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ORIGINAL ARTICLE

Validity of pressure pain thresholds in female workers with and without recurrent low back pain

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Abstract Recurrent low back pain (LBP) is a common pain condition in elderly workers in a variety of occupations, but little is known about its origin and the mechanisms leading to an often disabling sensation of pain that may be persistent or intermittent. In the present study we evaluated the pressure pain thresholds (PPTs) in subjects suffering from recurrent LBP, as well as in healthy controls, to investigate if recurrent LBP is associated with an increased sensitivity of the muscular and ligamentous structures located on the lower back. One hundred and six female workers, aged between 45 and 62 years and working either in administrative or nursing professions were examined. The subjects were classified into LBP cases and controls based on the Nordic questionnaire. Subjects indicating 8–30 or more days with LBP during the past 12 months were graded as cases. PPTs were measured on 12 points (six on each side of the body) expected to be relevant for LBP (paravertebral muscles, musculus quadratus lumborum, os ilium, iliolumbar ligament, musculus piriformis and greater trochanter), as well as on a reference point (middle of the forehead) using a digital dolorimeter. The PPTs on all points on the lower back highly correlated with each other and a high internal consistency was found with a Cronbach alpha coefficient > 0.95. There was a moderate and significant correlation of the PPT on the forehead with the PPT on the lower back with correlation coefficients ranging from 0.36 to 0.49. In LBP cases from administrative professions, the PPT on the forehead was significantly decreased ($P < 0.05$). The PPT on the lower back did not significantly differ between the four groups studied, namely nurses and administrative workers with and without recurrent LBP. These results give evidence that recurrent LBP is not associated with an altered sensitivity of the muscular and myofascial tissues in the lumbar region. Furthermore, they raise questions about the value of reference point measurements in recurrent LBP.

Keywords Pressure pain threshold · Low back pain · Reference point

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Introduction

Low back pain (LBP) is a widespread pain condition in the working population and its prevalence is especially pronounced in nurses [6, 20, 28]. It may be defined as an unpleasant sensation such as pain, strain, tension, or stiffness localized below the costal margin and above the inferior gluteal folds [27]. In about 85% of patients with LBP, no precise patho-anatomical diagnosis can be given [5]. From epidemiological studies in the working population, several physical and psychosocial risk factors for the occurrence of episodes of LBP were established [21]. Models incorporating these risk factors still fail to explain the occurrence of LBP to a satisfactory extent but they support the multifactorial character of LBP. This indicates that there must be other factors influencing the development of non-specific LBP.

It has been proposed, that the individuals' sensitivity to experimentally applied pressure pain might be an important determinant for the development of chronic musculoskeletal disorders [4], but little is known about the sensitivity to pressure stimuli in subjects suffering from recurrent LBP.

Dolorimetry is a psychophysical method to assess the forces required to provoke pain in distinct locations. The measure is called pressure pain threshold (PPT). The reliability of the dolorimetry has been shown [2, 24] and normative values for the assessment of tender points have been established [7, 13, 16, 17, 19]. The dolorimetry played an important role in the development and validation of criteria for the classification of fibromyalgia as a combination of widespread pain and tenderness in 11 of 18 defined tender points [29].

Previous studies in subjects being treated for non-specific LBP persisting for at least 3 months revealed an increased number of tender points compared to the normal population and 38% of the subjects met the criteria for the diagnosis of fibromyalgia [4]. Furthermore, they reported a highly significant association of tender point threshold with control point threshold. In another study, a reduced PPT on the thumbnail, as well as an augmented central pain processing, was found both in subjects suffering from chronic LBP as well as in subjects who met the American College of Rheumatology criteria for the diagnosis of fibromyalgia [11]. Thus, chronic LBP seems to come along with an altered central pain processing and a generally increased sensitivity to painful stimuli.

Against the background that in chronic LBP PPTs are generally decreased, it is of interest if PPTs are also decreased in subjects suffering from recurrent episodes of non-specific LBP. Furthermore, it is of interest if in recurrent LBP cases PPTs, measured on different locations, highly correlate with each other, as shown in a previous study [4], and if regions or structures with different sensitivity to pressure pain can be detected.

