

ORIGINAL REPORT

SOMATOSENSORY IMPAIRMENTS ARE COMMON AFTER STROKE BUT HAVE ONLY A SMALL IMPACT ON POST-STROKE SHOULDER PAIN

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Objective: To investigate whether somatosensory impairments are more common in individuals with post-stroke shoulder pain than in those without post-stroke shoulder pain and healthy controls.

Design: Descriptive analysis of a convenience sample.

Participants: Forty-nine individuals with stroke, 24 with and 25 without post-stroke shoulder pain (median age 65 years), and 11 age- and sex-matched healthy controls.

Methods: Perception and pain thresholds for cold, warm and heat (thermal thresholds), and pain thresholds for pressure and pin prick (mechanical thresholds) were assessed using quantitative sensory testing (QST). Passive range of motion, motor function, resistance to passive movements, light touch and proprioception were assessed in the upper extremities. Shoulder pain characteristics were recorded in the post-stroke shoulder pain group.

Results: There were no significant differences between the group with post-stroke shoulder pain and the group without post-stroke shoulder pain in any of the QST assessments, but more participants in the post-stroke shoulder pain group reported abnormal cold sensation in the affected side. Both stroke groups had generally higher thermal thresholds and more extreme low or high mechanical thresholds than the healthy controls.

Conclusion: Somatosensory impairments are common among individuals with stroke compared with healthy controls. The non-significant differences in QST thresholds between the group with post-stroke shoulder pain and the group without post-stroke shoulder pain indicate that somatosensory impairments have only a small impact on post-stroke shoulder pain.

Key words: shoulder pain; stroke; sensory thresholds.

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INTRODUCTION

Post-stroke shoulder pain (PSSP) is a common impairment (1–3) and occurs in approximately one-third of an unselected

stroke population (4). It usually develops during the first weeks or months after stroke onset (2–5), and the frequency and intensity of PSSP can vary considerably. It is often reported during arm movements, but can also occur at rest (4). PSSP can impede rehabilitation and prolong hospital stay (6). Although PSSP can improve during rehabilitation (2), studies have shown that it can be a long-lasting or persistent problem (4, 7–11).

PSSP is a complex and multifactorial phenomenon (3, 12). It has been associated with severe motor impairments (2–4, 13), sensory impairments (2, 14), spasticity (15–17) and decreased passive range of motion (ROM) (13). Factors that are particularly associated with persistent shoulder pain are decreased range of abduction, left-sided hemiparesis and pain frequency (11). While motor impairments, decreased range of motion and spasticity have been fairly well studied in persons with PSSP (3, 4, 11, 13, 17), there has been less research into somatosensory impairments.

Until recently PSSP has been considered as nociceptive, but newer findings indicate that somatosensory impairments, such as pain hypersensitivity, thermal and mechanical hyperalgesia and allodynia (i.e. indicative of central sensitization) may contribute to the development and maintenance of PSSP (18). In order to optimize the treatment of PSSP after stroke, it is important to identify symptoms of central or peripheral sensitization. An established method to assess somatosensory modalities is quantitative sensory testing (QST) (9, 10, 19). With this method, it is possible to study different parts of the somatosensory system. The analysis of thermal thresholds allows the assessment of A-delta and C-fibres, and analysis of mechanical thresholds allows the assessment of A-beta fibres. Only 3 studies have used QST to assess somatosensory impairments in persons with PSSP (9, 10, 20), and the interpretation of the findings, and the relationship between somatosensory impairments and chronic PSSP remain unclear.

Thus, the aim of this study was to investigate whether somatosensory impairments are more common in individuals with PSSP than in individuals without PSSP and healthy controls.

METHODS

Participants

A total of 49 individuals with stroke (24 with PSSP (PSSP group) and 25 without PSSP (non-PSSP group) and 11 healthy age- and sex-

matched controls (HC) participated in the study. All stroke participants were recruited from the Lund Stroke Register and the Departments of Neurology and Rehabilitation Medicine at Skåne University Hospital by screening medical records. Inclusion criteria were: stroke onset between 5 and 36 months prior to study enrolment, and decreased motor function in the affected arm. Inclusion criteria for PSSP participants were: pain in the affected shoulder for at least 4 months after stroke onset, and daily or almost daily pain. Exclusion criteria were: difficulty in communicating or in understanding test instructions, other conditions causing pain or sensory disturbances, and severe depression or other psychiatric symptoms.

