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THE INFLUENCE OF A DEPRESSED SCAPULAR ALIGNMENT ON UPPER LIMB NEURAL TISSUE MECHANOSENSITIVITY AND LOCAL PRESSURE PAIN SENSITIVITY

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ABSTRACT

Background: A depressed scapula alignment could lead to prolonged and repetitive stress or compression of the brachial plexus, resulting in sensitization of neural tissue. However, no study has investigated the influence of alignment of the scapulae on sensitization of upper limb neural tissue in otherwise asymptomatic people. In this case-control study, we investigate the influence of a depressed scapular alignment on mechanosensitivity of the upper limb peripheral nervous system as well as pressure pain thresholds (PPT).

Methods: Asymptomatic individuals with neutral vertical scapular alignment (n=25) or depressed scapular alignment (n=25) participated. We measured the upper limb neurodynamic test (ULNT1), including assessment of symptom response and elbow range of motion (ROM), and PPT measured over upper limb peripheral nerve trunks, the upper trapezius muscle and overlying cervical zygapophyseal joints.

Results: Subjects with a depressed scapula reported significantly greater pain intensity ($t=5.7$, $p<0.0001$) and reduced elbow extension ROM ($t=-2.7$, $p<0.01$) during the ULNT1 compared to those with a normal scapular orientation. Regardless of the location tested, the group presenting with a depressed scapula had significantly lower PPT compared to those with a normal scapular orientation (PPT averaged across all sites: normal orientation: 3.3 ± 0.6 Kg/cm², depressed scapula: 2.1 ± 0.5 Kg/cm², $p<0.00001$).

Conclusions: Despite being asymptomatic, people with a depressed scapula position have greater neck and upper limb neural tissue mechanosensitivity when compared to people with a normal scapula orientation. This study offers insight into the potential development of neck-arm pain due to a depressed scapular position.

Key Words: Scapula, cervical spine, neurodynamics

Highlights

- A depressed scapular position is associated with lower PPT over cervical sites.
- A depressed scapular position is associated with greater upper limb neural tissue mechanosensitivity.
- The findings help to appreciate the potential development of neck-arm pain due to an abnormal scapular position.

INTRODUCTION

Evidence has revealed an association between an aberrant scapular position and/or scapular motion (i.e. scapular dyskinesis) and the presence of neck pain, as recently reviewed by Cools et al.[9] In particular, studies have identified similar alterations in scapular orientation and motion in patients with mechanical neck pain, which are seen in people with painful shoulder disorders.[13, 16-18, 52, 56] Aberrant scapular posture and/or motion may contribute to painful neck disorders by adversely affecting mechanical stress on pain sensitive cervical structures.[4, 49] For instance, scapula depression is known to increase the strain forces throughout the brachial plexus [7, 21, 22] and compress the thoracic outlet structures between the clavicle and the first rib.[1, 50] Indeed, studies have demonstrated that restoration of normal scapular kinematics can induce positive effects on the cervical spine, in terms of range of motion (ROM) and pain.[2, 3, 15, 49]

People with neck pain frequently report symptoms with functional use of their upper limb and upper limb activities can be an aggravating factor.[30, 37] This may particularly be the case when a person presents with heightened nerve mechanosensitivity where upper limb movements may aggravate sensitized neural tissue. Neck pain associated with neural tissue mechanosensitivity is commonly labeled non-specific neck-arm pain,[10, 14] in the absence of neurological deficits. Clinically, it is characterized by pain in response to mechanical stimuli such as limb movements that cause nerve elongation, and by local tenderness on nerve trunk palpation.[45] Although scientific interest in the identification and management of patients with neck-arm pain symptoms has increased,[31, 42, 45-47] little is known about the specific consequences of altered scapular orientation on arm pain symptoms. A depressed scapular alignment has been related to the presence of neck and arm pain,[40, 44] altered cervical proprioception,[15] limited cervical ROM (e.g. cervical rotation)[15, 49] and decreased pressure pain threshold (PPT) over the upper trapezius muscle.[3, 25] Moreover, passive elevation of the scapula, either manually[15, 49] or using a taping technique,[24] reversed these limitations in pain and function. Theoretically, a depressed scapula may place prolonged and repetitive stress and/or compression on the brachial plexus, leading to sensitized neural tissue which may trigger the development of neck-arm pain symptoms.[40, 50, 51] Sensitization of neural tissue is commonly assessed with neurodynamic testing and the evaluation of PPTs over upper limb peripheral nerve trunks. However, no study has investigated whether a depressed scapular alignment is associated with sensitization of upper limb neural tissue in otherwise asymptomatic people.

