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A Preliminary Study

Heredia-Rizo, Alberto Marcos; Petersen, Kristian Kjær; Arendt-Nielsen, Lars; Madeleine, Pascal

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Title: Eccentric Training Changes the Pressure Pain and Stiffness Maps of Upper Trapezius in Females with Chronic Neck-Shoulder Pain: A Preliminary Study

Alberto Marcos Heredia-Rizo, PhD, [*] [†] [§] [‡] Kristian Kjær Petersen, PhD, [§] Lars Arendt-Nielsen, PhD, Dr. Med [§] [‡] Pascal Madeleine, PhD, [†]

[*] Department of Physiotherapy, Faculty of Nursing, Physiotherapy and Podiatry, University of Seville, Seville, Spain

[†] Sport Sciences, Department of Health Science and Technology, School of Medicine, Aalborg University, Aalborg, Denmark

[§] Center for Neuroplasticity and Pain (CNAP), SMI®, Department of Health Science and Technology, School of Medicine, Aalborg University, Aalborg, Denmark

[‡] SMI®, School of Medicine, Aalborg University, Aalborg, Denmark

Reprint requests to: Dr. Alberto Marcos Heredia-Rizo. Departamento de Fisioterapia. Facultad de Enfermería, Fisioterapia y Podología, Universidad de Sevilla, España. c/ Avicena s/n, 41009 Sevilla, Spain. E-mail: amheredia@us.es

Tlf: +34954486507 Fax: +34954486527

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Running title: Eccentric Training in Neck-Shoulder Pain

Objective: Between 50-67% of adults suffer from neck-shoulder pain, which may be associated with increased stiffness of neck muscles. We assessed pressure pain sensitivity and muscle stiffness maps of the upper trapezius in female computer users with and without chronic neck-shoulder pain, and investigated the effects of eccentric training on females with neck-shoulder pain.

Design: Cross-sectional (part 1) and open-label (part 2) study.

Setting: University.

Subjects: Twenty females with neck-shoulder pain were compared with 20 controls (part 1). In part 2, neck-shoulder pain participants followed a 5-weeks unilateral upper trapezius eccentric training program.

Methods: Topographical maps of pressure pain thresholds (pressure algometer) and muscle stiffness (myotonometer), using a 15-point grid covering myotendinous and muscle belly sites, and shoulder elevation force and range of elevation (dynamometer), were assessed at baseline and after training.

Results: There were no differences in pressure pain thresholds between sites ($P = .243$) or groups ($P = .068$), and significant differences in stiffness between myotendinous and muscle belly sites ($P < .001$), but not groups ($P = .273$). After training, pressure pain thresholds increased, stiffness decreased ($P < .005$), and shoulder elevation force and range of elevation improved ($P < .001$).

Conclusion: The lack of differences in upper trapezius pressure pain sensitivity and stiffness between females with or without neck-shoulder pain confirms no clear etiology among computer users reporting neck-shoulder pain. A 5-weeks eccentric training protocol showed positive effects on pressure pain sensitivity, stiffness, shoulder force and range of motion.

Key Words: Computer Work; Intervention; Muscle Viscoelastic Properties; Strength Training; Topographical Maps

Introduction

Neck-shoulder pain (NSP) is one of the leading cause of disability worldwide and a major socioeconomic burden,(1) where 50-67% of the population suffer from NSP during the lifespan.(2) Among computer users, women report higher NSP intensity, longer duration of symptoms, and impaired work ability compared with men.(3)

Pressure pain hyperalgesia can be assessed using pressure pain threshold (PPT) and is often reported in non-traumatic NSP.(4) Differences in pain responses within a muscle are common, with muscle belly (MB) sites being more sensitive to pressure pain than musculotendinous (MT) sites.(5, 6) Hence, the use of topographical pressure pain sensitivity maps is of emerging research and clinical value for quantitative sensory testing. This imaging technique is based on multiple PPT assessments within an area of interest, and may help to enhance the understanding of pain processing mechanisms in experimental and clinical pain.(7) There exists conflicting evidence when comparing local sensitization, using single standardized site assessments, in office workers with and without NSP.(6, 8, 9) Several factors, such as symptoms duration,(3) varying levels of pain and disability,(8) and a lack of spatial summation of pain from different body locations,(6) may account for these discrepancies. To date, a single study investigated topographical pressure pain sensitivity maps in computer users with low-intensity NSP compared with healthy controls.(6) Therefore, further research in individuals with higher pain intensity is warranted.

An abnormal resting muscle tone (or muscle tension) is suggested as a possible source of musculoskeletal pain, and increased stiffness of neck-shoulder muscles is observed in individuals with chronic NSP.(10, 11) Consequently, assessing of mechanical and viscoelastic properties of neck-shoulder muscles could be used to monitor NSP status and evaluate the efficacy of interventions.(12) Spatial distribution of the upper trapezius viscoelastic properties using topographical maps has been reported in pain-free individuals.(12) However, no previous study has assessed concurrently pressure pain sensitivity and muscle stiffness maps of the upper trapezius in female computer users with chronic NSP.

