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Shoulder-abduction force steadiness in individuals with neck pain with scapular dyskinesis

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ABSTRACT

Background: Neck pain is associated with scapular dyskinesis and impaired axio-scapular and shoulder muscle activity and function. However, there is little research on force steadiness, specifically during shoulder motion in patients with neck pain with scapular dyskinesis. Its relationship with characteristics of neck pain is also unknown.

Objectives: To investigate force steadiness at 20% and 50% of MVC of shoulder abduction (30 degrees) in persons with neck pain with scapular dyskinesis compared to asymptomatic controls and to determine its relationships with characteristics of neck pain.

Materials and methods: Fifty-two women and men (26 neck pain with scapular dyskinesis and 26 asymptomatic controls) were recruited to the study. Force steadiness of 30 degrees of shoulder abduction was measured at 20% and 50% of maximal voluntary contraction (MVC) and coefficient of variation (CV) of force values were calculated. Characteristics of neck pain included neck pain intensity, duration and disability and upper limb disability.

Results: There was no interaction between group and target force level (p=0.45). Main effects were found for group (p=0.003) and target force level (p<0.001). Participants in neck pain had significantly reduced force steadiness of isometric shoulder abduction at 20% and 50% of MVC compared to the control group (p<0.05, η^2_p =0.10 and p<0.001, η^2_p =0.26, respectively). There were no correlations between force steadiness and characteristics of neck pain (p>0.05).

Conclusion: Patients with neck pain with scapular dyskinesis had reduced shoulder abduction force steadiness at 20% and 50% of MVC. The relationships between force steadiness and characteristics of neck pain are still needed to be explored in further studies.

Introduction

Force steadiness, the ability to maintain a steady and precise force with specific target muscles involved has been suggested to be associated with pain.[1-3] Reduced force steadiness has also been considered as an independent predictor of functional performance.[4,5] Previous studies demonstrated that patients with neck pain had reduced force steadiness of the cervical muscles.[2,6] O'leary *et al*.[6] demonstrated that patients with neck pain had significantly decreased ability of maintain isometric contraction of the craniocervical muscles at 20% and 50% of maximal voluntary contraction (MVC) compared to healthy controls. Similarly, Muceli *et al*.[2] showed that women with neck pain exhibited significantly decreased force steadiness of cervical flexion. Poorer contraction accuracy in maintaining a steady contraction might reflect altered cervical afferent input in neck pain, such as direct damage to mechanoreceptors, sensitization

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of mechanoreceptors from neck pain, and/or sympathetic effects on muscle spindle sensitivity.[7]

Functions of the scapula and upper limb can potentially be affected by neck pain.[8,9] Patients with neck pain up to 80% had upper limb activities aggravating their neck pain and the neck and upper limb disabilities were also related to neck pain severity.[9] Altered scapular position and movement, termed scapular dyskinesis is often related to neck pain.[10] A recent study has reported a high percentage (90%) of scapular dyskinesis in office workers with neck and scapular complaints.[11] Patients with neck pain had reduced clavicular retraction and increased scapular downward rotation and protraction during elevation of arm movement compared to a healthy population.[12-14] The scapula shares common muscle attachments with the neck, through axio-scapular muscles, in particular upper trapezius and levator scapulae.[15] Thus altered scapular position and control may be associated with dysfunction of the axio-scapular muscles and may increase mechanical force to cervical structures.[10,16] Additionally, the scapula connects to the upper limb, so increased loads placed through the upper limb may alter scapular position and control and subsequently transmit to cervical structures, resulting in neck pain.[7,16]

According to mechanistic links between neck pain and scapular and upper limb dysfunction, altered force steadiness of the axio-scapular muscles to control the scapula during submaximal contraction of the shoulder can be expected. However, one clinical study found at baseline no differences in force steadiness during 30-second shoulder elevation at a target force of 30% of MVC between F-16 pilots with and without neck pain.[17] Yet, there is little research on force steadiness, specifically in patients with neck pain with scapular dyskinesis. It is also unknown if force steadiness is correlated with neck pain features (e.g., neck pain intensity, duration and neck and shoulder disabilities). The purposes of this study were 1) to investigate force steadiness at 20% and 50% of MVC of shoulder abduction (30 degrees) in persons with neck pain with scapular dyskinesis compared to asymptomatic controls and 2) to determine the relationships of force and neck pain features. The measure of 30 degrees of shoulder abduction was chosen for the study as it was considered to play an important role in upper limb function and activities of daily living, which requires a good scapular stability and control.[18] It was hypothesized that participants with neck pain with scapular dyskinesis would have reduced force steadiness (20% and 50% of MVC) compared to asymptomatic controls and there would be some relationships between force steadiness and neck pain features.

