Short-Term Reproducibility of Pressure Pain Thresholds in Masticatory Muscles Measured with a New Algometer

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The purpose of this project was to test the within-day and between-days reproducibility of a new and inexpensive algometer. Twelve symptom-free men and nine women participated. Pressure pain thresholds (PPTs) of the bilateral masseter and temporalis muscles were assessed during four sessions (mornings and afternoons of days 1 and 3). During each session, each palpation point of the masticatory muscles was measured four times. There was an interval of only a few seconds between measurements 1 and 2, and between measurements 3 and 4, respectively, while at least 5 minutes of rest were allowed between measurements 2 and 3. The PPT values between the morning and afternoon sessions and between days 1 and 3 were not significantly different. When the within-session reproducibility for all muscles was considered, only the PPT values between measurements 2 and 4 were not significantly different. Analysis of variance showed that the interindividual variability of PPT was 1.4 to 6.8 times higher than the variability observed within or between sessions and days. No gender difference was found.

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In patients who suffer from a temporomandibular disorder, masticatory muscle pain is a frequent symptom.[1] Tenderness upon muscle palpation, which indicates a decreased pressure pain threshold (PPT), is a common clinical sign in myofascial pain.[2] Pressure algometers enable the quantification of local muscle tenderness in patients with musculoskeletal disorders[3,4] and in asymptomatic subjects.[5]

In the investigation of PPTs many different algometers have been used. Most investigators have used commercial devices based on the mechanical spring-load principle or more expensive electronic instruments that incorporate strain gauges, while other authors have developed custom-made instruments.[4–6] Electronically driven instruments have been employed in laboratory settings, but they do not appear to be more precise than hand-held algometers, which are more suitable for clinical practice.[7]

The reliability of PPT measurements can be affected by several factors. To apply the pressure with a uniform rate, constant visual feedback must be given to the investigator.[8] In masticatory muscles, only more recent studies have been performed in such a controlled way.[4–7,9,10] Anatomic location should also be standardized to

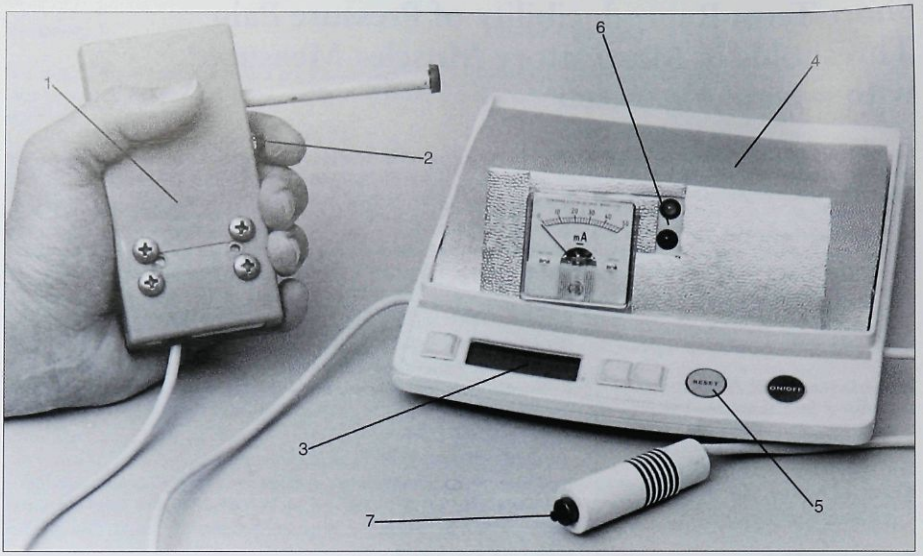

Fig 1 Pressure algometer: the hand-held stimulator (1) with reset button (2) covers the bar with the strain gauge; the readout apparatus consists of a display for the applied pressure (3), the amplifier with battery (4), and a reset button (5); the rate of the applied pressure is given with a rate control signal (6); and the investigated subject presses the button (7) when the PPT is reached.

achieve reliable data.[11] The degree of muscle contraction can also significantly affect PPT.[6,7] The quality of the instructions given to the participants is therefore important.[12] The elimination of investigator reaction time by the use of a push button was reported to increase the validity of the repeated PPT measurements, but not their reliability.[7]

A recent study[13] that used finger pressure palpation reported reasonable reliability at specific sites, provided that methodologic issues were properly addressed and the procedure was well-controlled. In spite of this finding, several studies[7,12,14] have suggested that pressure algometers should be used for reliable diagnostic procedures and valid clinical assessment.

