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THERMAL QUANTITATIVE SENSORY TESTING IN FIBROMYALGIA PATIENTS

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Fibromyalgia (FM) is a chronic disorder manifested by diffuse musculoskeletal pain, fatigue, sleep, and emotional disturbance. The disorder is probably associated with dysfunction of C and A delta peripheral nerve fibres. Thermal quantitative sensory testing (QST) was used to analyse thinly myelinated A delta fibres and nonmylinated C fibres, which function in the nociceptive sensory system, and the spinothalamic pathway. The observation that FM pain has neuropathic nature increased the value of QST as an additional diagnostic tool. The research group included 51 patients. Somatic symptoms were assessed using the Fatigue Severity Score (FSS), Fibromyalgia Impact Questionnaire (FIQ) and American College of Rheumatology (ACR) 2010 year diagnostic criteria. QST was performed by using thermal stimulus at wrist and feet. QST results were compared with 20 non-FM controls matched for age and sex. FM patients showed significant alteration of thermal perception and pain threshold compared with that in healthy controls, which demonstrated possible neuropathic pain nature in FM patients. Changes were more expressed in warm perception and heat pain threshold, which probably indicates that in FM patients C fibres are more damaged and warm perception and warm pain threshold are more sensitive, which may be used as FM diagnostics. We also found statistically significant negative correlations between warm and cold perception thresholds and between heat and cold pain thresholds, reflecting central sensitization or a defective pain inhibitory system.

Key words: *quantitative sensory testing, fibromyalgia, pain.*

INTRODUCTION

Quantitative sensory testing (QST) methods are used to evaluate sensory function for patients with the respective symptoms and for patients with increased risk of developing a neurological disease (Shy *et al.*, 2003). Thermal and also mechanical incentives are used to measure different sensor thresholds corresponding to different receptors, peripheral nerve fibre tips and different CNS tracts (Hanson *et al.*, 2007). If the test result is abnormal, this suggests sensory tract dysfunction from receptor to sensory cortex (Shy *et al.*, 2003). However, QST is used to a greater extent to evaluate dysfunction of small fibres, as large fibre function is possible to evaluate using standard investigative techniques (Cruccu *et al.*, 2009). Based on studies, QST can be used in cases of diabetic neuropathy, small fibre neuropathy, toxic neuropathy, uremic neuropathy and different neuropathic pain syndromes (Shy *et al.*, 2003). The latest studies show that QST can likely be used for prediction of response to treatment (Gustorff *et al.*, 2013). However, according to QST results, it is not possible to determine the level of dysfunction (peripheral or central nervous system), and therefore in all cases QST data should be interpreted together with the clinical picture and another diagnostic tests (EMG, nerve or skin biopsy, CT, MRI ect.) (Shy *et al.*, 2003). The German Research Network on Neuropathic Pain developed standardised QST protocol including 13 parameters for thermal and mechanical pain perception. This protocol allows to create a complete somatosensory profile for one region in 30 minutes (Rolke *et al.*, 2006). In the present study, we used 4 of the 13 parameters of thermal QST in analysis of thinly myelinated A delta fibres, nonmylinated C fibres and the spinothalamic pathway (Rolke *et al.*, 2006; Gruccu *et al.*, 2009).

Fibromyalgia (FM) is a chronic disorder manifested by diffuse musculoskeletal pain and additional somatic symptoms like fatigue, sleep, emotional disturbance, depression, cog-

nitive symptoms, gastrointestinal symptoms, and headache. FM has significant negative impact on a patient's daily functioning and leads to disability and poor quality of life (Lucas *et al.*, 2006; Sommer, 2010; Wolfe *et al.*, 2010). In one study, FM prevalence was determined to be between 2.0% and 4.7% (Branco *et al.*, 2008) and in another, between 0.7% and 3.3% (Sommer, 2010). Disorder is more common in the middle age. Females have FM 8 times more frequently than males (Albin *et al.*, 2008). Diagnosis is clinical and is based on the 1990 American College of Rheumatology (ACR) diagnostic criteria (Hakim *et al.*, 2010). According to these criteria, FM diagnosis can be established, if a patient has chronic widespread pain and on physical examination 11 or more of a possible 18 tender points are positive. A tender point can be considered as positive if an individual reports pain when a region is palpated with 4 kg of pressure. Chronic widespread pain is defined by diffuse musculoskeletal pain that is present daily three months or more, in sites on both sides of the body, both above and below the waist, as well as in the spinal region. Other possible reasons for pain need to be excluded (Hakim *et al.*, 2010; McCarberg and Clow, 2009).