Eccentric exercises, in which muscles producing force are lengthened, elicit superior neuromuscular adaptations compared with isometric or concentric training.(13) Repeated eccentric contractions may normalize deep tissue pain sensitivity,(14) result in a potent protective effect,(15) and induce health-promoting benefits.(16) Eccentric training may also influence the viscoelastic properties of the muscle,(12, 17) and differences in MT and MB sites' sensory and viscoelastic properties are expected to occur after eccentric exercises,(12) although the clinical relevance of these findings remain unclear. Muscles can produce higher maximal force eccentrically than concentrically, and with a lower energy cost.(18) Strength increase in neck muscles is correlated with a reduction in self-reported musculoskeletal pain and disability among females with computer-related NSP.(19) Hence, eccentric exercises may be a suitable intervention within this population. Nevertheless, the effects of eccentric training in the shoulder girdle have been scarcely investigated in neck-shoulder pain,(9, 12, 20) and there is no information about the changes in topographical maps following eccentric training interventions. Therefore, the aims of the study were two-folds. In part 1, we assessed pressure pain sensitivity and muscle stiffness maps of the upper trapezius in female computer users with and without chronic non-traumatic NSP. In part 2, we investigated the effects of a supervised 5-weeks unilateral eccentric training protocol on pressure pain sensitivity and stiffness maps of the upper trapezius, and shoulder maximum elevation force and range of elevation in female computer users with chronic NSP.

We hypothesized 1) a non-uniform distribution of pressure hyperalgesia, with higher pressure pain sensitivity and increased upper trapezius stiffness in women with NSP compared with healthy controls, and 2) reduced pressure pain sensitivity and upper trapezius stiffness, as well as increased shoulder elevation force and range of elevation after eccentric training in female computer users with chronic NSP. The data concerning the effects of eccentric training on clinical outcomes, including pain intensity and central pain mechanisms, have already been reported.(9) That study showed that eccentric training improved disability, reduced pain intensity and sensitization, and enhanced conditioned pain modulation in female computer workers with chronic NSP.

Methods

Design

The study consisted of a cross-sectional (part 1) and an open-label study (part 2). In part 1, female office workers with long-standing and non-specific NSP were compared with age and sex-matched controls from the same population-based cohort. In part 2, only women with chronic non-traumatic NSP underwent a 5-weeks worksite unilateral eccentric training protocol targeting the upper trapezius. The participants of the current study were the same as in a previous study investigating the effects of eccentric training on pain intensity and central pain mechanisms, e.g., temporal summation of pain and conditioned pain modulation (9). The study was conducted according to the ethical guidelines of the Helsinki Declaration and was reviewed and approved by the North Denmark Region Committee on Health Research Ethics (N-20160023). All participants provided written informed consent.

Participants

Female computer users, with or without complaint of persistent non-traumatic NSP, who responded to a public announcement, were recruited at Aalborg University. Women who worked with computers for a minimum of 20 hours per week and could speak and understand English were invited to participate. Using a body map chart, participants between 20 and 60 years presenting persistent non-specific NSP for more than 3 months, at least 30 days with pain during the last year,(21) and with a score > 2 on a 11-point numeric pain rating scale in their worst pain within the last 24 hours and their average pain during the week before data collection, were included in the NSP group.(3, 9) Women reporting no pain or occasional pain ≤ 2 on the numeric pain rating scale were assigned to the control group. Females who had been involved in regular strength training of the neck-upper extremities during the year before the study were excluded. Other exclusion criteria were evaluated using a screening questionnaire,(21) collecting information on pregnancy, a medical history of severe neurological or mental illnesses, whiplash injury, medical diagnosis of carpal tunnel syndrome or fibromyalgia, consumption of painkillers in the 24 hours before data collection, previous cervical spine or upper limb surgery, and diagnosed heart diseases.

All in all, 20 female computer users, aged 29-61 years, reporting long-lasting non-traumatic NSP, and 20 controls, aged 23-67 years, volunteered to participate in part 1. One participant with NSP dropped out following baseline due to medical problems, thus 19 females with NSP (mean age ± SD, 46.7 ± 6.1) completed the eccentric training regime (part 2). See Heredia-Rizo et al.(9) for the flowchart diagram, and further clinical and demographic characteristics of the participants.

Protocol

The same examiner collected all measurements. For part 1, demographic and clinical data,(9) and outcome measures were collected during a single session (baseline). The supervised 5-weeks eccentric training started and ended up 3-7 days after baseline and final assessment testing in line with previous guidelines.(20) Assessment sessions and training were carried out within the university facilities.

