Sensory and sympathetic disorders in chronic non-specific neck pain

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Summary

The signs of sympathetic and sensory nerve-related disorders are not widely investigated in chronic non-specific neck pain (NNP) patients. Thus, we performed skin temperature (Tsk), evaporation and touch threshold (TT) measurements to reveal possible dysfunctions at the fingertips of NNP patients (n=60) compared with healthy controls (n=11). Neck pain intensity was the main modifier of Tsk, and age the main modifier of TT in a multivariate model. On comparisons of the subgroups of NNP patients with unilateral (n=26) and bilateral (n=34) symptoms and controls, TT differed and Tsk tended to differ, the unilateral pain patients being found to demonstrate higher TT values on both sides. Interrelations between the measured parameters were found in the controls, but not in the patients. The NNP patients exhibited signs of functional impairment of innervation reflected in changes in tactile sensitivity and vasoactive sympathetic function. These changes may be based on both central and peripheral mechanisms, which possibly differ in patients with unilateral and bilateral symptoms.

KEY WORDS: chronic non-specific neck pain, skin surface evaporation, skin temperature, sympathetic nervous system function; touch thresholds

Introduction

Chronic neck pain is a very common problem in Western countries. In Finland, the incidence of the condition has been reported to be 15% in women and 9% in men (Kääriä et al., 2012). In a Finnish study, pain was found to be the reason for 40% of visits to primary care physicians, and neck pain was one of the most common types of pain reported (Mäntyselkä et al., 2001). All the structures in the neck and shoulder area (i.e. bones, nerves, discs, ligaments, muscles, facet joints and dura) are capable of evoking pain when irritated (Bogduk, 1984; Borghouts et al., 1998). In the majority of cases, however, no specific cause of the pain can be detected and these patients have been classified as affected by non-specific neck pain (NNP) with a predominantly mechanical and degenerative background (Bogduk, 1984).

Hence, pathological findings are only minor in neck pain. Nerve conduction studies can detect nerve lesions but they do not provide information on small nerve fiber function. Moreover, measurement methods serving to evaluate the function of sensory and sympathetic fibers are less used in patients without signs of radiculopathy. However, an association between neck pain and sensory disorders in the hands has previously been described (Reading et al., 2003), as has the presence of sensory and sympathetic disorders, consistent with a minor neuropathy, in non-specific arm pain (Greening, 2006).

The use of Semmes-Weinstein monofilaments to measure touch thresholds (TTs) is an old method of assessing sensory fiber function (Semmes et al., 1960; Bell-Krotoski and Tomancik, 1987). Systematic TT elevations have previously been demonstrated in patients with chronic cervicobrachialgia (Voerman et al., 2000). However, patients with non-specific neck-arm pain associated with heightened nerve mechanosensitivity did not show the sensory alterations in the maximal pain area and dermatome that were shown by those with cervical radiculopathy (Tampin et al., 2012).

Several techniques exist to assess abnormalities in small nerve fiber function. The extent of sweating has been found to be strongly related to electrodermal abnormalities, as for example in the sympathetic skin response (SSR), which has been recommended as a measure for investigating sympathetic nervous system function (Ellaway et al., 2010). The method has been claimed to detect nociceptive pain (Storm, 2008) and its use has also been attempted in patients with neck pain (Riley and Richter, 1975).

In previous studies, skin temperature (Tsk) measurements were used to reveal abnormalities related to

peripheral nerve injuries (Brelsford and Uematsu, 1985), and exceptional Tsk values were reported in cervical radiculopathy (Zhang et al., 1999). So et al. (1990), however, described Tsk abnormalities only distally in cervical radiculopathy patients. Vasomotor disorders have been demonstrated in other non-specific pain conditions, too (Greening et al., 2003; Sluiter et al., 2000).

Overall, sensory and sympathetic fiber-related disturbances accompanying NNP are not widely investigated. Thus, the aims of the present study were to analyze tactile perception, skin surface temperature and evaporation at the fingertips of NNP patients compared with healthy controls in order to reveal possible neck pain-associated functional abnormalities related to sensory and sympathetic innervation.

