Journal of Electromyography and Kinesiology 22 (2012) 829–834

Contents lists available at SciVerse ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Cervical spine posteroanterior stiffness differs with neck position

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ARTICLE INFO

Article history:
Received 12 August 2011
Received in revised form 24 April 2012
Accepted 24 April 2012

Keywords:
Cervical vertebrae
Musculoskeletal manipulations
Biomechanics
Range of motion
Articular
Physical therapy modalities

ABSTRACT

Purpose: Spinal stiffness is commonly considered when treating patients with neck pain, but there are few studies reporting the objective measurement of cervical spine stiffness or the possible kinesiological factors that may affect its quantification. The aim of this study was to determine if the position of the neck affects cervical spine stiffness.
Methods: An instrumented stiffness assessment device measured posteroanterior cervical spine stiffness at C4 of 25 prone-lying asymptomatic subjects in three neck positions in randomised order: maximal flexion, maximal extension, and neutral. The device applied five standardised mechanical oscillatory pressures while measuring the applied force and concurrent displacement, defining stiffness as the slope of the linear portion of the force–displacement curve. Repeated measures analysis of variance with Bonferroni-adjusted post hoc comparisons determined whether stiffness differed between neck positions.
Results: There was a significant difference in cervical spine stiffness between different neck positions ($F_{(1.6,38.0)} = 16.6$, $P < 0.001$). Stiffness was least in extension with a mean of 3.09 N/mm (95% CI 2.59, 3.58) followed by neutral (3.94, 95% CI 3.49, 4.39), and then flexion (4.32, 95% CI 3.96, 4.69).
Conclusion: When assessing cervical spine stiffness, neck position should be standardised to ensure maximal reliability and utility of stiffness judgments.

1. Introduction

The prevalence of neck disorders and their associated costs are high, and appear to be increasing (Martin et al., 2008). Around 30–50% of adults will experience neck pain in a 12 month period (Hogg-Johnson et al., 2008), and many do not achieve resolution of their symptoms (Haldeman et al., 2008). Neck pain poses a substantial burden on workers (Côté et al., 2008), reducing productivity and contributing to societal costs (Hansson and Hansson, 2005). Though a single most effective treatment for patients with neck pain remains elusive, many practitioners have used manual therapy techniques, or hands-on techniques generating joint movement, with some evidence of success (Hurwitz et al., 2008).

When selecting manual techniques appropriate for a patient's treatment, practitioners often apply posteroanterior (PA) oscillatory forces to the spine to assess vertebral movement and its resistance, i.e. spinal stiffness (Maitland et al., 2005; Scaringe and Kawaoka, 2005). Practitioners' interpretation of spinal stiffness and the patient's response to assessment determines the manual techniques to be used and spinal levels that will be treated (Maitland et al., 2005; Shirley, 2004). There are many factors that have been shown to affect spinal stiffness, as measured in the lumbar spine. Some of these include the characteristics of the force applied (magnitude (Kumar and Stoll, 2011; Latimer et al., 1998), direction (Caling and Lee, 2001), speed (Squires et al., 2001)), the patient's position (Edmondston et al., 1998) and breathing pattern (Shirley et al., 2003). However, there are no identified studies reporting the potential effects of kinesiological factors, such as patient position, on cervical spine stiffness. If potential confounding effects of cervical spine stiffness measurement can be identified and controlled, it will improve the reliability of cervical spine stiffness assessment leading to increased accuracy in the patient data upon which practitioners base their treatment decisions.

A difference in neck position is one factor that may affect a practitioner's interpretation of spinal stiffness. If the cervical spine is positioned outside of its neutral zone (i.e., into flexion or extension), increased tension in soft tissues either through stretch or muscle contraction may increase the stiffness of the overall structure of the neck. Though practitioners intend to consistently position the neck in neutral when assessing its stiffness (Maitland et al., 2005), no studies were identified reporting reliable methods for determining a standardised neutral position for manual assessment. Potential variations in position between assessment occasions may affect the accuracy of spinal stiffness interpretation, negatively influencing treatment decisions. The aim of this study

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http://dx.doi.org/10.1016/j.jelekin.2012.04.014

is to determine if the measurement of cervical spine PA stiffness differs with variations in neck position.

2. Method

A repeated measures within subject design was used to determine differences in cervical spine PA stiffness between different neck positions. Stiffness measurement was performed in vivo using a custom-designed device that applied a linear load to the spine over a single spinal vertebra. Stiffness was defined as force divided by displacement, averaged over repetitive cycles of loading. Cervical PA stiffness at C4 was measured in prone-lying in three neck positions (flexion, extension, and neutral). The study was approved by the University's Human Research Ethics Committee.

2.1. Equipment and measurement

A custom-designed device was used to measure cervical spine stiffness (Snodgrass et al., 2008). The device consists of a 12 V direct current (DC) motor (Model No. BM 4023-MA2, Shinko Electric Co. Ltd., Minato-Ku, Tokyo, Japan) that powers a gear drive, producing a forward and backwards movement of a stainless steel rod used as an indenter to apply standardised PA forces to the spine. The indenter is covered with a plastic tip 15 mm in diameter. Displacement of the indenter is measured using a DC-operated linear variable differential transformer (LVDT, Model No. DC-EC 1000, Schaevitz™ Sensors, Lucas Control Systems, Hampton, VA, USA). A compression and tension load cell (Model No. UMM-K050, Dacell Co. Ltd., Chungbuk, South Korea) measures resistance to movement. Voltage output is amplified (Strain Gauge Signal Conditioner, Model RM-044, Applied Measurement Australia, Sydney) and acquired using Labview 8.0 (National Instruments Corp., Austin, TX, USA). Force data (N) from the load cell and displacement data (mm) from the LVDT were collected at 100 Hz.