Deep Tissue Pressure Pain Sensitivity

PPT levels, defined as the minimum pressure to evoke pain, were evaluated using a handheld electronic pressure algometer (Somedic AB, Hörby, Sweden) with a 1-cm^2 contact rubber probe.(22) With the participant in prone position and using a perpendicular constant rate of 30 kPa/s, PPTs were measured twice for each spot in a 15-point geometrically shaped grid covering the upper trapezius of the most painful side (NSP group) or the same side matched for controls.(23) The average of the two measures was used for further analysis. Using a wax pencil, the C7-acromion distance (d) was recorded to set the grid (mean value of 17.1 ± 1.1 cm). Adjacent points were separated by 1/6 of the d value (2.8 ± 0.2), except for points 1 to 4 that were separated by 1/7 of d (2.4 ± 0.1). Points 1, 3, 5, 10 and 15 corresponded to the anatomical location of MT sites, and points 2, 4, 6, 7, 8, 9, 11, 12, 13 and 14 corresponded to MB sites.(12) Topographical pain sensitivity maps were generated with Matlab (The Mathworks, Natick, MA, USA). The assessments followed a random order, with a 30-s break between measurements to prevent bruising. As control spot, PPT was measured at point 7 on the contralateral side.

Upper Trapezius Muscle Stiffness

The viscoelastic properties of the upper trapezius were collected using a handheld myotonometer device (Myoton AS, Tallinn, Estonia). The device has proven to enable valid,(24) and reliable measurement of muscle stiffness.(12, 25) Muscle stiffness was computed as $S = m_{probe} \times a_{max} / \Delta l$, where “m” is the 18 g preload/mass of the myotonometer sensor (probe), “a_{max}” is the maximum amplitude of the acceleration signal, and Δl the probe displacement.(25) Similar to PPTs, two measurements were made on the most painful side (NSP group) or the same side matched for controls, using the 15-point grid described above. Point 7 was used as a control spot on the contralateral neck-shoulder.

Shoulder Elevation Force and Range of Elevation

The shoulder maximum isometric elevation force and range of shoulder elevation were measured on the most painful side (NSP group) or the matched side (control group) using a custom-built dynamic shoulder dynamometer (Aalborg University, Aalborg, Denmark).(26) While seated in upright position with back support and no feet support, participants were instructed to raise and lower both shoulders at the same time as much as possible without lateral bend. The distance between upper and lower positions was considered as the range of shoulder elevation. Then, participants were asked to adopt a natural position, and the shoulder pad of the dynamometer was lowered to the shoulder neutral position. Participants were verbally encouraged to perform maximum elevation force for 3 seconds in isometric condition.(20) The recordings of shoulder maximum elevation force and range of elevation were made three times (2-min break between every test), using the average value for the three measures for further analysis.

Eccentric Training Intervention

In part 2, a supervised 5-weeks intervention consisting of eccentric training of the most painful side with a dynamic shoulder dynamometer (12) was carried out. For more details on the eccentric training protocol, see (9,20).

Statistical Analysis

The G*Power software (version 3.1.9.2, Kiel University, Kiel, Germany) was used for sample size calculation. Using an alpha level of .05, a power of 80%, and in order to detect a 20% difference between groups x sites on PPTs,(27) 18 participants were required per group. To account for potential dropouts, 20 participants were included in each study group. The PASW Advanced Statistics (SPSS Inc, Chicago, IL), version 24.0, was used for statistical processing. The normality of the data distribution was checked with the Shapiro-Wilk test. For part 1, a mixed-model analysis of variance (ANOVA) was used to compare the differences in PPTs and stiffness between groups (NSP and control) and sites (MT and MB). For part 2, sites (MT, MB, and point 7 on the contralateral neck-shoulder), and sessions (before and after training) were introduced as within-subject factor in a full factorial repeated measures ANOVA (RM-ANOVA) to detect differences in PPTs and muscle stiffness. Changes in shoulder maximum elevation force and the shoulder range of elevation were analyzed with a full-factorial RM-ANOVA with sessions as within-subject factor. Bonferroni post-hoc comparison was used for pairwise comparisons. For part 2, the Spearman's rank test or Pearson product-moment correlation coefficient analysis were used to test for associations in females with NSP between baseline clinical data (pain intensities, PPTs and stiffness at MT and MB sites) and mean changes in the outcome measures after eccentric training. Statistical significance was set at a P value < .05.

Results

Females with and without neck-shoulder pain

Table 1 summarizes the mean PPT and muscle stiffness for MT and MB sites of the upper trapezius and the control location on the contralateral side, in females with and without chronic NSP. The ANOVA revealed no differences in PPT levels between sites (F = 1.383; P = .243; η^2 = .018) or groups (F = 3.429; P = .068; η^2 = .043). For muscle stiffness, there were significant differences between MT and MB sites (F = 56.484; P < .001; η^2 = .426), but not between groups (F = 1.220; P = .273; η^2 = .016). Further, no Group*Site interaction was observed for PPT (F = 0.435; P = .511; η^2 = .006) or muscle stiffness (F = 0.696; P = .407; η^2 = .009). Figures 1A and 1B show the topographical maps for PPT levels and stiffness of the upper trapezius in females with chronic NSP and control participants. In both groups, the pairwise comparisons revealed a non-uniform distribution of PPT levels in MT and MB sites, and increased muscle stiffness at MT sites compared with MB sites (P < .001).