Materials and methods

Subjects

The study group was composed of 60 patients with chronic NNP (36 women and 24 men, age range 30-49 years, Table I). The inclusion criteria were pain originating from the neck and shoulder area and having lasted for more than three months; the NNP diagnoses were confirmed by a neurologist. The subjects had no past history of neck and shoulder surgery, and had not undergone any physical or other therapy during the previous month. Other specific conditions such as cervical radiculopathy, rotator cuff tear, fibromyalgia and carpal tunnel syndrome were ruled out on the basis of clinical neurological examination.

The symptoms were unilateral in 26 (43.3%) and bilateral in 34 (56.7%) cases. Referred arm pain was reported by 28 (46.7%) of the patients and numbness by 26 (43.3%). The control group consisted of 11 healthy subjects (six women and five men, age range 23-66 years) with no current or past history of neck and shoulder pain or related disability, and no pathological signs on clinical neurological examination.

Subjects with general metabolic or cardiovascular diseases, those taking any kind of medication other than painkillers, and those with hand wounds were excluded.

The study plan was approved by the Research Ethics Committee, Hospital District of Northern Savo. All subjects provided written informed consent and completed a standard questionnaire.

Measurements

Subjects were asked to avoid using medications and cosmetics (on the hands) and not to engage in physical activity on the day of the study; they were also instructed to avoid smoking, eating and drinking coffee during the two hours prior to the recordings. Just before the measurements, all the subjects spent 20 minutes in a room with a temperature of 22-24°C in order to acclimatize them to the experimental environment. Tsk was measured using an infrared thermography camera with a resolution of 0.05˚C (IRTIS Ltd., Moscow, Russia) from a distance of one meter. Data were analyzed with IRTIS thermography software and the mean Tsk of the area at the center of the palmar side of each fingertip was calculated.

Skin surface evaporation (transepidermal water loss values, g/m²h) from the same point on each fingertip was measured using an evaporation measurement device (VapoMeter, Delfin Technologies Ltd, Kuopio, Finland).

Light TT values were measured at the same points on the fingertips. This was done using an Aesthesiometer (Somedic Sales AB, Sweden), which is a set of force-calibrated monofilaments numbered from 3 to 17. The subjects were seated with their eyes closed. To assess tactile sensation, the filaments were applied in ascending and descending order of magnitude. The trial was repeated five times for each fingertip and the response was regarded as positive if the touch of the filament was felt in three of the five trials. The lowest value evoking a touch sensation was taken as the TT.

Systolic (SBP) and diastolic blood pressure (DBP) were assessed using the Omron HEM-907 device (Omron Matsusaka Co., Matsusaka, Japan).

Table I - Characteristics of the study subjects and the mean values of skin temperature, evaporation and touch threshold in the fingers of neck pain patients with bilateral (n=34) and unilateral symptoms (n=26) and healthy controls (n=11).

Variable	Neck pain patients with bilateral symptoms	Neck pain patients with unilateral symptoms	Controls	p-value
Age (years)	40.7 (5.9; 30-49)	42.9 (4.9; 33-49)	38.5 (17.7; 23-66)	0.195
Gender (female/male)	21/13	15/11	6/5	0.898
Neck pain intensity (VAS 0-100)	47.6 (22.3; 8-83)	46.5 (18.9; 8-75)	–	0.833
Arm pain intensity (VAS 0-100)	35.4 (27.7; 0-88)	31.8 (25.6; 0-86)	–	0.638
Neck Disability Index (0-100)	27.3 (10.6; 12-54)	22.7 (7.4; 10-44)	–	0.080
Skin temperature, mean (°C)	30.0 (3.3; 20.7-34.6)	30.8 (3.5; 21.7-34.6)	32.2 (1.7; 29.1-34.6)	0.076
Evaporation, mean (g/m²/h)	86.1 (51.3; 27.2-272.8)	76.4 (59.4; 29.7-309.4)	100.5 (50.0; 32.3-198.0)	0.110
TT, mean	3.6 (0.9; 3-5.8)	4.2 (1.1; 3-6.6)	3.4 (0.8; 3-5.8)	0.044
TT variability, within hand, mean	0.75 (0.88; 0-3.5)	1.13 (0.8; 0-2.5)	0.45 (0.61; 0-2.0)	0.034

Data are presented as mean values (standard deviation; range). The Mann-Whitney U-test or t-test was used for two-group comparisons, while for three-group comparisons we used a chi-square test and Kruskal-Wallis test with post-hoc Mann-Whitney U-tests and Bonferroni corrections.
Abbreviations: SD, standard deviation; VAS, visual analog scale; TT, touch threshold.