Recruitment procedure

A flow-chart of the recruitment process of the stroke participants is shown in Fig. 1. After reviewing medical records, individuals who initially met the inclusion and exclusion criteria were first contacted by post with information about the study, then 1–2 weeks later by phone for an interview. This interview consisted of questions related to sensorimotor function, ability to perform daily activities, shoulder pain, general health and current pain medication. Individuals who met the inclusion and exclusion criteria and agreed to participate were then invited to the Department of Rehabilitation Medicine for physical examination and QST assessments. Out of a total of 167 potential participants, 118 were excluded or declined to participate

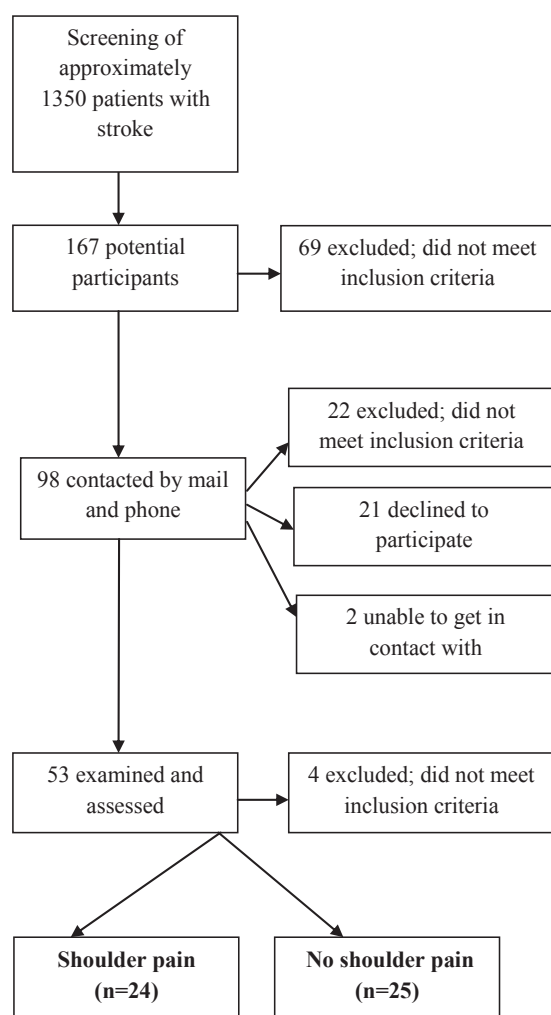


Fig. 1. Recruitment of stroke participants to the study.

and, subsequently, 49 stroke participants were included in the study. In addition, 11 sex- and age-matched HC were recruited among staff, relatives and friends. The inclusion criteria were: no history of stroke and no shoulder pain.

All participants gave their written informed consent to participate. The study was approved by the Regional Ethical Review Board in Lund, Sweden (Dnr 2011/471).

Demographics and participant characteristics

Before the assessments, the following demographic and participant-specific information were recorded: age, sex, hand dominance, height and weight (to calculate body mass index; BMI) and vocational situation. Stroke-specific characteristics were also recorded, such as independency in personal activities of daily living (P-ADL), walking ability, ability to grasp and release an object, side of lesion, type of stroke, stroke onset, length of stay in a rehabilitation unit, pain in other parts of the body and abnormal somatosensation in the affected side. Pain present in other parts of the body was registered in the lower extremities, the upper extremity (other than the paretic shoulder) and in the back, neck or head. Other abnormal sensation in the affected arm and leg was registered as numbness, tingling, tickling, stinging or stunning.