Effects of Eccentric Training

The ANOVA revealed significant differences in PPT levels between sessions (F = 24.624; P < .001; η^2 = .183), but not between sites (F = 2.603; P = .079; η^2 = .045), and significant differences in muscle stiffness between sessions (F = 13.526; P < .001; η^2 = .110) and sites (F = 58.860; P < .001; η^2 = .517). No Sessions*Site interaction was observed for PPT (F = 0.444; P = .643; η^2 = .008) or muscle stiffness (F = 1.103; P = .336; η^2 = .020). Figures 2A and 2B show the topographical maps for pressure pain sensitivity and stiffness of the upper trapezius in females with chronic NSP before and after training. The pairwise comparisons revealed a non-uniform distribution of PPTs in MT and MB sites after training, whereas stiffness remained significantly higher at MT sites compared with MB sites (P < .001). The PPTs of the MT and MB sites (table 1) increased by 51.1% and 40.8%, respectively, (P = .002, and P < .001), while the PPT over point 7 on the non-treated side increased by

37.7%, from before to after training (P = .011). The stiffness of the MT and MB sites (table 1) decreased by 13.1% and 12.3%, respectively, from before to after eccentric training (both, P < .001). No changes in the muscle stiffness over point 7 of the non-treated side occurred after training (P = .295).

The shoulder elevation force augmented by 57.9% from before (375.8 ± 111.3 N) to after (593.4 ± 141.7 N) eccentric training ($F = 21.504$; $P < .001$; $\eta^2 = .374$) (Figure 3A), and the range of shoulder elevation also increased from before (35.3 ± 9.4 mm) to after (51.4 ± 8.1 mm) training ($F = 28.942$; $P < .001$; $\eta^2 = .439$) (Figure 3B).

Correlation Analysis

Among females with NSP, significant negative correlations were found between: 1) the mean changes in PPTs at MB sites, and the baseline PPT at MT (r = -.620, P = .005), and MB sites (r = -.619, P = .005). All correlation data are included in table 2.

Discussion

Contrary to our first hypothesis, there were no differences in the topographical distribution of pressure pain sensitivity and muscle stiffness of the upper trapezius in female computer users with or without chronic non-specific NSP. As hypothesized, a worksite 5-weeks unilateral eccentric training program decreased pressure pain sensitivity, modified the viscoelastic properties of the upper trapezius, by means of reducing the muscle stiffness, and enhanced shoulder maximum elevation force and the range of shoulder elevation.

Pressure pain sensitivity in females with and without neck-shoulder pain

Our findings agree with those of Ge et al.(6) who reported similar topographical pressure pain sensitivity maps of the upper trapezius in computer users with or without NSP. These are also in line with previous research concluding no pressure pain hyperalgesia over the neck-shoulder region in office workers.(8, 28) Conflicting to this, local hyperalgesia to pressure stimuli, which has been depicted as a common feature of chronic NSP,(4) has been observed in females with NSP compared with healthy controls.(29, 30) It is suggested that varying levels of pain and disability,(8) pain duration,(3) and self-reported cognitive performance,(29) may influence quantitative sensory responses in computer users, which could explain the differences between studies.

There are spatial differences in pressure pain sensitivity within the muscle or region of interest. Hence, PPT levels have been suggested to be collected at several sites of the same muscle to monitor these possible differences.(31) Topographical pressure pain sensitivity maps reveal that MB sites tend to be more sensitive to pressure pain than MT sites, as explained by differences between muscle tendon and belly in blood flow, muscle thickness, and density and function of nociceptors.(5, 32, 33) This has been demonstrated in several studies,(5, 26, 32) and specifically in computer users with low-intensity chronic NSP.(6) Contrary to our expectation, we observed similar pressure pain sensitivity in MT and MB sites, and at the control location on the contralateral side. The contralateral side, however, should be cautiously used as a reference to identify abnormal sensory responses.(34)

Muscle stiffness in females with and without neck-shoulder pain

The use of non invasive and real-time measurements of muscle stiffness, e.g., ultrasound elastography,(35) has attracted broad research and clinical interest, and may help to individualize treatment approaches for chronic pain patients.(36) Ultrasound elastography provides a representation of the viscoelastic and mechanical properties of the tissue in the form of an elastogram.(37) It has been widely used in healthy subjects,(37, 38) and in clinical pain models, including individuals with self-reported increased stiffness of the neck-shoulder,(39) and with chronic non-specific NSP.(10, 40, 41) Within a given muscle, stiffness may not be uniform and commonly display spatial variability, regardless of the muscle state.(35) Measurements with ultrasound elastography are referred to a single standardized location. Contrary to this, topographical maps technology uses multiple site assessments,(7) and provides information of the distribution of muscle intrinsic elastic properties,(12) which may contribute to a better understanding of the mechanisms involved in tissue biomechanics.