The current intensity of neck and arm pain was evaluated using a visual analog scale (VAS 0-100; Scott and Huskinsson, 1976) and perceived disability was rated using the Neck Disability Index (0-100; Vernon and Mior, 1991). Mood (Rimon's Brief Depression Scale, 0-21; Keltikangas-Järvinen and Rimon, 1987) and autonomic disorders (13-dimension questionnaire, 0-39) were also self-reported. Patients indicated their symptom localizations by pain drawings.

Data analysis

Statistical analyses were performed using the SPSS Statistics 19.0 software (IBM Corp., Armonk, NY, USA). The mean Tsk, evaporation and TT values were each calculated as the sum of the values of the ten fingers divided by ten.

The side-to-side differences (δ) in the temperature, evaporation and perception thresholds were calculated. In the patients with unilateral pain, this was done by subtracting the mean values of the symptomatic from those of the healthy side, whereas in those with bilateral symptoms, and in the controls, the mean values of the left side were subtracted from those of the right side. A linear regression analysis was used to examine the influence of different factors on the findings and the interrelations between the measured parameters. The mean values of the parameters were compared between the NNP patient subgroups (those with unilateral and those with bilateral symptoms) and the controls using the Kruskal-Wallis test, Mann-Whitney U-test and t-test, and the differences between sides (δ) were analyzed with a paired samples t-test. A chi-square test was applied to analyze gender and TT distributions. The level $p<0.05$ was considered significant.

Results

The measured values varied widely between the subjects, the coefficient of variation (SD/mean x 100) being 11.0% in the NNP patients and 5.3% in the controls for Tsk, and 67.0% and 49.7% for evaporation, respectively. As regards the TTs, nominal forces ranging from 0.026 to 0.145 g were found (monofilament numbers ranging from 3 to 7 in the NNP patients and from 3 to 6 in the controls). The distribution of the TT values differed between the women and the men in the subgroup of NNP patients with bilateral symptoms and in the controls ($p<0.005$ for both, chi-square test, Fig. 1). The TT mean values were age-related in all the subjects ($B=0.277$, $p<0.05$) and, on subgroup analysis, also in the NNP patients with bilateral pain ($B=0.473$, $p<0.005$, linear regression analysis).

In the patients, the role of different factors such as age, gender, anthropometric characteristics, SBP, DBP, heart rate, pain intensity and other findings as modifiers of the measured parameters was evaluated using a model in which Tsk or evaporation or TT level was the dependent variable, and the other factors were entered one at a time into the model (linear regression analysis, Table II). Laterality of pain (uni-or bilateral) was found to predict TT values only ($B=0.264$; $p<0.05$). We then performed a stepwise regression analysis with all the other factors as the explanatory covariates. In this multivariate model, neck pain intensity was found to be the main predictor of Tsk ($B=0.331$; $p<0.05$) and age the main predictor