Unfortunately, the commercially available pressure algometers that provide constant visual feedback of the rate of applied pressure are very expensive. Therefore, a low-cost algometer that incorporates these features would be a valuable adjunct in clinical practice. The present study used and calibrated a self-developed and inexpensive algometer. To test the clinical performance of the algometer, the short-term reproducibility of PPT measurements was evaluated; a study design similar to that used in an earlier report was used.[15] The rationale was that if the stability of the PPT over a short time period could be shown to be comparable to that of previous studies, this algometer would be of clinical use. More information could also be gained about the importance of the interstimulus time interval with regard to the problem of sensitization of the palpation sites.

Good between-session reproducibility has been reported over periods of 1 to several weeks.[5,9] However, in longitudinal studies on temporomandibular disorders, the time of the measurement (morning or afternoon) may be important. The present study also aimed to investigate the possible influence of the time of day on PPT measurements.

Materials and Methods

The algometer consisted of a stimulator and a readout unit (Figs 1 and 2). Most of the elements for

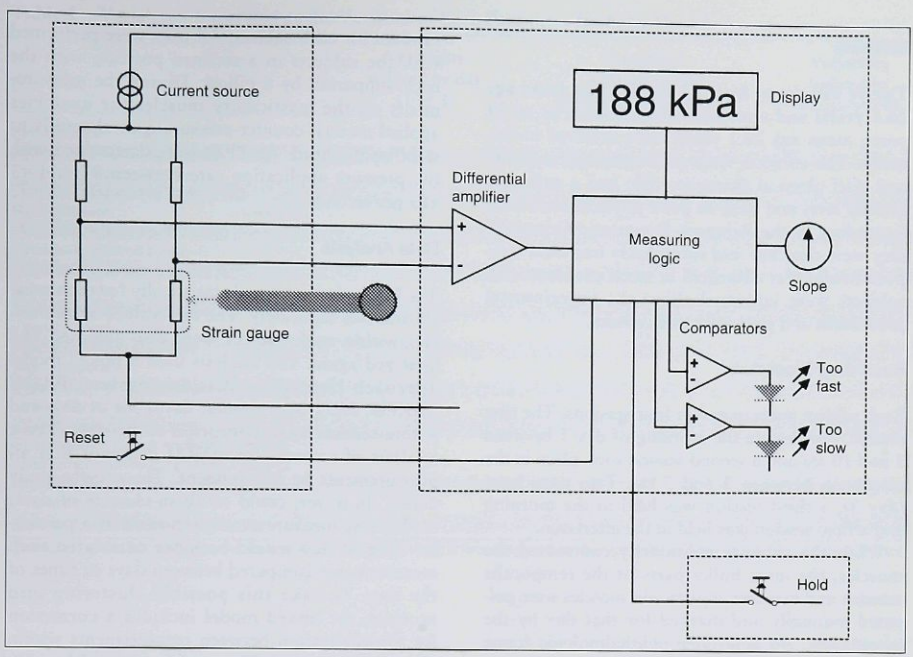

Fig 2 Schematic drawing of the algometer components and the electrical connections.

construction can be found in an electronic kitchen scale, but they were also available commercially. The stimulator was a metal rod perpendicularly attached to a bar with a strain gauge, which was covered by a plastic holder. When pressure was applied, the bar activated the strain gauge that was electrically coupled to the readout unit. Before the examiner applied any pressure, a button on the stimulator had to be pressed to reset the display to zero. To avoid damage to the skin, the tip of the probe was covered with semi-hard rubber 11 mm in diameter.

The readout apparatus was a commercially available unit with a battery, an electronic display, and a suitable amplifier for the strain gauge. The existing display of the electronic kitchen scale was perfectly suitable. When the investigated subject pressed a button, the amount of the applied pressure was permanently displayed.

Calibrating weights that were placed on the recording tip were used for linearity testing and calibration. The algometer was calibrated to a range of 0 to 5 kg. A linear relationship (Pearson's correlation coefficient $r = 1.00$) between the displayed results and the applied force was found over the operational range.

For convenience, resistors that converted the output directly into kPa (range = 0 to 1500 kPa) were built into the algometer. A daily control of the apparatus was performed: a Somedic calibrating weight with an equivalence of 100 kPa (Somedic) was applied to the recording tip to give display values of 100 kPa ± 2%. The rate of pressure application could be controlled with an electrical detecting unit that was connected parallel to the strain gauge. In the literature,[9,10,16] reliable measurements are most often reported with the use of a pressure rate of 30, 40, or 50 kPa per second. In the present study the rate of the applied pressure was between 37 and 43 kPa per second. A visual signal was given to the investigator if these values were exceeded. The total cost of the instrument was less than US $100.

