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a cross-sectional analysis

Liaghat, Behnam; Eshoj, Henrik; Juul-Kristensen, Birgit; Arendt-Nielsen, Lars; Skou, Søren T

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Behnam Liaghat*, Henrik Eshoj, Birgit Juul-Kristensen, Lars Arendt-Nielsen and Søren T. Skou

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Abstract

Background and aims: Traumatic anterior shoulder dislocation (ASD) is frequent in active populations and associated with a 39% higher risk of recurrent dislocation, which may cause persistent shoulder problems, pain, and impaired shoulder-related quality of life. While local and distant pressure pain sensitivity has been demonstrated in other shoulder conditions, little is known about the link between pressure pain sensitivity and ASD. The interesting aspect is whether recurrent dislocation – resulting in symptoms of longer duration – is associated with more pronounced pressure pain sensitivity, or if presence of pressure pain sensitivity may be part of the reasons why patients develop recurrent dislocation. Therefore, this study aimed at evaluating whether patients with recurrent ASD display greater pressure pain sensitivity and more painful body sites than patients with first-time ASD.

Methods: This was a cross-sectional analysis of baseline data from a randomized controlled trial including 34 patients with first-time ASD [82% male, mean (SD) age 26 (7) years] and 22 patients with recurrent ASD [96% male, mean (SD) age 25 (5) years]. Patients were assessed as follows: (1) assessment of local and distant pressure pain sensitivity evaluated by pressure pain thresholds (PPTs) using a handheld algometer on mm. trapezius superior, levator scapula, pectorales major, deltoideus, and tibialis anterior, (2) pain intensity at rest during the previous 24 h, (3) number of ASD, and (4) number of painful body sites on a region-divided body chart.

Results: The PPTs were not significantly different between first-time and recurrent ASD [mean (SD) kPa for m. trapezius superior 264 (110) vs. 261 (88), m. levator scapula 301 (157) vs. 325 (163), m. pectorales major 234 (163) vs. 269 (130), m. deltoideus 290 (166) vs. 352 (173), m. tibialis anterior 420 (202) vs. 449 (184)], two-way ANCOVA, adjusted for sex and age, $F(4,263) = 0.29$, $p = 0.88$. For both groups, the PPTs were lower at the shoulder sites than at m. tibialis anterior (difference 117–184 kPa, 95% CI range 33–267). Females had lower PPTs than males (difference 124 kPa, 95% CI 64–183). The number (SD) of painful body sites were 2.2 (1.9) for first-time ASD and 2.6 (5.4) for recurrent ASD, with no between-group differences, one-way ANCOVA, adjusted for sex and age, $F(1, 52) = 0.24$, $p = 0.63$. There was a strong correlation between PPTs at the shoulder and lower leg, $r = 0.84$, $p < 0.01$.

Conclusions: This study demonstrated no differences in local and distant pressure pain sensitivity or number of painful body sites between patients with first-time and recurrent ASD. Females had lower PPTs than males, and a strong correlation was found between PPTs at the shoulder and lower leg.

Implications: Patients with first-time and recurrent ASD seem to have similar pressure pain sensitivity, but lower

***Corresponding author: Behnam Liaghat,** Research Unit for Musculoskeletal Function and Physiotherapy, Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark, E-mail: bliaghat@health.sdu.dk
Henrik Eshoj: Research Unit for Musculoskeletal Function and Physiotherapy, Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark; and Quality of Life Research Center, Odense University Hospital, Department of Haematology, Odense, Denmark
Birgit Juul-Kristensen: Research Unit for Musculoskeletal Function and Physiotherapy, Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark
Lars Arendt-Nielsen: Department of Health Science and Technology, Centre for Sensory-Motor Interaction (SMI), Faculty of Medicine, Aalborg University, Aalborg, Denmark
Søren T. Skou: Research Unit for Musculoskeletal Function and Physiotherapy, Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark; and Department of Physiotherapy and Occupational Therapy, Næstved-Slagelse-Ringsted Hospitals, Slagelse, Denmark

PPTs compared to existing normative data, suggesting that it is relevant to evaluate the status of the pain system in these patients to prevent triggering or worsening of their symptoms. However, it remains unanswered how these changes affect the patients' ability to undergo rehabilitation, symptom response and long-term shoulder function.

Keywords: pain sensitization; pressure pain sensitivity; quantitative sensory testing – QST; pressure pain threshold; number of painful body sites; anterior shoulder dislocation.

1 Introduction

Traumatic anterior shoulder dislocation (ASD) is a frequent injury in active athletic individuals and is associated with a 39% higher risk of recurrent dislocation [1]. Following an ASD, patients display deficits in neuromuscular and proprioceptive systems as well as impaired rotator cuff strength and shoulder control [2–4]. In worse cases, patients experience persistent shoulder problems, chronic pain, and impaired shoulder-related quality of life [5]. These far-reaching impairments highlight why it is important to understand the neurophysiological mechanisms and adaptations in the pain system following a traumatic ASD.