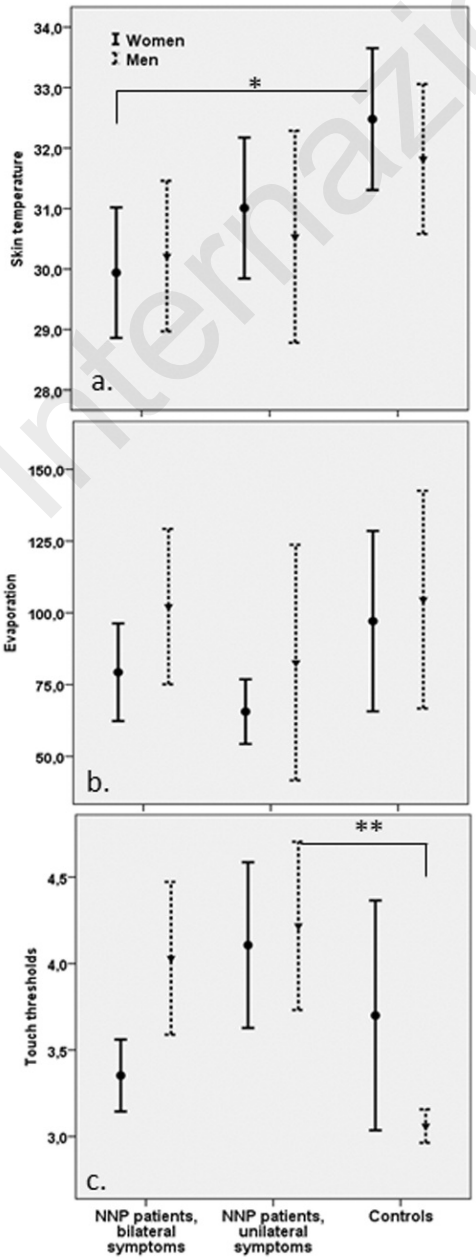

Figure 1 - Skin temperature (a), evaporation (b) and touch threshold values (c) (95% CI for mean) in the fingers of non-specific neck pain (NNP) patients with bilateral (n=34) and unilateral symptoms (n=26) and healthy controls (n=11), in men and women separately. * $p<0.05$ and ** $p<0.01$ between the groups, Mann-Whitney U-test was used for the subgroup comparisons.

of TT (B=0.319; p<0.05) in all the NNP patients. Considering the two patient subgroups, age (B=0.489, p<0.005) and arm pain intensity (B=0.408, p<0.01) were the main modifiers of TT only in bilateral pain, whereas neck pain intensity was a predictor of Tsk only in unilateral pain (B=0.461, p<0.05, Table II).

Touch threshold distribution differed between the NNP patients and controls when the recorded results from all fingertips were pooled together (chi-square test, p<0.005), and the mean Tsk values tended to be lower in the NNP patients than in the controls (p<0.1, Mann-Whitney U-test).

Comparison of the NNP patient subgroups and the controls revealed differences in the mean values and variability of TT (p<0.05 for both, Kruskal-Wallis test, Table I), and Tsk tended to differ. It was found that the TT mean values tended to be higher in the unilateral pain patients than in the patients with bilateral pain (p<0.1), whereas within-hand variability of TT (maximal-minimal) tended to be higher in the NNP patients with unilateral pain than in the controls (p<0.1, Mann-Whitney U-tests with Bonferroni corrections). When the recorded results from all fingertips were pooled together, TT distribution in the NNP patients with unilateral pain differed from that found both in the patients with bilateral pain and in the controls (p<0.00001 for both, chi-square test), but did not differ between the latter two groups.

The differences between TT and Tsk values recorded in the ulnar versus the radial areas (within the hand, index vs little finger) varied between the subgroups (p<0.05 and p<0.01, respectively, Kruskal-Wallis test): for TT they were higher (p<0.05) and for Tsk tended to be higher (p<0.1) in the NNP patients with unilateral pain than in the controls, and for Tsk were higher in the NNP patients with bilateral pain than in the controls (p<0.05, Mann-Whitney U-tests with Bonferroni corrections).

No differences emerged between the NNP patients with bilateral versus unilateral symptoms in any of the characteristics apart from the Neck Disability Index, which tended to be higher in the patients with bilateral symptoms (p<0.1, Mann-Whitney U-test, Table I). However, the TT values in the NNP patients with bilateral pain were significantly different from those recorded both on the healthy and on the symptomatic side of NNP patients with unilateral pain (p<0.001 and <0.00001, respectively, chi-square test, Fig. 2), whereas there was only a tendency towards a TT side-to-side difference in unilateral NNP (p<0.1). Also, the δ values for perception were higher in the NNP patients with unilateral symptoms than in those with bilateral symptoms (p<0.01, chi-square test).

The Tsk and evaporation mean values did not differ between the sides in the patients with unilateral pain. However, Tsk was higher on the symptomatic compared to the healthy side when measured at the ring finger (p<0.05) and tended to be higher (p<0.1) at the middle finger (paired samples t-test).

The relationship between the measured parameters was analyzed by pooling all the measured values. In this way, the TT values were found to be inversely related to evaporation in the controls and in the NNP

Table II - Predictors of fingertip skin temperature, evaporation and touch threshold values in chronic neck pain patients with bilateral (n=34) and unilateral symptoms (n=26).