Materials and methods

Participants

Sample size for this cross-sectional study was calculated using G*Power 3.1.9.4 based on our pilot study (10 neck pain participants and 10 healthy controls). Effect sizes were 0.35 and 1.20 for coefficient of variation (CV) for force at 20% and 50% of MVC, respectively. The smaller effect size was chosen for sample size calculation in this study. With a power of 0.80 and a significant level of 0.05, a total sample size required for the study was 52.

Fifty-two women and men (26 neck pain with scapular dyskinesis and 26 controls) aged between 18-55 years old, were recruited from local hospitals, physical therapy clinics, community, and university through social media (e.g., Facebook and Instagram). Age, gender, and body mass index were similar for both groups. Inclusion criteria for the neck pain group were a history of nonspecific neck pain for ≥3 months, an average pain intensity over the past week ≥30 mm on a Visual Analogue Scale (VAS),[19] and having scapular dyskinesis on the side ipsilateral to neck pain and the dominant arm. Participants in the control group had no history of neck pain for the past year and no clinical signs of scapular dyskinesis. The dominant arm was determined based on at least 2/3 activities: writing, grasping, and throwing.[20] Assessment of scapular dyskinesis was performed according to previous studies by an experienced physical therapist who was one of examiners in published reliability studies.[21,22] In brief, the scapular dyskinesis was observed during performed 5 repetitions of arm elevation in the scapular plane with a 1 kg weight for women and a 2 kg for men. Scapula dyskinesis was defined as the presence of either winging (prominence of any portion of the medial border or inferior angle away from the thorax) or dysrhythmia (premature, or excessive, or stuttering motion during elevation and lowering) for at least 3/5 trials.

Participants in both groups were excluded if they had a history of head and neck injury or surgery, shoulder problems, any musculoskeletal or neurological problems that could affect the scapular position and movement (e.g., scoliosis, torticollis, myofascial pain, and long thoracic nerve palsy), and/or any specific training or treatment of neck or shoulder girdle muscles over the past 12 months. The study was approved by the ethical review committee for research in humans, Faculty of Associated Medical Sciences, Chiang Mai University (AMSEC-64EX-030) and was conducted in accordance with the Declaration of Helsinki. All eligible participants signed an informed consent prior to commencement of the study. They were also asked to refrain from taking pain-relief medication at least 6 hours before testing.

Questionnaires

A general questionnaire was used to collect demographic data. Participants with neck pain were also asked to complete a 0-10 cm Visual Analogue Scale (VAS),[23] the Neck Disability Index-Thai version (NDI-TH),[24] and the disabilities of the arm, shoulder, and hand questionnaire-Thai version (DASH-TH).[25] The VAS was used to measure neck pain intensity with 0 indicating “no pain” and 10 indicating “as worst as imaginable pain”.[23] The NDI-TH was used to assess a patient's self-reported neck pain related disability.[24] It includes 10 items concerning pain intensity, headache, concentration, reading, sleeping, driving, work, personal care, lifting, and recreation. The possible total score ranges from 0 to 50, which can be expressed as a percentage. The DASH-TH was used to measure disability and symptoms related to upper extremity.[25] It consists of 30 items concerning physical function, symptom severity, and social or role function, with the possible total score ranging from 0 (no disability) to 100 (most severe disability). A higher score of the NDI-TH and DASH-TH indicates greater disability.

Experimental procedure

A dynamometer (ML003/D, Power Lab, ADInstrument, Bella Vista, Australia) were used to measure MVC and force steadiness of shoulder abduction. The raw force and position signals from a dynamometer were collected at a sampling frequency of 1,000 Hz and low-pass filter of 100 Hz. The measures of MVC and force steadiness were tested on the ipsilateral (more painful) side of neck pain or the dominant side for the control group. Participants sat upright with knees and hips at 90 degrees and feet flat on the floor. The arm being tested was attached to a resistance application pad of the dynamometer, approximately 3 cm above the lateral epicondyle with the shoulder abducted 30 degrees (using a universal goniometer), the elbow flexed 90 degrees and the forearm in neutral position (Figure 1). The other arm was placed on their side with the hand placed on their thigh. Participants were asked to perform MVC at 30 degrees of shoulder abduction three times and each time was hold for 5 seconds. A 60-second rest was provided between each trial. The highest value of MVCs was used to calculate relative target forces corresponding to 20% and 50% of MVC. Two practices were given for familiarization prior to testing.

