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A COMPARISON OF PRESSURE PAIN THRESHOLDS IN DIFFERENT TISSUES AND BODY REGIONS

Long-term Reliability of Pressure Algometry in Healthy Volunteers

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ABSTRACT. Pressure pain thresholds (PPTs) were measured in 12 healthy female volunteers with a hand-held electronic pressure algometer (Somedic®). The PPTs over 30 points, mainly located on the trunk, were measured in a randomized order. The measurements were repeated after one week and again 10–13 weeks later. Three spots over nerve tissue had lower PPTs than nearby muscle. There were no consistent differences between muscle and periosteum within the same region. Overall there was a tendency for points in the nape region to have the lowest PPT, and those in the lumbosacral region to have the highest. The shoulder points had intermediate values. The interindividual differences were great. There was no difference between the mean PPTs from the first session and those from the second session. However, at the third session, 10 weeks later, the average PPT value was substantially higher than in the previous sessions.

Key words: measurement, pain threshold, pressure algometer, reliability.

Disability due to musculoskeletal pain is of great medical and economic importance. Tenderness is the major, and sometimes only, symptom of musculoskeletal dysfunction, and the correct evaluation of tenderness (e.g. finding tender muscle bellies or tendons in work related myalgy/tendalgy or tender/trigger points in fibromyalgia) is an important diagnostic procedure. However, the quantification of tenderness by palpation is very subjective, which makes comparative studies difficult. Pressure algometry is a semiobjective method of determining pressure pain thresholds (PPTs). It has been used to measure the effects of drugs (4, 8, 16), overventilation (5), and stress (3), to document tender/trigger points (23, 27), to discriminate patients with fibromyalgia from healthy controls (18, 28, 30), to compare PPTs in different clinical settings (6, 11, 14, 19, 20, 22, 29), and to evaluate treatment (31). The pressure algometer has also been used to measure differences in PPT between various locations (2, 12, 17, 24, 29).

Only a few investigators have attempted to systematically analyse variations in PPT between different tissues and body regions. Fischer (10) has determined PPTs for ten trunk muscles and also determined the pressure pain tolerance over two bony sites and two muscle sites (9). Gerecz-Simon et al. (11) found a lower average PPT over bone than over muscle. However, the algometers used in these studies lacked an indicator of pressure rate application (a factor important for reliable results (7, 16)) and the pressure pain threshold/tolerance was indicated by the subject signaling pain or saying "stop" which makes the results dependent on the investigator's reaction time. Furthermore the bony and muscle sites were not located in the same body region which makes a comparison difficult.

The short-term reliability of the pressure algometer has been documented (2, 3, 16, 23, 24, 27). There are few reports of long-term reliability, the longest being over 8 weeks in the temporal region (24). A negative correlation between regional tenderness and PPTs in the temporal and occipital region has been documented (17). Reports of good (3, 12, 27) and variable (29) interobserver reliability have been published.

To evaluate tenderness correctly in different locations in patients, normal differences between tissues and body regions among healthy individuals need to be determined. A systematic and repeated study of many locations in one body region is necessary in order to determine consistent differences in sensitivity between different tissues and body regions. No previous study has addressed this vital issue. It is also necessary to document the normal variation in PPT between healthy subjects and in the same subject on

different occasions. Knowledge of the long-term reliability (more than two months) is of crucial importance if the method is to be used in patient follow-ups. However, no study has documented the long-term reliability when measuring locations relevant for clinical assessment in patients with musculoskeletal pain. The purpose of this study was to systematically test for PPT differences between tissues, body regions, and individuals, and to document the short- and long-term reliability of our pressure algometer. The study addressed the following questions:

1) Are there systematic differences in PPTs over different tissues (muscle bellies, tendon insertions, ligaments, periost, joint capsules and nerve tissue)?
2) Are there systematic differences in PPTs between body regions?
3) How great are the normal differences in average PPT values between healthy volunteers?
4) What is the short-term (one week) and long-term (10–13 weeks) reliability?

METHODS

Subjects

Twelve female volunteers average age 28 years, range 15–33 years, participated in the study. None of the subjects suffered from any musculoskeletal problems. No NSAID, other analgesics or hypnotics were being taken at the time of the study. All the subjects were right-handed. They all gave their informed consent to participate in the study.