Like in other musculoskeletal conditions initiated by tissue stress, patients with shoulder problems experience varied levels of sensitization, which is a nervous system phenomenon that can occur in conjunction with and influence the sensation of pain [6]. According to the International Association for the Study of Pain (IASP) [7], sensitization is defined in animals as "*Increased responsiveness of nociceptive neurons to their normal input, and/or recruitment of a response to normally subthreshold inputs*", and its severity is influenced by factors such as intensity [8] and duration [9] of symptoms. For humans different proxies for assessing heightened pain reactivity are used.

Sensitization can occur as peripheral sensitization locally at the injured body site or in the central nervous system (central sensitization) [7]. Clinically, pain sensitization can be estimated using quantitative sensory testing (QST), including pressure pain threshold (PPT), which assesses local or distant pressure pain sensitivity, which are indirect evidence of peripheral and central sensitization [10]. Relatively few studies have assessed pressure pain sensitivity in individuals with shoulder pain [11–13], but current evidence supports the presence of not only local pressure pain sensitivity in painful shoulder conditions including those with subacromial pain but also distant pressure pain sensitivity in the form of lower pain thresholds in distal healthy tissue [14–19].

Patients with traumatic ASD undergo an acute incident of severe tissue stress and tissue damage in the shoulder region (e.g. Bankart lesion characterized by damage to the anteroinferior part of the glenoid labrum and the capsule surrounding the joint), which may trigger a local pressure pain sensitivity response. Previous research has suggested that tissue stress could be just one factor initiating a transition of pain from local (acute) pressure pain sensitivity to distant pressure pain sensitivity by activating various sensitization processes [10] and increase the perception of pain [16, 19–21]. Little is known about local and distant pressure pain sensitivity in patients with traumatic ASD, but a key element of recurrent dislocation is sustained tissue stress and symptoms over long durations, which can potentially be harmful and explain the development of chronic shoulder problems in these patients [22].

The primary aim of this study was to compare PPTs at the shoulder (local pressure pain sensitivity), PPTs at the lower leg (distant pressure pain sensitivity) and number of painful body sites between patients with traumatic first-time and recurrent ASD.

2 Methods

2.1 Study design

This was a secondary analysis of cross-sectional data from a randomized controlled trial (RCT) [23]. Reporting was conducted according to the STROBE guidelines for cross-sectional studies [24]. All patients gave informed consent before being enrolled, the study was conducted in accordance with the Helsinki declaration, it was approved by the local Ethics Committee for the Region of Southern Denmark (project ID: S-20140093), and the RCT was registered at ClinicalTrials.gov (NCT02371928).

2.2 Patients

In total, 56 patients were included in the study from three orthopaedic shoulder units in the regions of Southern and Northern Denmark. As this was an explorative analysis of an RCT, no sample size and power calculations were performed for the outcomes presented here. Eligibility criteria were males and females aged

18–39 years with a traumatic ASD (first-time or recurrent event, with a maximum of up to five anterior dislocations verified by patient register and/or subjective evaluation). Furthermore, patients were required to have a minimum of one radiological verified ASD and self-reported shoulder problems in the week prior to assessment for inclusion, e.g. reduced ability to perform specific shoulder movements during sports/leisure activity and/or work. Exclusion criteria included humeral fracture and/or bony Bankart lesion warranting surgery, prior surgery in the affected shoulder, suspected competing diagnosis (e.g. rheumatoid arthritis, cancer, neurological disorders, fibromyalgia, schizophrenia, suicidal tendency, borderline personality disorder or obsessive compulsive disorder), sensory and motor deficits in neck and shoulder, pregnancy, inability to write and speak Danish.

2.3 Procedures

The following parameters were assessed in all patients: (1) assessment of pressure pain sensitivity evaluated by PPTs at the shoulder (local pressure pain sensitivity) and the lower leg (distant pressure pain sensitivity), (2) pain intensity at rest during the previous 24 h, (3) number of ASD, and (4) number of painful body sites on a region-divided body chart [25, 26].

2.4 Assessment of pain intensity, number of painful body sites and dislocation

As part of a larger test battery, data was collected regarding anthropometry (height/weight), pain intensity at rest within the latest 24 h using a Numeric Pain Rating Scale (NPRS; 0–10 score, 10 = worst imaginable pain), self-reported shoulder instability using the Western Ontario Shoulder Instability Index (WOSI; 0–2100 better to worse), number of dislocation registered as number of shoulder reductions treated in an orthopaedic unit, clinical test for anterior shoulder instability using apprehension, relocation and surprise (yes/no) tests, and number of painful body sites in which the patient shaded body sites with pain in the previous 24 h on a region-divided body chart (26 sites in total).

