Manual Therapy 22 (2016) 109–115

Contents lists available at ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original article

Factors associated with cervical kinematic impairments in patients with neck pain

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ARTICLE INFO

Article history:
Received 30 January 2015
Received in revised form
1 September 2015
Accepted 24 October 2015

Keywords:
Kinematics
Velocity
Neck pain
Sensorimotor

ABSTRACT

Background and aim: Cervical kinematics have functional relevance and are important for assessment and management in patients with neck disorders. A better understanding of factors that might influence cervical kinematics is required. The aim of this study was to determine any relationships between altered kinematics to the symptoms and signs of sensorimotor impairments, neck pain and disability and fear of neck motion in people with neck pain.

Method: Kinematics were measured in 39 subjects with chronic neck pain using a customized virtual reality system. Range of cervical motion, mean and peak velocity, time to peak velocity percentage, number of velocity peaks and accuracy were derived. Correlations between these measures to self-reported (neck pain intensity, disability, fear of motion, dizziness, visual disturbances) and sensorimotor measures and regression analyses were conducted.

Results: Range and velocity of motion of cervical rotation appeared to be most related to visual disturbances and pain or dynamic balance. Nevertheless these relationships only explained about 30% of the variance of each measure.

Conclusion: Signs and symptoms of sensorimotor dysfunction should be considered and monitored in the management of altered cervical rotation kinematics in patients with chronic neck disorders. Future research should consider the effects of addressing these factors on neck kinematics and vice versa to aid functional recovery in those with neck pain.

1. Introduction

Assessment and management directed towards specific impairments such as cervical range of motion (ROM) and neuromuscular control, rather than specific anatomical structures, is the current recommended approach for neck pain (Borghouts et al., 1998; Hogg-Johnson et al., 2008). An important function of the cervical spine is quick and precise head movement in reaction to surrounding stimuli. Consequently research into impairments associated with altered cervical kinematics, such as velocity and accuracy of movement, in those with neck pain has been gaining attention (Woodhouse and Vasseljen, 2008; Röijezon et al., 2010). Studies suggest that velocity measures in particularly, are highly sensitive and specific to patients with neck disorders (Sarig Bahat et al., 2014a) and have relevance to functional activities such as driving (Röijezon et al., 2008; Takasaki et al., 2013). Thus these cervical kinematic impairments would appear to be highly relevant for clinical assessment and management considering the specific importance of quick and accurate neck motion for many daily functional activities (Sjölander et al., 2008; Röijezon et al., 2010; Sarig-Bahat et al., 2010). Recent research has been considering factors that might influence the ability to move the neck fully, quickly and precisely in order to assist management and gain functional recovery in those with neck pain.

Some studies have demonstrated an association between range, velocity and smoothness of cervical motion and patients' subjective reports of pain intensity and disability, and also fear of neck motion (Howell et al., 2012; Sarig Bahat et al., 2013). However, others have not found these associations (Röijezon et al., 2010). It is possible that other factors, such as dizziness and visual disturbances commonly reported in those with neck pain (Treleaven et al., 2003) might be exacerbated when performing quick or large head movements and thus may influence range, velocity and or accuracy of neck movement. These additional symptoms are also associated with objective disturbances to sensorimotor control, such as

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http://dx.doi.org/10.1016/j.math.2015.10.015
1356-689X/

impaired head control and postural stability (Treleaven, 2008) and subsequently might also be associated with altered cervical kinematics. If any of these factors are associated with altered cervical kinematics, it may be appropriate to specifically address these to gain improvements in cervical kinematics or vice versa.

Thus, the primary aim of this study was to determine if factors such as dizziness handicap, visual disturbances, functional balance, joint position error (JPE), neck pain intensity, related disability, and fear of neck motion are associated with objective cervical kinematic measures (range, velocity and accuracy of head motion) in people with chronic neck pain. Ultimately, a better understanding of the relationship between these factors could improve the management of impaired cervical kinematics and or these symptoms, and facilitate functional recovery in those with chronic neck pain. In cases of findings of strong correlations between any factors, it might also reveal potential redundancy amongst these multiple measures that are commonly evaluated in neck pain.

2. Methods

2.1. Participants

Patients with chronic (greater than 3 months) neck pain, aged 18 years or over and with a neck disability index (NDI) score greater than 10% were sought to participate in this study. The study was conducted at the Neck Pain and Whiplash Research Unit at University of Qld. Participants were recruited via advertising in the local community.