The device sits within a frame attached to the base of a treatment table with a normal padded surface (SX3 Physioline Series, Model No. 50251, Chattanooga Group Inc., Sydney, Australia). A custom-made piece of foam (Dunlop utility foam AA23-130) with a cut out for the face was positioned under a subject's head and shoulders to facilitate subject comfort. For safety, the maximum displacement was set at 30 mm, and maximum force at 80 N. The actual amount of force applied to each subject was relative to the magnitude of resistance from their tissues as the mechanical oscillations were applied by the DC motor, set at 85% of its maximum, or 10.2 V. At this setting, displacement is 14 mm if resistance is 70 N; greater resistance results in less displacement, and less resistance results in greater displacement. This setting also corresponds with the average force used by therapists (65–80 N) when applying posteroanterior cervical techniques that move into spinal resistance (Snodgrass et al., 2009, 2010).The reliability of this equipment to measure in vivo cervical spine stiffness is satisfactory (SEM $\leqslant$ 0.83 for different vertebral levels, and ICC between measurement occasions on different days 0.84, 95% CI 0.74–0.90) (Snodgrass et al., 2008).

Stiffness data was collected by applying five oscillations of standardised mechanical force at 1 Hz using the device. This method simulates a practitioner's assessment of stiffness, as an oscillatory frequency of 1 Hz is comparable to that applied by practitioners (Snodgrass et al., 2009). A custom-written program in Labview 8.0 produced force (y-axis) by displacement (x-axis) curves representing the forward movement of the indenter rod for each of the five oscillatory cycles. Stiffness (N/mm) was defined as the slope of the linear portion of the force–displacement curves for cycles two through five. Cycle one was excluded as it has been shown to be consistently different to cycles two through five in previous studies (Latimer et al., 1996; Shirley et al., 2002; Shirley, 2004; Snodgrass et al., 2008). The linear portion of the force–displacement curves occurred between 7 and 40 N of applied force and this range was used to standardise stiffness calculations, as it has been shown that stiffness values vary when calculated within different ranges of applied force (Latimer et al., 1998). The linear region was selected by calculating the linearity of the slopes of different regions of the force–displacement curves, and determining a single standard portion of the curve demonstrating the most linearity across subjects.

2.2. Subjects

Twenty-five subjects were recruited for the study based on power and sample size estimations (Dupont and Plummer, 1990) that indicated a 1 N/mm difference between positions could be detected if the within-group SD was 1.7 N/mm (average SD of cervical spine stiffness measurements at two levels in a previous study) (Snodgrass et al., 2008). Subjects were eligible if they were between 18 and 50 and had not sought treatment for neck pain or headache in the previous 12 months. They were asymptomatic in order to reduce potential confounding effects of symptoms or previous cervical spine injuries. Potential subjects were excluded if they had any cervical disorders or conditions where manual treatment of the spine might be contraindicated, such as inflammatory or infectious diseases affecting the neck, instability, nerve root pain, or symptoms potentially related to the vertebrobasilar system including dizziness, diplopia, nausea, feelings of fainting, dysarthria or dysphagia (Maitland et al., 2005). These exclusions ensured the safety of the stiffness assessment procedure for all subjects.

2.3. Data collection

The fourth cervical vertebra (C4) was identified using surface palpation of bony landmarks (Field, 2001) and marked by a single physiotherapist researcher. C4 was selected as it has been shown to be the midpoint of the cervical lordotic curvature (Harrison et al., 1996), which meant the device could be aligned vertically to the spinous process and treatment plinth and the application of force would be approximately perpendicular to the spinal curvature at that level whether the spine was flexed or extended. C4 stiffness was measured in three prone positions including maximal flexion, maximal extension and cervical spine neutral. The order that positions were tested was randomized.

Subjects were positioned manually by a single physiotherapist researcher into flexion, extension and neutral. For flexion and extension, the therapist positioned the subject's neck at its maximal range of motion possible (without any subject reported discomfort) in prone while lying on the apparatus (Fig. 1). The neutral position was determined using standard clinical methods which describe positioning the cervical spine at the mid-point between flexion and extension (Dutton, 2004; Maitland et al., 2005). The reliability of positioning the cervical spine in neutral was not evaluated in this study, and there were no studies identified that reported any specific methods for manually positioning the cervical spine in neutral. Thus, standard clinical methods were used, and the same physiotherapist researcher positioned subjects for all tests to potentially increase the consistency of neutral positioning.

Prior to testing, the C4 cervical vertebrae was preconditioned with the neck in a neutral position by applying five cycles of force to the C4 spinous process using the stiffness assessment device. Preconditioning allows the soft tissues around the spine to undergo normal stretching that may occur during initial stiffness assessment (Lee and Evans, 1992; Shirley et al., 2002). Previous research