Absolute and Relative Facial Pressure-Pain Thresholds in Healthy Individuals

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Aims: *To investigate and compare absolute pressure-pain threshold (PPT) levels and ratios between craniofacial test and reference sites during consecutive PPT recordings, as well as over a 6-month period, in healthy individuals. This study also investigated PPT differences between genders and the clinical usefulness of different reference sites in the craniofacial region.* **Methods:** *Twelve female and 12 male healthy individuals participated in the first examination. Six months later, 9 females and all of the males returned for a second examination. An electronic algometer was used to make 5 consecutive recordings of PPTs with a 2-minute interval at 3 reference sites: mental protuberance (PRO), first metacarpal bone (MET), and frontal bone (FRO), as well as at 3 test sites: temporomandibular joint, masseter muscle, and temporalis muscle.* **Results:** *Absolute PPTs decreased significantly for all test sites during the 5 recordings, while they increased significantly between the examinations. No ratio with FRO as a reference site changed significantly. The males had significantly higher absolute PPTs than the females at PRO and FRO sites.* **Conclusion:** *This study shows that absolute PPT levels in healthy individuals change significantly during consecutive PPT recordings, as well as over a 6-month period; this limits the usefulness of such measurements. This study also shows that the use of relative PPTs with the FRO as a reference site is useful, both for comparison between groups and for longitudinal studies.*
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Key words: pain measurement, masseter muscle, pain threshold, sensory thresholds, temporal muscle, temporomandibular joint

Tenderness in the temporomandibular joint (TMJ) and masticatory muscle is a clinical manifestation in most musculoskeletal disorders in the craniofacial region. To assess the magnitude of this aspect of lowered nociceptive thresholds, digital palpation has been used to examine patients with symptoms from this region. However, it is difficult to standardize this technique and to quantify the degree of tenderness. Pressure algometry has therefore been used as a complement to other approaches and has proven useful for identifying tender points as well as for assessing treatment results.[1,2] Algometry, unlike other techniques, has the obvious advantage of triggering the same type of nociceptors as does digital palpation,[3] but it is only partly objective. Subjects tend to present higher pressure-pain thresholds (PPTs) at the first recording, and therefore these recordings should be discarded.[1,4] Differences in absolute PPT levels between genders have also been reported, along with changes in PPTs over time.[4–10]

The use of an electronic pressure algometer has been investigated in several earlier studies.[9–11] One advantage with an electronic algometer compared to a "manual" algometer is that the time lag due to the subject's reaction to the painful stimuli is minimal, while the examiner does not contribute at all. In addition, the applied pressure and pressure rate are displayed, and the pressure rate can thus be kept constant.[1,3] The reliability and validity of this device, as well as the intra- and interoperator variability regarding absolute PPT values, have been investigated and found to be acceptable.[4,10–12] To further increase the reliability of PPT recordings, earlier investigators have suggested the use of the mean value of the second and third tests.[1] Furthermore, Kosek et al[7] suggested that since the relative PPTs remain fairly constant for each individual between different locations, it could be possible to design a system with a reference site to bypass general drifts in PPTs over time. However, there are no studies available that have investigated this matter.

The aim of this study was to investigate and compare absolute PPTs and ratios between test sites and reference sites in the craniofacial region for consecutive PPT recordings and for recordings over a 6-month period in healthy individuals. In addition, the clinical usefulness of different reference sites and differences between genders regarding absolute PPT levels and ratios were investigated.

Materials and Methods

Subjects

Twelve females and 12 males participated in the first examination. The mean age of the males was 29 years (SD 10 years) and the mean age of the females was 35 years (SD 12 years). Inclusion criteria were no prior treatment of general or local joint or muscle symptoms, no current subjective symptoms from the TMJ or masticatory muscles, and no headache at either examination. At the second examination 6 months later, 9 females and all 12 males participated. All individuals in our study were students or staff associated with the clinic. The study was approved by the local Ethical Committee at Huddinge Hospital, Huddinge, Sweden (409/98).