The aim of the present study was to assess the PPTs from different muscular and myofascial locations on the lower back, as well as on a bony reference point (middle of the forehead) in subjects with recurrent LBP and in healthy controls working either in administrative (sitting) or nursing professions.

The study was part of the European cost shared project Neuromuscular assessment in the elderly worker NEW (contract Nr. QLRT-2000–00139) and all tests were approved by the ethical committee of the Canton of Zurich.

Materials and methods

Population

One hundred and six female volunteers, aged from 45 to 62 years, and working for at least 20 h/week, either in administrative or in nursing professions, were recruited. The presence of musculoskeletal disorders during the previous 12 months, as well as current problems in different body regions were assessed using the Nordic questionnaire [14], which contains five categories for the frequency of complaints during the last 12 months. These categories are never, 1–7 days, 8–30 days, more than 30 days and every day. The subjects rated their current problems in the lower back using a visual analogue scale (VAS 0–10).

Subjects were divided into controls and subjects with recurrent LBP. The LBP controls indicated 0 or 1–7 days with problems from the lower back in the last 12 months. Subjects indicating LBP on 8–30 or more days during the previous 12 months were classified as recurrent LBP cases. In order to confine the presence of wide spread musculoskeletal disorders within the study group, subjects who indicated problems on more than 30 days from more than three body parts were excluded from the study. Current headaches must be considered as potentially confounding factors for PPT measurements on the forehead and were therefore assessed prior to the dolorimeter measurements. A detailed description of the study groups is provided by Table 1.

All subjects underwent an extensive medical screening and only cases that suffered from non-specific recurrent LBP were included. Furthermore, subjects with hypertension, angina pectoris, fever, pregnancy, use of prescribed lung or heart medicine, or rest heart rate of more than 120 beats/min were excluded from the tests. This was done in order to avoid co-morbidity within the study group.

Dolorimetry

The PPT was assessed using the Digital Dolorimeter LC 100 N (AC Engineering, Basle, Switzerland). The device consists of a hemispherical probe (diameter 9 mm, area 1.27 cm^2), which is connected to a force gauge.

Table 1 Description of the four groups

Means and standard deviations (in brackets) of age and weight as well as frequency of self-reported low back pain (LBP), occurrence of musculoskeletal complaints in other body regions during the last 12 month, frequency of current headaches and LPB during the last week

[a]Subject indicated 1–7 days with LBP in the last year

	Recurrent LBP		Healthy control	
	Nurses $N = 23$	Secretaries $N = 15$	Nurses $N = 33$	Secretaries $N = 35$
Age (years)	51.9 (4.5)	52.7 (4.8)	51.8 (4.8)	52.9 (5.1)
Weight (kg)	69.9 (10.8)	70.0 (14.7)	63.1 (9.4)	63.9 (14.7)
Frequency of LBP				
1–7 days/year	0	0	15	6
8–30 days/year	12	8	0	0
> 30 days/year	9	6	0	0
Every day	2	1	0	0
Regional musculoskeletal complaints (> 30 days/year)				
None	14	6	30	31
In 1 body region	7	6	3	4
In 2 body regions	2	2	0	0
In 3 body regions	0	1	0	0
Frequency of current headaches	12 (52.2%)	9 (60.0%)	6 (18.2%)	11 (31.4%)
Number of subjects with LBP during last week	14	11	1[a]	0
Average LBP (VAS 0–10) during last week	2.3 (2.4)	2.0 (2.5)	0.1 (0.5)	0

We selected six bilateral points that we expected to be relevant for LBP and which represent different structures, ligaments, tendons and muscles. Since there were only few studies measuring PPT on the lower back [13, 16, 17, 19] and no standards are published for PPT measurements on the lower back, we used points that could clearly be identified by anatomical landmarks. The following six bilateral points were selected (see also Fig. 1 from cranial to caudal):

- Paravertebral muscles (M. longissimus/M. erector trunci), 3 cm lateral from lumbar vertebra L1.
- Musculus quadratus lumborum, 5 cm lateral from lumbar vertebra L3.
- Os Ilium, highest point on crista iliaca.
- Iliolumbar ligament, middle of the triangle given by processus costarius of lumbar vertebra L4 and L5 as well as crista iliaca.
- Musculus piriformis, intersection of the two lines from Spina iliaca anterior superior to the coccyx and from the M. trochanter mayor to the spina iliaca posterior superior. This represents the normal position of M. piriformis, which could partly be overlaid by M. gluteus medius.
- Greater trochanter, posterior to the trochanteric prominence.

