Scand J Rehab Med 30: 3–8, 1998

PRESSURE ALGOMETRY IN HEALTHY SUBJECTS: INTER-EXAMINER VARIABILITY

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ABSTRACT. The purpose of this study was to estimate inter-examiner reliability of head and neck algometry. Pain perception thresholds were assessed with a mechanical pressure algometer in 21 healthy individuals. Thresholds were assessed at 13 symmetrical points on each side of the head and neck, at the deltoid muscle and at the median finger. The pressure range of the instrument proved insufficient to study the pain perception threshold on the finger, however. Two different examiners carried out one or two examinations in each subject during one day. The sequence of investigations was varied randomly.

The inter-examiner reliability was found to be good, with a mean intra-class correlation coefficient (ICC) of 0.75. Intra-examiner reproducibility was excellent (mean ICC = 0.84). The mean inter-examiner coefficient of variation was 18.7%, while the mean coefficient of repeatability (CR) was 1.60 kg/cm^2. In comparison, the mean intra-examiner coefficient of variation was 15% while the mean CR was 1.29 kg/cm^2. Statistically significant differences between examiners were found for the frontal point ($p < 0.01$), while a trend towards lower thresholds in one of the two observers was seen in 10 of the 13 non-significant points. Inter-examiner reliability of side differences was excellent, with CR = 1.23 kg/cm^2. In conclusion, manual algometry with a rather inexpensive mechanical device has a good to excellent inter-rater reliability. When studying patients, however, the possible bias introduced by different examiners should be taken into account, both regarding study design and data analysis.

Key words: algometry, headache, pain, pain pressure threshold.

INTRODUCTION

Disability due to musculoskeletal pain is a frequently occurring phenomenon and is of medical and economical relevance. The quantification of pain becomes important and pressure algometry has proven useful for identifying tender spots and trigger points and, furthermore, in the assessment of treatment results (1, 10, 11, 13–15, 18, 19). Fagius & Wahren (9) pointed out, however, that the reliability of sensory modality threshold measurements may be less than what is reported in most studies.

Earlier methodological studies on pain perception thresholds (PPT) have often partly used inadequate statistical methods like the Pearson correlation coefficient to assess the reliability of the results obtained, while more appropriate methods like reporting the actual distributions of test–retest differences (e.g. the coefficient of repeatability) (2) or calculating the intra-class correlation coefficient (12) seldom have been applied. Only a few previous studies have provided actual estimation of test–retest differences within examiners (5, 15, 19).

Inter-examiner reliability of pressure algometry has been studied previously (6, 7, 18, 20, 24), but between-examiner coefficients of variation or coefficients of repeatability have not been reported in those investigations. The reliability of asymmetry measures, which may be of importance in headache research, for instance, has only recently been paid attention to (1). Therefore, the purpose of the present study is to estimate inter-examiner variability of the algometry method (as compared to the intra-examiner variability) in various cephalic and extracephalic areas in healthy individuals. In addition, we wanted to estimate the inter-examiner reliability of side-difference PPT measurements.

MATERIALS AND METHOD

Subjects

Twenty-one healthy volunteers (15 males and 6 females) with a mean age of 29.1 ± 12.4 years (range 20–67 years) were examined. All the test subjects were right-handed and none