This study addresses this topic by investigating the influence of a depressed scapular alignment on mechanosensitivity of the upper limb peripheral nervous system in asymptomatic people. In addition, the effect of a depressed scapular alignment on PPT was evaluated at sites over the upper trapezius, cervical spine (i.e. zygapophyseal joints) and neural tissue. It was hypothesized that people with a depressed scapula would be more sensitized to upper limb neurodynamic testing and would display lower PPT over nerve, muscle and joints indicative of higher pain sensitivity. This study stands to shed light on the potential development of neck-arm pain due to an abnormal scapular position.

METHODS

Participants

College age students with neutral vertical scapular alignment (n=25) or depressed scapular alignment (n=25) volunteered to participate in this case-control study. Recruitment of potential volunteers was conducted at the University through poster advertisement. Volunteers who met the inclusion criteria were then evaluated as they reached the laboratory.

Subjects with a depressed scapula alignment were included if they reported no history of orthopedic or neurological conditions in the cervical spine or upper limbs over the last 12 months. The scapula was considered depressed when both the superior angle of the scapula and the lateral border of the acromion, were below the spinal process of the second thoracic vertebra.[3, 40] Subjects who displayed other combination of these anatomical landmarks were excluded (n=24). Subjects were also excluded if they had current neck pain, a previous cervical spinal fracture, had shoulder, elbow or wrist pain, a diagnosis of diabetes, cancer, or inflammatory disorders, or previous history of surgery in the cervical spine or upper limbs. In addition, they were instructed not to take any analgesics or antidepressants 24-48 hours prior to the study session.

Data collection took place at the *BLINDED* from September to November 2015. All participants received an information leaflet and gave written informed consent prior to the study commencement and the rights of the subjects were protected. The study was approved by the local Institutional Ethics Committee and all the procedures were conducted according to the Declaration of Helsinki.

Procedure

Participants were initially examined by an investigator to ensure they fulfilled the inclusion and exclusion criteria. Neck movements (flexion, extension, lateral flexion, rotation) were tested in a sitting position. Participants were first instructed to actively move the neck in the different physiological directions to their end range. If no pain was present, the examiner gently applied passive overpressure into the end position to ensure pain was not reproduced.[8] Then, the scapular static posture assessment was performed while subjects were in a standing position with the arms relaxed by their sides. The dominant side was chosen for the assessment. The examiner marked three anatomical sites with a demographic pen: superior angle of the scapula (SAS), lateral border of the acromion (A), and spinal process of the second thoracic vertebra (ST2). Scapular alignment was categorized as: (1) “normal” (considered only in relation to scapular elevation and depression), if the SAS and A were on the same level or above ST2, and (2) “depressed”, if SAS and A were below ST2.[2, 3] If any other combination of positions of these reference points were found, then the subject was excluded from the study. After performing the postural assessment, all marks on the skin were removed to ensure blinding (to the group the subject was assigned) of the examiner who was responsible for performing the measurements. Validation of reference points for palpation of the scapula and thoracic spine have been previously demonstrated by Lewis et al.[26]

Subjects who met the criteria for a normal or depressed scapular position, continued with the examination procedure. It consisted of performing the upper limb neurodynamic test (ULNT1) including assessment of symptom response and elbow ROM, followed by PPT measured over upper limb peripheral nerve trunks, the upper trapezius muscle and cervical zygapophyseal joints. All measurements were performed in the same order on the same side of the scapula categorized previously as depressed or normal and were conducted by the same investigator who was blinded to the patient status, unaware of the study objectives. The examiner had more than 15 years of experience as a physiotherapist in the management of musculoskeletal pain and was highly experienced with the methods used.