We also wanted to include a so-called reference point, i.e. a point on which PPT is not likely to be altered due to LBP. Non-tender points within the same muscle have been proposed as reference points when studying tender points [8]. Since we measured standardized points instead of tender points and therefore concentrated on non-specific muscular sensitivity, the reference point should be a non-muscular location. We chose the middle of the forehead as a reference point, as recommended by Fredriksson [9] who studied different facial reference points.

The measurements were conducted by two specially trained and experienced examiners blinded to the LBP status of the subject and using the same test protocol. The pressure was applied at a right angle to the skin surface and the pressure was increased steadily at a rate of approximately 1 kp/s. The subject was instructed to say 'stop' as soon as the sensation of pressure became too unpleasant or turned into pain. The test was stopped as soon as the subject indicated pain, and the final force applied was recorded. To avoid haematomas, the test was also stopped when a load of 6 kp was reached and 6 kp was recorded. In case the administering therapist observed signs of pain such as jerking or grimacing with pain, the measurement was repeated. At the beginning, one test measurement was made on the subjects' forearm to demonstrate how it works. For all measurements, except for those on the greater trochanter where the subject was lying on the side, the subject was in prone position.

The points on the lower back were consecutively measured and then immediately measured again in the same order. The reference point in the middle of the forehead was measured at the very beginning and measured again at the end of the examination. To avoid negative effects of the previous measurement, such as changed sensitivity of the tissue after admission of the first pressure stimulus, the location just proximal (in respect to fiber direction) to the original position was chosen for the repeated measurement.