	Skin temperature		Evaporation		Touch thresholds	
	Unilateral Beta; Sign.	Bilateral Beta; Sign.	Unilateral Beta; Sign.	Bilateral Beta; Sign.	Unilateral Beta; Sign.	Bilateral Beta; Sign.
Gender (female/male)	-0.069; 0.739	0.042; 0.816	0.256; 0.238	0.213; 0.277	0.05; 0.809	0.376; 0.028
Age (years)	0.115; 0.577	-0.203; 0.248	-0.011; 0.959	0.065; 0.742	0.014; 0.946	0.473; 0.005***
Body mass index	0.113; 0.582	0.255; 0.145	0.173; 0.431	0.09; 0.647	-0.015; 0.943	0.155; 0.382
SBP (mm Hg)	-0.136; 0.509	-0.072; 0.687	0.148; 0.502	0.079; 0.689	-0.122; 0.553	0.278; 0.112
DBP (mm Hg)	-0.107; 0.603	-0.114; 0.936	-0.003; 0.991	0.2; 0.308	-0.11; 0.593	-0.1; 0.575
Heart rate (beats/min)	0.228; 0.263	0.122; 0.491	0.23; 0.291	0.169; 0.39	-0.152; 0.46	-0.202; 0.251
NDI (0-100)	0.116; 0.574	0.155; 0.38	0.307; 0.155	-0.104; 0.599	-0.152; 0.46	-0.012; 0.947
Neck pain (0-100)	0.441; 0.024*	0.262; 0.135	0.203; 0.354	0.09; 0.648	-0.092; 0.654	0.274; 0.117
Arm pain (0-100)	0.172; 0.401	0.162; 0.359	0.263; 0.226	-0.248; 0.203	-0.042; 0.84	0.389; 0.023**
Duration of condition (years)	0.081; 0.701	-0.012; 0.946	0.064; 0.779	0.117; 0.554	-0.146; 0.486	-0.247; 0.159
Constant or episodic pain	-0.031; 0.88	-0.191; 0.28	-0.115; 0.601	-0.174; 0.377	0.311; 0.122	0.127; 0.475
Referred arm pain (yes/no)	0.182; 0.374	0.165; 0.351	-0.199; 0.311	0.249; 0.252	-0.108; 0.599	-0.018; 0.919
Numbness (yes/no)	0.367; 0.065	-0.145; 0.413	0.313; 0.146	0.032; 0.87	-0.088; 0.668	0.102; 0.567
Autonomic disorders (0-39)	0.428; 0.029	0.2019; 0.214	0.181; 0.408	-0.246; 0.207	0.093; 0.599	0.098; 0.633
Depression score (0-21)	0.184; 0.368	0.291; 0.095	0.313; 0.146	-0.267; 0.169	-0.132; 0.521	0.191; 0.278

Data were analyzed by logistic univariate and multivariate stepwise regression models.

* p<0.05; ** p<0.01; *** p<0.005, on multivariate stepwise regression models.

Abbreviations: Sign., significance; SBP, systolic blood pressure; DBP, diastolic blood pressure; NDI, Neck Disability Index

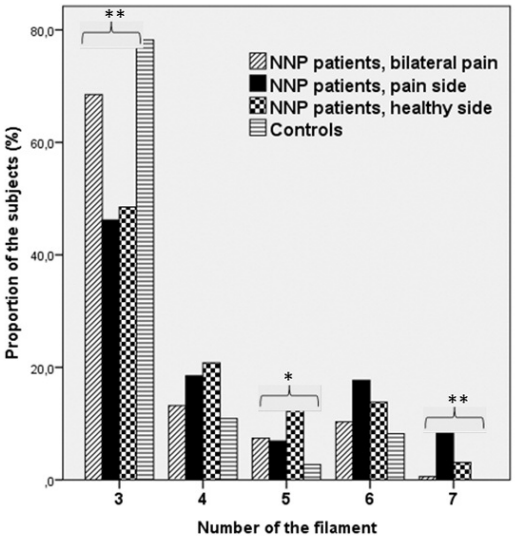

Figure 2 - The results of the touch threshold measurement in the groups of patients with bilateral neck pain (n=34) and unilateral neck pain (n=26, painful and healthy sides), and in healthy controls (n=11) showing the proportion (%) of the subjects giving positive responses to the monofilaments from 3 to 7, * p<0.05, ** p<0.0001 between the groups, Chi-square test.

patients with unilateral pain (B=-0.253; p<0.01 and B=-0.274; p<0.0005, respectively), but to Tsk only in the controls (B=-0.533; 0.00001). The values of Tsk and evaporation were interrelated in the controls (B=0.542; p<0.0001, linear regression analysis) but not in the NNP subgroups.