The pressure algometer

The pressure algometer (Somedic AB, Farsta, Sweden) consisted of a gun-shaped handle with a pressure-sensitive strain gauge at the tip. It was connected to a power supply, an amplifier and a display. The tip was round, with a diameter of 10 mm and covered with 2 mm of neoprene rubber to avoid adverse skin pain stimuli due to sharp metal edges. The display showed pressure (in kPa) and a scale indicating the rate of pressure force increase. The scale enabled the examiner to keep any desired rate of pressure increase. In this study a rate of 50–60 kPa/s was chosen. The subject indicated pain threshold by pressing a push-button which froze the current pressure value on the digital display. The algometer was calibrated before measuring each subject.

Anatomical sites studied

To cover clinically interesting structures in the nape, shoulder and lumbar back, 27 sites on the right side of the body were chosen (see Fig. 1). The sites involved not only different regions, but also different tissues such as periost, tendon insertions, ligaments, joint capsules, muscle bellies and nerve tissue. Three structures were measured bilaterally.

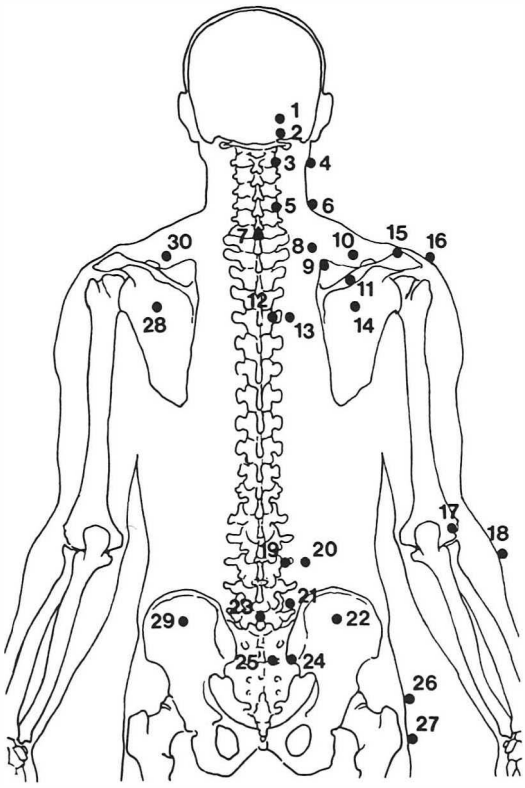

Fig. 1. Locations measured.

1 1 cm above linea nuchae superior
2 1 cm below linea nuchae inferior
3 Processus transversus C2, dorsal aspect
4 Processus transversus C2, lateral aspect
5 Processus transversus C5, dorsal aspect
6 Processus transversus C5, lateral aspect
7 Processus spinosus C7
8 Musculus levator scapulae
9 Angulus superior scapulae
10 Musculus supraspinatus dexter
11 Middle of spina scapulae
12 Processus transversus T5
13 2 cm lateral of processus transversus T5
14 Musculus infraspinatus dexter
15 Over the acromioclavicular joint
16 Acromion, anterior aspect
17 Epicondylus lateralis humeri
18 Musculus brachioradialis/Nervus radialis
19 Processus transversus L3
20 3 cm lateral of point 19
21 Midway between L5-Crista iliaca posterior superior
22 Musculus gluteus medius dexter, dorsal aspect
23 Ligamentum interspinale L5–S1
24 Spina iliaca posterior superior
25 Sacrum level with S2, 2 cm lateral from midline
26 Musculus gluteus medius, lateral aspect
27 Trochanter major
28 Musculus infraspinatus sinister
29 Musculus gluteus medius sinister, dorsal aspect
30 Musculus supraspinatus sinister