Participants were excluded if they had any of the following: preexisting vestibular pathology; cervical fracture/dislocation; systemic diseases; neurological/cardiovascular/respiratory disorders affecting physical performance; history of traumatic head injury; inability to provide informed consent; or pregnancy.

The study received approval from the human ethics committee at University of Qld. Each participant provided a written consent before data collection.

2.2. Self-reported measures

All participants completed a general questionnaire concerning demographic characteristics and their history of neck pain. They also completed questionnaires related to their neck pain intensity, disability, dizziness, visual disturbances, fear of motion, and fast head motion.

1. *Neck Disability Index % (NDI)* is a 10 item self-rated instrument assessing disability due to neck pain (Vernon and Mior, 1991; Vernon, 2008).
2. *Visual Analogue Scale (VAS)* using 100 mm line representing pain intensity. Patients were requested to indicate the point on the lines that best represented their average level of neck pain in the past week.
3. *The Dizziness Handicap Index short form (DHIsf)* (Tesio et al., 1999), where a low score out of 13 indicates greater levels of perceived handicap associated with dizziness.
4. *Visual disturbances* score was generated from the sum of the product of the severity (0–3) and frequency (0–4) rating for each of 4 symptoms (sensitivity to light, need to concentrate to read, eye strain, and visual fatigue) with a maximal score of 48. These symptoms were chosen as they have previously been seen to be most prevalent and troublesome in patients with neck pain (Treleaven and Takasaki, 2014).
5. *Tampa Scale of Kinesiophobia* (TSK) is a reliable 17-item questionnaire used to assess fear of movement in neck pain (Cleland et al., 2008).
6. *The pictorial fear of activity for the cervical spine* (PfactS-C) is a 19-item questionnaire which reflects the magnitude of fear of neck movements. Higher averaged scores (0–10) indicate greater fear of neck movements (Turk et al., 2008).

2.3. Kinematic measures

Cervical kinematic measures were collected using a customized VR system (Fig. 1). This VR system consisted of off-the-shelf hardware and customized software. Hardware included a head-mounted display with a motion tracker built in (Wrap™ 1200VR by Vuzix, Rochester, New York), equipped with gyroscopes, accelerometers and magnetometers. An interactive three-dimensional (3D) virtual environment was developed using the Unity-pro software, version 3.5 (Unity Technologies, San Francisco). Three interactive modules; range of motion (ROM), velocity and accuracy were used to enable elicitation of cervical motion by the patient's response to the provided visual stimuli.

During all three VR modules, the virtual pilot flying the red airplane is controlled by the patient's head motion and interacts with targets or lines appearing from four directions (flexion, extension, right rotation, left rotation). A full kinematic report for each patient was generated. The VR system and methodology has previously been described in detail (Sarig-Bahat et al., 2009; Sarig Bahat et al., 2010, 2014b).

Cervical roll, pitch, and yaw data were retrieved from the VR assessment tracking data. The data were low-pass filtered (6th order Butterworth low pass filter with a 10 Hz cut-off). Kinematic measures were analysed for each participant by calculating the mean value of the three best results for each of the following measures (Sarig Bahat et al., 2010). Measures 1–5 considered movement in flexion, extension, and left and right rotation.

1. *The maximal active cervical range of motion.*
2. *Peak velocity* (Vpeak, °/s) refers to the maximal velocity value recorded during the period of time from motion initiation (target appearance) to target hit.
3. *Mean velocity* (Vmean, °/s) refers to the mean value of velocity from motion initiation to target hit.
4. *Number of velocity peaks* (NVP) refers to the number of velocity peaks from motion initiation to target hit, indicating motion smoothness.
5. *Time to peak velocity percentage (TTP%)* was defined as the time from motion initiation to peak velocity moment, as a percentage of total movement time and is a reflection of the acceleration/deceleration ratio of the velocity profile.
6. *Head movement accuracy* was collected during the accuracy module where the participant was required to keep the pilot's head on the virtual moving target. Motion accuracy was defined as the difference between target position and participant's head location in degrees. This difference (target position – player's head position) in the same plane of the direction of motion was derived from the sum of the trials for each movement direction (sagittal and horizontal).

2.4. Sensorimotor measures

1. *Cervical joint position error (JPE)* was measured using the three-space Fastrak system (Polhemus, Navagation Science Division, Kaiser Aerospace, Vermont, USA) according to an established measurement method of returning the head to the neutral position with eyes closed following an active head movement while seated (Treleaven et al., 2003). The difference between the