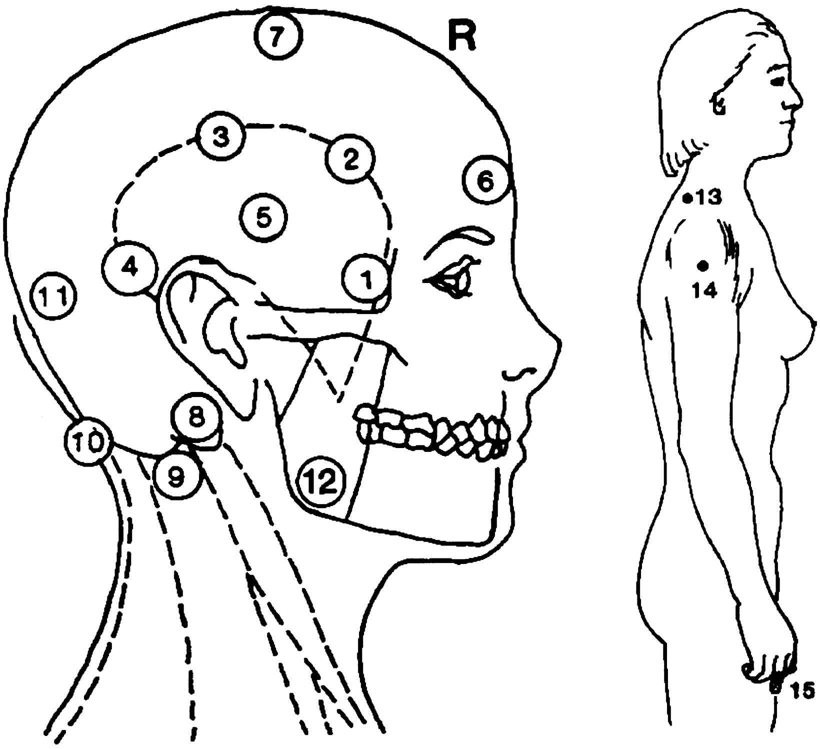

Fig. 1. Location of the 15 points routinely studied: (1) anterior fibres of temporal muscle, above the zygomatic arch in the middle part between lateral edge of the eye and the anterior part of the helix; (2) anteromedial fibres of temporal muscle identified by palpation; (3) medial fibres of temporal muscle identified by palpation; (4) posterior fibres of temporal muscle.; (5) central fibres of the temporalis muscle, above the superior margin of the ear; (6) frontal muscle, 2 cm above the emergence of supraorbital branches of the trigeminal nerve; (7) vertex, 2 cm from the midline; (8) mastoid process; (9) superior insertion of the sternocleidomastoid muscle; (10) insertion of the trapezius muscle; (11) emergence of the greater occipital nerve; (12) the masseter muscle in front of the mandibular angle; (13) the middle trapezius muscle (midline between the spinous process of C7 and acromion); (14) the central part of deltoid muscle; (15) distal phalang, the middle finger's distal phalang, dorsal surface behind the nail.

were medicated at the time of the testing, to the best of our knowledge.

The pressure algometer

Pain perception thresholds have been assessed with the pressure algometer (made commercially available by Pain Diagnostic and Thermography Corporation, Pain Threshold Meter, Model PTH-AF2). The apparatus consists of a 1 cm diameter hard rubber tip, attached to the plunger of a pressure (force) gauge. The dial of the gauge is calibrated in kg/cm^2. To cover clinically significant structures in the head, nape of the neck and shoulder and to involve different tissues, such as periost, tendon insertions, muscle bellies and nerve tissues, 15 points were specifically marked bilaterally (Fig. 1). All points were localized by palpation and marked with a felt-tipped pen.

Procedure

Each individual was investigated during three consecutive sessions (Table I), each session consisting of a set of single-point measurements repeated twice. The mean of the three values within each session was used in further calculations. Measurement were made by two different investigators

Table I. *Study design with two different investigators (A = F.A.; B = G.L.)*[a]

Sequence no.	Sequence of investigation by examiners: Session 1	Session 2	Session 3	No. of subjects
I	***A***	A	***B***	5
II	***B***	B	***A***	4
III	***A***	***B***	B	1
IV	***B***	***A***	A	3
V	***B***	***A***	B	4
VI	***A***	***B***	A	4

[a]Each session consisted of three consecutive measurements of the 15 points on both sides. The intra-session mean of the three consecutive measurements was used in the data analysis. Only the first of the two A – B difference pairs (in bold italics) was used in the analysis in Table II.

(A = F.A. and B = G.L.) on the same day, with the test subject in sitting position. The interval between the end of one session and the beginning of the next one was approximately 2–3 minutes.