On the painful side in the unilateral pain patients, evaporation values were different in fingers with different TT values (3-7, p<0.00005, Kruskal-Wallis test); on the healthy side in these patients and in the controls Tsk differed significantly in relation to TT values (p<0.05 and p<0.0005, respectively) and evaporation tended to do so (p<0.1 for both). The subjects with higher TTs were older than the others. However, among NNP patients of very similar age, mean values of Tsk were found to be lower in fingers with lower TT (monofilament 3) than in those with high TT (monofilament 7, p<0.01) values, and evaporation values in the former were almost double those found in the latter (p<0.0001, Mann-Whitney U-test).

Sixteen of the patients and two of the controls had fingertip Tsk values of less than 30°C. While the absolute δ values for Tsk (p<0.0001, Mann-Whitney U-test) differed between the warm- and cold-handed patients, neither evaporation and TT values nor the δ values for these parameters were found to differ. When 'cold-handers' were excluded, to avoid the influence of coldness on the results, the mean values of evaporation and TT still differed between the three subgroups (p<0.05 for both, Kruskal-Wallis test), with evaporation being lower and TT higher in the NNP patients with unilateral pain compared with the controls (p<0.05, Mann-Whitney U-test).

Discussion

In the present study, the mean values and variability of TT differed and those of Tsk tended to differ between the subgroups of NNP patients with unilateral and bilateral symptoms and the healthy controls. Tactile sensations are known to be predominantly mediated by larger myelinated A-beta afferents. On the other hand, Tsk is to a large extent dependent on the amount of local circulation regulated through the thin and unmyelinated sympathetic efferents, as is evaporation. Our results thus indicate that the function of both nerve fiber types may be impaired in NNP, but the sensory deficit seemed to be more prominent.

Measurement of TT with Semmes-Weinstein monofilaments (Semmes et al., 1960) has been reported to provide reliable data (Bell-Krotoski and Tomancik, 1987). In previous studies, systematic TT increases in cervical dermatomes of patients with chronic cervicobrachialgia were reported (Voerman et al., 2000), and sensory disturbances in the hands were found to be associated with neck pain (Reading et al., 2003).

However, in the study by Tampin et al. (2012), patients with non-specific neck-arm pain associated with heightened nerve mechanosensitivity did not show such sensory disorders. In our study, TT values and within-hand variability differed between the three subgroups and were highest in NNP with unilateral pain.

In line with the study by Stohler et al. (2001), who reported greater pain-induced sensory loss in men than in women, we found TT to differ between the sexes, except in the NNP patients with unilateral pain. Halar et al. (1987), on the other hand, found no gender differences in the threshold values in any sensory modality.

In the present study, Tsk, dependent on sympathetic regulation, tended to differ between the three subgroups, the fingertips being coldest in the NNP patients with bilateral symptoms and warmest in the controls. Previous thermography studies attempted mainly to identify higher δ Tsk as a sign of unilateral impairment (Zhang et al., 1999; So et al., 1990). In cervical radiculopathy, So et al. (1990) reported abnormal Tsk findings only distally, without any relation to the involved cervical root. In line with their results, we previously (Zaproudina et al., 2013) observed similar Tsk abnormalities in NNP patients only in the cold distal areas. Actually, vasomotor abnormalities in the upper limbs have also been demonstrated in other non-specific pain conditions (Greening et al., 2003; Sluiter et al., 2000). Thus, it seems that the coldness of the fingers may be a sign of more general vascular disorders in NNP. In fact, given that the δ values in Tsk were higher in colder skin, this coldness may accentuate possible local abnormalities, however, the TT differences between the three subgroups cannot be explained by the coldness alone.

In our study, the evaporation values differed between the three subgroups, being lower in the NNP patients with unilateral pain than in the controls, only when we excluded 'cold handers'. Interestingly, the proportion of

'cold handers' was non-significantly higher among the NNP patients than the controls. This is probably due to pathophysiological mechanisms that are similar in different chronic pain conditions (Leistad et al., 2008). In line with this, the autonomic disorder and depression scores showed a relationship with Tsk in our study.