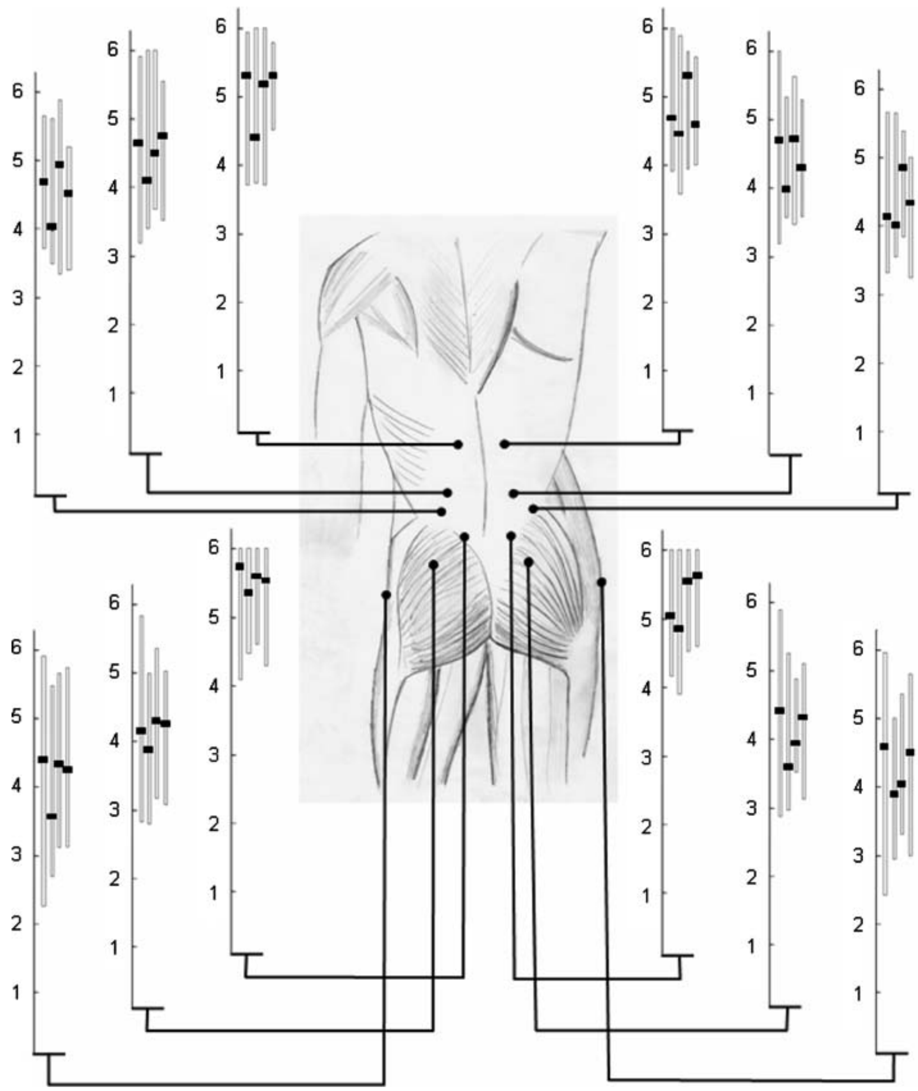

Fig. 1 For each of the 12 points studied on the lower back, the median and interquartile range of the pressure pain thresholds (in kp) are displayed as box-plots. For each location, a group of four box plots is displayed. These four box-plots represent the four subpopulations studied: nurses with low back pain (*LBP*), administrative worker with LBP, nurses without LBP and administrative worker without LBP (*from left to the right*). As the measurements were stopped when a load of 6 kp was reached, the scales are accordingly truncated at 6 kp

Statistics

Statistical analysis was carried out by use of SAS® System™, version 8.02 (SAS Institute, Cary, NC, USA). A two tailed Wilcoxon rank test was used to compare the two repeated measurements on each anatomical site. The Cronbach coefficient alpha was computed to test the relationship between PPTs from the different locations for consistency. The Spearman rank correlation was computed to estimate the relationship between the PPTs on the lower back with the reference site on the forehead. The rank correlation was also used to estimate associations of self-rated LBP and potentially confounding variables with PPT.

The subjects were split up according to LBP status and profession into four groups: nurses and secretaries with and without LBP (see Table 1). The nonparametric Kruskal–Wallis test was used to compare the averaged PPT on the low back, as well as on the forehead, between the four different groups.

A two-factor analysis of variance (ANOVA) was carried out with group (case nurses/case secretaries/control nurses/control secretaries) and current headache (yes/no) as factors for averaged PPT on the lower back and on the forehead.

The Kruskal–Wallis test was also used to compare the ratings of the two examiners. Although there was no difference between the PPT index formed from all twelve measurements on the lower back, there were significant differences between the ratings of the two examiners on 4 of the 12 points measured. These differences were present only in one of the four groups studied (secretaries without LBP). The Cronbach alpha of the 12 low back points remained high (> 0.95) in all groups when analyzing these subjects measured by the two examiners separately. This gives evidence that the differences found can be attributed to different sensitivities of the subjects and are not influenced by the examiners. This was confirmed by a three-factor ANOVA that was carried out for the averaged PPT on the lower back with LBP status (case/control), profession (nurse/secretary) and examiner (A/B) as factors, which confirmed that there was no relevant ($F < 0.5$) influence of the examiners.

A significance level of $P < 0.05$ was considered as significant.

Results

The two repeated measurements of the PPTs highly correlated with each other ($R > 0.7$) and did not significantly differ. Therefore, the mean of the two repeated measurements of each point was used for further analysis.

The median and inter-quartile ranges of the PPT in the lower back are shown for the four subgroups studied in Fig. 1. The endpoint of the measurement, which was set to 6.00 kg/1.27 cm^2, was reached in 23% of the measurements on the lower back and in three cases (2.8%) on the forehead.

There was a high correlation of the PPTs determined on the same anatomical sites between the left and right side ranging from 0.82 to 0.86. Considering all twelve points on the lower back, there was a high correlation of the PPT among each other. Spearman correlation coefficients ranged from 0.59 to 0.87. Rank correlation of the PPT on the forehead ($PPT_{forehead}$) with the PPTs in the 12 points on the lower back was moderate and ranged from 0.36 to 0.51. Correlation coefficients for the four subpopulations are provided in Table 2.