2.5 Assessment of pressure pain sensitivity using PPT

The PPTs were measured using a handheld algometer with a 1 cm^2 probe (Algometer Type II; Somedic AB, Hoerby, Sweden), applied perpendicular to the skin at a constant rate of 30 kPa/s. Pressure was increased until the patient felt the pressure changed from a sense of pressure to pain and pressed a button defining the PPT (rated in kPa). Before the actual test, one or more test experiments were performed on the dorsal aspect of the hand until the patient had understood the purpose of the experiment. The patient was informed that the test was not about examining how much pain they could tolerate but finding the exact transition from pressure to pain. Measurements at the shoulder sites were only performed in the affected/injured side, and none of the patients had bilateral ASD. Exact measurement sites were found with a tape measure and marked with a pen (Fig. 1). Locations tested at the shoulder (local pressure pain sensitivity) were m. *trapezius superior*, on top of the muscle belly halfway between the spinosi of C7 and lateral border of acromion; m. *levator scapula*, 2 cm above the superior angle of the scapula (in line with fibers); m. *pec. major*, 5 cm below the center of the clavicle halfway between the sternoclavicular joint and lateral border of acromion; and m. *deltoideus* (middle part), 3 cm proximal to the distal humeral insertion. At the lower leg (distant pressure pain sensitivity), m. *tibialis anterior* on the opposite side of the affected shoulder was tested 5 cm distal to tuberositas tibia and on top of the muscle belly. For m. trapezius superior, the patient was sitting erect on a couch with feet on the ground, arms down, hands resting on thighs. For m. levator scapula, the patient was lying prone with neck in neutral and both arms in neutral with the back of the hand resting on the couch. For the three remaining muscles, the patient was lying supine with neck in neutral supported by a pillow and arms resting in neutral. Both elbows were supported by a small towel to achieve neutral position and avoid stretching mm. pectorales major and deltoideus, and with hands resting on the anterior part of the hips.

2.6 Statistical analysis

Patient characteristics were tested for normality and presented with descriptive statistics. Continuous data was normally distributed (QQ-plots and histograms) and presented as means (SD) and dichotomous data as frequency (%). To assess differences in demographics between patients with first-time or recurrent ASD, unpaired *t*-tests were used. For dichotomous outcomes, 2-sided Fisher's exact test was applied.

To assess group differences in outcome measures, preliminary checks were conducted to ensure that there

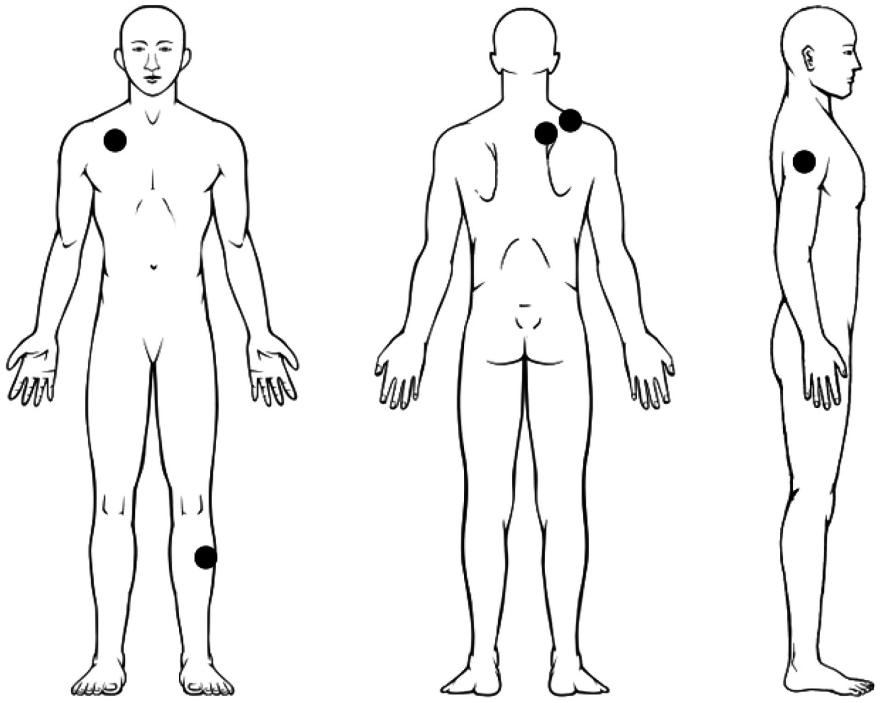


Fig. 1: Locations tested with pressure pain threshold at the shoulder (mm. trapezius superior, levator scapula, pectorales major, deltoideus) and the lower leg (m. tibialis anterior).

Table 1: Patient characteristics of patients with first-time and recurrent anterior shoulder dislocation.