Algometric Recording

The PPT was defined as the minimum pressure needed to evoke a recognizably painful sensation in the subjects. The PPT was assessed by an electronic pressure algometer (Somedic Production AB) consisting of a hand-held probe, a pistol grip, and a display unit. The tip of the probe has a flat, circular rubber tip with an area of 1.0 cm^2. A linearly increasing pressure (50 kPa/s) was applied; the subject reported the first sensation of pain by pressing a button on a device connected to the probe that "froze" the current PPT level on the display. The same investigator performed all algometer recordings. Since the electronic algometer presents the pressure rate used, we considered all registrations to be within acceptable pressure rate limits.

Definition of Sites

The craniofacial test and reference sites used for the PPT recordings are defined in Table 1 and shown in Fig 1.

Recording Procedure

Each subject sat in a dental chair in an upright position. The right side of the body was selected for the investigation. To minimize the error of the location of the applied pressure, the test sites were marked with a dot (Fig 1). The PPTs were then assessed in the order mental protuberance (PRO), first metacarpal bone (MET), frontal bone (FRO), temporomandibular joint (TMJ), masseter muscle (MAS), and temporalis muscle (TEM). This procedure was repeated 4 more times with an interval of 2 minutes between each site. In the subsequent analysis, the mean absolute PPT levels and PPT ratios for each subject from the second and third recordings were used and denoted as PPT_{23}.[1] To accustom the subject to the experimental situation, PPT recordings were performed 3 times at each of the TMJ, MAS, and TEM sites on the left side of the body, with an interval of 2 minutes between the recordings on each site.

Statistical Analyses

The ratio was defined as the absolute value of a test site divided by the absolute value of a reference site, eg, TMJ/FRO or MAS/PRO.

The distribution of the levels was tested for normality with the Kolmogorov-Smirnov test, and all variables showed a normal distribution. The

Table 1 Definition of Test and Reference Sites

Site	Definition
Test sites	
TMJ	Lateral pole of the temporomandibular joint condyle with the mouth closed
MAS	On the masseter muscle, one third of the way from the mandibular angle, at the sagittal center of the muscle belly
TEM	Two cm superior to the superior margin of the zygomatic arch over the temporalis muscle
Reference sites	
PRO	Five mm superior to the central part of the mental protuberance
MET	Center of the medial-superior surface on the first metacarpal bone with the palm held face down
FRO	One cm superior to glabella on the frontal bone

The algometer was applied perpendicular to the skin surface over these sites (see Fig 1).

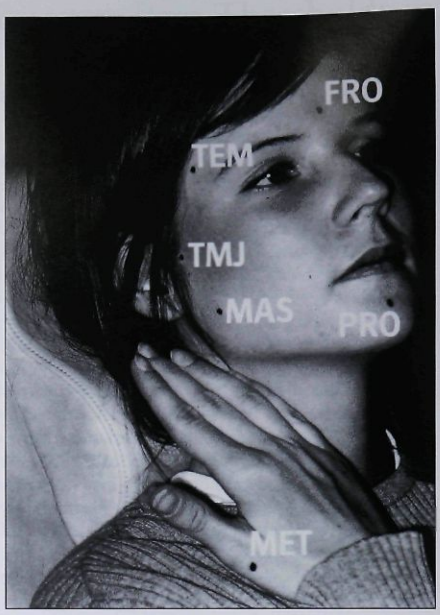

Fig 1 (*Right*) Test and reference sites used in this study. TMJ = temporomandibular joint; MAS = masseter muscle; TEM = temporalis muscle; PRO = mental protuberance; MET = first metacarpal bone; FRO = frontal bone.

significance of the change in PPT during the 5 consecutive recordings was tested with 1-way analysis of variance (ANOVA) for repeated measures, with Bonferroni's test for multiple comparisons as a post hoc test. The coefficient of variation (CV) for the second and third measurements was calculated as $SD_{23} \times 100/PPT_{23}$. The significance of the differences between genders was evaluated with Student's independent *t* test. The significance of the differences between the first and the second examinations was tested with Student's dependent *t* test. The correlation between the first and second examinations regarding the absolute PPT_{23} levels or ratios was tested with the Pearson correlation test. A significance level below 0.05 was considered significant.