In 2010, ACR presented new FM diagnostic criteria, which include somatic symptom assessment, and these criteria can be easily used in primary care. The new criteria also consider FM diagnosis, when somatic symptoms are widely presented and are more expressed than pain (Wolfe *et al.*, 2010).

Despite the fact that FM etiology and pathogenesis remains unclear (Albin *et al.*, 2008), studies suggest that FM pain has neuropathic nature (Dworkin and Fields, 2005; Martinez-Livan, 2012). Previous studies have shown reduction in dermal unmyelinated nerve fibre bundles in skin samples of patients with FM, compared with that in control groups, whereas myelinated nerve fibres were not affected (Uceyler *et al.*, 2013). Structural and functional imaging studies of the central nervous system have led to the concept that FM is a disorder of central sensitisation or a defective pain inhibitory system (Sommer, 2010).

The observation that FM pain has neuropathic nature increases the value of QST as an additional diagnostic tool.

Previous studies showed the difference of thermal QST results between FM patients and a control group, but the results differ (Klauenberg *et al.*, 2008; Plauf *et al.*, 2009; Pavlakovic and Petzke, 2010; Blumenstiel *et al.*, 2011; Tampina *et al.*, 2012; da Silva *et al.*, 2013; Uceyler *et al.*, 2013).

The aim of the study was to identify changes in thermal perception and pain threshold of FM patients in correlation with clinical symptoms.

MATERIALS AND METHODS

Population. The research group included 51 patients undergoing treatment in the outpatient clinic of Pauls Stradiņš Clinical University Hospital. All patients gave written consent for participation in the study. The Rīga Stradiņš University Ethics Committee gave permission for the study.

The FM diagnosis was based on ACR diagnostic criteria of 1990 (McCarberg, 2009; Hakim, 2010).

Exclusion criteria were previously known polyneuropathy, diabetes mellitus, and lumbar or cervical radiculopathy clinical symptoms.

Of the 51 patients included in the study 50 were female, and 1 was male. Average age was 51.71 years (min – 24 years, max – 72 years, SD ± 10.31). Average duration of symptoms was 7.97 years (min – 0.5 year, max – 30 years, SD ± 11.98). Average age of disease at onset was 43.73 years (min – 12 years, max – 70 years, SD ± 11.98).

Before observation, 10 (19.61%) patients had not received prior medical treatment, and 33 (64.7%) patients had received combined therapy with at least two medications.

Antidepressants were most frequently used in therapy; they were received by 28 (54.9%) patients of 51 patients included in the study. In 24 (47.06%) cases, anticonvulsant therapy was used, 17 (33.33%) patients received muscle relaxants, 5 (9.80%) patients — atypical neuroleptics, 5 (9.80%) patients — opioid analgesics, 6 (11.76%) patients — benzodiazepine, 2 (3.92%) patients — nonselective beta blockers, and 18 (35.29%) patients — antipyretic analgesics.

Symptom assessment. To evaluate pain and somatic symptoms and influence of disorders on the quality of life, patients were interviewed using several questionnaires.

Forty-one patients were examined with 2010 ACR diagnostic criteria for FM. The questionnaire consisted of two parts: 1) widespread pain index and 2) symptom severity score to evaluate patient fatigue, cognitive symptoms and other possible somatic symptoms. The maximal score in first part was 19 and in the second part — 12. FM diagnosis is considerable if the score in first part is equal or more than 7 and in the second part equal or more than 5, or if score in the first part is from 3 till 6 and in the second part equal to or more than 9 (Wolfe *et al.*, 2010).

All patients were interviewed to determine the Fatigue Severity Scale (FSS). The maximal score was 63. The score of 36 or more indicates chronic fatigue (Lauren, 2015).

To estimate FM influence on quality of life, we used the Fibromyalgia Impact Questionnaire (FIQ) for all patients. The maximal score is 100. A score of 50 corresponds to the average rating for patients with FM, and a score above 70 indicates severe course of disease (Bennett, 2005; Assumpacao *et al.*, 2010).

Quantitative sensory testing. Forty-nine patients were tested using thermal QST.