Procedure

All measurements were made by the same investigator (EK) with the subjects in a relaxed prone position. The subjects were carefully informed that the investigation aimed at determining the individual pain threshold, not pain tolerance. The algometer was demonstrated and the subjects were instructed to push the button exactly at the moment when the pressure sensation turned into a pain sensation. The structures were localized by palpation and marked with a pen. A plastic template was made for each subject and removed before the measurements started. Two test measurements at spots not included in the study were made before beginning each session to familiarize the subjects with the procedure. The push-button was always held in the hand on the side not being measured. Measurements were made over the 30 spots in a randomized order. Two successive determinations (3–10 seconds in between) were made at each location. The average duration of each session was 40 minutes. The same measurements were repeated after one week and then again approximately 10 weeks later. The sites were palpated, marked and then checked against the template and corrections were made if necessary. The PPTs were obtained using the order of measurement from the first visit. At the last session a final extra measurement with only one pressure application per spot followed the two regular measurements. The same spots were thus remeasured once after 20–30 minutes.

Statistical methods

The statistical analysis is based on the assumption of normal distribution. A three-way analysis of variance was used to determine the influence of the following factors on PPT: 1) anatomical location, 2) individual, 3) order of pressure application in the series and day of examination. Tukey's test, (HSD) (21) was used for multiple comparison of mean PPT. For comparison of differences between two means considered singly, Fischer's test, (LSD) (21) was used. The significance level chosen was $p < 0.05$.

Table I. *Mean pressure pain thresholds (PPT) from all series, standard error (S.E.) and coefficients of variation (C.V.)*

For comparisons of differences between two means considered singly, Fishers's test (LSD) was used. If the difference between the mean PPT for two different sites is 32.1 kPa or more then it is significant at the level of $p < 0.05$. A difference of 42.3 kPa or more is significant at the level of $p < 0.01$ and a difference of 53.9 kPa or more is significant at the level of $p < 0.001$. For multiple comparison of differences between two means, Tukey's test was used. If the difference between the mean PPT for the different sites is 61.4 kPa or more then it is significant at the level of $p < 0.05$. A difference of 68.5 kPa or more is significant at the level of $p < 0.01$ and a difference of 77.1 kPa or more is significant at the level of $p < 0.001$. Standard error (S.E.) and coefficients of variation (C.V.) were calculated for every location measured.

Measured locations	Mean PPT (kPa)	S.E.	C.V. (%)
1 1 cm above linea nuchae sup.	288	13.2	42.3
2 1 cm below linea nuchae inf.	222	10.0	41.1
3 Proc. transv. C2 dorsal asp.	220	11.8	48.9
4 Proc. transv. C2 lat. asp.	144	5.1	32.6
5 Proc. transv. C5 dorsal asp.	222	10.0	41.4
6 Proc. transv. C5 lat. asp.	150	6.0	36.7
7 Proc. spinosus C7	335	26.6	72.9
8 M. Levator scapulae dx.	301	11.8	36.1
9 Angulus sup. scapulae	308	17.1	50.8
10 M. Supraspinatus	368	18.6	46.4
11 Middle of spina scapulae	323	20.6	58.4
12 Proc. transv. T5	348	17.6	46.2
13 2 cm lat. of proc. transv. T5	303	15.8	47.9
14 M. Infraspinatus	374	24.3	59.5
15 Acromioclavicular joint	333	16.8	46.3
16 Acromion	319	18.1	51.8
17 Epicondylus lat. humeri	388	21.5	50.8
18 M. Brachiorad./N. Radialis	183	12.5	62.7
19 Proc. Transv. L3	455	22.8	45.9
20 3 cm lat. of point 19	299	14.3	43.7
21 Midway betw. L5-crista iliaca post. sup.	394	13.2	30.6
22 M. Gluteus med. dx. dorsal asp.	329	16.4	45.7
23 Lig. interspin. L5-S1	413	20.6	45.9
24 Spina iliaca post. sup.	369	15.8	39.1
25 Sacrum level with S2, 2 cm lat. from midline	455	21.4	43.0
26 M. Gluteus med. lat. asp.	335	17.5	48.0
27 Trochanter major	343	15.2	40.6
28 M. Infraspinatus sin.	316	19.2	55.8
29 M. Gluteus med. sin. dorsal asp.	299	15.1	46.4
30 M. Supraspinatus sin.	337	14.3	38.8