Upper limb neurodynamic test (ULNT1)

The ULNT1 was performed following a standardized sequence described by Butler,[6] which consisted of 1) shoulder girdle fixation, 2) shoulder abduction, 3) wrist extension, 4) supination, 5) shoulder external rotation, and 6) elbow extension. The starting position for the test was also standardized, with subjects positioned in supine, without a pillow, and with their arms alongside their bodies and legs straight.

The response to the application of the ULNT1 was investigated. Explanation and instructions regarding the procedure, and measures performed were given to the participant. Specifically, participants were instructed to indicate at which point (phase) during the test they began to perceive symptoms (i.e. point of onset of symptoms), and when it felt too uncomfortable to continue with the movement (i.e. the point of pain tolerance).[28, 29] In addition, subjects had to report the quality and distribution of their symptoms at the point of tolerance. Pain intensity and elbow extension ROM were measured at the point of tolerance. The ULNT1 was performed only once. Excellent intra-rater and good inter-rater reliability of ULNT1 measures have been confirmed in an asymptomatic population.[36] Precision has also been shown to be acceptable for both intra-rater and inter-rater measurements.[36]

Symptom response

A numerical rating scale (NRS, 0 no symptoms - 10 the most intense pain imaginable) was used to measure the intensity of pain at the point of tolerance during the ULNT1. The point of pain tolerance was considered the point at which the sensation perceived by the patient was too uncomfortable to continue with the test.[28, 29] To describe the quality or nature of perceived symptoms during the ULNT1, participants had to choose between the following descriptors: stretching, pain, tingling, pricking, numbness and burning, or a combination of several. The test-retest reliability for the NRS has been demonstrated to be moderate to high, varying from 0.67 to 0.96 and the convergent validity is 0.79 to 0.95.[20]

Range of motion

Measurement of elbow extension during the ULNT1 was performed using a digital goniometer (Digital Absolute Axis Goniometer, Baseline$^{(R)}$), with the center of the goniometer placed over the medial epicondyle, the fixed arm of the goniometer following the longitudinal axis of the humerus pointing towards the lateral border of the acromion, and the mobile arm following the longitudinal axis of the cubitus pointing toward the styloid process of the radius.[34] Reliability and validity of ROM measurements during neurodynamic tests for the upper limb have been widely demonstrated.[33, 41]

Pressure Pain Thresholds

Specific sites of the peripheral nerve trunks of the median, radial and ulnar nerves were identified on the dominant side by manual palpation and marked for PPT measurement. The median nerve was identified and tested with the subject in supine, with the arm in elbow extension and external shoulder rotation. It was palpated in the cubital fossa medial to and immediately adjacent to the tendon of the biceps brachii muscle.[43] The ulnar nerve was also identified and tested in supine, with the arm abducted (90º) and externally rotated (90º), and the elbow in 90º of flexion. It was palpated in the groove between the medial epicondyle and the olecranon.[43] Finally, the radial nerve was identified and tested with the subject in a sitting position, with the arm relaxed. The nerve was palpated where it passes through the lateral intermuscular septum, between the medial and lateral heads of the triceps, to enter the mid to lower third of the humerus.[43] These peripheral nerve palpation points were chosen for their accessibility and ease of the application of the algometer probe. Moreover, they are common sites used for palpation of peripheral nerve trunks which have shown moderate inter-tester reliability.[41]

PPT was measured over the upper trapezius muscle on the dominant side, at the midpoint between the spinous process of C7 and the lateral border of the acromion with the subject positioned in sitting. With the subject then positioned in prone, PPT were measured over the C2/C3 and C5/C6 zygapophyseal joints.