The measurements were performed randomly, according to the scheme in Table I. The subjects were assigned randomly to one of the six sequences.

All the subjects were specifically instructed to indicate when the pressure became painful. The subjects were informed that the investigation was aimed at determining the pain threshold, and not pain tolerance. The rate of pressure increase was approximately 2 kg/cm^2/second). (This was also the case in a previous publication (1), and not 0.1 kg/s as was inadvertently written.)

Statistics

The individual test 1 − test 2 ($t_1 - t_2$) intra-examiner differences and inter-examiner differences ($e_A - e_B$) were calculated for each subject's PPT for each of the 15 points measured on the right and left sides. For sequences I and II, inter-examiner differences were calculated from sessions 1 and 3. For sequences V and VI, intra-examiner differences were calculated from sessions 1 and 3. Thus, the differences were approximately balanced regarding order in the sequence, i.e. BA ($n = 11$) or AB ($n = 10$), and 0 or 1 session interposed ($n = 9$ and $n = 12$, respectively, Table I).

Pain perception threshold data analysis was first performed on pooled right and left side data. The coefficient of repeatability (CR) was estimated for each point as two standard deviations of the inter-individual differences (10). Thus, approximately 95% of repeated observations will have a difference in the range mean ± CR. In addition, the intra-individual coefficient of variation (ICV) was estimated as SD ($t_1 - t_2$)/mean(t_1,t_2) and SD ($e_A - e_B$)/mean(e_A,e_B) (6). The inter-individual coefficient of variation (CV) for PPT was also computed for examiner A and B separately.

The intra-class correlation coefficient (ICC) was calculated for the PPT at each point, as described by Fleiss (12). The ICC is the fraction of variance that is caused by the variation between subjects. Thus, if the variance between tests (or examiners) is small compared to the variance between subjects, then ICC is close to 1. According to Fleiss, ICC values above 0.75 generally mean "excellent" reliability (12).

In addition, the right − left side differences were calculated. Intra- and inter-examiner CRs were estimated for the side difference variables. Paired Student's *t*-test was applied to assess if the mean differences between examiners were significantly different from zero. A two-sided probability value of 0.05 was regarded as significant.

RESULTS

As for the finger, many subjects did not report pain until the maximum pressure had been reached (11 kg/cm^2). Thus, the results for this point have not been reported. Pooled right + left data (Tables II and III) and right − left differences (Table IV) were analysed.

The mean PPT values at each point obtained by examiner A and B in the first session were not significantly

Table II. *Pain pressure thresholds (PPT) for examiner A and B and inter-examiner differences (right and left sides are pooled)*

		PPT mean values and SD				Examiner A – Examiner B difference				Between subjects CV	
		Examiner A		Examiner B						Examiner A	Examiner B
Point	Location	mean (kg/cm^2)	SD	mean (kg/cm^2)	SD	mean (kg/cm^2)	CR (2SD) (kg/cm^2)	ICC	ICV (%)	%	%
1	Temporal	4.01	0.98	4.09	1.22	−0.08	1.48	0.77	18.3	24.4	29.8
2	Temporal	3.75	0.89	3.91	1.13	−0.16	1.42	0.75	18.6	23.8	28.8
3	Temporal	4.90	1.21	4.87	1.21	0.03	1.79	0.74	18.3	24.7	24.8
4	Temporal	4.94	1.33	5.15	1.48	−0.21	2.00	0.75	19.8	27.0	28.7
5	Temporal	4.45	1.13	4.67	1.36	−0.22	1.63	0.78	17.9	25.4	29.2
6	Frontal	3.83	0.95	4.20	1.08	−0.37*	1.26	0.76	15.7	24.7	25.6
7	Parietal	4.71	1.24	4.81	1.55	−0.10	1.90	0.78	20.0	26.5	32.2
8	Mastoid	4.36	1.18	4.33	1.22	0.03	1.85	0.71	21.3	27.1	28.2
9	SCM	3.91	1.04	4.15	1.36	−0.24	1.73	0.74	21.4	26.7	32.7
10	Trapezius	4.07	0.84	4.34	1.19	−0.27	1.55	0.70	18.5	20.7	27.3
11	GON	4.43	1.08	4.48	1.32	−0.05	1.68	0.76	18.9	24.3	29.5
12	Masseter	2.52	0.62	2.48	0.56	0.03	1.06	0.61	21.2	24.5	22.3
13	Trapezius	4.35	1.35	4.48	1.33	−0.12	1.14	0.91	13.0	31.1	29.6
14	Deltoid	5.03	1.29	5.33	1.67	−0.29	1.90	0.78	18.3	25.7	31.4
Mean across all points		4.23	1.08	4.38	1.26	-0.14	1.60	0.75	18.7	25.5	28.6