RESULTS

Fig. 1 illustrates the locations of the investigated sites. Table 1 shows the mean pressure pain thresholds (PPT), the standard error (S.E.) and the coefficient of variation (C.V.) from all series. When sites over cervical plexus (4, 6) were compared with nearby muscle sites (3, 5), a lower PPT ($p < 0.001$) was found over the nerve sites. M. brachioradialis/N. radialis (site 18) had a lower PPT ($p < 0.001$) than epicondylus lateralis humeri (site 17) and M. infraspinatus (site 14), its closest muscular site, (Fig. 2). No consistent differences in sensitivity were found between periosteum and muscle (Fig. 3). The acromioclavicular joint (site 15) did not differ from the periosteum of acromion (site 16). The tendon insertion of M. levator scapulae (site 9) did not differ in PPT from the belly of M. levator scapulae (site 8). However, we also found some significant differences within the same tissues and body regions. M. supraspinatus (site 10) had higher PPT ($p < 0.001$) than M. levator scapulae (site 8), and sacrum (site 25) had higher PPT ($p < 0.001$) than spina iliaca posterior superior (site 24), which calls for attention when interpreting the data.

Three spots were measured bilaterally to allow a comparison of the dominant and non-dominant sides. The PPT of M. infraspinatus (sites 14 and 28) was higher ($p < 0.001$) on the right side. In M. supraspinatus (sites 10 and 30) and M. gluteus medius (sites 22 and 29) there were tendencies to higher PPT values on the dominant, right side (Fig. 4).

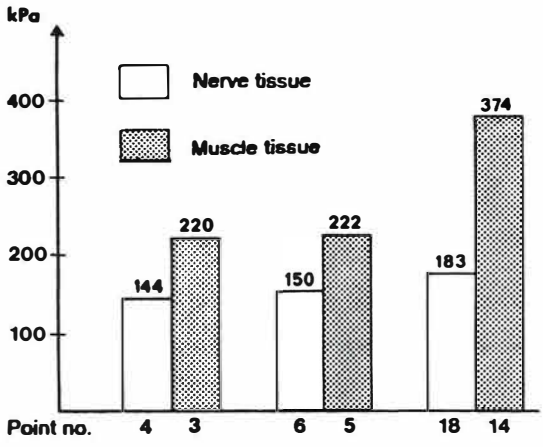

Fig. 2. Mean PPT values for all series for sites over nerve tissue (sites 4, 6, 18) compared with sites over nearby muscle tissue (sites 3, 5, 14). Sites over nerve tissue all had significantly lower PPT values ($p < 0.001$) than nearby muscle sites.

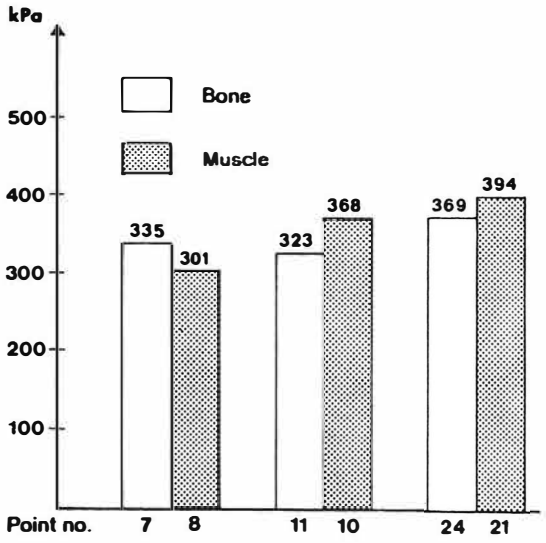

Fig. 3. Mean PPT values for all series for sites over bone (sites 7, 11, 24) compared with nearby muscle sites (sites 8, 10, 21). The spinal process of C7 (site 7) had significantly higher PPT ($p < 0.05$) than M. Levator scapulae (site 8). Spina scapulae (site 11) had lower PPT ($p < 0.01$) than M. Supraspinatus (site 10) and spina iliaca posterior superior (site 24) had lower PPT ($p < 0.05$) than the dorsal part of M. gluteus medius (site 21).