Results

Changes During Consecutive Recordings

The significant differences between the first and the 4 subsequent PPT recordings regarding absolute levels and ratios are shown in Table 2. For the female subjects, all absolute PPT levels at the first recording were significantly higher than 2 or more of the subsequent recordings. In the males, the absolute PPT levels of the test sites at the first recording were significantly higher than 2 or more of the subsequent recordings for the TMJ, MAS, and TEM sites. Regarding the ratios, the first recordings showed significantly higher ratios for MAS/MET and for TEM/MET in the females and TEM/PRO in the males. The ratios with the reference site FRO did not change significantly during the 5 recordings. There were no significant differences in CV between absolute PPT_{23} and PPT_{23} ratios.

Differences Between Genders

Table 3 shows the differences in PPT_{23} between the genders. Absolute PPT levels were significantly higher in the male subjects for PRO and FRO. Regarding the ratios, the male subjects had a significantly lower TMJ/FRO ratio than the females for PPT_{23} (Table 3).

Table 2 Significant Differences* Between the First and Subsequent Measurements of Pressure-Pain Threshold to Linearly Increasing Pressure in Healthy Individuals at the First Examination

	Measurement in female subjects (n = 12)					Measurement in male subjects (n = 12)				
	2nd	3rd	4th	5th	*P*	2nd	3rd	4th	5th	*P*
Absolute values										
TMJ		•	•	•	< 0.001			•	•	< 0.001
MAS	•	•	•	•	< 0.001	•	•	•	•	< 0.001
TEM	•	•	•	•	< 0.001	•	•	•	•	< 0.001
PRO			•	•	< 0.001					0.811
MET			•	•	0.004					0.868
FRO		•	•	•	< 0.001					0.257
Ratios										
TMJ/PRO					0.508					0.402
MAS/PRO					0.324					0.085
TEM/PRO					0.072			•		0.036
TMJ/MET					0.362					0.969
MAS/MET		•	•	•	< 0.001					0.191
TEM/MET			•	•	< 0.001					0.088
TMJ/FRO					0.560					0.763
MAS/FRO					0.511					0.198
TEM/FRO					0.071					0.242

*Bonferroni multiple comparison test, • = significant difference versus first measurement.
Test sites: TMJ = temporomandibular joint; MAS = masseter muscle; TEM = temporalis muscle. Reference sites: PRO = mental protuberance; MET = first metacarpal bone; FRO = frontal bone.

Table 3 Mean Pressure-Pain Thresholds (in kPa), Standard Deviations, and Coefficient of Variation for the Second and Third Recordings and Significance of Gender Differences

	Absolute values			Ratio PRO			Ratio MET			Ratio FRO		
	PPT	SD	CV	PPT	SD	CV	PPT	SD	CV	PPT	SD	CV
Females (n = 12)												
TMJ	178	70	39	1.20	0.38	32	0.56	0.19	34	0.86	0.27	31
MAS	119	52	44	0.80	0.32	40	0.38	0.18	47	0.57	0.19	33
TEM	132	70	53	0.89	0.39	44	0.42	0.22	52	0.63	0.21	33
PRO	158	76	48									
MET	332	114	34									
FRO	216	90	42									
Males (n = 12)												
TMJ	237	105	45	1.00	0.20	20	0.50	0.16	32	0.66	0.24	36
MAS	163	81	50	0.69	0.19	28	0.36	0.11	31	0.46	0.21	46
TEM	202	113	56	0.87	0.34	39	0.41	0.11	27	0.57	0.26	46
PRO	248	125	50									
MET	520	317	61									
FRO	388	191	49									
P values												
TMJ	0.137			0.078			0.401			0.046*		
MAS	0.125			0.272			0.483			0.168		
TEM	0.082			0.936			0.859			0.557		
PRO	0.044*											
MET	0.073											
FRO	0.012*											

*Significant difference.
Test sites: TMJ = temporomandibular joint; MAS = masseter muscle; TEM = temporalis muscle. Reference sites: PRO = mental protuberance; MET = first metacarpal bone; FRO = frontal bone.