There was a high internal consistency of the PPT on the 12 points located on the lower back. Cronbach coefficient alpha for the 12 low back points was > 0.95 in the whole study group as well as in the four subgroups. A factor analysis of the 12 low back points identified only one factor with factor loadings for all single PPTs ≥ 0.79. This indicates that all points measured on the lower back represented one common dimension. Therefore, there was no need to treat these 12 points separately and they were averaged to $PPT_{low\ back}$ for further analysis.

The $PPT_{low\ back}$ was significantly higher than the PPT of the forehead in all four groups. $PPT_{low\ back}$ did not differ between the four groups studied ($P = 0.68$, Fig. 2). The Kruskal–Wallis test showed a marginally significant difference ($P = 0.049$) of the PPT on the forehead between the four groups (Fig. 2). Low back cases from administrative professions were most sensitive to pressure pain on the forehead and the least sensitive were healthy administrative workers. The nurses were in-between, and lower PPTs were found in cases.

The analysis of variance ANOVA showed a weak significant influence of current headache on the PPT of the forehead ($F = 4.3$, $P = 0.04$) but highly significant influence of current headache on the $PPT_{low\ back}$ ($F = 22.0$, $P < 0.0001$). PPTs of forehead and lower back were not associated with age, weight, or the number of body regions with complaints during the previous 12 month.

Solely considering subjects with recurrent LBP, there was a non-significant negative association of PPT of the forehead with self-rated current LBP in nurses (Spearman rank correlation $R_s = -0.38$, $P = 0.07$). In

Table 2 Average spearman rank correlation coefficients and range (in margins) of the pressure pain thresholds (PPT) of the 12 points on the lower back amongst each other (left) and of the 12 low back points with the reference point (right)

	Rank correlation of PPT among low back points	Rank correlation of PPT between forehead and low back points
Study group	0.73 (0.59–0.87)	0.43 (0.36–0.51)
Cases nurses	0.75 (0.50–0.95)	0.49 (0.37–0.61)
Controls nurses	0.67 (0.25–0.90)	0.36 (0.13–0.56)
Cases secretaries	0.71 (0.52–0.95)	0.36 (0.24–0.51)
Controls secretaries	0.70 (0.53–0.89)	0.48 (0.38–0.58)

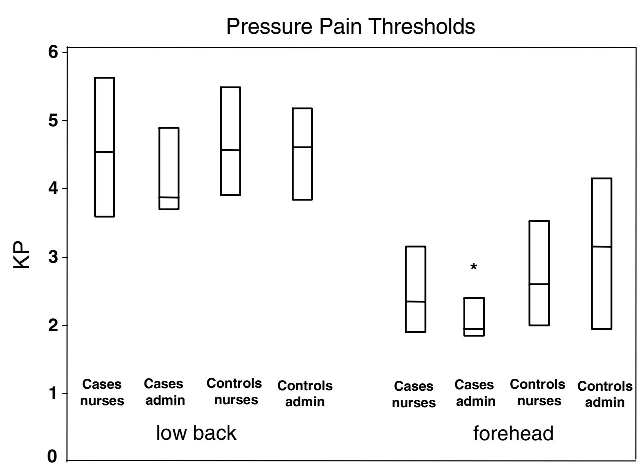

Fig. 2 Pressure pain threshold on the lower back did not differ between the four groups studied, nurses and administrative worker with and without recurrent LBP namely ($P = 0.68$). In secretaries suffering from recurrent LBP, a marginally significant ($P = 0.049$) reduction of PPT on the forehead was found. The *boxes* represent median and inter-quartile range of the PPT in the four groups studied

secretaries there was no significant association of $PPT_{forehead}$ with self-rated current LBP.

The $PPT_{low\ back}$ was not significantly correlated with current LBP assessed by questionnaires in the groups studied.

Discussion

Methodological considerations

The present study focused on local and general sensitivity to pressure pain in female idiopathic LBP patients and healthy controls from two different vocational groups, i.e. secretaries and nurses.