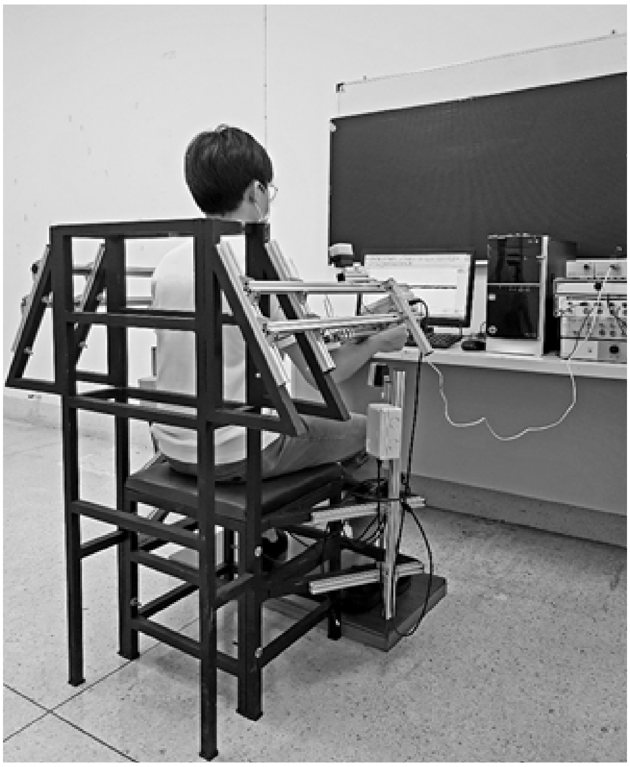

***Figure 1**. Participant position during maximal voluntary contraction (MVC) and force steadiness tests of 30 degrees of shoulder abduction.*

For the force steadiness test, a computer monitor was positioned approximately 1 meter in front of participants. The target force (20% or 50% of MVC) was displayed on the monitor with a horizontal line showing changes in the exerted force. Participants were given standard instructions to "attempt to stay as close as possible to the target force". Each target force was tested randomly three times with an interval of 10 minutes between each target force. Each trial was held for 15 seconds with a 60-second rest between trials.[26] Participants were asked to maintain an upright position in order to avoid any compensation. Participants were also asked to rate any pain occurring during the test on a 0 - 10 numerical rating scale (NRS). All measures were assessed by an independent examiner who was blinded to the participants' condition.

Data management

All force data were analyzed using LabChart v8.1.5 software (ADInstrument, Bella Vista, Australia). Force steadiness was measured for the intermediate 10 seconds to avoid range of the ramping up and down of force production.[26] Force steadiness was calculated as the coefficient of variation (CV) of the exerted force and expressed as a percentage (CV=standard deviation (SD)/mean forcex100).[27] Increased CV of force represents reduced ability to maintain a steady muscle contraction (steadiness of force).

Statistical analysis

Descriptive statistics, independent t-test, and Chi-square were used to determine differences in participants' characteristics between groups. Shapiro-Wilk test was used to test for normality of outcome variables. Mann-Whitney U test was used to analyze a difference in the MVC between groups. A mixed model analysis of variance with the Bonferroni's correction was used to analyze differences between groups for the CV values at 20% and 50% of MVC. Effect size was calculated using partial eta squared (η_p^2): small ≥0.01, moderate ≥0.06, and large ≥0.14.[28] Pearson's correlation coefficient was used to determine the relationships between the CV values and characteristics of neck pain. A significance level was set at 0.05. All statistical analysis were conducted using SPSS package.

Results

Participants

Table 1 presents demographic data and neck pain characteristics of participants. There were no significant differences between groups with respect to age, gender, and body mass index (all p>0.05). All participants in both groups were right-handed.

Table 1 Demographic data for the neck pain and control groups.