Table 4 Mean Pressure-Pain Thresholds (in kPa) and Standard Deviations for Test and Reference Sites of the Second and Third PPT Recordings at the First and Second Examinations and Significance Levels of the Differences Between Examinations

	Examination 1		Examination 2		
	Mean	SD	Mean	SD	*P*
Females (n = 9)					
Absolute PPT					
TMJ	187	71	276	93	0.036*
MAS	123	51	207	63	0.021*
TEM	136	72	223	111	0.015*
PRO	166	77	283	101	0.004*
MET	341	114	501	159	0.021*
FRO	226	92	394	130	0.003*
Ratios					
TMJ/FRO	0.888	0.280	0.747	0.157	0.057
MAS/FRO	0.561	0.158	0.576	0.174	0.777
TEM/FRO	0.618	0.142	0.570	0.182	0.422
Males (n = 12)					
Absolute PPT					
TMJ	237	105	325	65	0.017*
MAS	163	81	272	137	0.020*
TEM	202	113	297	133	0.027*
PRO	248	125	358	114	0.011*
MET	520	317	756	223	0.016*
FRO	388	191	638	319	0.015*
Ratios					
TMJ/FRO	0.656	0.239	0.573	0.178	0.256
MAS/FRO	0.458	0.208	0.463	0.212	0.943
TEM/FRO	0.573	0.261	0.514	0.210	0.524

*Significant difference.
Test sites: TMJ = temporomandibular joint; MAS = masseter muscle; TEM = temporalis muscle. Reference sites: PRO = mental protuberance; MET = first metacarpal bone; FRO = frontal bone.

Variation over a 6-Month Period

Table 4 shows the absolute PPT_{23} levels, as well as the corresponding ratios with FRO as the reference site for the first and second examinations. All absolute PPT_{23} values were significantly higher at the second examination than at the first for both females. No ratio changed significantly between the 2 examinations.

There were no significant correlations between the first and second examinations for the absolute PPT_{23} levels or ratios.

Discussion

This study shows that absolute PPT levels decrease during 5 consecutive recordings but increase over a 6-month period in the craniofacial region of healthy individuals. In addition, a ratio with FRO as a reference site seems to be the most useful for assessment of PPT levels at the TMJ, MAS, and TEM sites. This ratio does not change significantly over a 6-month period.

During the 5 consecutive recordings, the absolute PPT levels decreased in a similar manner for both genders and for the different sites. The absolute PPT levels of the first recording were significantly higher than most subsequent recordings with respect to the test sites in both genders, which indicates that the value from the first recording should be discarded. This is supported by the findings of Nussbaum and Downes,[1] who found that the mean of the second and third recordings proved the most reliable; it therefore was used in this study.

Kosek et al[7] found differences in PPT levels between different body regions; also, PPT levels were increased 9 to 12 weeks after the first recording. On the other hand, relative PPT levels over different locations seemed to remain fairly constant. Kosek et al therefore suggested the use of relative PPT levels to bypass drifts over time.[7] This was the reason for the present investigation of PPT ratios, ie, a ratio between absolute levels for a test and a reference site.

Several factors should be considered when choosing a reference site. The site should be easily accessible for PPT recording and located in an anatomic region seldom affected by musculoskeletal disorders. In addition, the soft tissue thickness below the skin surface should be as small as possible and comprise minimal muscle tissue volume to minimize muscle pain as a response to the pressure.