All PPT were measured with an electronic pressure algometer (Force Dial model FDK 20, Wagner Instruments). The algometer probe tip was applied perpendicularly to the skin at a rate of $1kg/cm^2/s$, apart from the measures over the cervical spine where the tip of the algometer was placed at a 45° angle between the frontal and sagittal plane. PPT was measured three times at each site with a 30 s rest period between each measurement. A familiarization phase preceded the formal measurements, where participants were instructed on the procedure and the examiner practiced with them at a remote site (forearm). After providing standardized instructions to the subjects, they were asked to indicate the moment when pressure changed to pain, which correspond to the definition of the PPT. They were told repeatedly that recording the first sensation of pain was the aim and not tolerance to pressure. All PPT measurements were always performed in the same order (median nerve, ulnar nerve, radial nerve, upper trapezius muscle, C2/C3 and C5/C6 zygapophyseal joints).

Pressure algometry is a valid and reliable method to measure PPT,[48] with studies showing good repeatability of measurements in the neck region.[55] For example, The ICCs calculated to examine the reliability between the two examiners for PPT measures over the median, radial and ulnar nerve trunks in asymptomatic people range between 0.92 and 0.97, indicating excellent inter-examiner reliability.[43]

Statistical Analysis

All statistical analyses were conducted using the software Statistical packages for the social sciences for Windows (SPSS release 22). For all statistical analyses, a value of $p<0.05$ was considered statistically significant.

Before comparisons, all data were tested for normality using the Shapiro-Wilk test and normal distribution of the data was confirmed. Pain intensity and range of elbow extension during the ULNT1 were compared between groups using independent t-tests. PPT was evaluated using a two-way ANOVA with group (normal scapula, depressed scapula), and location (median nerve, radial nerve, ulnar nerve, upper trapezius, C2/C3, C5/C6) as factors. Significant differences revealed by ANOVA were followed by post-hoc Student-Newman-Keuls (SNK) pair-wise comparisons and interactions were explored.

RESULTS

TABLE 1 presents the baseline characteristics of the participants. No differences were observed for age, gender, weight or body mass index. The mean age of all subjects was 19.4 ± 2.8 years, mean weight 58.8 ± 8.9 Kg, and mean height 168.6 ± 7.3 cm.

Overall, the group of subjects with a depressed scapula reported significantly greater pain intensity ($t=5.7$, $p<0.0001$) and reduced elbow extension range of motion

($t=-2.7$, $p<0.01$) during the ULNT1 compared to those with a normal scapular orientation (**FIGURE 1**). **TABLE 2** presents the percentage of subjects reporting sensations of pain, stretching, tingling, pricking, numbness and burning during the ULNT1.

The PPT was dependent on group allocation ($F=371.6$, $p<0.0000001$) and location ($F=9.5$, $p<0.0000001$) but not on the interaction between group and location ($F=1.0$, $p>0.05$). Across both groups, PPT were higher over the radial nerve compared to all other sites except for the ulnar nerve (all SNK: $p<0.001$). PPT recorded over the ulnar nerve were also higher than all other sites apart from the radial nerve (all SNK: $p<0.05$). Regardless of the location tested, the group presenting with a depressed scapula had significantly lower PPT compared to those with a normal scapular orientation (PPT averaged across all sites: normal orientation: 3.3 ± 0.6 Kg/cm^2, depressed scapula: 2.1 ± 0.5 Kg/cm^2, $p<0.00001$; **FIGURE 2**).