A Medoc Pathway device (TSA-II, Medoc, Israel) for estimation of thermal QST. The device generates a defined and calibrated impulse within certain limits allowing to evaluate small nerve fibre (A_ and C) function (Anonymous, 2009; Cruccu *et al.*, 2009). During the test, a probe that warmed or cooled patient's skin was attached to the skin of the patient. Starting with an adapting temperature (32 °C), the probe generated a calibrated thermal stimulus, depending on the test method. In the current study we used the limits method, by which the temperature of the stimulus continuously increased or decreased. The patient stops the increase or decrease of the stimulus when a predefined sensation is perceived. The temperature during the test can rise up to +50 °C and fall to +20 °C. If the maximal or minimal temperature limit is reached, the device stops and returns to the adapting temperature. During the test, the patient cannot see the screen (Rolke *et al.*, 2006; Anonymous, 2009). The used method allows to estimate warm and cold hypoesthesia, hyperesthesia (allodynia) and heat hypoalgesia. Warm and cold perception thresholds were determined four times each in course; cold and heat pain perception thresholds were determined three times each in course. Patients were tested on wrist and foot dorsal surfaces.

To compare a single patient's QST data with the group mean of age and gender matched healthy controls (HC), the data were Z-transformed for each parameter as follows: Z-score = (Mean $_{\text{single patient}}$ – Mean $_{\text{controls}}$)/SD $_{\text{controls}}$.

A Z-score value higher than 1.95 and lower than –1.95 indicated significant differences in threshold compared to that of the control group. A Z-score of zero represented a value corresponding to the group mean of the HC subjects (Plauf *et al.*, 2009).

RESULTS

Symptom assessment. Among patients tested using 2010 ACR diagnostic criteria for FM (41 in total), in 40 (97.50%), in 2 (4.88%) patients confirmed with FM, somatic symptoms were expressed more than pain. In one patient, FM diagnosis by 2010 ACR diagnostic criteria was not confirmed, likely due to clinical improvement.

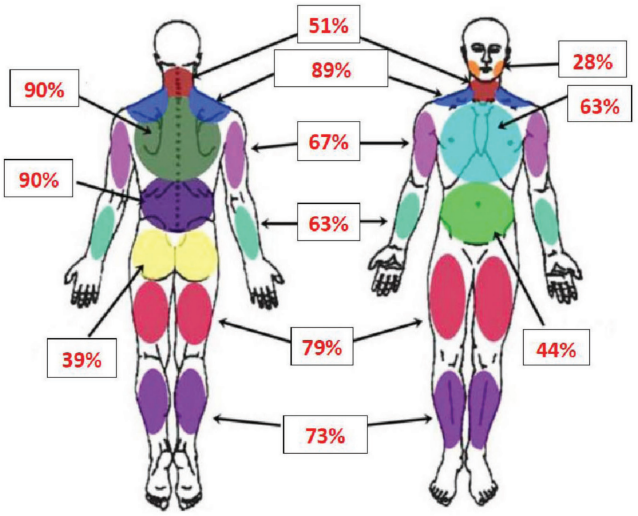

Fig. 1. Frequency of painful regions in FM patients (assessed by 2010 ACR diagnostic criteria).

The estimated mean widespread pain index in the patients was 12.15 (min – 3, max – 18, SD ± 3.99) ($p < 0.0001$).

More frequent areas of pain were lower and upper parts of the back (90%) and shoulders (89%). More than 70% of patients reported pain in their legs, and more than 60% in arms (Fig. 1).

The mean symptom severity score was 8.15 (min – 4, max – 11, SD ± 1.62) ($p < 0.0001$). Data on somatic symptom frequency and severity are shown in Tables 1 and 2.

Table 1

SOMATIC SYMPTOM SEVERITY ASSESSED BY 2010 ACR DIAGNOSTIC CRITERIA (patient number and percentage of total)

	Fatigue	Fatigue upon awakening	Cognitive symptoms
No symptoms	0	4 (9.76%)	
Slight or mild problems; generally mild or intermittent	0	16 (39.02%)	15 (36.59%)
Moderate; considerable problems; often present and/or at a moderate level	20 (48.78%)	17 (41.46%)	18 (43.90%)
Severe: pervasive, continuous, life disturbing problems	21 (51.22%)	4 (9.76%)	8 (19.51%)

Table 2

SOMATIC SYMPTOMS FREQUENCY ASSESSED BY 2010 ACR DIAGNOSTIC (patient number and percentage of total)