Overall there was a tendency for the nape region (sites 1–6)) to have the lowest PPT values, the shoulder region (sites 7–16) to have intermediate values and the lumbo-sacral region (sites 19–27) to have the highest

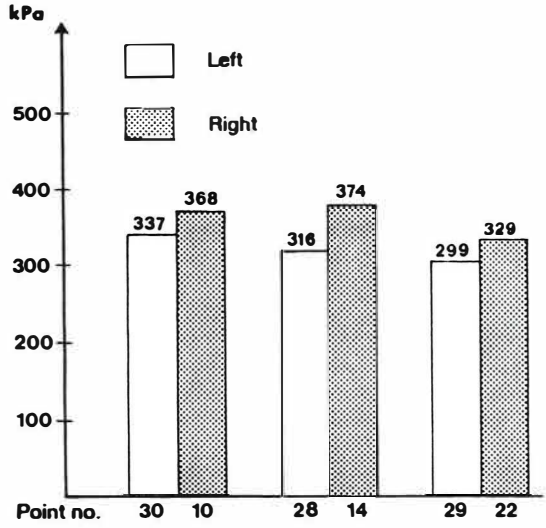

Fig. 4. Mean PPT values for all series for muscle sites on the left and right side of the body. There was a tendency for lower PPT values on the left side but the difference is significant ($p < 0.001$) only for M. infraspinatus (sites 14, 28).

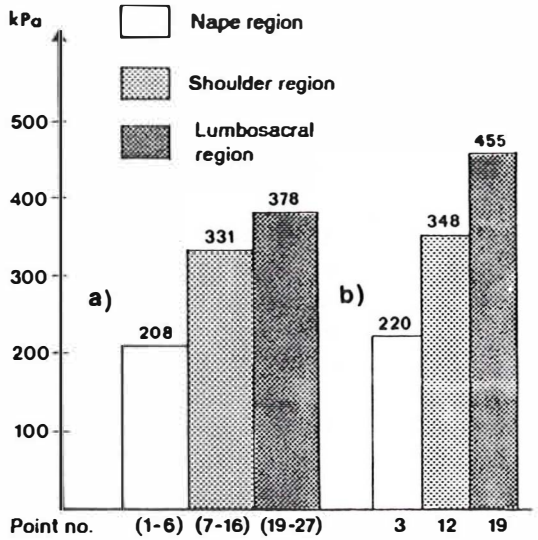

Fig. 5. Mean PPT values for all series for muscle sites at the nape (sites 1–6), shoulder region (sites 7–16) and the lumbosacral region (sites 19–27). There is a significant difference between the nape and the shoulder region ($p < 0.01$) and the nape and the lumbosacral region ($p < 0.001$) but no significant difference between the shoulder region and the lumbosacral region. For comparable sites over the transverse processes of C2, T5 and L3 (sites 3, 12, 19), the PPT increases ($p < 0.001$) for distal sites.

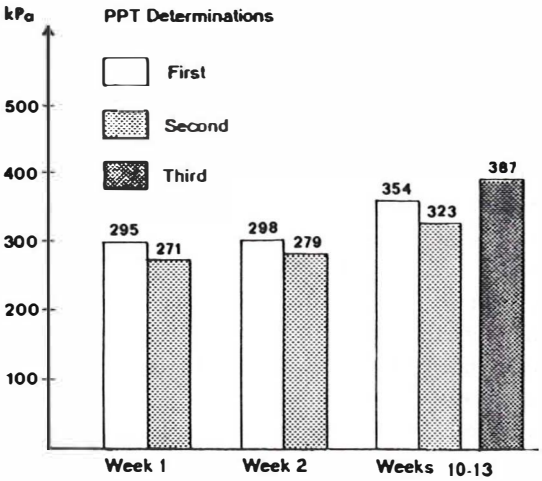

Fig. 6. Mean PPT values for all sites from the first PPT determination at first, second and third measuring sessions compared with the second PPT determination (3–10 seconds later) in these sessions. The mean PPT value from the first determination was higher ($p < 0.001$) than from the second. The mean PPT for the third PPT determination on the third measuring session (20–30 minutes later) was significantly higher ($p < 0.001$) than for the first (and second) determinations in that session.

values, the average values being 208 kPa, 331 kPa and 377 kPa respectively. There was a significant difference ($p < 0.01$) between the nape and shoulder region and between the nape and the lumbosacral region ($p < 0.001$), but no significant difference between the shoulder region and the lumbosacral region. For the comparable sites over the transverse processes of C2, T5 and L3 (sites 3, 12, 19) the PPT increased ($p < 0.001$) with distal location. This is illustrated in Fig. 5. The interindividual differences were very great. The mean PPT values of the most and the least sensitive individuals differed by a factor of 2–3 in every measuring session.