The 3 investigated reference sites are all easily accessible and they have thin soft tissue above the periosteum, with only a thin muscle tissue layer (if any). The FRO and PRO sites are located in areas seldom affected by musculoskeletal disorders, but pressure on the PRO site can indirectly elicit pain sensations from the TMJ site, since it may cause mechanical loading of the TMJ. The PPTs at the FRO reference site did not change significantly during the 5 recordings, and the FRO site thus satisfies all criteria mentioned above for a reference site. Vatine et al[3] suggested that the use of bony areas for assessment of pain will improve reliability, since bony areas permit placement of the algometer on a well-defined area, thus preventing interference arising from the movement of soft tissue. In particular, this may occur with PPT recordings over muscles. This further strengthens the suggestion that the FRO site is a useful reference site.

There is some evidence that masticatory muscle activity may play a role in some tension-type headaches,[13] and it has been suggested that patients with tension-type headache have a generalized decrease in PPTs.[14] However, other studies have found no difference between patients with tension-type headache and healthy individuals regarding PPTs.[15] The PPT ratio, however, is not affected by a general change in PPTs, which is a major advantage. Since the absolute levels of the test sites, but not the ratios with the FRO reference site, decreased significantly during consecutive recordings, the use of a ratio with FRO as reference site seems to be the most appropriate. In addition, there was no significant difference regarding the reliability between the absolute values and the ratios, indicating that the ratios have at least as high a reliability as the absolute levels, which in several studies have been found to be very high.[10,11,16]

The significantly higher absolute PPT in males than in females observed in this study for 2 of the sites is in agreement with earlier investigations.[5,6,10,17] The ratios differed less than the absolute levels between genders, but there was a significant difference with respect to TMJ/FRO. Female and male subjects should thus be compared with caution regarding absolute levels and ratios, and future studies including assessment of PPTs should therefore consider separate investigations of the genders.

The differences in absolute PPTs between the first and second examinations were remarkably large; the absolute PPT levels were 36% to 74% higher at the second visit than at the first visit. In addition, there were no significant correlations between the absolute PPT levels at the first and the second examinations, which indicates a random rather than a systematic variation. These findings show that there is an increase in average absolute PPTs in healthy individuals upon consecutive PPT recordings, but also that there are large individual variations in PPT between 2 occasions. Kosek et al[7] reported that absolute PPT levels increased approximately 20% during a 9- to 12-week interval. In our study, all PPT recordings were performed by 1 investigator at both examinations and with the same algometer and pressure rate. The algometer was calibrated before each examination. The importance of the pressure rate on the absolute PPT levels has been investigated in earlier studies, and higher pressure rates cause higher PPT levels.[18] The algometer used in our study displays the pressure rate used, which increases the accuracy and reproducibility of the measurement. It is therefore unlikely that the differences in PPT over time in this study are a result of differences in pressure rates or recording procedures. In addition, since there were no significant correlations between the first and second examinations regarding absolute PPT levels or ratios, systematic errors are unlikely. The increase in absolute PPTs could, however, be due to individual variation or the possibility that the subjects became accustomed to the PPT measurement. It could also be a result of failure of exact relocation of the pressure probe at the second examination 6 months later, the fact that the recordings were made during different seasons, or perhaps also differing stress levels at the 2 examinations. However, although these and other unknown factors result in a large PPT variation between individuals and over time, the findings in our study were statistically significant and thus justify the use of ratios.

The ratios did not change significantly between the first and second examinations. Considering the fact that the absolute PPT levels did change, our study indicates that the use of a PPT ratio is a rational alternative to the use of absolute PPT levels. This applies both to comparison between groups as well as within groups in cross-sectional or longitudinal studies, eg, evaluation of treatment effects.

This study shows that absolute PPT levels change significantly during consecutive recordings and over a 6-month period in healthy individuals. Although these findings limit their usefulness, this study also shows that relative PPT levels with the FRO as a reference site are clinically useful, both for comparison between groups as well as for cross-sectional or longitudinal studies.

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