	First-time dislocation (*n* = 34)	Recurrent dislocation (*n* = 22)	*p*-Value
Age, mean years (SD)	26 (7)	25 (5)	0.56
Sex, male *n* (%)	28 (82)	21 (96)	0.84
Weight, mean kg (SD)	84.0 (19.8)[a]	82.4 (15.8)	0.75
Height, mean cm (SD)	178 (7.6)[b]	181 (8.6)	0.18
Analgesic medication (medically prescribed), *n* (%)	3 (9)	3 (14)	0.68
Number of shoulder reductions treated in an orthopaedic unit, *n* (%)			
Unknown, but more than 1	–	4 (18)	
1	34 (100)	–	
2	–	9 (41)	
3	–	5 (23)	
4	–	3 (14)	
5	–	1 (4)	
Mean pain intensity NPRS past 24 h (SD), 0–10	3.4 (2.1)	3.1 (2.2)	0.61
Positive anterior shoulder instability test *n* (%)			
Apprehension	34 (100)	20 (95)[b]	1.00
Relocation	31 (91)	15 (71)[b]	0.68
Release	28 (82)	17 (81)[b]	1.00
Mean WOSI overall score (SD), 0–2100	1064.0 (373.2)	1048.3 (371.5)	0.88
Mean physical symptoms (SD), 0–1000	374.1 (183.5)	387.2 (191.2)	0.80
Mean sports/recreation/work (SD), 0–400	239.5 (101.5)	230.7 (73.1)	0.73
Mean lifestyle (SD), 0–400	236.7 (85.7)	220.9 (97.7)	0.53
Mean emotions (SD), 0–300	213.6 (67.5)	209.5 (63.8)	0.82

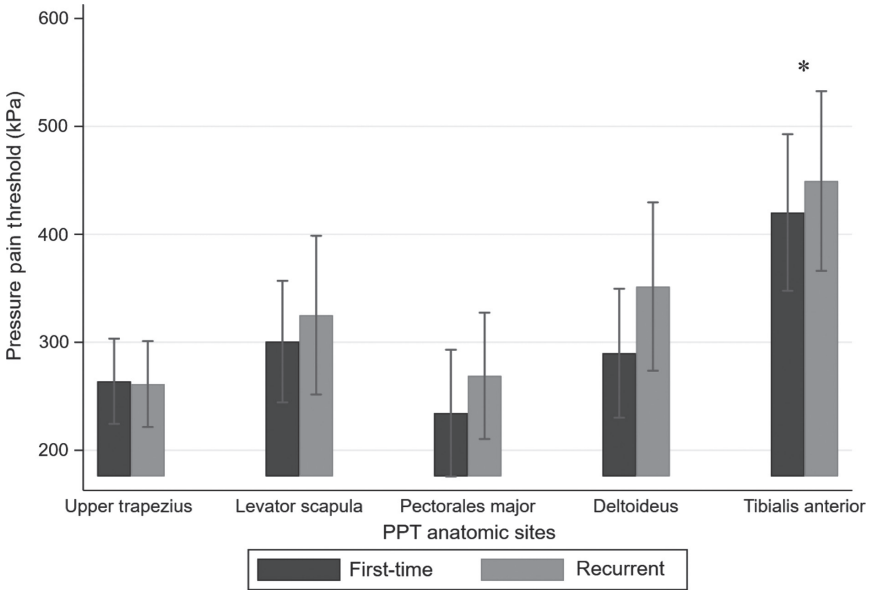
NPRS = numeric pain rating scale; WOSI = Western Ontario Shoulder Instability Index.
[a]Missing data = 2; [b]Missing data = 1.

was no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measurement of the covariate. A two-way ANCOVA was conducted to assess group differences in PPT with site (muscle locations) and ASD status (first-time, recurrent) as factors, adjusting for sex and age. A one-way ANCOVA was conducted to assess group differences in the number of painful body sites with ASD (first-time, recurrent) as factor, adjusting for sex and age. Due to equal variance but unequal sample size, Tukey–Kramer was used as a post hoc test in case of significant ANCOVA factors or interactions.

An unpaired *t*-test was used to assess between-sex differences in PPTs. Pearson's product-moment correlations were used to assess the relationship between shoulder PPTs, lower leg PPTs, painful body sites, and pain intensity, while correlations with the number of dislocation were conducted using Spearman's ρ. The strength of association was defined as follows: $0.1 < |r| < 0.3$ small correlation, $0.3 < |r| < 0.5$ medium/moderate correlation, and $|r| > 0.5$ large/strong correlation [27]. All statistical analyses were performed using STATA (StataCorp, 2015, Stata Statistical Software: Release 15.1, College Station, TX, USA: StataCorp LP.), and *p*-values of less than 0.05 were considered significant.

3 Results

Characteristics of the patients in the two groups were similar (Table 1) [23]. The PPT data was missing for one patient in the first-time ASD group. The two-way ANCOVA demonstrated that PPTs were not different between first-time and recurrent ASD for any of the tested muscles, crude analysis, $F(4, 265) = 0.27$, $p = 0.90$, adjusted for sex and age, $F(4,263) = 0.29$, $p = 0.88$ (Fig. 2). For both groups, the PPTs were lower at all shoulder sites than at m. tibialis anterior (difference 117–184 kPa, 95% CI range 33–267), and females had lower PPTs than males (difference 124 kPa, 95% CI 64–183). The mean (SD) number of painful body sites were 2.2 (1.9) for first-time ASD and 2.6 (5.4) for recurrent ASD, with no between-group difference in the one-way ANCOVA, crude analysis, $F(1, 54) = 0.21$, $p = 0.65$, adjusted for sex and age [$F(1, 52) = 0.24$, $p = 0.63$] (Fig.