Upper extremity assessments

The following impairments were assessed, first in the unaffected arm and then in the affected arm: passive ROM, motor function, resistance to passive movements, light touch and proprioception. Passive ROM in abduction and external rotation, with the participant in a supine position, were assessed using a goniometer (11). Motor function of the upper arm and hand as well as advanced hand activities were assessed with the Swedish version of the Modified Motor Assessment Scale (M-MAS) (21, 22). The subscales range from 0 to 5, where 5 = normal or almost normal motor function and 0 = no motor function; the maximum total score for each arm is 15 points and restrictions in motor function are here reported as severe to moderate (0–11 points) and mild to no restriction (12–15 points). Resistance to passive movements in the elbow was assessed according to the Modified Ashworth Scale (23) with the participants lying in a supine position. The scale ranges from 0 to 4, where 0 = no increase in muscle tone, 1–3 = some degree of increased muscle tone, and 4 = rigidity in flexion or extension; increased muscle tone is here reported as ≥ 1 . Light touch in the upper arm and forearm, hands and fingers were assessed using a cotton swab and recorded as normal, diminished, increased or absent. Proprioception was assessed in the thumbs and wrists using a 3-point scale, where 2 = all 4 attempts correct, 1 = 3/4 attempts correct and 0 < 3/4 attempts correct (24, 25).

Shoulder pain characteristics

In the PSSP group, the following data were recorded: shoulder pain onset, pain location, pain during movements and/or at rest, pain at touch, pain intensity, pain quality and intake of medication for the shoulder pain. Shoulder pain onset was recorded as: occurring within 2 months or after 2 months post-stroke. Pain location was recorded as: shoulder pain, shoulder and arm pain, or arm pain. Shoulder pain during movements and/or at rest and pain during touch was assessed as “yes” or “no”. Shoulder pain intensity was evaluated during the past 48 h using a 0–100-mm visual analogue scale for pain (VAS-P) marked at one end “no pain” and at the other “worst imaginable pain” (in Swedish). The pain quality was assessed as dull ache, stabbing/cutting, scurrying/radiating, burning, muscle cramps or tiredness; several pain qualities could be chosen by the participant. The pain medication was unchanged on the day of the assessment.

Quantitative sensory testing

Thermal thresholds were assessed with the MSA Thermotest (Somedic AB, Hörby, Sweden). The thermal tests included cold detection thresholds (CDT), warm detection thresholds (WDT), cold pain thresholds (CPT) and heat pain thresholds (HPT). The mechanical tests, i.e.

pressure pain thresholds (PPT) and pin-prick pain thresholds (PPPT), were assessed with the Algometer (Somedic AB, Hörby, Sweden) and the SenseBox Electronic von Frey. The method of limits was used, i.e. the intensity of the stimulus applied to the skin was increased (or decreased) until the subject perceived a stimulus or felt it painful. The detection threshold was defined as the minimum intensity of a stimulus perceived as stimulus, and the pain threshold as the minimum intensity of a stimulus perceived as painful (26). A higher cold detection threshold or cold pain threshold means that cold or cold pain is perceived at a lower temperature and a higher warm detection threshold or heat pain threshold means that warm or heat pain is perceived at a higher temperature. A higher pressure pain threshold or pin-prick pain threshold means that pressure or pin-prick pain is perceived at a greater pressure. The QST protocol in this study was adapted from the protocol originally developed by Rolke et al. (27).

During the QST, the participants were assessed sitting in a comfortable chair with arm rests and the feet on the floor, the upper arm at 0° abduction and the elbow at 90° flexion. The participants were not allowed to see the computer screen during the assessment. They used a handheld switch in their unaffected/dominant hand and were instructed to press the switch when they felt cold/warm sensations, cold/heat pain or discomfort, and pressure/pin-prick pain or discomfort. When the participant pressed the switch, the assessment stopped. All QST assessments were performed by the same examiner (EE) and lasted approximately 1 h.

Thermal testing. The thermal thresholds were performed in the following order: cold detection, warm detection, cold pain and heat pain, respectively. A thermode, 25 × 50 mm, with an initial temperature of 32°C and a speed of 1°/s, was applied to the skin. During the cold tests the temperature gradually decreased until a minimum of 10°C. During the warm/heat tests the temperature gradually increased, with a maximum temperature of 50°C. The thermal test was first performed in the unaffected/dominant leg (i.e. reference point), thereafter in the unaffected/dominant upper arm and, finally, in the affected/non-dominant upper arm. On the leg, the thermode was placed on the distal part of the vastus medialis muscle and on the upper arm over the middle part of the middle portion of the deltoid muscle. In all locations, 4 repetitions were performed with 4–6 s rest between each assessment. The results are presented as medians of the 4 assessments for each variable.