Dry mouth	30 (73.17%)	Frequent urination	24 (58.54%)
Pain in upper abdomen	18 (43.90%)	Hives/welts	12 (29.27%)
Diarrhea	15 (36.59%)	Ringing in ears	30 (73.17%)
Muscle weakness	36 (87.80%)	Bladder spasms	11 (26.83%)
Headache	36 (87.80%)	Muscle spasms	29 (70.73%)
Hearing difficulties	23 (56.10%)	Dry eyes	17 (41.46%)
Raynauld's	11 (26.83%)	Pain/cramps in abdomen	18 (43.90%)
Depression	33 (80.49%)	Loss of appetite	14 (34,15%)
Constipation	13 (31.71%)	Rash	10 (24.39%)
Dizziness	34 (82.93%)	Vomiting	6 (14.63%)
Sun sensitivity	19 (46.34%)	Hair loss	19 (46.34%)
Nausea	22 (53.66%)	Heartburn	22 (53.66%)
Nervousness	36 (87.80%)	Fever	25 (60.98%)
Chest pain	20 (48.78%)	Numbness/tingling	35 (85.37%)
Remembering problem	37 (90.24%)	Blurred vision	31 (75.61%)
Itching	19 (46.34%)	Oral ulcers	3 (7.32%)
Insomnia	36 (87.80%)	Loss/change in taste	8 (19.51%)
Shortness of breath	29 (70.73%)	Irritable bowel syndrome	17 (41.46%)
Wheezing	13 (31.71%)		

Table 3

RESULTS OF QUANTITATIVE SENSORY TESTING (QST)

		FM (mean ± SD)	HC (mean ± SD)
CDP		min – 20.00 °C, max – 31.23 °C (29.00 °C ± 2.37)	min – 27.51 °C, max – 31,15 °C (29.76 °C ± 0,86)
WDP		min – 33.85 °C, max – 42.78 °C (37.35 °C ± 2.10)	min – 33.51 °C, max – 35.87 °C (34.66 °C ± 0,73)
CPT		min – 20.00 °C, max – 28.63 °C (22.03 °C ± 2.49)	min – 20.00 °C, max – 20.20 °C (20.30 °C ± 0.68)
HPT		min – 37.87 °C, max – 49.82 °C (44.92 °C ± 2.71)	min – 41.94 °C, max – 45.34 °C (43.69 °C ± 1.06)
Mean threshold difference between legs and arms (mean threshold in legs minus mean threshold in arms)			
CDT		–1.64 °C (arms mean – 29.82 °C, legs mean 28.18 °C)	0.62 °C (arms mean – 29.45 °C, legs mean 30.07 °C)
WDT		3.57 °C (arms mean – 35.57 °C, legs mean 39.14 °C)	–0.08 °C (arms mean – 34.7 °C, legs mean 34.62 °C)
CPT		0.06 °C (arms mean – 22.00 °C, legs mean 22.06 °C)	–0.19 °C (arms mean – 20.39 °C, legs mean 20.20 °C)
HPT		1.21 °C (arms mean – 44.31 °C, legs mean 45.52 °C)	–0.32 °C (arms mean – 43.85 °C, legs mean 43.53 °C)
Right – left side difference 2 °C (patients number in total (patients in percentage of all))			
CDT	Between arms	6 (12%)	2 (10%)
	Between legs	13 (27%)	1 (5%)
WDT	Between arms	16 (33%)	3 (15%)
	Between legs	24 (49%)	5 (25%)
CPT	Between arms	16 (33%)	2 (10%)
	Between legs	5 (10%)	2 (10%)
HPT	Between arms	15 (31%)	3 (15%)
	Between legs	16 (33%)	6 (30%)

CDT, cold detection threshold; WDT, warm detection threshold; CPT, cold pain threshold; HPT, heat pain threshold; FM, fibromyalgia patients; HC, healthy control

According to the Fatigue Severity scale, 49 (96%) patients of 51 had chronic fatigue ($p < 0.0001$), and two patients had a score less than 36. The mean score was 53.86 (min – 25, max – 63, SD ± 8.9) ($p < 0.0001$).

The FIQ mean score was 64.43 (min – 25.72, max – 95.45 SD ± 15.06) ($p < 0.0001$). Nine (18%) patients of 51 had a score less than 50.22 (43%) patients had a score between 50 and 70 and 20 (39%) patients of 51 had a score more than 70, indicating severe course of disease ($p < 0.0001$).

Quantitative sensory testing. The QST results for FM and the control group are shown in Table 3 and Figures 2 and 3.

Estimation of perception and pain threshold mean values from all tested surfaces showed that in the FM group, six (12%) patients had a cold detection threshold (CDT) less than 27 °C (min – 20.00 °C, max – 26.15 °C, 23.92 ± 3.04; mean ± SD), indicating extreme cold hypoesthesia ($p < 0.0001$). Four (8%) patients had a warm detection threshold (WDT) above 40 °C (min – 40.73 °C, max – 42.78 °C, 41.79 ± 0.87; mean ± SD), indicating extreme warm hypoesthesia ($p < 0.0001$). Twenty-five (51%) patients had a heat pain threshold (HPT) above 45 °C (min – 45.10 °C, max – 49.82 °C, 47.20 ± 1.10; mean ± SD), indicating extreme heat hypoalgesia ($p < 0.0001$). Two (4%) patients had a cold pain threshold (CPT) above 27 °C, indicating extreme cold hyperalgesia and two (4%) patients had a HPT below 40 °C, indicating extreme heat hyperalgesia. In seven patients (14%), we observed a paradox heat sensation — a subject experienced cold as hot.