There was a difference between the two immediate (3–10 seconds) consecutive PPT determinations in all series, (Fig. 6). The second determination gave lower PPTs ($p < 0.001$). The mean PPT was 8.6%, 6.5%, and 8.6% lower, respectively, in the second pressure application than in the first. On the third measuring occasion one final extra measurement with only one pressure application per spot followed the regular determinations about 20–30 minutes later. The PPT values were then 9.8% ($p < 0.001$) higher than the first pressure application in that session.

The total mean PPT (283 kPa) obtained from the first series did not significantly differ from the total mean PPT (289 kPa) from the second series one week later. The total mean PPT (339 kPa) from the third series (first two determinations, 10–13 weeks later) was higher ($p < 0.001$) than the mean PPT from the previous two series. The relative mean PPT of individual spots remained fairly constant. The nape region (sites 1–6) had lower PPTs in every subject in all seven PPT determinations than the shoulder region (sites 7–16) and the lumbosacral region (sites 19–27). The shoulder region had lower PPTs than the lumbosacral region in 78.6% of the determinations. However, if only the five sites with the highest PPTs from the lumbosacral region were considered, the shoulder region (sites 7–16) had lower PPTs than these lumbosacral sites (sites 19, 21, 23, 24 and 25) in 96.4% of the determinations.

DISCUSSION

The results showed that there are differences in PPT between different tissues. The extremely low threshold of the spot over the proximal part of M. brachioradia-

lis in healthy individuals is interesting since this spot is frequently reported as a tender/trigger point in patients with e. g. fibromyalgia (1). The threshold was only about 47% of the nearby "periosteum-point" of the lateral humeral epicondyle. This might be explained by the passage of the radial nerve branches through the muscle tissue (13). The other two sites with underlying nerves (plexus cervicalis) also had extremely low PPT. Their PPT was only 65% and 68% respectively of the nearby control sites over processus transversus C2 and C5. Lower PPT values for sites with underlying nerves have not been reported in earlier studies. We found no consistent differences between PPT values of muscle bellies and bony sites when compared within the same body region. However, in agreement with earlier studies (24, 29) significant differences between the same tissue in the same body region occurred. Local differences in skin sensitivity to pressure pain might possibly explain these differences. We found no difference in PPTs between the site over the acromioclavicular joint and the periost of acromion. Since the tip of the algometer tended to slip off the joint, these values might not be correct.

The results show differences in PPTs between different body regions. The nape region had low PPTs in every measuring series, with values only about 55% of those of the lumbosacral region, where the least sensitive spots were found. The thresholds of the shoulder region were about 85% of those of the lumbosacral region. These results tally with earlier publications (10, 12, 28). If we suppose that the pressure pain is mediated by C-fibres with a conduction velocity of 0.6–2 m/s (25, 26), then it will take about 0.25–1.3 seconds more for the subject to react to caudal (site 19) than cranial (site 3) stimulation. In this study we used a pressure application rate of 50–60 kPa/s, thus this mechanism could explain a maximal difference of 70 kPa between the two sites. The difference between the mean PPT values for the transverse process of C2 (site 3) and the transverse process of L3 (site 19) was 255 kPa, so this cannot be the only explanation of the difference in sensitivity.