In the current study, no differences in stiffness of the upper trapezius were observed between females with or without NSP. Contrary to this, individuals with persistent neck-shoulder complaints reported increased stiffness of the upper trapezius compared with healthy controls.(10, 11) Changes in stiffness of the neck-shoulder muscles in computer users appear to be associated with the individual perceived stress,(42) and the sustained muscle contraction during repetitive tasks.(10) The influence of ergonomic aspects on neck muscles stiffness, such as the visual display terminal height,(43) or the head posture,(44, 45) is controversial. Muscle stiffness is subjective in nature, highly variable between individuals, and usually self-determined.(36) However, it remains uncertain whether increases (e.g., enhancement of passive stability) or decreases (e.g. reduction of passive tension) in muscle stiffness are beneficial. In the present study, stiffness was higher at MT sites compared with MB sites, as previously reported in healthy male subjects.(12) This non-uniform distribution of muscle stiffness may reflect differences in the density of sensory afferents between muscle belly or tendon,(12) although this remains unclear.

Effects of Eccentric Training

Eccentric-only training programs can be accomplished with less perceived effort and low metabolic cost compared with traditional resistance training.(46) The impact of eccentric training has been widely investigated for the treatment of tendinopathies,(47) but its efficacy on chronic musculoskeletal pain has been scarcely assessed.

The present study investigated the changes in the topographical distribution of pressure pain sensitivity and muscle stiffness of the upper trapezius following eccentric training, while changes in clinical outcomes and central pain mechanisms have been recently reported.(9) In this study, eccentric training increased the PPT levels above the 20% clinically meaningful threshold (27) at MT and MB sites of the treated upper trapezius, and at the control location of the non-treated side. These PPT changes in the uninvolved side were similar to those reported after combining stretching and strengthening exercises in individuals with shoulder pain.(48) The correlation analysis showed that those females with the lowest PPTs at baseline responded better to eccentric training and achieved higher changes in pressure pain sensitivity. This finding maybe hints that PPT in the future could be a biomarker to help stratifying responders versus non-responders to a given intervention. The current results support the protective role of repeated eccentric exercises,(9, 14, 26) and suggest cross-transfer effect of unilateral strength training in the unexercised limb.(49) For the topographical pain sensitivity map, the improvement in PPT levels after training was similar in MT and MB sites, which is in agreement with former studies,(32) but contrary to previous research showing site-dependent effects of eccentric exercises on pressure pain responses.(5, 50) Eccentric training may elicit centrally mediated changes in pain sensitivity.(14) Alternatively, it can improve musculature supporting movement around the treated joint, depicted by decreased stiffness, and results in pain relief.(51) It is, however, unclear which of these mechanisms are responsible for the pain alleviation observed in the current study.

Contrary to the assumption that eccentric training may have little effect on the contractile properties of the muscle,(52) the current findings showed that upper trapezius stiffness decreased uniformly after training in MT and MB sites. These changes, however, did not surpass the minimum detectable threshold at MT (101 N/m) or MB (51 N/m) locations.(12) The decrease in stiffness could indicate a reduction in the number of attached cross bridges and increased fascicules length following eccentric training.(53) Homogeneous responses in the muscle viscoelastic properties occur when edema is evenly distributed after repeated eccentric contractions.(54) Similar to our findings, stiffness decreases after repetitive submaximal eccentric exercises of the upper limb,(55) and following low-intensity eccentric hamstring exercise.(56) Muscle stiffness may increase after a first bout of eccentric contractions.(12, 17) Then, this increase is attenuated after a second bout,(17) and stiffness tends to return to baseline values within a week.(57) Opposite to this, increased stiffness has been reported up to 3 weeks after repeated eccentric contractions.(54)

In opposition to the present results, a single set of eccentric contractions has shown to evoke non-uniform changes in the muscle viscoelastic properties.(12) An increased stiffness of MT sites and a decreased stiffness of MB sites of the upper trapezius has been recently reported 24 hours after performing consecutive eccentric contractions.(12) The use of different techniques to assess muscle stiffness, and the differences in the number of sets, repetitions and sessions in the training protocols make difficult to compare among studies. Furthermore, most of previous research in this field assessed muscle stiffness after a single session, which does not reflect training practice. To date, this is the first study to evaluate changes in topographical maps of upper trapezius muscle stiffness following a supervised 5-weeks eccentric training regime.

High-intensity strength training produces an increase in muscle size (e.g. hypertrophy),(58) leading to higher force and increased range of motion.(59, 60) Following eccentric training, the average increase in the shoulder elevation force was of 58.1%, similar to previous studies.(20, 61) Additionally, the range of shoulder elevation improved by 45.6%, in line with findings from Kay et al.(59) and Mahieu et al.(62), who observed that dorsiflexion increased after a 6-weeks eccentric training protocol for the calf muscles. The improvements in shoulder strength and elevation range could be attributed to the combination of motor unit recruitment and neural changes during training,(20) and to the decrease of upper trapezius stiffness.(63) Sensorimotor disturbances, e.g., reduced range of motion,(64) jerky movements, and poor position sense acuity,(65) have been associated with NSP. The loss of sensorimotor abilities may result in altered afferent inputs, which could play a role in the development of recurrent NSP,(66) and symptoms of central sensitization.(67) Therefore, these positive adaptations to repeated eccentric exercises may be beneficial to prevent risk of injury,(59) and pain chronification.(9)The loads for the eccentric training regime were carefully chosen to gradually increase intensity, to develop a feasible protocol, and to avoid adverse events. Further, such motor improvements have mostly important functional implications, i.e. a decreased relative shoulder load.