DISCUSSION

This is the first study which has evaluated the influence of a depressed scapular alignment on upper limb neural tissue mechanosensitivity in a healthy population. As hypothesized, subjects with a depressed scapula displayed significantly greater upper limb neural tissue mechanosensitivity than those with a normal scapular orientation, as reflected by greater pain intensity and reduced elbow extension ROM during the ULNT1 and lower PPT measured at the median, radial and ulnar nerve trunks. In addition, lower PPT recorded over the upper trapezius and C2/C3 and C5/C6 zygapophyseal joints were also found in those subjects with a depressed scapula alignment as compared to subjects with a normal scapular orientation.

An excessive stretch or compression being placed on the brachial plexus as a consequence of scapula alignment may explain the greater upper limb neural tissue mechanosensitivity observed in the individuals with a depressed scapula alignment. It is well documented that prolonged elongation and compression of the neural tissue may disrupt several nerve processes, such as microcirculation or axonal transport,[23, 35, 54] which are mechanisms involved in neural tissue mechanosensitivity.[11]

The physical examination for people with neck-arm pain symptoms suspected to be related to neural tissue sensitivity include assessment of posture, movement dysfunction, neurodynamic tests, mechanical allodynia in response to nerve palpation and clinical tests (e.g. Spurling's test) aiming to find a local cause for the neural tissue mechanosensitization.[12] Clinicians are often advocated to look for shoulder girdle elevation as it is an antalgic posture commonly adopted by patients to relieve provocation on a mechanosensitive upper limb neural tissue.[12] However, the relationship between shoulder girdle depression and neural tissue sensitization has been poorly evaluated with only a few studies showing a positive association.[1, 44] Based on anecdotal evidence, some have emphasized the potential role of a depressed scapula position in the development of neck-arm pain symptoms with recommendations to assess its clinical relevance by means of manual correction of scapula malpositioning.[19, 50, 51] Our study serves to quantify, for the first time, a relation between a depressed scapular alignment and an increase of upper limb neural tissue mechanosensitivity.

Besides greater neural tissue sensitization, the group presenting with a depressed scapula had significantly lower PPT over the upper trapezius muscle compared to those with a normal scapular orientation. These results are consistent with previous studies which also reported increased pain sensitivity over the upper trapezius in young healthy populations with scapular depression.[3, 25] This increase in muscle tissue sensitivity has been interpreted as a reaction to the constant strain on the upper trapezius muscle, which is maintained in an overstretched position as a consequence of the depressed scapular alignment.[3, 38] Interestingly, we also found lower PPT in the zygapophyseal joints of C2/C3 and C5/C6 of the depressed scapula group. This may not be surprising as it has been proposed that a depressed scapular alignment may affect neck function by way of the attachments of the cervicoscapular muscles (i.e. upper trapezius, levator scapulae).[49] The increased pain sensitivity over the facet joints may thus be the result of the constantly downward pull exerted by the cervicoscapular muscles on their cervical insertions due to the depressed scapular alignment.[3, 49] The association between scapula alignment and PPT measured over the cervical zygapophyseal joints was recently demonstrated by Lluch et al.[27] An immediate increase in PPT measured at the most symptomatic cervical zygapophyseal joint was reported after an active scapular correction exercise to a neutral position in people with chronic neck pain and scapula dyskinesis.

The most common sensory response reported by subjects from both groups with the application of the ULNT1 was "stretching", which is in agreement with Lohkamp et al.[28] The term "stretching" is not predominantly neurogenic, therefore the source of sensory response we obtained with the application of the ULNT1 might not be solely neural tissue.[32, 53] Interestingly, the terms "tingling" and "burning", which imply a neurogenic component in symptom response, were more frequently reported by the group with a depressed scapula alignment. This finding is consistent with the greater neural tissue sensitization reported in that group. Results of the current study provide further evidence that asymptomatic individuals have a certain level of nerve mechanosensitivity and can report a variety of sensory responses at the end range of neurodynamic tests.[28, 29, 33] Therefore, to be confident that a neurodynamic test is most likely identifying a patient with increased nerve mechanosensitivity, the test needs to reproduce at least part of the patient's current symptoms and these symptoms should change with structural differentiation.[33]

