Ultrasound in Med. & Biol., Vol. ■, No. ■, pp. 1–13, 2016

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2015.12.022

● *Original Contribution*

CHANGES IN DORSAL NECK MUSCLE FUNCTION IN INDIVIDUALS WITH CHRONIC WHIPLASH-ASSOCIATED DISORDERS: A REAL-TIME ULTRASOUND CASE–CONTROL STUDY

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(*Received* 26 *July* 2015; *revised* 16 *December* 2015; *in final form* 21 *December* 2015)

Abstract—Impaired neck muscle function leads to disability in individuals with chronic whiplash-associated disorder (WAD), but diagnostic tools are lacking. In this study, deformations and deformation rates were investigated in five dorsal neck muscles during 10 arm elevations by ultrasonography with speckle tracking analyses. Forty individuals with chronic WAD (28 women and 12 men, mean age = 37 y) and 40 healthy controls matched for age and sex were included. The WAD group had higher deformation rates in the multifidus muscle during the first ($p < 0.04$) and 10th (only women, $p < 0.01$) arm elevations compared with the control group. Linear relationships between the neck muscles for deformation rate (controls: $R^2 = 0.24$–0.82, WAD: $R^2 = 0.05$–0.74) and deformation of the deepest muscles (controls: $R^2 = 0.61$–0.32, WAD: $R^2 = 0.15$–0.01) were stronger for women in the control group versus women with WAD, indicating there is altered interplay between dorsal neck muscles in chronic WAD. (E-mail: gunnel.peterson@liu.se) © 2016 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Whiplash injury, Ultrasonography, Neck muscles, Spine.**

INTRODUCTION

The annual incidence of whiplash injury is 200–300 per 100,000 in the general population (Holm et al. 2008; Styrke et al. 2012) and is defined as a sudden acceleration–deceleration movement of the head that can cause both joint and soft tissue injuries in the neck (Siegmund et al. 2009). Despite decades of research, the mechanisms responsible for the burden in chronic whiplash-associated disorder (WAD) are not well understood, and diagnostic tools are lacking. The neck muscles surrounding the cervical spine and the deep neck muscle layers play an important role in maintaining a stable base for the postural control of the neck (Mayoux-Benhamou et al. 1994; Panjabi 1992). Impaired ventral neck muscle function has been reported in chronic neck pain (Falla et al. 2004, 2011; Jull et al. 2004) and WAD (Cagnie et al. 2010; Elliott et al. 2010; Jull et al. 2004; Peterson et al. 2015a; Sterling et al. 2003), but the function of the neck extensor muscles in WAD is not as well studied.

Elliott et al. (2008a) found fatty infiltrate in the extensor muscle in WAD using magnetic resonance imaging (MRI). Functional MRI studies have reported altered neck muscle activity after induced pain in healthy individuals (Cagnie et al. 2011) and in individuals with neck pain (O'Leary et al. 2011). Electromyography (EMG) studies have revealed that not all dorsal muscles act synergistically as extensors; the splenius capitis muscle can activate during neck flexion in some healthy individuals (Keshner et al. 1989; Siegmund et al. 2007), and higher levels of extensor muscle co-activation in neck pain have been reported (Lindstrom et al. 2011). Surface EMG has revealed increased activity in superficial neck extensors in WAD (Bexander and Hodges 2012; Juul-Kristensen

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et al. 2013), but when controlling for differences in movement velocity, no differences were found between people with WAD and healthy controls (Vikne et al. 2013). Small invasive EMG studies have reported decreased and less defined activity in the deep semispinalis cervicis muscle in those with WAD (Schomacher et al. 2012), and the multifidus muscle was affected by eye movement (Bexander and Hodges 2012).