Our findings should be cautiously interpreted for several reasons. First, the sample size was appropriate for methodological purposes, but relatively small from a clinical perspective. Second, the examiner was not blinded to participants' allocation group. Intra-rater reliability is good for PPT,(68) and myotonometer assessments (69) over the neck-shoulder region. Hence, this somehow reduces the possible bias of an un-blinded examiner. Third, there was no control group for part 2, thus the results after training could potentially be influenced by a learning effect. Fourth, healthy controls did not undergo the eccentric training program. Thus, the mechanisms underlying the changes in muscle stiffness observed in females with NSP cannot be precisely described. Fifth, psychosocial features may influence the ability to modulate pain through exercise-induced hypoalgesia,(70) but were not evaluated. Sixth, assessment of myofascial trigger points was not conducted when PPT measures were collected. Hence, the presence of either active or latent myofascial trigger points may have confounded group results.(71) Finally, training intensities were set based on the baseline shoulder maximum elevation force, and not adjusted for increases in force that may have occurred during training. Further research is warranted in other muscles and in different population to understand the clinical impact of eccentric training on clinical outcomes and muscle viscoelastic properties.

Conclusion

The lack of differences in spatial distribution of pressure pain sensitivity and stiffness of the upper trapezius in female computer users with or without chronic non-specific NSP seen in part 1 adds to the emerging view in this field.(6) These findings may support the contention that there is no clear etiology among computer users reporting NSP, and processes other than physical and physiological may contribute to the pain experience in this population. Additionally, the preliminary results of a 5-weeks repeated eccentric training program (part 2) are novel, underlining reduced pressure pain sensitivity and muscle stiffness, as well as augmented functional capacity of the trained painful shoulder among females with chronic NSP. Future research should investigate the long-term effects of strength training protocols on topographical maps of the neck-shoulder region in patients with NSP, and compared those with a control group in a randomized controlled trial.

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Conflicts of interest

No conflicts reported

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Table 1. Pressure pain thresholds (kPa), and muscle stiffness (N/m) of the most painful upper trapezius (NSP group) or the matched side (controls), and at control location (middle point of contralateral upper trapezius muscle belly)

Location		Control Group (n = 20)	NSP Group Before Eccentric Training (n = 19)	NSP Group After Eccentric Training (n = 19)
Musculotendinous	PPT	282.2 ± 109.4 (231.1 - 333.4)	226.1 ± 103.2 (177.8 - 274.4)	341.6 ± 109.6 (288.7 - 394.4) *
(MT) Sites	Stiffness	327.5 ± 55.9 (301.3 - 353.7)	330.4 ± 50.8 (306.6 - 354.2)	287.3 ± 47.8 (264.3 - 310.4) *
Muscle Belly	PPT	241.2 ± 98.1 (195.3 - 287.1)	214.5 ± 88.1 (173.3 - 255.7)	302.1 ± 88.8 (259.2 - 344.9) *
(MB) Sites	Stiffness	237.8 ± 42.8 (217.8 - 257.8)	258.7 ± 41.1 (239.4 - 277.9)	226.8 ± 20 (217.2 - 236.5) *
Control Location	PPT	196.1 ± 69.2 (163.7 - 228.5)	194.6 ± 89.4 (152.8 - 236.5)	268.5 ± 75.4 (212.9 - 324.1) *
Contralateral Side	Stiffness	203.8 ± 52.1 (179.4 - 228.2)	209.8 ± 59.3 (181.2 - 238.4)	195.9 ± 27.9 (182.5 - 209.3) *

Data are expressed as mean ± SD (95% confidence interval).

Abbreviations: NSP, Neck-Shoulder Pain; PPT, Pressure Pain Threshold

** Indicates statistically significant differences from before to after eccentric training (P < .05)*

Table 2. Correlation coefficient matrix between baseline pressure pain and stiffness at myotendinous and muscle belly sites of the upper trapezius and mean changes in the outcome measures after eccentric training in females with neck-shoulder pain.

	Baseline PPT MT	Baseline PPT MB	Baseline Stiff MT	Baseline Stiff MB	Change NPRS (24h)	Change NPRS (week)	Change PPT MT	Change PPT MB	Change Stiff MT	Change Stiff MB	Change MEF
Baseline PPT MT	1	_	_	_	_	_	_	_	_	_	_
Baseline PPT MB	**.967 ***	1	_	_	_	_	_	_	_	_	_
Baseline Stiff MT	.014	.058	1	_	_	_	_	_	_	_	_
Baseline Stiff MB	-.262	-.233	.351	1	_	_	_	_	_	_	_
Change NPRS (24 h)	.166	.255	.178	.044	1	_	_	_	_	_	
Change NPRS (week)	.047	.178	.197	.005	**.616***	1	_	_	_	_	_
Change PPT MT	-.435	-.379	-.102	.080	-.262	-.198	1	_	_	_	_
Change PPT MB	**-.619***	**-.620***	-.100	.134	-.205	-.232	**.946***	1	_	_	_
Change Stiff MT	.152	.120	-.282	-.118	-.601	-.551	.135	-.012	1	_	_
Change Stiff MB	.518	.437	.144	-.309	-.107	.007	-.158	-.261	.341	1	_
Change MEF	-.436	-.435	.188	.536	.147	.002	.265	.343	-.330	-.474	1

