Clinical Biomechanics 35 (2016) 27–36

Contents lists available at ScienceDirect

Clinical Biomechanics

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

Relationship between neck acceleration and muscle activation in people with chronic neck pain: Implications for functional disability

Sharon M.H. Tsang [a,*], Grace P.Y. Szeto [a], Raymond Y.W. Lee [b]

[a] Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong
[b] School of Applied Sciences, London South Bank University, United Kingdom

ARTICLE INFO

Article history:
Received 24 November 2015
Accepted 12 April 2016

Keywords:
Acceleration
Cervical spine
Functional disability
Electromechanical coupling
Neck pain
Thoracic spine

ABSTRACT

Background: Previous study has found that people with chronic neck pain moved with a consistently compromised acceleration/deceleration at their cervical and thoracic spines. This study examined the strength of the association between the electromyographic activities and the acceleration/deceleration of the cervical and thoracic spine, and its correlation with the functional disabilities in individuals with neck pain.
Methods: Time history of the cervical and thoracic acceleration/deceleration and EMG activity was acquired in thirty-four subjects with chronic neck pain and thirty-four age- and gender-matched asymptomatic subjects during active neck movements. The strength of the association between the electromyographic activity of spinal muscles and the cervical and thoracic acceleration/deceleration was determined using cross-correlation method. Relationship between the strength of this association and the severity of the functional disabilities in neck pain group was examined using correlation analysis.
Findings: The strength of the association between cervical and thoracic acceleration/deceleration and electromyographic activities was significantly lower in neck pain group. Significant negative correlations were found between the functional disability level and the strength of this defined association in the symptomatic group.
Interpretation: The compromised capability of the spinal muscles to produce acceleration/deceleration in the neck pain group may imply an impaired electromechanical coupling of these spinal muscles when performing neck movements. Significant negative correlation of the degree of functional disabilities suggests that the present approach can be used as an objective and specific evaluation of the dynamic performance of the spinal muscles and its relationship with the functional disabilities in neck pain subjects.

1. Introduction

Chronic neck disorders often result in physical impairments and functional disabilities (Picavet and Schouten, 2003; Webb et al., 2003). Various factors have been proposed as contributors to the functional limitations in individuals with chronic neck pain (NP) (Côté et al., 2008). Neuromuscular adaptations associated with dysfunction of muscle properties and/or control strategies have been frequently reported in literature (Falla, 2004; Falla et al., 2004a). Adaptations of muscle properties include atrophy, fatty infiltration, changes in contractile properties, membrane properties, and type proportions of the muscle fibres as revealed by various technologies (Falla et al., 2004b; Kristjansson, 2004). Changes in motor control strategies associated with NP include adaptations of the spatial and temporal characteristics of muscle activity as reported by electromyographic (EMG) studies. Reduced activation of the deep layer muscles and over-activity of the superficial muscles of the neck are the classic spatial features representing motor control dysfunction in NP sufferers (Falla et al., 2004a, 2004b; Szeto et al., 2005; Tsang et al., 2014). In addition, delayed activity of the deep cervical muscle, prolonged activation of the spinal muscle, and reduced relative resting periods are the other manifestations of impaired temporal features in neuromuscular adaptations in neck pain patients (Falla et al., 2004a, 2004b).

Surface electromyography is a useful method frequently applied to examine the association between neuromuscular changes and neck pain (Falla et al., 2004c, 2004d; Szeto et al., 2005). Despite the good to excellent reliability of these normalization methods shown within individuals for amplitude analysis of EMG activity, it remains difficult to fully comprehend the muscle recruitment pattern without studying its temporal features. Studying the muscle recruitment pattern is particularly important for the human neck due to the complexity and redundancy of the spinal musculatures. Examination of the timing and pattern of activation of the individual muscles of the spine helps enhance understanding of the actual relationship of the muscles activation and the spinal movements which reflects their capacity to generate and

* Corresponding author at: Room ST 535, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong
E-mail addresses: Sharon.Tsang@polyu.edu.hk (S.M.H. Tsang), Grace.Szeto@polyu.edu.hk (G.P.Y. Szeto), R.Lee@lsbu.ac.uk (R.Y.W. Lee).

http://dx.doi.org/10.1016/j.clinbiomech.2016.04.006
0268-0033/

sustain a torque, as well as the efficiency in offering stability for movement to take place at the spine.

The cross-correlation method quantifies the strength of association of two sets of signals over a period of time (e.g. a movement cycle). We proposed the use of cross-correlation to examine the strength of the association between spinal movement and EMG activity during dynamic neck movements. Based on Newton's second law of motion, force produced by the contractions of the muscles contributes to acceleration at the joint (Siebert et al., 2007). As a result, the strength of the association between spinal acceleration and muscle activity can serve as an indicator to quantify the electromechanical coupling and function of different muscles across the neck region (Panjkota and Zanchi, 2006). This method is frequently used in sports performance analysis, as it helps review the quantitative relationship between the motions of one particular segment of the human body and the muscles involved (Glazier et al., 2003; Li and Caldwell, 1999). Furthermore, the phase shift data obtained from cross-correlation analysis inform of the phasic relationship of the development of force relative to EMG onset, which is defined as the electromechanical coupling of muscle contraction (Cavanagh and Komi, 1979; Thelen and Schultz, 1994). In addition, it is crucial to examine whether the electromechanical coupling as indicated by the relationship between the spinal acceleration/deceleration and the muscle activation found in individuals with NP is associated with the extent of functional limitation. Such an association would help direct rehabilitation strategies to restore optimal muscle performance and functional ability.