Both the expensive MRI and invasive EMG are difficult to apply in routine clinical practice, and MRI does not provide information on the interplay between muscle layers. Real-time ultrasound imaging measures the mechanical function in the muscle, the elongation and shortening of the muscle (*i.e.*, deformation), and the speed with which deformation occurs (*i.e.*, deformation rate). This method has been used to detect altered ventral neck muscle function in individuals with chronic WAD (Peterson et al. 2015b) and altered muscle function in the semispinalis capitis muscle after decompression surgery for cervical disc disease (Peolsson et al. 2015). The strength of real-time ultrasound is that it can non-invasively evaluate both superficial and deep muscle function simultaneously. To the best of our knowledge, this method has not been used to investigate dorsal neck muscle function in people with WAD.

The aim of the present study was twofold: (i) to compare mechanical neck muscle function, deformation and deformation rate in five dorsal neck muscles in individuals with chronic WAD versus healthy controls during repetitive arm elevation, and (ii) to investigate if the interplay in deformation and deformation rate between these muscles differs between the WAD and control groups.

METHODS

Participants

Forty individuals (28 women and 12 men; mean age = 37 y, SD = 11.2 y) with chronic WAD, including 29 individuals with WAD grade II (neck pain and musculoskeletal signs) and 11 individuals with WAD grade III (neck pain plus neurologic signs), were included in the study. The participants were recruited consecutively for ultrasound investigation among patients enrolled in a randomized controlled trial (Peolsson et al. 2013). Inclusion criteria were persistent symptoms associated with a whiplash injury 6 mo to 3 y before study entry; WAD grade II or III; age 18–63 y; persistent neck pain rated >20 mm and/or neck disability index (Vernon and Mior 1991) >20%; dominant neck pain on the right side of the neck; and right-handedness. Exclusion criteria were signs of traumatic brain injury at the time of whiplash injury; known or suspected serious pathology; previous fracture or luxation in the cervical spine; contraindication to exercise; neuromuscular diseases; rheumatologic disease; previous neck pain causing more than 1 mo of sick leave in the year before the whiplash injury; severe mental illness; current alcohol or drug abuse; and an inability to understand spoken and written Swedish.

For comparison, 40 healthy controls matched for age and sex (mean age = 37 y, SD = 11.4 y) were recruited from university staff, hospital staff and acquaintances. Exclusion criteria were present or past neck problems; trauma to the neck or head, including whiplash injury; neck or low back pain; rheumatologic or neurologic disease; or generalized myalgia.

The baseline characteristics of the participants are provided in Table 1. The study was approved by the Regional Ethics Review Board and was conducted

Table 1. Baseline characteristics of participants in the study*

	WAD (n = 40)	Healthy controls (n = 40)	*p* Value
Female, n (%)	28 (70%)	28 (70%)	1.0
WAD grade II/III	29/11	0	
Age (y)	37.4 (11.2)	37.4 (11.4)	1.0
Injury duration (mo)†	21.2 (8.5)	0	
Body mass index (kg/m^2)			
Male	25.0 (4.8)	26.3 (3.6)	0.48
Female	24.5 (6.4)	22.5 (2.5)	0.14
Physical activity level, median (range)‡	2.0 (2.0–3.75)	3.5 (4.0–4.0)	0.001
Neck disability index§	32.4 (13.9)	1.4 (1.8)	<0.001
Pain in previous week (VAS)‖	45.9 (18.7)	1.1 (2.2)	<0.001
Fatigue, median (range)¶	3.3 (2.0–5.0)	0.1 (0.0–0.0)	<0.001

WAD = whiplash-associated disorder; VAS = visual analogue scale.
* Data are given as means (standard deviations) unless otherwise noted.
† Months since whiplash injury; range = 6–36 mo.
‡ Physical activity level over the last year; 1 = inactivity, 2 = low activity, 3 = moderate activity, 4 = high activity.
§ Range = 0–100%, with higher scores representing higher disability.
‖ Average pain in the prior week; range = 0–100 mm, with higher ratings representing higher pain intensity.
¶ Borg CR10 scale (Borg 1990), anchored with 1 = no fatigue, 10 = extremely strong fatigue.