Normative values for PPT have been published [7, 13, 17, 19], but comparison of our data with published values is difficult since PPT may depend on reaction time of the subject and the examiner, on age and gender [23] and potentially on the cultural background of the subjects studied [25]. But beside these factors that are difficult to be standardized, other factors such as diameter and shape of the plungers used, vary among the different studies published. There is a trade-off between the selectivity of small plungers and the ability of large plungers to transmit the pressure to the muscles underlying the skin [7]. Furthermore, it was hypothesized that small plungers might induce pain in the skin rather than in the deep muscle [8]. We used hemispherical plungers due to our supposition that they have several advantages compared to planar ones: they lead to a more uniform transmission of the pressure to the tissue underlying the skin when the force is not applied exactly in a right angle to the surface and there is no risk of squeezing the skin at the edges of the plunger.

In several publications, the PPT was reported as a pressure that is the force applied divided by the contact area of the plunger with the skin. According to geometrical laws, the surface of a helical tip is twice the surface of a planar tip with the same diameter. However, in the case of a helical plunger, the "active" surface is difficult to determine, since it depends on the plasticity of the skin and of the tissues underlying the skin.

Therefore, the pressure is not a useful measure and we recommend reporting diameter and shape of the measurement tip used and the force applied in order to improve comparability of dolorimetry measurements.

We decided to set an upper threshold of 6 kp in order to prevent haematomas caused by the PPT measurements. This threshold was reached in 23% of all measurements on the lower back, but only in three measurements on the forehead. This ceiling effect further complicated a statistical comparison with published data [15, 17], which was collected using the same instrumentation but without setting an upper threshold value.

Discussion of results

There was a considerable variation of PPTs among subjects, so that a search for relationships between personal factors and PPTs was justified. Considering the PPTs of the different points measured on the lower back differences were marginal, although we included different anatomical structures, such as bony points (Os ilium), tendons (Greater Trochanter), as well as muscular (M. piriformis, M. quadratus lumborum, paravertebral muscles) and ligamentous (iliolumbar ligament) points.

We could show that for each subject PPTs of 12 different points on the lower back and from four different anatomical structures represented one common dimension as they all highly correlated with each other (see Table 2). Furthermore, we found that PPT on the lower back does not discriminate between healthy subjects and subjects with recurrent, non-specific LBP. Therefore, a classification of LBP patients similarly to the classification of fibromyalgia patients or a mapping of the sensitivity to pressure pain by means of PPT on these standardized locations seems to be impossible.

A limitation of the method used could be that we examined points defined by anatomical landmarks, instead of searching for trigger points. This was done in order to improve the reliability of the measurements assessed by two examiners, and because it was assumed that the amount and precise location of trigger points varies over time. The sequence of the points measured was fixed and the reference point was measured at the start and at the very end of the examination. This standardization was chosen with respect to clinical application, to speed up the assessment, and facilitate reliable measurements by different examiners. Since there was no difference between the repeated measurements in any of the points, we think the standardization of the measurement order was not a limitation.

The only point that significantly discriminated between healthy subjects and subjects with idiopathic LBP was the "reference" point on the forehead even though this holds true only for the secretaries group studied. The concept behind reference point measurements is that the reference point should reflect an individuals' overall pressure pain sensitivity and thus local sensitivity can be distinguished from general sensitivity [22]. Depending on the objective, different concepts for reference point selection are suggestive: The deltoid muscle was studied as a muscular control point because it rarely is the site of trigger points [1]. In studies dealing with fibromyalgia the thumbnail or the third metatarsal are often used as control sites [29]. The forehead was proposed as an advisable control point for PPT measurements since it is easily accessible and the reliability of PPT measurements was shown to be high [1, 10, 12]. The limitation of the forehead as a control site is that it is prone to be affected by current headaches and therefore it is not used in the diagnosis of fibromyalgia. We chose the forehead as a control site due to its favorable properties and its spatial and structural difference to the sites we measured on the lower back and we controlled for current headaches as a potentially confounding variable.

There was a considerable overlap of the PPTs measured in the four groups studied. Compared to the other three groups, PPTs in LBP cases from administrative professions were decreased in the lower back and on the forehead, but the level of significance was reached only on the forehead.