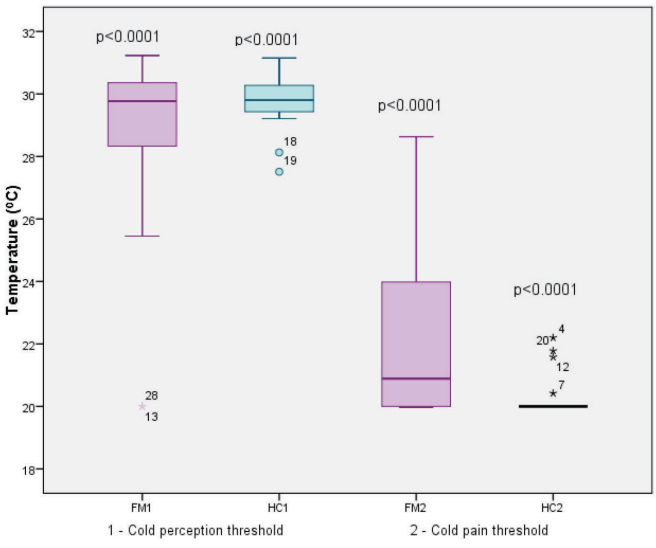

Fig. 2. Cold perception and cold pain thresholds results for FM and HC. FM, fibromyalgia patients; HC, healthy control

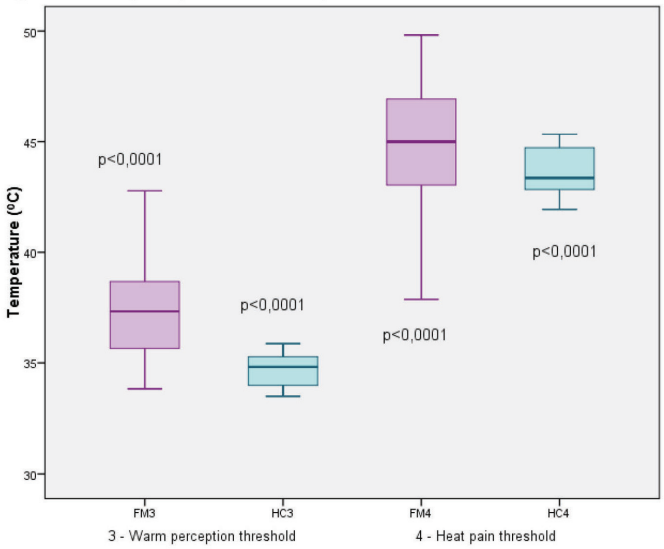

Fig. 3. Warm perception and heat pain thresholds results for FM and HC.

FM, fibromyalgia patients; HC, healthy control

In the HC group, we did not observe cold hypoesthesia below 27 °C, warm hypoesthesia above 40 °C or cold hyperalgesia above 27 °C. Three (15%) patients had heat hypoalgesia above 45 °C.

Comparing the FM and HC groups, we observed a large left-right side difference in FM and larger difference in threshold between arms and feet. Forty-five (92%) of FM patients had a left-right side difference more than 2 °C at least in one modality, while in the in HC group, 15 (75%) patients showed a left-right side difference more than 2 °C at least in one modality.

According to z-scores mean values for comparison to the control group, 69% of all patients had loss of warm sensation (warm hypoesthesia), which was more prominent in feet (63% of all patients) than in arms (18% of all patients). Forty-seven percent of all patients had loss of heat pain sensation (heat hypoalgesia), also more prominent in feet (37% of all patients) than in arms (29% of all patients). Twenty-two percent of all patients had loss of cold sensation (cold hypoesthesia), in feet — 27% of all patients, in arm — 6% of all patients. Fourteen percent of all patients had increased heat pain sensation (heat hyperalgesia), which was more prominent in arms (18% of all patients) than in foot (4% of all patients). Forty-one percent of all patients had increased cold pain sensation, compared to the control group (cold hyperalgesia), without a significant difference between feet and arms. Z-scores results of thermal quantitative sensory testing are presented in Figures 4–7.

Correlations. There was found statistically significant ($p < 0.01$) moderate negative correlation (r = -0.553) between cold perception threshold and warm perception threshold (Fig. 8) and statistically significant ($p < 0.01$) moderate negative correlation (r = -0.535) between cold pain threshold and heat pain threshold (Fig. 9). We also found a significant ($p < 0.01$) moderate positive correlation (r = 0.415) between the FIQ and the FSS scores (Fig. 10).