	Neck pain (n=26)	Controls (n=26)	*p* value
Age (year)	30.69±8.25	33.04±10.86	0.39
Gender (male/female, n)	7/19	7/19	1.00
Body mass index (kg/m²)	22.67±2.39	22.50±2.47	0.80
Neck pain intensity (0-10 VAS, cm.)			
Over the past week	5.38±1.23	-	-
On testing day	4.96±1.34	-	-
Neck pain duration (months)	32.27±23.82	-	-
Neck disability (% NDI-TH)	19.23±8.54	-	-
Upper extremity disability (% DASH-TH)	16.54±9.83	-	-

Data are presented with mean±SD, otherwise as indicated. VAS: visual analogue scale, NDI-TH: neck disability index-Thai version, DASH-TH: the disabilities of the arm, shoulder, and hand questionnaire-Thai version.

Maximal force

Mean and standard deviation (SD) values of MVC for the neck pain and control groups were 130.58±51.73 newtons and 142.24±52.70 newtons, respectively. No significant difference in the MVC value was found between groups (*p*=0.26). Thirteen participants (50.0%) in the neck pain group reported neck pain during performing the MVC test (NRS=5.25±1.59). None of asymptomatic controls reported pain.

Force steadiness

There was no significant interaction between group and target force level [F (1, 50) =0.57, *p*=0.45]. There were significant main effects of group [F (1, 50) =9.90, p=0.003] and target force level [F (1, 50) = 174.56, *p*<0.001]. When comparing between groups, the mean CV values at 20% of and 50% of MVC were significantly higher in the neck pain group compared to the control group ($p<0.05$, η^2_p =0.10 and $p<0.001$, η^2_p =0.26, respectively) (Figure 2). Four participants in the neck pain group (15.4%) reported neck pain during testing at 20% of MVC (NRS=3.42±0.50) and 12 participants (46.2%) at 50% of MVC (NRS=4.75±1.38). None of asymptomatic controls reported neck pain.

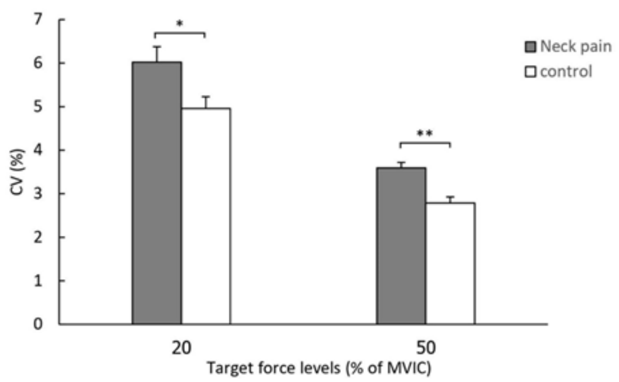

Figure 2*. Means and standard deviations of 30 degrees of shoulder abduction force steadiness at 20% and 50% of maximal voluntary contraction (MVC) between the neck pain and control groups. (* p<0.05, ** p<0.001).*

Relationships between force steadiness and characteristics of neck pain

There were no correlations between the CV values at 20% and 50% of MVC and characteristics of neck pain (VAS, NDI-TH, DASH-TH, pain duration) (all *p*>0.05) (Table 2).

Table 2 Correlations between the CV values at 20% and 50% of MVC and characteristics of neck pain.

	CV at 20% MVC		CV at 50% MVC	
	r	*p* value	r	*p* value
Pain intensity (0-10 VAS, cm.)	-0.08	0.72	0.00	0.99
Pain duration (months)	0.29	0.15	0.03	0.90
NDI-TH (%)	0.04	0.83	0.04	0.84
DASH-TH (%)	0.00	1.00	-0.09	0.67

VAS: visual analogue scale, NDI-TH: neck disability index-Thai version, DASH-TH: the disabilities of the arm, shoulder, and hand questionnaire-Thai version.

Discussion

The results of this study demonstrated that patients with neck pain with scapular dyskinesis had reduced force steadiness at submaximal contractions (20% and 50% of MVC) of 30 degrees of shoulder abduction compared to asymptomatic controls. This may suggest that the steadiness of muscle contractions during shoulder abduction is associated with scapular dysfunction in neck pain. Additionally, it may suggest impaired shoulder/scapular sensory-motor control associated with neck pain.[29,30] To our knowledge, this is the first study investigating neuromuscular function (quantified as submaximal force steadiness) during shoulder abduction in patients with neck pain with scapular dyskinesis. Nonetheless, the results of this study are in accordance with previous findings of changes in sensory manifestations and motor performance during low load, repetitive work simulation in chronic neck-shoulder pain,[29] and deficits in upper limb coordination and position sense acuity in patients with neck pain.[30] Additionally, the results of this study are in line with findings of a previous study demonstrating reduced steadiness of shoulder abduction in patients with subacromial impingement syndrome (SIS).[3] It was noted that no difference in the MVC were observed between the neck pain and control groups, which contradicting the pain-adaptation model.[31] However, this result is consistent with a previous study demonstrating no difference in the MVC between patients with neck pain with scapular dysfunction and controls.[32] As neck pain intensity and disability in our participants with neck pain are mild to moderate, thus it is possible that ability to generate a maximum contraction of shoulder movement is less likely to be influenced by pain in the neck.