Mechanical testing. The PPT was assessed with an electronic algometer, using a probe with a pressure diameter of 1 cm² and a slope of 50 kPa/s. The pressure started at 10 kPa, and the examiner gradually increased the pressure until the participant pressed the switch. The maximum pressure was set to 1000 kPa. The unaffected/dominant arm was first assessed and thereafter the affected/non-dominant arm. The probe was pressed on 3 points: upper, middle and lower part of the middle deltoid muscle. The PPT procedure was repeated once (i.e. 2 assessments at each point), yielding a total of 6 measurements. The results are presented as the median of the 6 measurements.

The PPPT was assessed with an electric von Frey transducer, using a 0.2 mm tip diameter with a speed of 10 g/s. The PPPT started at 10 g and the examiner gradually increased the pressure until the participant pressed the switch. The maximum pressure was set to 400 g. The PPPT was assessed once in 3 points in the upper, middle and lower part of the deltoid muscle, anteriorly and posteriorly, respectively. The unaffected/dominant arm was first assessed and thereafter the affected/non-dominant arm, yielding measurements from 6 points in each arm. The results are presented as the median of the 6 measurements.

Statistical analysis

Data were analysed using the IBM SPSS Statistics version 20 (IBM Corporation, Armonk, New York, USA). The demographic data and data for upper extremity assessments for each group (PSSP, non-PSSP and HC) are presented as frequencies and median (range). The QST data are presented as median (range). To determine between-group differences, the Mann-Whitney *U* test was used for the continuous variables (age, BMI, stroke onset, passive ROM and QST). The χ^2 test

and Fisher's exact test were used for the categorical variables (sex, hand dominance, vocational situation, side of lesion, type of stroke, pain in other parts of the body, abnormal somatosensation, motor function, somatosensory function and resistance to passive movements). The Wilcoxon signed-rank test was used for pairwise comparisons (affected/non-dominant side compared with unaffected/dominant side). *p*-values less than 0.05 were considered statistically significant.

RESULTS

Demographics and participant characteristics

All participants except 3 (2 in the PSSP group and one in the non-PSSP group) reported that they were independent in P-ADL, and all except one (in the non-PSSP group) walked independently with or without a walking aid. Ten participants (5 in the PSSP group and 5 in the non-PSSP group) had some difficulties grasping and releasing an object with their affected hand. All but one had undergone rehabilitation up to 6 months after stroke onset.

The demographics and characteristics for the participants are presented in Table I. Forty-six percent of subjects in the PSSP group and 32% in the non-PSSP group had a right hemispheric lesion. No significant differences in demographics were seen between the PSSP group and the non-PSSP group, except for vocational situation ($p=0.02$) and self-reported abnormal cold sensation ($p=0.02$). Significant differences were also found between the PSSP group and the HC regarding vocational situation ($p=0.02$).

A total of 58% in the PSSP group and 40% in the non-PSSP group reported pain present in other parts of the body. Twelve participants in the PSSP group and 8 in the non-PSSP group reported pain in the lower extremities. Seven participants (4 in the PSSP group and 3 in the non-PSSP group) reported pain in the upper extremity other than the paretic shoulder. Four participants (one in the PSSP group and 3 in the non-PSSP group) reported pain in their back or neck, and one participant in the PSSP group reported headache. No participant was diagnosed with complex regional pain syndrome (CRPS) or central post-stroke pain (CPSP) at the time of study enrolment.

Abnormal sensation was reported by 29% of subjects in the PSSP group and by 28% in the non-PSSP group. Four participants in the PSSP group and 5 in the non-PSSP group reported abnormal sensations in both their upper and lower extremities. One participant in the PSSP group and one in the non-PSSP group reported abnormal sensation in the upper extremity, and 2 participants in the PSSP group and one in the non-PSSP group reported abnormal sensations in the lower extremities. The most commonly reported abnormal sensation was numbness.

Upper extremity assessments

In Table II, data on passive ROM, motor function, resistance to passive movements, light touch and proprioception are presented. The PSSP group had significantly reduced passive shoulder abduction ($p<0.001$) and had a more restricted motor function in their upper extremity ($p=0.03$) compared with the non-PSSP group.