SCM, sternocleidomastoid muscle; GON, greater occipital nerve; CR, coefficient of repeatability = 2 standard deviations (SD) of the intra-individual differences; ICC, intra-class correlation coefficient (mean of right and left); ICV, intra-individual coefficient of variation (standard deviation of intra-individual differences/overall mean); CV, coefficient of variation (between subjects); *$p < 0.01$.

Table III. *Pain pressure thresholds (PPT) for test 1 and test 2 and intra-examiner test–retest differences (right and left side data have been pooled)*[a]

		PPT mean values and SD				Test 1–Test 2 difference			Within subjects ICV		
		Test 1		Test 2					Ex A + Ex B	Examiner A	Examiner B
Point	Location	Mean (kg/cm^2)	SD (kg/cm^2)	Mean (kg/cm^2)	SD (kg/cm^2)	Mean (kg/cm^2)	CR (2SD) (kg/cm^2)	ICC	ICV (%)	ICV (%) ($n = 12$)	ICV (%) ($n = 9$)
1	Temporal	4.08	1.15	4.20	1.32	−0.12	1.54	0.82	18.6	21.3	14.6
2	Temporal	3.85	1.07	3.84	1.03	0.02	1.09	0.87	14.2	12.1	16.9
3	Temporal	5.07	1.29	4.87	1.15	0.19	1.39	0.83	14.1	11.1	18.3
4	Temporal	5.15	1.50	4.79	1.12	0.36	1.58	0.79	16.0	10.7	21.4
5	Temporal	4.66	1.26	4.43	1.31	0.23	1.07	0.90	11.8	11.7	12.0
6	Frontal	4.00	1.06	3.80	0.89	0.20	1.15	0.82	14.7	13.9	15.9
7	Parietal	4.90	1.32	4.98	1.39	−0.09	1.32	0.88	13.5	12.4	15.2
8	Mastoid	4.54	1.29	4.21	1.21	0.33	1.46	0.80	16.7	12.6	21.9
9	SCM	4.14	1.29	3.93	1.10	0.21	1.33	0.84	16.5	15.6	17.7
10	Trapezius	4.27	1.03	4.24	1.11	0.04	1.12	0.87	13.1	13.4	11.6
11	GON	4.52	1.15	4.49	1.15	0.02	0.98	0.91	10.9	10.9	10.9
12	Masseter	2.61	0.65	2.59	0.67	0.01	0.96	0.75	18.6	15.7	20.9
13	Trapezius	4.51	1.34	4.67	1.46	−0.16	1.40	0.88	15.4	17.3	10.8
14	Deltoid	5.15	1.50	5.37	1.64	−0.22	1.69	0.85	16.1	17.1	14.9
Mean across all points		4.39	1.21	4.32	1.18	0.07	1.29	0.84	15.0	14.0	15.9

[a]Test 1 and test 2 PPT values are reported for examiner A and B combined. Number of subjects = 21 unless specified otherwise. Abbreviations: see legend to Table II. Ex = examiner.

different for 13 of 14 points. For the frontal point 6, however, examiner B scored a higher threshold (paired Student's *t*-test: $p < 0.01$), and he also tended to score slightly higher threshold values in 10 of the 13 non-significant points (Table II). The inter-examiner repeatability was good with mean ICC = 0.75 (Table II).