This group difference in the reference point was only marginally significant, and since we made no corrections for multiple testing, we cannot necessarily confirm the different PPTs on the forehead in the four groups studied. Nevertheless, this finding indicates that the inter-individual variability of PPT measurements cannot be overcome by reference point measurements. This has to be considered in further research: In several studies, ratios between local PPT and a reference measurement were calculated and compared between groups [9, 10] or a system with a reference site was proposed in order to improve the reliability of repeated measurements [13]. But, when using ratios between points in an area of interest and a reference site, there is a need to control the reference point for differences between the groups studied. Otherwise, the ratios calculated may show a group effect exactly contrary to the true one.

We assessed current headaches as a potential confounder for the reference point PPT measurements but found only a weak association of current headaches with PPT on the forehead. On the other hand, we found a highly significant association of PPT on the lower back with the occurrence of current headaches. Considering the PPTs in the different body regions, we found a moderate but significant correlation of the sensitivities on the forehead and in the lower back. Taken together, these findings imply that LBP in our study group was not an isolated, strictly local problem but was reflected in different dimensions, although we tried to confine the presence of wide spread pain by excluding subjects who indicated problems from more than three body regions exceeding 30 days during the last 12 month. Furthermore, the sensitivities to pressure pain in the lower back and on the forehead did not fully represent one common dimension. This rather weak relationship of PPTs in different body regions with each other is in contrast with previous findings in chronic LBP patients where measurements from the 18 fibromyalgia points and reference points (forehead and bilateral thumbnail) highly correlated with each other [4]. This finding in chronic LBP patients is in agreement with studies showing an increased central pain processing in chronic LBP patients in response to a pressure stimulus of 2 kg which was applied to the thumbnail [11]. The difference compared to the studies cited above may be due to the diverse populations studied. The chronic LBP cases were all under medical treatment for LBP and 38% of the subjects met the criteria for the diagnosis of fibromyalgia. However, we studied subjects that were still working, and thus needed to cope with their pain in the workplace and in daily life. It may be postulated that a generalization of increased pain sensitivity and successful coping with pain in daily life would exclude each other. Within the framework of this cross-sectional study it cannot be answered what might be first and what be second.

In this study the subjects were from two distinctly different vocational groups, administrative workers doing mainly sedentary work, and nurses doing physically demanding work. Of course the two vocational groups do not only differ in their work demands but most probably have different personalities and different coping strategies to deal with possible LBP. Thus, it is of interest that in administrative workers with LBP we observed an increased sensitivity to pressure pain, which reached significance for the forehead. This finding could be explained by different "fear avoidance" behavior in administrative workers than in nurses. Nurses need to move and postural demands are defined by the patient's need, thus special attention to pain sensation will be of limited help when trying to avoid painful episodes, and it seems a better strategy to suppress feelings of pain. On the contrary, subjects doing sedentary work can easier adopt relieving postures and may avoid pain-provoking movements. Therefore, paying attention to the sensation of pain may be used as a partly effective coping strategy. This could lead to an increased intentional focus on painful events or an increased fear of pain and thus to lower ratings of the PPT. Such ideas were also developed in an earlier study [26]. An alternative explanation could be that compared to administrative workers, nurses suffering from recurrent LBP profit from beneficial effects of moderate physical activity at the work site. Such beneficial effects on general well-being [18] and even on tender point PPTs [3] have been shown in subjects suffering from fibromyalgia. Nevertheless, these findings have to be reproduced in further studies and monitored for psychosocial confounders before a generalization can be made.

In our setting, it was not possible to objectify self-rated current LBP by an increased sensitivity to pressure pain. There was no association of current LBP with PPT in the groups studied. This could be due to the fact that we did not measure the tender points but used standardized protocol based on anatomical landmarks. It is also possible that we just overestimated the relevance of local tenderness in idiopathic LBP.

Conclusions

Pressure pain thresholds in the lower back over four anatomical structures assessed by using a digital dolorimeter represent one common dimension and do not discriminate between the four groups, administrative worker and nurses with and without non-specific, recurrent LBP.

Significantly reduced PPT in the reference point located on the forehead was found only in one of the four groups studied (administrative workers with recurrent LBP).

These results give evidence that recurrent LBP is not strongly associated with a generally increased sensitivity of the muscular and ligamentous tissues in the lumbar region and they raise questions about the value of reference point measurements in LBP.

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