Subjects

Twelve men (aged from 22 to 36 years; mean age 26.6 years) and nine women (aged from 21 to 34 years; mean age 24.1 years) were involved in this study. The subjects were physiotherapy students and staff physical therapists who had a sufficient activity level and were in good physical condition. According to the Research Diagnostic Criteria,[17] they were clinically and subjectively free from temporomandibular disorders or neck problems. All subjects were informed about the experimental procedures and gave informed consent.

Recording Procedure

Each subject participated in four sessions. The first session was held in the morning of day 1 between 8 and 10 AM and a second session took place in the afternoon between 3 and 5 PM. Two days later (day 3), a third session was held in the morning and a final session was held in the afternoon.

While the subjects voluntarily contracted the muscles, the most bulky parts of the temporalis anterior and masseter superficialis muscles were palpated manually and marked for that day by the investigator. An adjustable ophthalmologic frame was fixed on the nose and the ears. A translucent, malleable plastic template with coordinate lines was fixed to the frame and applied to the skin. Each muscle site had three coordinates in reference to the frame, the nose, and the ear. These coordinates were used to relocate the palpation sites on day 3.

After the muscle sites were marked there was a relaxation period of approximately 5 minutes. Standard instructions were then given to the subjects: "A pressure will be applied to the skin with a constant rate. At the point at which the sensation of pressure changes to a sensation of pain, you have to press the button." The definition of "threshold" was repeated to avoid confusion with "tolerance." Subjects were instructed to relax their masticatory muscles, and the test procedure was demonstrated on the right forearm.

The PPTs of the muscle sites were measured in the following sequence with intervals of a few seconds between sites: right temporalis, right masseter, left thumb, right masseter, right temporalis, left temporalis, left masseter, right thumb, left masseter, and left temporalis. After an interval of 5 minutes the entire procedure was repeated. This process resulted in four measurements for each masticatory muscle point per session. The choice to start with the right or left side was made at random for each subject. All tests were performed with the subjects in a reclined position with the neck supported by a pillow. During the measurements on the masticatory muscles the examiner applied manual counter-pressure contralaterally to stabilize the head. All PPTs were determined with the pressure application rate between 37 and 43 kPa per second.

Data Analysis

The PPTs were analyzed statistically for each muscle and side separately. The PPT values of all muscles within each subject were also summed and analyzed again. The analysis used a mixed model approach (Statistical Analysis System, PROC MIXED, SAS), with gender, day, time of day, and within-session measurements as covariates. Classic analysis of variance (ANOVA) demands that all measurements be independent. The present study design, however, could result in clusters of data; in this case measurements performed at a particular time of day would be more correlated than measurements compared between days or times of the day. To take this possible clustering into account, the mixed model includes a correction for the correlation between measurements within the same individual. The model corrected for subject variability and allowed the effect of day and time of day to be subject-dependent. The variability of each parameter was compared to the measurement error.

Results

Analysis of variance showed that the variability of the PPT values induced by the day or the time of day was less important than the variability of the measurement itself. The interindividual variability of PPT was 1.4 to 6.8 times higher than the variability observed between measurements, sessions, or days (Table 1). No statistical difference with respect to gender was observed for any of the muscles ($P > 0.541$). Table 2 shows the P values for the other confounding factors: day, time of day, and within-session measurements.

For each palpation site, the first PPT of a session was significantly higher than the second one of the same session ($P = 0.0001$). Similarly, the third PPT was always significantly higher than the fourth one ($P = 0.0001$ to 0.008). For both the masseter and temporalis muscles the second measurement was significantly different from the

Table 1 Variability Expressed as the Variance of Each Parameter for Each Muscle

	Variability induced by day (1 or 3)	Variability induced by time (morning or afternoon)	Variability induced by measurement
Left masseter			
Variability induced by subject	6.8		
Variability induced by day		0.9	
Variability induced by time			0.6
Right masseter			
Variability induced by subject	1.4		
Variability induced by day		6.0	
Variability induced by time			0.2
Left temporalis			
Variability induced by subject	6.7		
Variability induced by day		2.0	
Variability induced by time			0.4
Right temporalis			
Variability induced by subject	3.3		
Variability induced by day		–	
Variability induced by time			0.9
Summation of the left and right masseter and temporalis muscles within a subject			
Variability induced by subject	4.8		
Variability induced by day		3.4	
Variability induced by time			0.5

Example: for the left masseter the interindividual variability was 6.8 times higher than the variability induced by the day of measurement.