Table I. Demographics and characteristics of the participants with post-stroke shoulder pain (PSSP), without shoulder pain (non-PSSP) and healthy controls (HC), and the difference between the groups

Demographics and characteristics	PSSP (n=24)	Non-PSSP (n=25)	HC (n=11)	Significance tests ^a		
				PSSP vs non-PSSP	PSSP vs HC	Non-PSSP vs HC
Age, years, median (range)	65 (45–81)	64 (44–77)	64 (55–74)	>0.30	>0.30	>0.30
Male, n (%)	19 (79)	16 (64)	7 (64)	0.24	>0.30	>0.30
Right dominant hand, n (%)	24 (100)	24 (96)	10 (91)	>0.30	>0.30	>0.30
BMI, median (range)	29 (22–35)	26 (19–39)	26 (21–28)	0.11	0.06	>0.30
Vocational situation, n (%)				0.02	0.02	>0.30
Working ≥50%	2 (8)	9 (36)	5 (46)			
Sick leave or pension ≥50 %	22 (92)	16 (64)	6 (55)			
Right hemispheric lesion, n (%)	11 (46)	8 (32)	na	>0.30	na	na
Stroke type, n (%)				>0.30	na	na
Cerebral infarction	20 (83)	18 (72)	na			
Haemorrhage	4 (17)	7 (28)	na			
Stroke onset, months, median (range)	13 (5–33)	15 (5–35)	na	0.21	na	na
Ongoing pain in other parts of the body, n (%)	14 (58)	10 (40)	na	0.20	na	na
Abnormal cold sensation in affected side, n (%)	7 (29)	1 (4)	na	0.02	na	na
Other abnormal sensation in affected side, n (%)	7 (29)	7 (28)	na	>0.30	na	na

^aDifference between groups: the Mann-Whitney *U* was used for the variables age, BMI and stroke onset, and the χ^2 test and Fisher's exact test for the variables sex, hand dominance, vocational situation, side of lesion, type of stroke and characteristics for pain and sensation.

na: not applicable; BMI: body mass index.

Shoulder pain characteristics

In 75% of the participants in the PSSP group, the pain in the paretic shoulder had occurred within 2 months after stroke onset. At study enrolment, the pain had lasted 12 (4–31) months. In a majority (96%), the pain was located to the shoulder and/or upper arm. Pain during movements was reported by 63%, whereas pain during both movements and at rest was reported by 33%. Moderate to severe pain, i.e. ≥ 40 mm in VAS-P during the past 48 h, was reported by 67% of the participants. The most frequently reported pain qualities were dull ache (67%), stabbing/cutting (46%) and scurrying/radiating pain (42%). Moreover, 13% perceived pain during touch. Nine participants in the PSSP group used analgesics for their shoulder pain. In addition, 1 participant used gabapentin and 4 used a selective serotonin reuptake inhibitor (SSRI). In addition, 1 participant

in the non-PSSP group used gabapentin and 4 used an SSRI, for pain, epilepsy and/or depression.

Quantitative sensory testing

QST measurements data are shown in Tables III and IV. There were no significant differences between the PSSP group and the non-PSSP group for any of the QST assessments. The only QST measurement that approached significance was in the thermal tests, where the PSSP group had higher CDT ($p=0.052$), i.e. perceived cold in the affected arm at a slightly lower temperature than the non-PSSP group. The PSSP group had also significantly higher CDT ($p\leq 0.01$) and warm detection thresholds (WDT) ($p\leq 0.04$) than the HC, in both upper arms and in the leg (i.e. the reference point), as well as higher heat pain thresholds (HPT) ($p=0.001$) in the affected arm. The

Table II. Upper extremity assessments of participants with post-stroke shoulder pain (PSSP), without shoulder pain (non-PSSP) and healthy controls (HC), and the difference between the groups