Pressure pain threshold, mean kPa (SD)	First-time	Recurrent
Upper trapezius	263.9 (110.0)	261.3 (88.0)
Levator scapula	300.7 (156.8)	325.2 (162.7)
Pectorales major	234.5 (163.4)	268.9 (129.6)
Deltoideus	289.9 (166.3)	351.7 (172.5)
Tibialis anterior	420.2 (202.0)	449.4 (184.2)

Fig. 2: Pressure pain thresholds (PPTs) (kPa) in patients with first-time and recurrent anterior shoulder dislocation at the shoulder sites mm. upper trapezius, levator scapula, pectorales major and deltoideus and at the lower leg site m. tibialis anterior. *Significant difference between PPTs at the m. tibialis anterior and at the shoulder sites, $p < 0.05$.

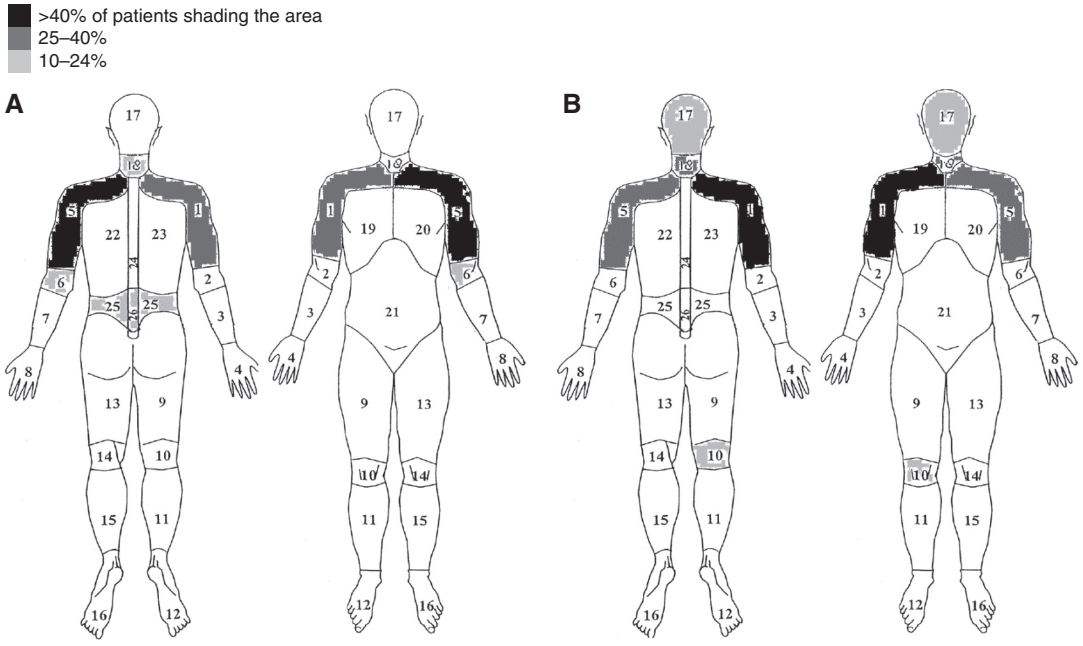


Fig. 3: Number of painful body sites (26 sites in total) in patients with traumatic first-time anterior shoulder dislocation (A) and recurrent dislocation (B), showing no group differences [one-way ANCOVA (site: first-time or recurrent), crude analysis, F (1, 54) = 0.21, $p = 0.65$], adjusted for sex and age [F (1, 52) = 0.24, $p = 0.629$].

Table 2: Correlation between shoulder pressure pain thresholds (PPTs), lower leg PPTs, pain intensity, number of painful body sites and number of dislocation for all patients.

	PPT shoulder	PPT leg	Painful body sites	Pain intensity
PPT shoulder				
PPT leg	0.84[a]			
p-Value	**<0.01**			
Painful body sites	−0.10	0.04		
p-Value	0.47	0.78		
Pain intensity	0.10	0.05	0.23	
p-Value	0.48	0.71	0.09	
Number of dislocation	0.16	0.15	−0.04	−0.17
p-Value	0.23	0.27	0.77	0.22

Pearson's product-moment correlations were used to assess the relationship between shoulder PPTs, lower leg PPTs, painful body sites, pain intensity, while correlations with the number of dislocation was conducted using Spearman's ρ.
[a]Significance $p < 0.05$.

3). There was a strong correlation between PPTs at the shoulder and lower leg, r = 0.84, $p < 0.01$ (Table 2).