Abbreviations: MT, myotendinous sites; MB, muscle belly sites; NPRS, numeric pain rating scale; PPT, pressure pain threshold; Stiff, stiffness; MEF; shoulder maximum elevation force

Figure Legends

Figure 1 Pressure pain threshold (PPT (kPa); 1A) and muscle stiffness (N/m; 1B) maps from the upper trapezius muscle in female computer users with chronic neck-shoulder pain and matched controls

Figure 2 Pressure pain threshold (PPT (kPa); 2A) and muscle stiffness (N/m; 2B) maps from the upper trapezius muscle in females with neck-shoulder pain before and after 5-weeks unilateral eccentric (ECC) training.

Figure 3 Mean ± standard deviation of shoulder maximum elevation force (N; 3A) and range of elevation (mm; 3B) in female computer users with neck-shoulder pain before (white) and after (black) 5-weeks eccentric training.

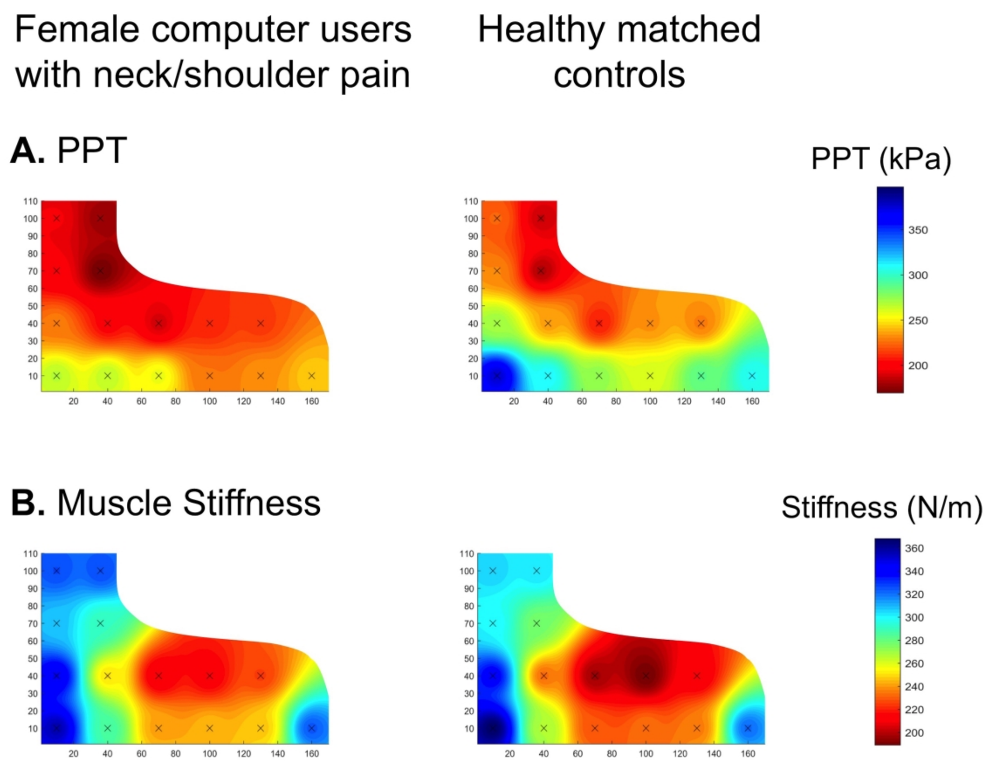

Figure 1 Pressure pain threshold (PPT (kPa); 1A) and muscle stiffness (N/m; 1B) maps from the upper trapezius muscle in female computer users with chronic neck-shoulder pain and matched controls

461x390mm (300 x 300 DPI)