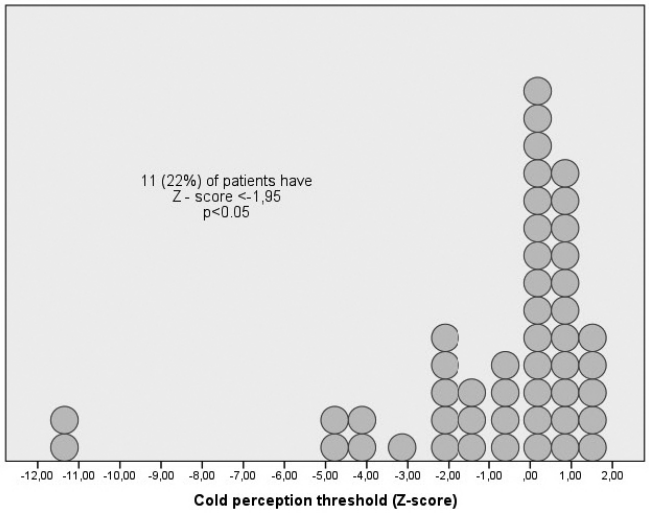

Fig. 4. Cold perception threshold z-score.

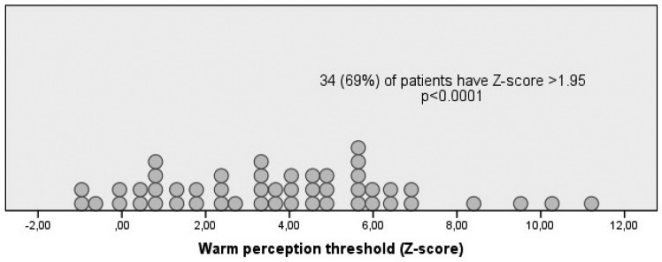

Fig. 5. Warm perception threshold z-score.

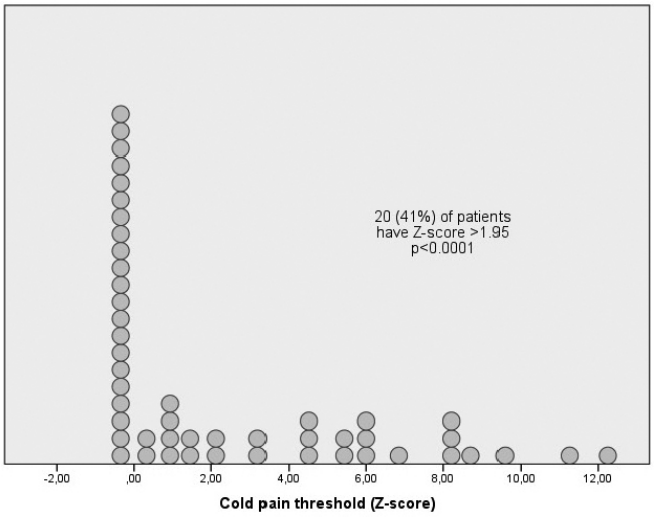

Fig. 6. Cold pain threshold z-score.

DISCUSSION

This study described clinical characteristics of FM patients and demonstrated significant differences in thermal QST parameters between FM and HC groups. The QST results of FM patients in all modalities were more variable than in the

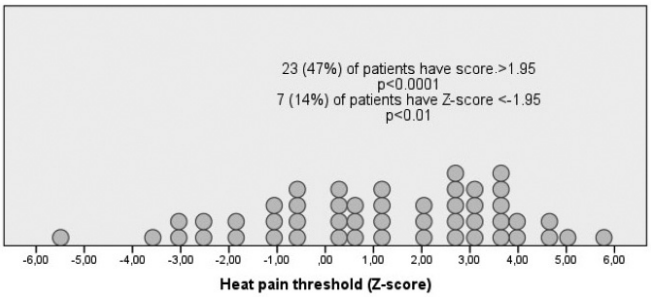

Fig. 7. Heat pain threshold z-score.