4 Discussion

The present study demonstrated no statistically significant differences in pressure pain sensitivity at the shoulder or the lower leg or in number of painful body sites between patients with first-time and recurrent traumatic ASD. Females had lower PPTs than males, and PPTs at the shoulder and lower leg were strongly correlated.

The primary finding of interest is that patients with first-time or recurrent ASD seem to be equally affected in pain sensitivity in response to pressure. Considering that patients with recurrent dislocation have had symptoms for long durations, one would intuitively expect that their pain system was more affected resulting in lower pressure pain sensitivity [22]. An explanation for the lack of between group-difference could be that the changes in the pain system in this population are more related to the acute inflammatory response [28] that occurs just after the traumatic dislocation and settles after a short period of time (e.g. 5–7 days). This would increase pain levels acutely regardless of the number of dislocation, since the acute response to injury is hypothetized to be similar every time. This is partly supported by the fact that patients from both groups in this cross-sectional analysis had similarly high levels of pain intensity, a known associate of sensitization and more painful body sites [20], and comparable shoulder impairments, as reported previously [22]. Another important aspect to consider is that although we included several relevant PPT sites at the shoulder, none of the selected shoulder sites covered the rotator cuff muscles, which are of significant importance in populations with joint instability such as anterior shoulder

instability because of their anatomic position near the joint and their functional importance for controlling the compression and shear forces of the humeral head [29, 30]. Particularly the supraspinatus muscle is densely populated with nociceptors that likely contribute to the generation of sensitization [31], but also the muscles on the anterior side of the shoulder such as subscapularis, biceps and anterior deltoideus are mechanically stressed following an ASD. However, the reasons for not testing these muscles were because of the relatively large test-battery in the RCT as well as using anatomic sites that seemed relevant for shoulder stability (scapular and shoulder-joint near muscles) and PPT sites most commonly used for other shoulder problems at that time [14, 29, 30].

Unlike this patient-group suffering from traumatic ASD, studies have investigated pressure pain sensitivity in patients with other shoulder problems in comparable age groups [12, 15, 16, 18]. Lower PPTs have been reported for subacromial impingement syndrome in 20–38-year-old patients [16, 18] and shoulder pain in 18–52-year-old patients [15] compared to healthy controls. The observed PPTs at the shoulder and lower leg from this study are generally consistent with PPT levels demonstrated for similar shoulder sites and m. tibialis anterior for those with subacromial impingement syndrome [16, 18]. Upper trapezius PPT is very often used in studies investigating sensitivity levels before and after exercise bouts, and comparing the PPT levels with previously reported values, PPT values obtained in this study seem to be consistently lower than PPT levels in healthy young adults under 40 years [31–33]. The lower PPT at m. tibialis anterior compared to normative data for healthy adults suggests that distant pressure pain sensitivity is present and indicates the presence of central sensitization. These observations suggest that pressure pain sensitivity in patients with ASD is an important parameter to assess in relation to diagnosing the severity of symptoms and managing them in a rehabilitation process, where the patients could respond poorly to treatment due to worsening of their symptoms [19, 34]. Females were found to have lower PPT than males, which is consistent with the results of most studies conducted on healthy and symptomatic populations [35–37].

Pain at one anatomical site is often associated with pain at an adjacent site or the same site on the other side of the body [38], which corresponds well with our data on patients with ASD, who averagely had pain at more than two body sites. We found no significant differences in the number of painful body sites between the two groups. However, it seems that more patients in the first-time ASD group reported symptoms in the elbow, which could be a sign of a more extensive injury the first time the shoulder dislocates, while patients in the recurrent group reported more symptoms in the head.

4.1 Strength and limitations

Due to the exploratory nature of the analysis, the results must be interpreted with caution. Firstly, it is important to acknowledge that since the sample size was determined based on the primary RCT, the non-significant findings of this analysis could merely be a result of a type II error. However, the reported differences were small, indicating that even with a larger sample size any potential differences would not be clinically relevant. The current measurements were performed only 3–6 weeks after the latest ASD, and precise symptom duration was not collected. As such, we cannot rule out that the findings are explained by the painful inflammatory process that follows after an acute traumatic injury. The data is also limited, because PPT-measurement is just one factor when assessing sensitization in painful conditions, where other measurements such as suprathreshold heat pain responses and psychological factors such as fear-avoidance could provide useful knowledge about potential changes and adaptations in the pain system. The strengths of the study are that the analysis was built upon data from an RCT thereby strengthening the standardization of testing procedures, and the fact that data was collected in clinical practice with a clinically applicable setup for measurement of PPT.

4.2 Conclusion

This study demonstrated no significant differences in local or distant pressure pain sensitivity or number of painful body sites between patients with first-time and recurrent traumatic ASD. Females had lower PPTs than males, and a strong correlation was found between PPTs in the shoulder and at the lower leg.