The finding that the PPT of the second immediate consecutive measurement were about 8% lower is interesting. It shows that one cannot expect the same value when repeating a measurement soon after the first one. Nor can one wait for 20-30 minutes and expect the same result as initially, since it will give about 10% higher values. This phenomenon has not earlier been documented. In some studies no differences have been found when remeasuring PPTs, however, the time intervals differ from ours or are not reported (16, 24, 27). Brennum et al. (2) found no significant differences in PPTs during consecutive measurements with 10 second intervals, but there was a tendency for lower PPTs on the second PPT determination. They performed 30 measurements with this interval while we performed 360, which might explain why we found a significant difference when they did not. Hogeweg et al. (12) also found a significant effect of repeated pressure application within a short time interval but did not specify the effect. The lowered threshold on the second consecutive measurement in our study may be due to focusing attention on the spot measured, an effect of central summation, or a result of local irritation. However, in the third series when a third measurement was made 20–30 minutes later, there was again an increase in PPT, even though indentation marks in the skin were seen. Most subjects spontaneously declared that the measuring sessions has been a pleasant moment of relaxation. During the third pressure application in the third series, the subjects could have reached a maximum of relaxation. Furthermore, the afferent stimulation of 60 times pressure against skin and deeper structures might cause acupuncture-like effects, e.g. endorphin release. This might be avoided in a clinical situation where fewer locations need to be measured.

The short-term reliability (one week) is very good. Nine to twelve weeks after the second series we found an increase in PPT compared to the first or second session. The reason for this is unclear. Series one and two were made in early summer and the third series in late summer/early autumn. Most subjects had their summer vacations in between and it is possible that they were less stressed and fitter, which might have influenced the measurements (3). Jensen et al. (16) also documented an increase in PPT in the course of five repeated determinations at weekly intervals, while Ohrbach & Gale (24) reported no major difference between sessions up to 8 weeks after the first session. The increase in PPT over time was evenly distributed over all the locations measured. The nape region had lower PPTs in every subject and every PPT determination than the shoulder region and the lumbosacral region. The shoulder region had lower PPTs than the five least sensitive lumbosacral sites in 81 of 84 determinations. The relative levels of PPT over differ-

ent locations thus remained fairly constant. This shows that the method has limitations when comparing PPT values for a certain location in one individual from time to time, since these values vary even in healthy subjects. However, since the relative PPT values between the different locations remain fairly constant for each individual, it may be possible to design a system with reference sites to bypass these general drifts in PPT values over time.

The algometer makes it possible to quantify tenderness. It is our belief that the algometer can be a valuable complement to other clinical methods in the evaluation of different treatments of musculoskeletal pain. Since the individual PPT values tend to increase with repeated measurements over time, it might be dubious to try to establish absolute normal reference values for different structures. Instead, a system with reference sites might prove useful.