The aims of the present study were, first, to examine the strength of the relationship of the acceleration/deceleration and the muscle activity of the cervical and thoracic spine during active neck motion, and second, to examine whether the level of this relationship correlates with functional limitations reported in people with NP.

2. Methods

2.1. Participants

Thirty-four participants with chronic neck pain (25 female and 9 male) (NP group) and thirty-four age- and gender-matched asymptomatic participants (AS group) volunteered for the study. The inclusion criteria for the NP group included neck pain which had either lasted longer than three months continuously or had presented mostly over the previous 12 months with non-traumatic onset history. The severity of the neck condition had to have required medical care. Participants in the AS group were recruited if they had been symptom-free in all spinal regions in the previous 12 months. Participants were excluded if they had known neurological or orthopaedic disorders, previous surgery or trauma to the brain or spine, sensory or vestibular conditions, bony abnormalities, deformities of the trunk, or rheumatic disease. Prior to data collection, ethical approval for this study and the written consent of all participants to the experimental procedures were obtained, and participants were informed of any potential risks. Participant demographics are presented in Table 1. The average pain intensity and functional disability reported by the participants recruited to the NP group was 38.97 (SD = 15.85) using the Numeric Pain Rating Scale 0–100 (NPRS 101) and 29.96% (SD = 11.94) using the Northwick Park Disability Questionnaire (NPQ) respectively (Cleland et al., 2008; Leak et al., 1994). Independent t-test analysis revealed that there was no significant difference between the demographic characteristics of the two groups.

Table 1
Group demographic data with mean (SD). (BMI = Body Mass Index).

Variable	Asymptomatic (n = 34)	Neck Pain (n = 34)	*P* value
Age (years)	34.35 (9.08)	38.44 (10.87)	0.700
Female (n = 25)	33.64 (9.90)	36.72 (9.89)	0.276
Male (n = 9)	34.22 (8.17)	41.44 (1.17)	0.137
Height (m)			
Standing	1.64 (0.08)	1.63 (0.07)	0.290
Sitting	0.88 (0.04)	0.87 (0.04)	0.834
Weight (kg)	59.34 (10.36)	58.23 (11.13)	0.698
BMI (kg/m^2)	22.07 (3.11)	21.77 (3.03)	0.563

2.2. Acceleration/deceleration of the cervical and thoracic spine

An electromagnetic tracking device (Fastrak, Polhemus Inc. Colchester, VT, USA) was used to measure movements of the cervical and thoracic spine. Three motion sensors were placed over the head and spine to measure the kinematics of the cervical and thoracic regions at a sampling frequency of 120 Hz with each sensor measured 40 times per second (Fig. 1). The first sensor was mounted on a small plastic plate secured to a non-elastic strap wrapped around the skull and positioned over the external occipital protuberance (O). The second and third sensors were attached to the skin overlying the first (T1) and twelfth (T12) thoracic spinous processes using double-sided tape. The kinematics of the cervical and thoracic spinal regions was derived from the relative orientation between the O and T1 sensors the T1 and T12 sensors respectively. The kinematic output comprised 3 × 3 direction cosine matrices that described the movements of the corresponding spinal regions based on mathematical techniques and computation of the angular displacement described in previous research (Grood and Suntay, 1983; Pearcy and Hindle, 1989).

2.3. Electromyography of the cervical and thoracic spinal muscles

Electromyographic activity was measured by surface electromyography using the Telemyo system (Noraxon, USA Inc.) with a sampling frequency of 1024 Hz. Five pairs of muscles – both sides of the upper trapezius (UTr), the cervical erector spinae (CES) at C4 level, the sternocleidomastoid (SCM), and the thoracic erector spinae at T4 (TES 4) and T9 (TES 9) level – were examined with disposable disc-shaped Ag-AgCl surface EMG electrodes (10 mm ø) with an inter-electrode distance of 20 mm. The surface EMG electrodes were applied to the five

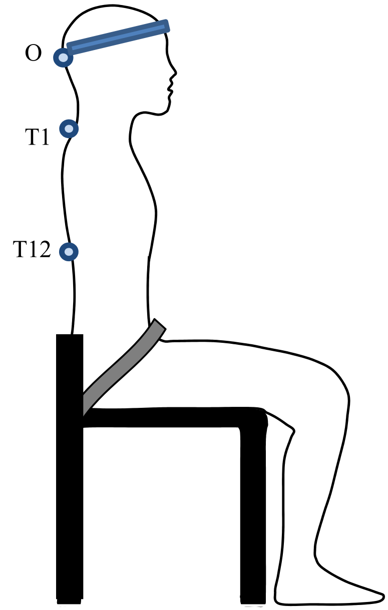

Fig. 1. The experimental setup in sitting with the electromagnetic motion tracking sensor positioned at the occiput (O), spinous process of the first thoracic spine (T1) and the twelfth thoracic spine (T12) for measurement of the cervical and thoracic spine kinematics.