Table IV. *Right – Left differences: mean values and repeatability*

		Mean right – left values				Repeatability			
		Examiner A		Examiner B		Examiner A – Examiner B		Test 1 – Test 2	
Point	Location	Mean (kg/cm^2)	SD	Mean (kg/cm^2)	SD	Mean (kg/cm^2)	CR (2SD) (kg/cm^2)	Mean (kg/cm^2)	CRR (2SD) (kg/cm^2)
1	Temporal	0.16	0.95	0.41	1.18	−0.25	1.60	−0.41	1.80
2	Temporal	0.16	0.43	0.15	0.53	0.01	1.11	0.20	0.83
3	Temporal	−0.04	0.46	−0.07	0.52	0.04	1.23	−0.05	1.04
4	Temporal	−0.29	0.77	−0.34	0.69	0.04	1.41	−0.01	1.37
5	Temporal	−0.05	0.69	0.06	0.74	−0.10	0.96	0.26	0.89
6	Frontal	−0.01	0.42	−0.11	0.54	0.10	1.09	−0.20	1.14
7	Parietal	−0.13	0.67	0.21	0.50	−0.34	1.59	0.05	1.27
8	Mastoid	−0.06	0.95	0.17	0.71	−0.23	1.55	−0.10	1.18
9	SCM	−0.24	0.74	−0.14	0.51	−0.09	1.55	−0.13	1.60
10	Trapezius	−0.05	0.34	0.03	0.23	−0.08	0.46	−0.17	0.77
11	GON	0.31	0.36	0.15	0.31	0.16	1.03	0.08	0.82
12	Masseter	0.12	0.47	0.00	0.44	0.12	1.06	−0.03	0.98
13	Trapezius	−0.20	0.65	−0.06	0.73	−0.13	1.45	−0.07	1.10
14	Deltoid	−0.03	0.69	0.34	0.51	−0.37*	1.19	0.01	1.53
Mean across all points		−0.02	0.61	0.06	0.58	−0.08	1.23	−0.04	1.17

Abbreviations: see legend to Table II; *$p < 0.01$.

As expected, the intra-examiner reproducibility (mean ICC = 0.84) was better than inter-examiner repeatability (Table III). The within-subject ICVs were similar in examiner A and B (Table III).

The across-location mean coefficient of repeatability was 1.29 kg/cm^2 for intra-examiner differences (Table III) and slightly higher, i.e. 1.60 kg/cm^2, for inter-examiner differences (Table II). For the side differences, the across-location mean coefficients of repeatability were even better; i.e. 1.17 kg/cm^2 for intra-examiner and 1.23 kg/cm^2 for inter-examiner differences (Table IV).

Mean side differences were similar for examiner A as compared to examiner B in 13 of the 14 points. Only for the deltoid point was a significant difference found (Student's *t*-test: $p < 0.01$). Moreover, the between-subject variation (SD) was considerably less for side differences (Table IV) than for PPT as such (Table II), indicating that fewer subjects may be needed in PPT studies of intra-individual asymmetry as compared to group comparisons of PPT as such.

DISCUSSION

The validity of quantification of the PPT is still a matter of debate. Besides, the phenomenon of pain perception evaluation in different types of headaches has been the object of considerable interest in recent years (3, 4, 16, 17, 21, 22). In a previous study, the test reproducibility within a single test session and the day-to-day variation was good (1).

Generally speaking, one shortcoming of the manual pressure algometer is the difficulty in assessing objectively the rate in pressure exerted by the examiner. In fact, it is rather difficult to increase the pressure gradually at any predetermined rate without appropriate training. As for the frontal location and the deltoid muscle, the tip of any algometer tends to slip off the muscle (particularly at the frontal muscle). The pressure values may therefore not be correct and, sometimes, a repetition of the measurement may be necessary.