Based on the results of this study, one could argue that the prolonged excessive and repetitive stress to the cervical and neural tissue structures secondary to the depressed scapula alignment might lead to cumulative trauma leading to the onset of neck and arm pain symptoms in an otherwise asymptomatic population. In this regard, Azevedo et al[3] suggested that prolonged scapular depression may, over time, be a contributor to cervical dysfunction. However, due to the design of the current study, we cannot imply that people with lower PPT values in the neck region and upper limb neural tissue will develop symptoms in the future. Alignment is only one of multiple factors contributing to the development of mechanical pain.[39] Future studies could prospectively investigate whether a depressed scapula position in healthy individuals may be a potential factor for contributing towards the development of pathology in the neck-arm region.

Limitations

We recruited subjects from a healthy population so our results cannot be extrapolated to a patient population. In addition, due to the nature of the study and to the fact that only healthy subjects were assessed, the possible clinical benefits of using strategies to elevate the scapula for decreasing upper limb neural tissue mechanosensitivity are yet unknown. Studies investigating the effects of scapular elevation or upper limb support on neck-arm symptoms in patients with non-specific neck-arm pain and a depressed scapula are therefore necessary in order to unravel the role of scapula depression in neural tissue sensitization.

Although, no differences were observed between groups for age, gender, weight or body mass index, we did not document other potentially important factors such as ethnicity, socioeconomic status and general health status.

It is possible that neurodynamic test responses have a cognitive-affective influencing element. For instance, Beneciuk et al.[5] showed that pain catastrophizing, but not pain related fear, kinesiophobia or anxiety, influenced responses during neurodynamic testing in asymptomatic people. In the current study, we did not use a screening tool to rule out potential cognitive-affective influencing elements or potential differences between groups. However, since we recruited college-aged students without orthopaedic and neurological problems, most likely there were not strong cognitive or affective modulating elements which could have affected the results. Additionally, measurement error and bias cannot be discarded since all measurements were taken by the same person however, the methods used are established and reliable.

CONCLUSIONS

Our results show that healthy young subjects with a depressed scapular position had significantly lower PPT over the cervical zygapophyseal joints and upper trapezius and greater upper limb neural tissue mechanosensitivity when compared to subjects with normal scapula position. These observations offer some insight into the potential development of neck-arm pain due to a depressed scapular alignment.

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TABLES

Table 1: Baseline characteristics of the participants. Mean ± SD.

Characteristic	Normal alignment (n=25)	Depressed scapula (n=25)
Gender (% women)	72%	72%
Age (years)	18.9 ± 2.4	19.0 ± 2.8
Weight (Kg)	62.1 ± 9.8	59.1 ± 9.2
Height (cm)	170.6 ± 8.5	169.2 ± 6.3
BMI (Kg/m^2)	21.2 ± 2.4	20.5 ± 2.2
Dominant hand (% right)	96%	100%
Current neck pain (% yes)	0%	0%
Pain with neck movement (% yes)	0%	0%

Table 2: Report of symptoms other than pain at the point of tolerance of the ULNT1.

Symptom	Normal alignment	Depressed scapula
Stretching (% Yes)	96%	88%
Tingling (% Yes)	12%	52%
Prickling (% Yes)	0%	0%
Numbness (% Yes)	12%	12%
Burning (% Yes)	0%	4%

FIGURE LEGENDS

Figure 1: Mean and SD of pain intensity and elbow extension range of motion during the ULNT1 in subjects with a depressed or normal scapular orientation.

Figure 2: Mean and SD of pressure pain thresholds recorded over the peripheral nerve trunks of the median, radial and ulnar nerves and over the C2/C3 and C5/C6 zygapophyseal joints in subjects with a depressed or normal scapular orientation.