	PSSP (n=24) Affected arm	Non-PSSP (n=24) Affected arm	HC (n=24) Non-dominant arm	Significance tests ^f		
				PSSP vs non- PSSP	PSSP vs HC	Non- PSSP vs HC
Passive abduction in shoulder; degrees, median (range) ^a	90 (40–160)	130 (80–180)	160 (120–180)	<0.001	<0.001	0.02
Passive external rotation in shoulder, °, median (range) ^b	40 (0–70)	50 (10–60)	60 (40–70)	0.12	<0.001	<0.001
Motor function in upper extremity, n (%) ^b				0.03	<0.001	0.02
0–11, severe–moderate restriction	18 (75)	11 (44)	0 (0)			
12–15, no–mild restriction	6 (25)	14 (56)	11 (100)			
Resistance to passive movements in the elbow ≥ 1 , n (%) ^c	11 (46)	7 (28)	na	0.20	na	na
Light touch absent or diminished in the arm and/or hand, n (%) ^d	6 (25)	6 (24)	na	>0.30	na	na
Proprioception absent or diminished in the wrist and/or hand, n (%) ^{d,e}	4 (17)	5 (20)	na	>0.30	na	na

^aGoniometer; ^bModified Motor Assessment Scale according to Uppsala Akademiska Hospital; ^cModified Ashworth Scale; ^dAccording to Fugl-Meyer; ^eData for 1 participant in the PSSP group is missing due to surgery; ^fDifference between groups; the Mann-Whitney *U* test was used for the variables passive abduction and passive external rotation, the χ^2 test and Fisher's exact test were used for the variables motor function, resistance to passive movements, light touch and proprioception. na: not applicable.

non-PSSP group had significantly higher CDT ($p \leq 0.03$) than the HC in both upper arms, and higher WDT ($p = 0.04$) in the affected arm as well as in the reference point.

There were no significant differences in the mechanical tests (i.e. PPT and PPPT) between the 3 groups (cf. Table III). There were wide ranges in PPT thresholds (i.e. ≤ 200 or ≥ 600 kPa) or PPPT thresholds (i.e. ≤ 100 or ≥ 300 g) in 43% of the stroke participants and in 18% of the HC.

When the affected arm was compared with the unaffected arm, higher thermal thresholds in CDT ($p = 0.001$) and HPT ($p = 0.05$) were found in the PSSP group, whereas higher mechanical thresholds in PPT ($p = 0.004$) and PPPT ($p = 0.05$) were found in the non-PSSP group.

DISCUSSION

The aim of this study was to investigate whether somatosensory impairments were more common in individuals with PSSP than in individuals without PSSP and HC. There were no significant differences in the QST assessments between the stroke groups, but more participants in the PSSP group reported abnormal cold sensation in the affected side. Both stroke groups had generally higher thermal thresholds than the HC, and more extreme low or high values in mechanical thresholds were found among the stroke participants than the HC.

Somatosensory impairments after stroke have previously been associated with PSSP (2). Two recently published studies used QST to assess somatosensory changes in persons with PSSP (9, 10). These studies were of similar design to our study with regard to sample size, recruitment, inclusion criteria, type of stroke, time post-stroke, and type of measurements. Roosink et al. (9) studied 48 individuals with stroke (19 with PSSP and 29 without PSSP) and found that somatosensory impairments were more common in individuals with persistent PSSP compared with those without PSSP. Increased abnormal cold sensation, allodynia, hypoalgesia and hyperalgesia to pressure, as well as higher thresholds for touch and electrical stimuli were found in the PSSP group. Zeilig et al. (10) studied 30 stroke survivors (16 with PSSP and 14 without PSSP) and reported higher thermal thresholds in the affected side in the PSSP group compared with the non-PSSP group, but also between both stroke groups and the healthy controls. Furthermore, they found that hyperpathia, allodynia and dysesthesia were more common in the PSSP group than in the non-PSSP group. Thus, these 2 studies suggest that neuropathic mechanisms may play a role in PSSP. However, our results do not support their findings (9, 10). We found abnormal QST thresholds in both the PSSP group and the non-PSSP group compared with the HC, but no significant differences between the PSSP and non-PSSP participants.