4.3 Implications

Patients with first-time and recurrent ASD seem to have similar pressure pain sensitivity with lower PPTs compared to existing normative data [16, 18, 31–33], suggesting that it is relevant to understand and evaluate the status of the pain system in these patients to prevent triggering or worsening their symptoms. However, it remains unanswered how these changes affect the patients' ability to

undergo rehabilitation, their symptom response and long-term shoulder function.

Authors' statements

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Conflict of interest: B. Liaghat, H. Eshoj, B. Juul-Kristensen, and L. Arendt-Nielsen have nothing to disclose. S. Skou reports personal fees from Journal of Orthopaedic & Sports Physical Therapy, grants from The Lundbeck Foundation, personal fees from Munksgaard, outside the submitted work; and Being co-founder of GLA:D. GLA:D is a non-profit initiative hosted at University of Southern Denmark aimed at implementing clinical guidelines for osteoarthritis in clinical practice.

Informed consent: All patients gave informed consent before being enrolled, and the study was conducted in accordance with the Helsinki declaration.

Ethical approval: The study was approved by the local Ethics Committee for the Region of Southern Denmark (project ID: S-20140093).

References

[1] Olds M, Ellis R, Donaldson K, Parmar P, Kersten P. Risk factors which predispose first-time traumatic anterior shoulder dislocations to recurrent instability in adults: a systematic review and meta-analysis. Br J Sports Med 2015;49:913–22.

[2] Edouard P, Gasq D, Calmels P, Degache F. Sensorimotor control deficiency in recurrent anterior shoulder instability assessed with a stabilometric force platform. J Shoulder Elbow Surg 2014;23:355–60.

[3] Smith RL, Brunolli J. Shoulder kinesthesia after anterior glenohumeral joint dislocation. Phys Ther 1989;69:106–12.

[4] Zuckerman JD, Gallagher MA, Cuomo F, Rokito A. The effect of instability and subsequent anterior shoulder repair on proprioceptive ability. J Shoulder Elbow Surg 2003;12:105–9.

[5] Levine WN, Flatow EL. The pathophysiology of shoulder instability. Am J Sports Med 2000;28:910–7.

[6] Arendt-Nielsen L, Fernandez-de-Las-Penas C, Graven-Nielsen T. Basic aspects of musculoskeletal pain: from acute to chronic pain. J Man Manip Ther 2011;19:186–93.

[7] IASP Terminology. 2017. Available at: https://www.iasp-pain.org/Education/Content.aspx?ItemNumber=1698.

[8] Herren-Gerber R, Weiss S, Arendt-Nielsen L, Petersen-Felix S, Di Stefano G, Radanov BP, Curatolo M. Modulation of central hypersensitivity by nociceptive input in chronic pain after whiplash injury. Pain Med 2004;5:366–76.

[9] Fernandez-de-Las-Penas C, Ge HY, Arendt-Nielsen L, Cuadrado ML, Pareja JA. The local and referred pain from myofascial trigger points in the temporalis muscle contributes to pain profile in chronic tension-type headache. Clin J Pain 2007;23:786–92.

[10] Graven-Nielsen T, Arendt-Nielsen L. Assessment of mechanisms in localized and widespread musculoskeletal pain. Nat Rev Rheumatol 2010;6:599–606.

[11] Noten S, Struyf F, Lluch E, D'Hoore M, Van Looveren E, Meeus M. Central pain processing in patients with shoulder pain: a review of the literature. Pain Pract 2017;17:267–80.

[12] Sanchis MN, Lluch E, Nijs J, Struyf F, Kangasperko M. The role of central sensitization in shoulder pain: A systematic literature review. Semin Arthritis Rheum 2015;44:710–6.

[13] Borstad J, Woeste C. The role of sensitization in musculoskeletal shoulder pain. Braz J Phys Ther 2015;19:251–7.

[14] Alburquerque-Sendin F, Camargo PR, Vieira A, Salvini TF. Bilateral myofascial trigger points and pressure pain thresholds in the shoulder muscles in patients with unilateral shoulder impingement syndrome: a blinded, controlled study. Clin J Pain 2013;29:478–86.

[15] Coronado RA, Simon CB, Valencia C, George SZ. Experimental pain responses support peripheral and central sensitization in patients with unilateral shoulder pain. Clin J Pain 2014;30:143–51.

[16] Hidalgo-Lozano A, Fernandez-de-las-Penas C, Alonso-Blanco C, Ge HY, Arendt-Nielsen L, Arroyo-Morales M. Muscle trigger points and pressure pain hyperalgesia in the shoulder muscles in patients with unilateral shoulder impingement: a blinded, controlled study. Exp Brain Res 2010;202:915–25.

[17] Hidalgo-Lozano A, Fernandez-de-las-Penas C, Calderon-Soto C, Domingo-Camara A, Madeleine P, Arroyo-Morales M. Elite swimmers with and without unilateral shoulder pain: mechanical hyperalgesia and active/latent muscle trigger points in neck-shoulder muscles. Scand J Med Sci Sports 2013;23:66–73.