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REFERENCES

1. Bengtsson, A., Henriksson, K-G., Jorfeld, L., Kågedahl, B., Lennmarken, C. & Lindström, F.: Primary fibromyalgia – a clinical and laboratory examination of 55 patients. Scand J Rheumatol *15:* 340–347, 1987.
2. Brennum, J., Kjeldsen, M., Jensen, K. & Staehelin Jensen, T.: Measurements of human pressure-pain thresholds on fingers and toes. Pain *38:* 211–217, 1989.
3. Buchanan, H. M. & Midgley, J.-A.: Evaluation of pain threshold using a simple pressure algometer. Clin Rheumatol *6:* 510–517, 1987.
4. Clutton-Brock, J.: Pain and the barbiturates. Anaesthesia *16:* 80–88, 1961.
5. Clutton-Brock, J.: The cerebral effects of overventilation. Br J Anaesth *29:* 111–113, 1957.
6. Dahl, J., Rosenberg, J., Molke Jensen, F. & Kehlet, H.: Pressure pain thresholds in volunteers and herniorrhaphy patients. Acta Anaesthesiol Scand *34:* 673–676, 1990.
7. Davenport, J.: Pressure-pain thresholds in the oral cavity in man. Arch Oral Biol *14:* 1267–1274, 1969.
8. Dundee, J. & Moore, J.: Alternations in response to somatic pain associated with anaesthesia. An evaluation of a method of algesimetry. Br J Anaesth *32:* 396–406, 1960.
9. Fischer, A.: Pressure tolerance over muscles and bones in normal subjects. Arch Phys Med Rehabil *67*: 406–409, 1986.
10. Fischer, A.: Pressure algometry over normal muscles. Standard values, validity and reproducibility of pressure threshold. Pain *30:* 115–126, 1987.
11. Gerecz-Simon, E., Tunks, E., Heale, J.-A., Kean, W. & Buchanan, W.: Measurement of pain threshold in patients with rheumatoid arthritis, osteoarthritis, ankylosing spondylitis, and healthy controls. Clin Rheumatol *8:* 467–474, 1989.
12. Hogeweg, J. A., Langereis, M. J., Bernards, A. T., Faber, J. A. & Helders, P. J.: Algometry. Measuring pain threshold, method and characteristics in healthy subjects. Scand J Rehabil Med *24:* 99–103, 1992.
13. Hollinshead, W. H.: Anatomy for surgeons. vol 13, pp. 375, 379. Hoeber & Harper, New York, 1958.
14. Huskisson, E. & Dudly Hart, F.: Threshold and arthritis. BMJ *4:* 193–195, 1972.
15. Jaeger, B. & Reeves, J.: Quantification of changes in myofascial trigger point sensitivity with the pressure algometer following passive stretch. Pain *27:* 203–210, 1986.
16. Jensen, K., Orbaek Andersen, H., Olesen, J. & Lindblom, U.: Pressure-pain threshold in human temporal region. Evaluation of a new pressure algometer. Pain *25:* 313–323, 1986.
17. Langemark, M., Jensen, K., Jensen, T. & Olesen, J.: Pressure pain thresholds in chronic tension-type headache. Pain *38:* 203–210, 1989.
18. Lautenschläger, J., Brückle, W., Schnorrenberger, C. & Müller, W.: Die Messung von Druckschmerzen im Bereich von Sehnen und Muskeln bei Gesunden und Patienten mit generalisierten Tendomyopathie. Z Reumatol *47:* 397–404, 1988.
19. McCarty, D., Gatter, R. & Phelps, P.: A dolorimeter for quantification of articular tenderness. Arthritis Rheum *8:* 551–559, 1965.
20. Merskey, H. & Evans, P.: Variations in pain complaint threshold in psychiatric and neurological patients with pain. Pain *1:* 73–79, 1975.
21. Miller, R. G. Jr.: Simultaneous Statistical Inference. Springer Series in Statistics, Springer-Verlag, Berlin, 1981.
22. O'Driscoll, S. & Jayson, M.: Pain threshold analysis in patients with osteoarthrosis of hip. BMJ *3:* 714–715, 1974.
23. Ohrbach, R. & Gale, E.: Pressure pain thresholds, clinical assessment, and differential diagnosis: reliability and validity in patients with myogenic pain. Pain *39:* 157–169, 1989.
24. Ohrbach, R. & Gale, E.: Pressure pain threshold in normal muscles; reliability, measurement effects, and topographic differences. Pain *37:* 257–263, 1989.
25. Patton, H.: Special properties of nerve trunks and tracts. *In* Neurophysiology (eds. T. Ruch, H. Patton, J. Woodbury & A. Towe), pp. 66–95. W. B. Saunders Company, Philadelphia, 1962.
26. Perl, E. D.: Pain and nociception. *In* Handbook of Physiology (ed. I. Darian-Smith), vol. 3, pp. 915–928. Williams & Wilkins Company, Baltimore, Maryland, 1984.
27. Reeves, J., Jaeger, B. & Graff-Radford, S.: Reliability of the pressure algometer as a measure of myofascial trigger point sensitivity. Pain *24:* 313–321, 1986.
28. Simms, R., Goldenberg, D., Felson, D. & Mason, J.: Tenderness in 75 anatomic sites. Arthritis Rheum *31:* 182–187, 1988.
29. Takala, E-P.: Pressure pain threshold on upper trapezius

and levator scapulae muscles. Scand J Rehabil Med *22:* 63–68, 1990.
30. Tunks, E., Crook, J., Norman, G. & Kalaher, S.: Tender points in fibromyalgia. Pain *34:* 11–19, 1988.
31. Vernon, H., Aker, P., Burns, S., Viljakaanen, S. & Short, L.: Pressure pain threshold evaluation of the effect of spinal manipulation in the treatment of chronic neck pain: A pilot study. J Manipulative Physiol Ther *13:* 13–16, 1990.

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