific therapeutic exercise in the MDT concept in different patient populations.

CONCLUSION

The present study demonstrated that initial neck posture has differing effects on the pattern of upper and lower cervical segmental movement in full cervical extension in young healthy individuals. These findings support the rationale for retraction followed by extension when exercise aims to influence the lower cervical segments as employed in the MDT concept, although further studies are required in different populations with neck symptoms.

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Manual Therapy
Editors
Dear Dr. Ann Moore and Dr. Gwendolen Jull

Manuscript title: The influence of initial neck posture on cervical segmental movement at end range extension – normative data with a radiographic analysis

Thank you very much for the review of our manuscript. Please find the revised manuscript, tables, and figures with changes made according to reviewers' suggestions. Please find a separate document where there are responses for comments from the reviewers. Revised parts in the text were highlighted in red. We believe that this process has strengthened the manuscript.

Your consideration of this manuscript for publication in Manual Therapy journal will be very much appreciated.

Your sincerely,

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CAPTIONS TO FIGURES AND FIGURE LEDGENDS

Figure 1. A device with a water level.

Figure 2. Definitions of the sagittal rotation angle and translation between Occiput-C1, and C1-2.

Intervertebral translation between Occiput and C1 vertebra was not defined nor measured.

1a; Superior margin of the anterior tubercle of atlas
1b; Inferior margin of the anterior tubercle of atlas
1c; Superior margin of the posterior tubercle of atlas
1d; Inferior margin of the posterior tubercle of atlas
2a; Anterior and inferior corner of C2
2b; Posterior and inferior corner of C2
θ; Segmental sagittal rotation at Occiput-C1
θ’; Segmental sagittal rotation at C1-2

Figure 3. Definitions of the sagittal rotation angle and translation from C2-3 to C6-7.

2a; Anterior and inferior corner of C2
2b; Posterior and inferior corner of C2
θ’’ ; Segmental sagittal rotation at C2-3
θ’’’; Segmental sagittal rotation at C3-4

Figure 4. Bland-Altman Plot of the Pro-Ex in translation at the C3-4, which has the highest value in ICC$_{(1,2).}$

A; The value of the first measurement (millimetres)

B; The value of the second measurement (millimetres)

Mean; Mean of the difference between A and B (0.05 mm)

SD; Standard deviations of the differences between A and B (0.3 mm)

Figure 5. Bland-Altman Plot of the Ex in translation at the C4-5, which has the lowest value in $ICC_{(1,2).}$

A; The value of the first measurement (millimetres)

B; The value of the second measurement (millimetres)

Mean; Mean of the difference between A and B (0.2 mm)

SD; Standard deviations of the differences between A and B (1.0 mm)

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