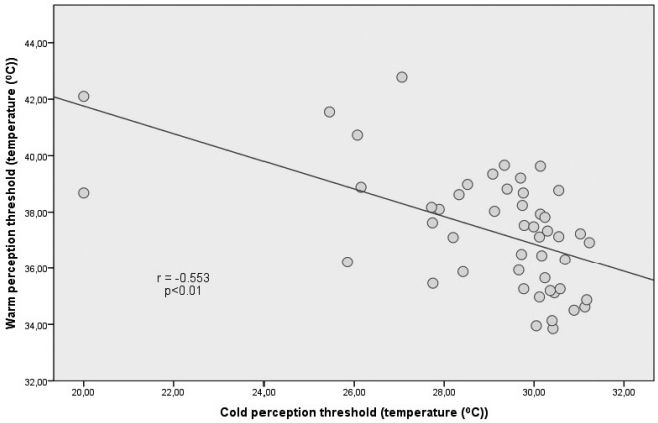

Fig. 8. Correlation between warm perception thresholds and cold perception thresholds.

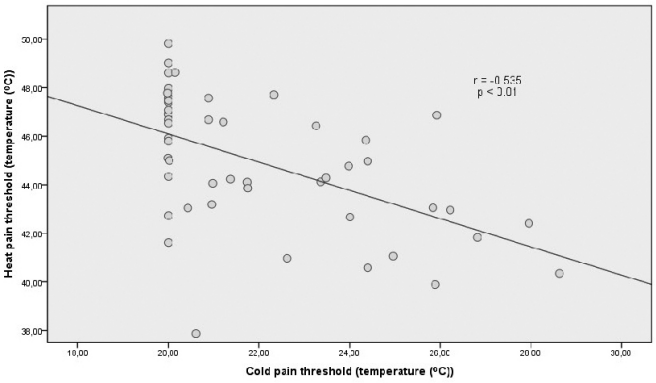

Fig. 9. Correlation between cold pain thresholds and heat pain thresholds.

HC group. However, thermal sensory profiles of the FM group were predominantly characterized by loss of function (hypoesthesia, hypoalgesia) in warm and heat pain sensation, which was more pronounced in foot than in arms. Some patients showed also loss of cold sensation, mostly in feet. Cold pain sensation characterized by gain sensation (hyperalgesia) occurred in similar proportions in arms and feet. Also, 14% of patients had increased heat pain sensation, mostly in arms. Many previous studies have shown significant differences in thermal QST compared with a control group, but the results differ: some studies reported increased thermal sensitivity in FM patients, while others found decreased thermal sensitivity in FM patients compared with that in the control group (Klauenberg *et al.*, 2008; Plauf *et al.*, 2009; Pavlakovic and Petzke, 2010;

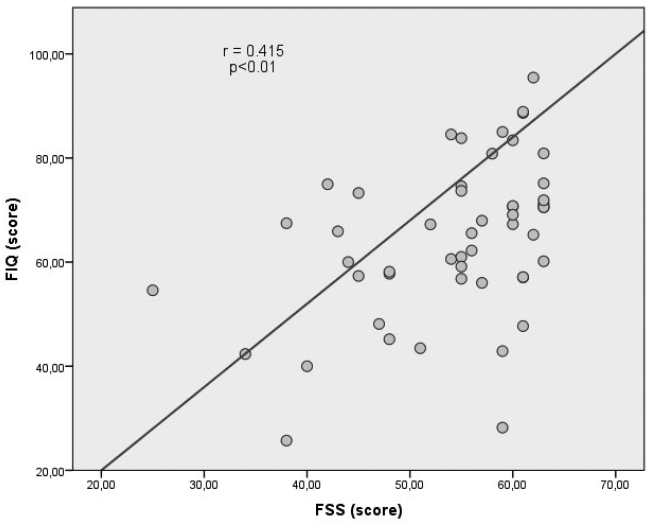

Fig. 10. Correlation between FSS and FIQ scores.

FSS, Fatigue Severity Scale; FIQ, Fibromyalgia Impact Questionnaire

Blumenstiel *et al.*, 2011; Tampina *et al.*, 2012; da Silva *et al.*, 2013; Uceyler *et al.*, 2013). This suggests heterogeneity of FM and the possible existence of different subgroups (Tampina *et al.*, 2012). For warm perception, C fibres are responsible for deep and burning pain, and A delta fibres for cold sensation and sharp pain (Lauria, 2005). In our study we found that warm perception and heat pain threshold are more impaired and are more significantly different from control group, comparing with cold perception and cold pain threshold. This might indicate that in FM patients, C fibres are more damaged, and that warm perception and warm pain thresholds are more sensitive modalities for use as a FM diagnostic.