The inter-examiner reliability was good in the present study although it was (as expected) lower than the intra-examiner reliability. Previous studies on inter-observer reliability of manual algometers do not seem to provide estimates of inter-examiner variation magnitude (6, 13, 18, 20, 23, 24). Dundee & Moore (8) reported the average within-examiner differences in readings to be considerably larger in untrained as compared to trained observers. Significant variation in means between observers has been reported previously for non-cephalic locations (6, 13, 23). A trend towards a systematic difference in mean scores between observers was also noted in the present study. Thus, even if the reliability is good, as in our study, it is highly recommended that the design is strictly balanced if more than one observer takes part in patient studies.

We found inter-examiner ICV to be only marginally larger than intra-examiner ICV (18.7 vs. 15.0%), and the CR was not more than 0.31 kg/cm^2 greater for inter-observer as compared to intra-observer differences. Inter-examiner reliability with the more expensive, commercially available electronic algometer has been studied for the head and neck area by Chung et al. (7). The latter study did not estimate the magnitude of variation, however. Nevertheless, the performance of the rather inexpensive algometer used here, both in terms of inter-rater reliability and cost/benefit, seems promising as compared to the more expensive electronic device that has been used in many recent PPT studies (3, 5, 7, 15, 17, 19, 21, 22).

The intra-examiner repeatability was excellent in our study, as judged by ICC analysis. We found that the ICV for head and shoulder locations was between 11 and 19%. Comparable ICVs have been reported previously with the electronic algometer. The ICV was 14% within 60 minutes (15) and approximately 18% within 15 minutes in the temporal region (19), while 14% was reported for the finger and toes (5). Thus, the intra-examiner reliability seems to be as good with the inexpensive mechanical algometer as with the more expensive electronic one, although the interval between sessions was shorter in the present study than in the last mentioned studies (5, 15, 19).

The Pearson correlation coefficient has been used extensively to assess inter-rater reliability (13, 18, 20, 23). The serious shortcomings of this measure in the present context has been underlined by Bland & Altmann (2) and Brennum et al. (5). Intra-class correlation coefficients are definitely to be preferred over the product-moment correlation analysis (12). Tunks et al. (24) reported high mean generalizability coefficient values of 0.85 both for intra- and inter-rater reliability in a combined group of fibromyalgia patients and controls with a new manual algometer in the temporal, occipital and trapezius regions. These coefficients are similar to the ICC used in the present study. In general we also found good inter-examiner reliability, with ICC values ranging between 0.61 and 0.91. One drawback with ICCs is that a large between-subject CV will make the correlation look better artificially. Neither the CR nor the ICV has this limitation.

Several authors have found a high correlation between right and left side PPT (5, 7, 13, 14). Lack of significant mean side difference has even been interpreted as a sufficient measure of reliability! (11). The present study was not designed to investigate the PPT in relation to handedness, however, and a fixed order of stimulation was used. Rather, our interest in side differences is related to the fact that algometry may be of considerable value in the evaluation of unilateral headaches (3, 4). The reliability of asymmetry measures has only recently been paid attention to however (1). In the present study we provide, for the first time, as far as we know, estimates of inter-observer reliability of side differences. The CRs for side differences were less than the CRs for PPT . Thus, smaller sample sizes are needed in studies of asymmetry as compared to studies of thresholds as such.

Previous clinical studies have shown cephalic PPT differences between tension-type headache patients and healthy individuals (17, 22) and between cervicogenic headache patients and controls (4), while algometry thresholds were identical in tension headache, migraine and non-headache subjects in a large population-based study (16). Age, sex and handedness are generally considered as possible non-disease-related sources of variation, while the possible effect of different raters has apparently not always been specified or analysed. In our opinion, inter-examiner variation should also be taken into consideration both during study design and data analysis in order to reduce bias, which can weaken or increase differences between populations.

ACKNOWLEDGEMENT

The authors are indebted to Professor Ottar Sjaastad for fruitful criticism.

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Accepted March 13, 1997

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