The axio-scapular muscles are required to stabilize and control the scapula during the submaximal contraction of shoulder abduction.[33,34] Previous studies found altered muscle recruitment patterns of the axio-scapular muscles in individuals with neck pain compared to asymptomatic controls.[32,35,36] A recent study has also shown relationships between chronic non-specific neck pain and delayed activation of the shoulder and axio-scapular muscles (i.e., anterior and middle deltoid, upper and lower trapezius).[37] Additionally, there is evidence suggesting impaired axio-scapular muscles in neck pain patients with altered scapular control/function.[32,36] Zakharova-Luneva *et al*.[32] found that neck pain patients with scapular dysfunction had changes in the lower trapezius activity during performing isometric contraction of shoulder abduction and external rotation compared with healthy controls. Likewise, Szeto *et al*.[36] demonstrated that office workers with work-related neck and upper limb disorders had altered muscle recruitment patterns of the axio-scapular muscles compared to asymptomatic controls. Thus, the reduced force steadiness may be associated with impaired scapular control and function, in particular 30 degrees of shoulder abduction, which requires neuromuscular control to stabilize the scapular and shoulder joint.[33,34] On the other hand, the reduced force steadiness in neck pain may be as a consequence of a disturbance in cervical afferent input from the neck joint and muscle receptors.[2,6,7] Impaired mechanoreceptors due to articular damage, chronic pain, and impaired muscle functions may lead to a decrease in proprioceptive.[38] Additionally, there may be sensitization of mechanoreceptors or muscle spindles from pain and altered motor unit control strategy within painful muscles.[39] It was noted that some participants with neck pain in this study reported increased neck pain during performing the test, in particular at a higher level whereas none of asymptomatic controls reported pain. Submaximal isometric contraction of shoulder abduction may impart significant mechanical stress to the cervical structures through muscle attachments that extend into the cervical spine.[10,16]

There were no relationships between the force steadiness and any characteristics of neck pain (i.e., neck pain intensity, duration, and neck and upper limb disabilities). The results may imply that force steadiness of shoulder abduction is independent of neck pain features. A high variation of neck pain duration was observed in our participants with neck pain, but its relationship with force steadiness was not found. However, it was noted that variations of pain intensity and neck and upper limb disabilities were small. Thus, no relationships of these parameters and force steadiness may alternatively be due to such small variations in the sample characteristics. Regardless of population and methodology, a previous study of patients with hand osteoarthritis found a small positive correlation between grip force steadiness and the DASH score.[40] A study of patellofemoral pain also found a positive correlation between knee extensor force steadiness and self-reported pain (VAS) during the force-matching task.[41] Given no available evidence of relationships between force steadiness of shoulder abduction and characteristics of neck pain, conclusion on this matter cannot be drawn and further research is still needed to confirm the results.

There are some limitations of this study. Sample size was estimated from group comparisons of the CV values, but not for the relationships of force steadiness and characteristics of neck pain. More female participants were recruited into the study, although there was no difference in gender between the neck pain and control groups. Use of upper limb in daily activities may affect force steadiness, but it was not recorded in the study. Additionally, there were small variations in the characteristics of the sample, in particular pain intensity and disability. Further research with a larger sample size may help confirm the correlation results. Future research should investigate if reduced force steadiness is associated with any specific tasks of upper limb activities in neck pain patients with scapular dyskinesis. Activity of the axio-scapular muscles would also provide further information about the contribution of the muscle impairment and reduced force steadiness.

Conclusion

This study demonstrated reduced force steadiness at 20% and 50% of MVC of 30 degrees of shoulder abduction in patients with neck pain with scapular dyskinesis. The results of this study may be beneficial in developing rehabilitation of axio-scapular muscle controls for patients with neck pain with scapular dyskinesis. However, no relationships of force steadiness and neck pain characteristics were demonstrated.

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