Based on the German Research Network of Neuropathic Pain (DFNS) standardized protocol for QST, all QST parameters are region specific, and there is no significant left – right side difference (Rolke *et al.*, 2006). In our study we found that there was no significant difference in cold and heat perception and pain threshold between feet and hands in HC, but there was a significant difference in warm perception threshold, heat pain threshold and cold perception threshold in FM patients. On feet, warm perception threshold and heat pain threshold were higher than the threshold on hands, while the cold perception threshold was lower. Cold pain thresholds on hands and feet in FM were similar. We also found that FM patients, compared with the HC group, had a more frequent left – right side difference greater than 2 °C. This finding indicates sensory function impairment in FM patients. Previous studies also showed similar results (Klauenberg *et al.*, 2008).

We clinically examined patients using the 1990 ACR diagnostic criteria, and also 80% of patients were examined using the 2010 ACR diagnostic criteria. According to the 1990 ACR FM diagnostic criteria, 12 of 18 points are localised on the upper part of the body (shoulders, neck, upper back) and arms (Hakim *et al.*, 2010), but in our study we found that more patients had pain in their legs (73% had

pain in their lower leg, 79% — in the upper leg) than in arms (63% had pain in the lower arm and 67% in the upper arm, 51% — in the neck). This finding can also explain the more significant differences in pain and perception thresholds in feet compared with hands. We also found that FM patients had a high level of fatigue (based on the Fatigue Severity Scale and 2010 ACR diagnostic criteria for FM). This finding is consistent with previous studies indicating that 20 to 70% of FM patients showed Chronic Fatigue syndrome according to diagnostic criteria and in the reverse direction, 35 to 70% patients with Chronic Fatigue syndrome also had positive FM diagnostic criteria (Aaron *et al.*, 2000). The present study also showed that FM patients have many other somatic symptoms like: cognitive disturbance, insomnia, depression, etc. (based on 2010 ACR diagnostic criteria for FM). The 1990 ACR diagnostic criteria do not include assessment of somatic symptoms, and thus are incomplete and have limited use (Wolfe *et al.*, 2010).

We found statistically significant linear correlation between warm and cold perception thresholds and also between cold and heat pain thresholds, what suggests that in FM, both A delta and C nerve fibres are impaired or indicates central sensitization or defective pain inhibitory system (Sommer, 2010).

No statistically significant linear correlations between QST results and clinical symptoms were found. Similar results were obtained also in other studies (Desmeules *et al.*, 2003). This possibly occurred because QST results or questionnaires results were modified by medication, as some patients continued its use at the time of examination, or possibly, patients were tested on feet and hand dorsal surface, but not in the most painful area.

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TERMĀLA KVANTITATĪVA SENSORA TESTĒŠANA FIBROMIALĢIJAS PACIENTIEM

Fibromialģija (FM) ir hroniska slimība, kas izpaužas ar difūzām muskuloskeletālām sāpēm, nogurumu, miega un emocionāliem traucējumiem. Slimība, iespējams, ir saistīta ar A delta un C nervu šķiedru disfunkciju. Termāla kvantitatīva sensora testēšana (QST) analizē mazmielinizētas A delta nervu šķiedras un nemielinizētas C nervu šķiedras, kas atbild par nociceptīvo sensoru sistēmu un spinotalāmisko ceļu. Pieņemot, ka FM sāpēm ir neiropātisks raksturs, pieaug arī QST vērtība kā papildus diagnostiskam testam. Pētījumā tika iekļauts 51 pacients. Slimības simptomi tika objektivizēti, izmantojot Noguruma smaguma skalu *(Fatigue Severity Scale),* Fibromialģijas ietekmes anketu *(Fibromialgia Impact Questionnaire)* un 2010. gada *American College of Rheumatology* (ACR) FM diagnostiskos kritērijus. QST tika veikta ar termālo stimulu pēdu un plaukstu dorsālajās virsmās. QST rezultāti tika salīdzināti ar 20 atbilstoša vecuma un dzimuma kontroles grupas pacientiem. FM pacientiem tika konstatēta ievērojama aukstuma un siltuma percepcijas un sāpju sliekšņu atšķirība, salīdzinot ar kontroles grupas pacientiem, un tas norāda uz neiropātisko sāpju raksturu FM pacientiem. Izmaiņas ir vairāk izteiktas siltuma percepcijas un karstuma sāpju sliekšņos. Iespējams, tas liecina, ka FM pacientiem C šķiedras ir vairāk skartas un siltuma percepcijas un karstuma sāpju sliekšņi ir jūtīgākas modalitātes, ko var izmantot FM diagnostikā. Tika arī atklātas statistiski ticamas negatīvas korelācijas starp siltuma un aukstuma percepcijas sliekšņiem un starp karstuma un aukstuma sāpju sliekšņiem, kas var norādīt uz centrālo sensibilizāciju vai defektīvo sāpju inhibējošu sistēmu FM pacientiem.