[18] Paul TM, Soo Hoo J, Chae J, Wilson RD. Central hypersensitivity in patients with subacromial impingement syndrome. Arch Phys Med Rehabil 2012;93:2206–9.

[19] Gwilym SE, Oag HC, Tracey I, Carr AJ. Evidence that central sensitisation is present in patients with shoulder impingement syndrome and influences the outcome after surgery. J Bone Joint Surg Br 2011;93:498–502.

[20] Valencia C, Kindler LL, Fillingim RB, George SZ. Investigation of central pain processing in shoulder pain: converging results from 2 musculoskeletal pain models. J Pain 2012;13:81–9.

[21] Valencia C, Kindler LL, Fillingim RB, George SZ. Stability of conditioned pain modulation in two musculoskeletal pain models: investigating the influence of shoulder pain intensity and gender. BMC Musculoskelet Disord 2013;14:182.

[22] Arendt-Nielsen L, Graven-Nielsen T. Translational musculoskeletal pain research. Best Pract Res Clin Rheumatol 2011;25:209–26.

[23] Eshoj H, Rasmussen S, Frich LH, Jensen SL, Sogaard K, Juul-Kristensen B. Patients with non-operated traumatic primary or recurrent anterior shoulder dislocation have equally poor self-reported and measured shoulder function: a cross-sectional study. BMC Musculoskelet Disord 2019;20:59.

[24] von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, Initiative S. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol 2008;61:344–9.

[25] Skou ST, Roos EM, Simonsen O, Laursen MB, Rathleff MS, Arendt-Nielsen L, Rasmussen S. The efficacy of non-surgical treatment on pain and sensitization in patients with knee osteoarthritis: a pre-defined ancillary analysis from a randomized controlled trial. Osteoarthritis Cartilage 2016;24:108–16.
[26] Skou ST, Roos EM, Simonsen O, Laursen MB, Rathleff MS, Arendt-Nielsen L, Rasmussen S. The effects of total knee replacement and non-surgical treatment on pain sensitization and clinical pain. Eur J Pain 2016;20:1612–21.
[27] Cohen J, editor. Statistical power analysis for the behavioral sciences, 2nd ed. New York: Routledge, 1998:567.
[28] Gallo J, Raska M, Kriegova E, Goodman SB. Inflammation and its resolution and the musculoskeletal system. J Orthop Translat 2017;10:52–67.
[29] Park G, Kim CW, Park SB, Kim MJ, Jang SH. Reliability and usefulness of the pressure pain threshold measurement in patients with myofascial pain. Ann Rehabil Med 2011;35:412–7.
[30] Ribeiro IL, Camargo PR, Alburquerque-Sendin F, Madeleine P, Fernandez-de-las-Penas C, Salvini TF. Topographical pressure pain sensitivity maps of the shoulder region in individuals with subacromial pain syndrome. Man Ther 2016;21:134–43.
[31] Vaegter HB, Bjerregaard LK, Redin MM, Rasmussen SH, Graven-Nielsen T. Hypoalgesia after bicycling at lactate threshold is reliable between sessions. Eur J Appl Physiol 2019;119:91–102.
[32] Vaegter HB, Dorge DB, Schmidt KS, Jensen AH, Graven-Nielsen T. Test-retest reliability of exercise-induced hypoalgesia after aerobic exercise. Pain Med 2018;19:2212–22.
[33] Alsouhibani A, Vaegter HB, Hoeger Bement M. Systemic exercise-induced hypoalgesia following isometric exercise reduces conditioned pain modulation. Pain Med 2019;20:180–90.
[34] Nijs J, Goubert D, Ickmans K. Recognition and treatment of central sensitization in chronic pain patients: not limited to specialized care. J Orthop Sports Phys Ther 2016;46:1024–8.
[35] Neziri AY, Scaramozzino P, Andersen OK, Dickenson AH, Arendt-Nielsen L, Curatolo M. Reference values of mechanical and thermal pain tests in a pain-free population. Eur J Pain 2011;15:376–83.
[36] Sheffield D, Biles PL, Orom H, Maixner W, Sheps DS. Race and sex differences in cutaneous pain perception. Psychosom Med 2000;62:517–23.
[37] Arendt-Nielsen L, Simonsen O, Laursen MB, Roos EM, Rathleff MS, Rasmussen S, Skou ST. Pain and sensitization after total knee replacement or nonsurgical treatment in patients with knee osteoarthritis: Identifying potential predictors of outcome at 12 months. Eur J Pain 2018;22:1088–102.
[38] Coggon D, Ntani G, Palmer KT, Felli VE, Harari R, Barrero LH, Felknor SA, Gimeno D, Cattrell A, Vargas-Prada S, Bonzini M, Solidaki E, Merisalu E, Habib RR, Sadeghian F, Masood Kadir M, Warnakulasuriya SS, Matsudaira K, Nyantumbu B, Sim MR, et al. Patterns of multisite pain and associations with risk factors. Pain 2013;154:1769–77.