Soo Hoo et al. (20) studied mechanical pain thresholds in 40 individuals with chronic stroke (20 with PSSP and 20 without PSSP). These authors reported lower PPT thresholds in the PSSP group than in the non-PSSP group, and concluded that this indicated hypersensitivity for pressure. Roosink et al. (9) found no differences in PPT in their study groups, but

Table III. Quantitative sensory testing of the upper arms of participants with post-stroke shoulder pain (PSSP), without shoulder pain (non-PSSP) and healthy controls (HC), and the difference between the groups

	PSSP (n=24)			Non-PSSP (n=25)			HC (n=11)			Significance tests ^a					
	A		UA	A		UA	ND		D	PSSP vs non-PSSP		PSSP vs HC		Non-PSSP vs HC	
	Median (range)	Median (range)	Median (range)	Median (range)	Median (range)	Median (range)	Median (range)	Median (range)	Median (range)	A	UA	A/ND	UA/D	A/ND	UA/D
CDT, °C	28.8 (10.0–30.3)	29.7 (12.7–31.3)	29.8 (10.0–31.4)	29.9 (28.4–31.3)	30.7 (27.7–31.3)	30.9 (28.0–31.1)	0.052	>0.30	<0.001	0.01	0.009	0.03	>0.30	>0.30	>0.30
CPT, °C	10.0 (10.0–28.5)	13.6 (10.0–27.3)	10.0 (10.0–27.2)	10.0 (10.0–29.3)	10.0 (10.0–27.1)	10.0 (10.0–26.9)	>0.30	>0.30	>0.30	>0.30	>0.30	>0.30	>0.30	>0.30	>0.30
WDT, °C	38.4 (34.5–50.0)	39.6 (34.7–49.5)	37.8 (34.6–49.7)	37.6 (34.6–46.9)	36.0 (34.4–39.1)	36.2 (34.7–42.1)	>0.30	>0.30	0.005	0.04	0.04	0.21	0.005	0.04	0.21
HPT, °C	48.8 (43.4–50.0)	47.8 (39.6–50.0)	48.6 (36.2–50.0)	47.8 (38.3–50.0)	46.4 (37.9–49.6)	47.6 (39.3–49.9)	>0.30	>0.30	0.001	>0.30	0.01	>0.30	0.001	>0.30	>0.30
PPT, kPa	351 (182–1000)	365 (186–1000)	525 (77–1000)	435 (68–1000)	350 (175–521)	374 (142–641)	>0.30	>0.30	>0.30	>0.30	>0.30	>0.30	>0.30	>0.30	>0.30
PPPT, g	212 (59–400)	147 (26–400)	207 (39–400)	178 (47–400)	150 (70–314)	169 (115–346)	>0.30	>0.30	>0.30	>0.30	0.20	>0.30	>0.30	0.20	>0.30

^aDifference between groups, the Mann-Whitney U test was used. A: affected side (stroke participants); UA: unaffected side (stroke participants); D: dominant side (HC); CDT: cold detection threshold; CPT: cold pain threshold; WDT: warm detection threshold; HPT: heat pain threshold; PPT: pressure pain threshold; PPPT: pin-prick pain threshold measured with Electric von Frey (EvF).

Table IV. Quantitative sensory testing of the vastus medialis muscle in the unaffected leg (reference point) of participants with shoulder pain (PSSP), without shoulder pain (non-PSSP) and healthy controls (HC), and the difference between the groups

	PSSP (n=24) Median (range)	Non-PSSP (n=25) Median (range)	HC (n=11) Median (range)	Significance tests ^a		
				PSSP vs non-PSSP Median (range)	PSSP vs HC Median (range)	Non-PSSP vs HC Median (range)
CDT, °C	28.9 (10.0–31.0)	30.4 (25.2–31.2)	30.6 (28.5–31.0)	0.08	0.008	0.28
CPT, °C	10.0 (10.0–26.8)	10.0 (10.0–30.5)	10.0 (10.0–21.1)	>0.30	>0.30	>0.30
WDT, °C	35.4 (34.7–40.3)	35.4 (34.3–38.3)	34.6 (34.2–35.2)	>0.30	<0.001	<0.001
HPT, °C	45.9 (40.2–49.9)	45.8 (36.9–50.0)	45.5 (40.0–48.2)	>0.30	>0.30	>0.30

^aDifferences between groups, the Mann-Whitney *U* test was used.