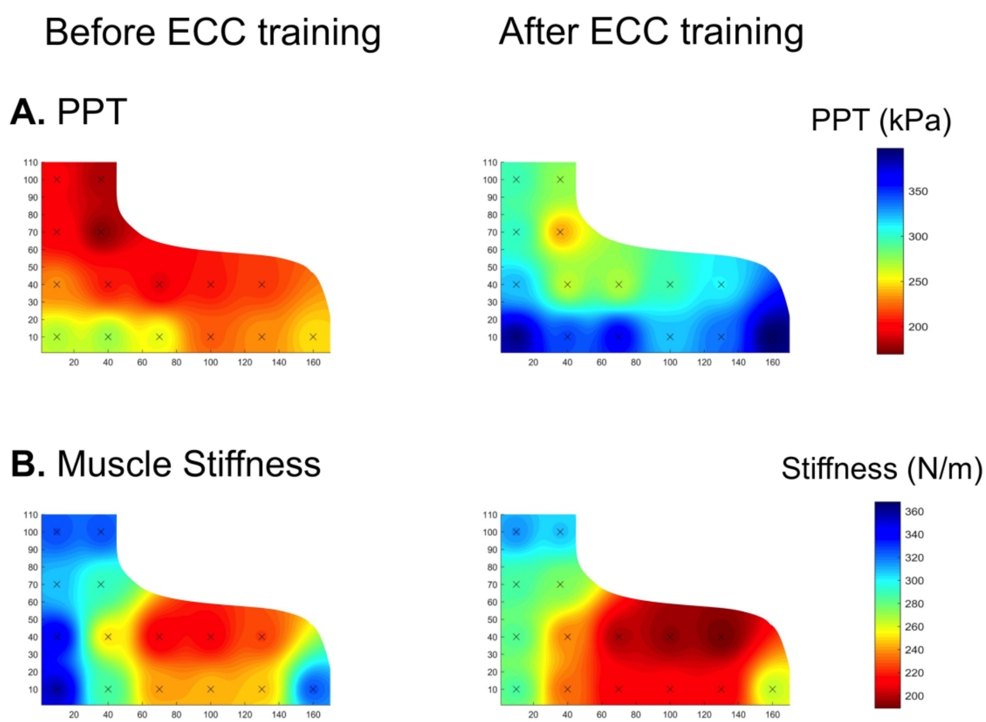

Figure 2 Pressure pain threshold (PPT (kPa); 2A) and muscle stiffness (N/m; 2B) maps from the upper trapezius muscle in females with neck-shoulder pain before and after 5-weeks unilateral eccentric (ECC) training.

461x390mm (300 x 300 DPI)

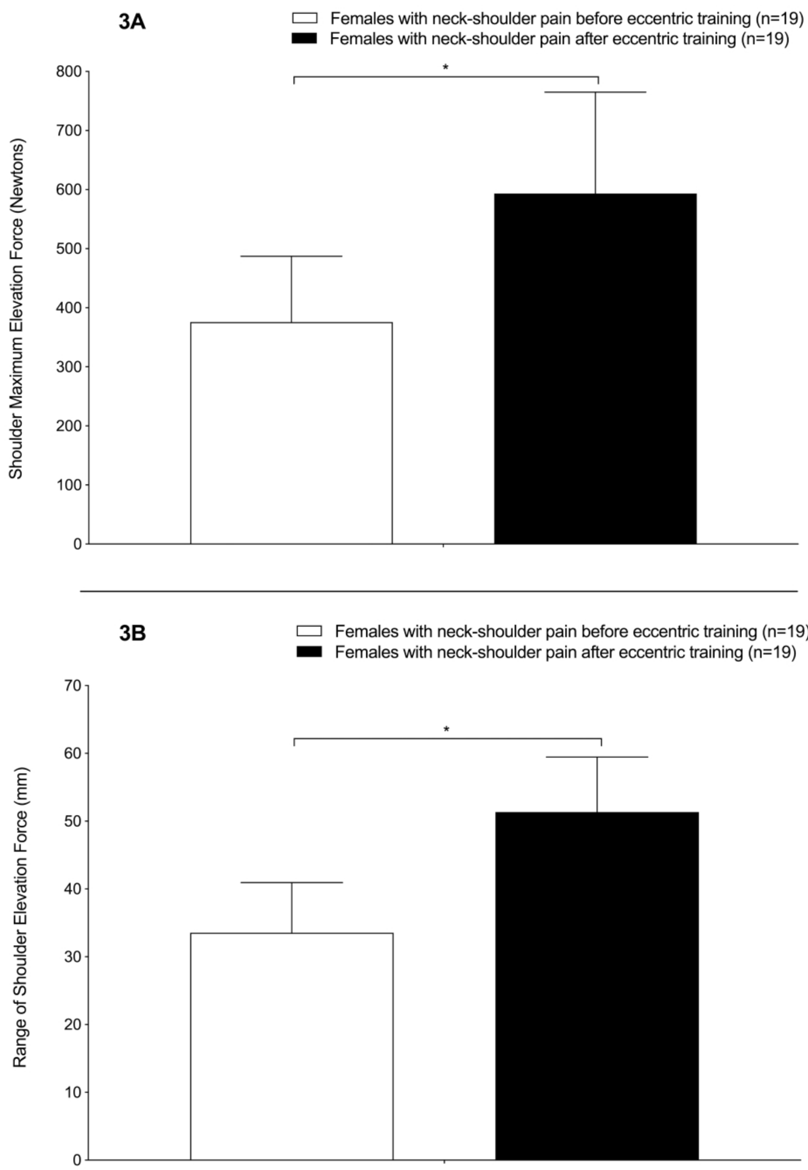

Figure 3 Mean ± standard deviation of shoulder maximum elevation force (N; 3A) and range of elevation (mm; 3B) in female computer users with neck-shoulder pain before (white) and after (black) 5-weeks eccentric training.

331x474mm (300 x 300 DPI)