In the study by Riley and Richter (1975), changes in electrodermal reactions in the skin corresponded well to painful areas in patients with neck and arm disorders. However, although evaporation may be a sensitive indicator of the sympathetic dysfunction in NNP, values measured at the fingers also reflect emotional reactions (Van Dooren et al., 2012). Variations in psychophysiological characteristics among individuals may, in part, have contributed to the extremely high variability of the measured evaporation and Tsk values (Wallin and Charkoudian, 2007), which may limit the use of these measurements as a diagnostic tool. Previously, Park et al. (1994) recommended combined use of the SSR and thermography in peripheral neuropathy. In our study, both microcirculation (as revealed by Tsk) and sweating, regulated by the sympathetic nervous system, seem to be affected in NNP patients' hands. Tsk and evaporation were interrelated in our healthy subjects but not in the NNP patients. However, this relationship has been described to be complicated (Wallin and Charkoudian, 2007).

Pain stimuli are known to influence the sympathetic nerve traffic to the skin and elicit constriction of the cutaneous vessels; in addition, pain-induced psychological stress activates skin vasoconstrictor and sudomotor nerves (Wallin and Charkoudian, 2007). In our study, pain intensity was the main Tsk predictor and also influenced TT in the NNP patients with bilateral symptoms.

The causes of the sensory deficit as well as the sympathetic disorders in NNP could be either peripheral and/or central in origin. Greening (2006) claimed that in non-specific arm pain, nerves that have sustained minor injury are capable of producing neuropathic symptoms and that these conditions are more common than previously suspected. Changes in sensory thresholds and also impairment of the sympathetic fibers have been shown in non-specific arm pain (Greening et al., 2003; Greening, 2006).

In our study, the findings of a higher within-hand variability of TT, a greater TT difference between ulnar and radial areas, as well as the greater δ values for TT in unilateral pain may indicate some local changes in cases clinically diagnosed as NNP, and TT values were dependent on the laterality of the symptoms. However, an inhibitory influence of experimental pain on touch perception has been reported (Stohler et al., 2001) and this effect was not limited to the symptomatic area. In patients with trapezius myalgia, a bilaterally decreased tactile sensitivity was found in the area of referred pain suggesting impaired central somatosensory processing (Leffler et al., 2003). Stohler et al. (2001) concluded that increased TTs are a direct result of the activation of nociceptors, as previously described also in cervicobrachialgia (Voerman et al., 2000), thus supporting the role of mechanisms related to central sensitization of nociceptive pathways in chronic neck pain (Sheather-Reid and Cohen, 1998; Voerman et al., 2000). In line with those results, in the present study, the changes in TT in NNP patients with unilateral pain compared to those with bilateral pain were seen on both the symptomatic and the healthy sides. Westermann et al. (2011) found a sensory impairment of both large and small fiber function in chronic non-neuropathic pain and concluded that this slight sensory deficit was not necessarily a sign of neuropathy.

Our study presents several limitations: the screening of the patients was based on clinical neurological examination but electroneurophysiological investigations were not performed. Therefore, the NNP subgroups may not have been completely homogeneous due to variable origin of neck pain, and may also possibly have included some cases with a subtle nerve root compression or also other subclinical upper limb musculoskeletal disorders; this may explain the high variability of the results, especially in the patients with unilateral pain. The NNP patients were older than the controls (although the age difference was not statistically significant), which may have had a confounding effect because TTs are clearly age-related, as indicated also in an earlier report (Halar et al., 1987). Moreover, the results were abnormally distributed in the small control group.

In summary, functional impairment of sensory and sympathetic innervation of the fingertips in patients clinically diagnosed as affected by NNP was shown in the present study by the skin TT, evaporation and temperature measurements, which were found to be different in NNP patients with unilateral and bilateral symptoms. The underlying mechanisms are still to be clarified but may involve either modulation of central nervous system function or direct irritation of the peripheral nerves leading also to central changes. However, multifactorial mechanisms and interrelations between these parameters may have a confounding effect on the results, and more studies of such disorders are needed in chronic, acute and subacute neck pain. As a practical application, our findings indicate that patients with clinically diagnosed non-specific neck pain may show both sensory and autonomic disorders in their fingertips.

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