CDT: cold detection threshold; CPT: cold pain threshold; WDT: warm detection threshold; HPT: heat pain threshold.

described wide ranges in PPT among all stroke participants, indicating both hypoalgesia and hyperalgesia for pressure. In our study, wide ranges in PPT were found in both the PSSP and the non-PSSP group, but there were no significant differences between the groups.

Abnormal QST thresholds in other parts of the body, distal to the pain, have been found in previous studies. Zeilig et al. (10) found abnormal thermal thresholds in the affected leg and Soo Hoo et al. (20) found abnormal mechanical thresholds in the unaffected leg. Their results support the presence of a neuropathic component affecting the perception of pain. In our study, distal thermal thresholds were assessed in the unaffected leg (i.e. the reference point). Since no significant differences were found between the PSSP group and the non-PSSP group in the present study, we could not confirm the presence of a widespread neuropathic component.

More participants in the PSSP group than in the non-PSSP group in our study had reduced passive shoulder abduction, were more restricted in their upper extremity motor function and reported abnormal cold sensation in the affected side. Reduced range of motion in the shoulder (11, 13) and restricted motor function in the upper extremity (2, 4, 13) have been found previously in individuals with PSSP. Abnormal cold sensation has also been reported previously in individuals with PSSP and interpreted as somatosensory changes (9, 28) or vasomotor changes (29). Furthermore, a majority of the PSSP participants in our study reported pain during movements. This was also reported by Zeilig et al. (10), who considered it as movement allodynia, a symptom similar to neuropathic pain. However, as pain during movements is common among individuals with PSSP (11), movement allodynia is difficult to evaluate.

There are various plausible explanations for the different results in the present and previous studies (9, 10, 20). Even if the study design in previous studies appear similar to our study, differences in stroke location, characteristics and intensity of shoulder pain as well as use of medication could have influenced the results. It is possible that some medication used by participants in the PSSP group could have affected their perception of pain, and thereby led to the non-significant difference between the groups. All participants continued their medication throughout the study, as was the case in the studies by Roosink et al. (9) and Soo Hoo et al. (20). Further research is needed to assess QST in individuals with PSSP, with and without this type of medication.

Moreover, in studies of persons with diseases other than stroke, findings in QST assessments also differ. Lewis et al. (30) found increased cold pain thresholds in persons with low back pain compared with those without pain, indicating a possible augmented central pain process. Hurtig et al. (31) assessed persons with fibromyalgia and healthy controls. They found that cold and heat pain, but not perception thresholds, differed significantly between persons with fibromyalgia and healthy subjects, and that decreased cold pain thresholds were related to clinical symptoms in the participants with fibromyalgia.

Study strengths and limitations

A strength of this study is that we included a rather homogenous stroke population with the exception of shoulder pain as well as healthy controls. The sample size was rather small, but comparable to previous studies (9, 10, 20). However, an increased sample size would have enabled us to generalize the results to a larger part of the stroke population. Even if the HC in our study were rather few, they were matched regarding age and sex to the stroke participants. Since QST assessments require good compliance from participants, individuals with severe deficits after stroke were not included in this study, even though PSSP is common in these individuals. Another limitation is that the lowest limit for CPT in the QST equipment was set to 10°. For half of the stroke participants and half of the HC, the CPT was registered at 10°, which could have influenced the results.

Clinical implications and future research

Persistent PSSP is a complex and multifactorial problem with several possible causes, which may exist alone or in combination. Somatosensory impairments may have a role in PSSP, but the evidence is still unclear, since these impairments are common in individuals both with and without PSSP.

Assessments in individuals with PSSP in clinical settings should include not only assessments of motor function, range of motion and resistance to passive movements, but also accurate somatosensory testing including allodynia in the local pain area as well as in other parts of the body distal to the pain. It is difficult to assess PSSP in individuals with severe disability, and information about pain in daily situations, as well as information from spouses and caregivers, is therefore of great importance. Our knowledge of the risk factors and other

factors contributing to shoulder pain after stroke is increasing, but it remains unclear as to how PSSP impacts on the ability of individuals to perform daily activities, their perceived participation and life satisfaction.

Conclusion

Somatosensory impairments are common among individuals with stroke compared with healthy controls. The non-significant differences in QST thresholds between individuals with and without PSSP indicate that somatosensory impairments have only a small impact on PSSP.

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