Table 2 *P* Values of Confounding Factors: Day, Time of Day, and Within-Session Measurements

	Left masseter	Right masseter	Left temporalis	Right temporalis	Summation	Left thumb	Right thumb
Day	0.5127	0.4611	0.9608	0.7514	0.5759	0.7903	0.0800
Time	0.1497	0.7776	0.3677	0.0585	0.7848	0.7273	0.5242
1 vs 2	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*	0.0293*	0.0469*
1 vs 3	0.5278	0.0223*	0.5334	0.0034*	0.0036*		
1 vs 4	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*		
2 vs 3	0.0001*	0.0002*	0.0001*	0.0373*	0.0001*		
2 vs 4	0.2454	0.2712	0.9468	0.5698	0.5580		
3 vs 4	0.0005*	0.0074*	0.0001*	0.0082*	0.0001*		

*P = 0.05 was considered significant.
Summation = summation of PPT values of the left and right masseter and temporalis muscles within a subject.
1 = first palpation of a given muscle in each session; 2 = second palpation; 3 = third palpation, 5 minutes after 2; 4 = final palpation.

third measurement (see Table 2). No significant differences were found between measurements 2 and 4. The first PPT of the thumb eminence was significantly higher than the second one (P = 0.029). When the values for the masseter and temporalis muscles were summed within one subject, only the differences between the second and the fourth measurements were not significantly different. The differences between the morning and afternoon sessions and the days of measurement were not significant for either the individual muscles or the summed PPTs within a subject.

Discussion

This project was undertaken to evaluate the short-term reproducibility of PPTs in healthy subjects. In contrast to our previous report,[15] which used a commercially available unit (Somedic), the present experiments tested a new inexpensive algometer that was developed by the authors. The reproducibility of the measurements was comparable between the custom-made and commercially available algometers. In both studies the variability induced by the day or the time of day was less important than the variability of the measurement itself. Even taking into account the low power of the present study, this minimizes the importance of the time of the measurement in healthy subjects. No information about within-day fluctuation of PPTs in patients is presently available. The high interindividual variability in the present study is consistent with previous reports.[8,15]

When the within-session variability was considered, the first and third PPTs of a session were significantly higher than the second and last (fourth), respectively. For a given muscle the rest interval between the first and second measurements and between the third and the fourth measurements was less than 1 minute. The within-session variability can therefore be explained by sensitization of the tissues caused by the short interval between the consecutive measurements. The second and fourth measurements of the same muscle site were not significantly different ($P = 0.2454$). The rest interval in the present study was at least 5 minutes. The current findings are in accordance with the results of Ohrbach and Gale,[5] where no measurement effects were found between trials with a 4- to 5-minute interval. The finding that the first PPT in the present study was always higher than the successive measurements is a noteworthy factor to be taken into account for further studies. The first PPT assessment has been shown to be highly variable.[18] It has also been reported that the mean of the first two measurements is a better estimate of PPT than one measurement alone.[5] For future studies we suggest a longer interval between consecutive measurements, or the elimination of the first PPT. With the second method the score would be defined as the mean of the remaining successive measurements. This procedure would both prevent the variability of the first measurement (possibly caused by an arousal reaction of the subject upon the first presentation of a new and potentially painful stimulus), and avoid sensitization of the tissues beneath the palpation site, which could influence accurate measurements.

The lack of gender differences reported here is consistent with previous reports that have used the same measurement methods in masticatory muscles.[4,8,15] However, the number of subjects in the present study is too small to draw conclusions in this respect.

The finding that intersubject variability is significantly more important than small diurnal or between-day differences strongly favors a longitudinal within-subject design for future studies. The inexpensive custom-made algometer yielded clinical performance results that were comparable to those of commercially available units.

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Resumen

Reproductibilidad a Corto Plazo de los Umbrales de Dolor a la Presión en los Músculos Masticatorios Medidos con un Nuevo Algómetro

El propósito de este proyecto fue el de probar la reproductibilidad dentro del día y entre los días, de un algómetro nuevo y de bajo costo. En este estudio participaron 12 hombres y 9 mujeres asintomáticos. Se evaluaron los umbrales del dolor a la presión (UDP) de los músculos maseteros y temporales bilaterales, durante cuatro sesiones (mañanas y tardes de los días 1 y 3). Durante cada sesión, cada punto de palpación de los músculos masticatorios fue medido cuatro veces. Sólo hubo un intervalo de unos pocos segundos entre las medidas 1 y 2, y entre las medidas 3 y 4, respectivamente, mientras que se permitieron al menos 5 minutos de descanso entre las medidas 2 y 3. Los UDP entre las sesiones de las mañanas y las tardes y entre los días 1 y 3 no fueron significativamente diferentes. Cuando se consideró la reproductibilidad dentro de las sesiones en todos los músculos, sólo los valores de los UDP entre las medidas 2 y 4 no fueron significativamente diferentes. El análisis de varianza demonstró que la variabilidad entre los individuos de los UDP resultó ser 1,4 a 6,8 veces mayor que la variabilidad observada dentro o entre las sesiones y días. No se encontraron diferencias entre los géneros.

Zusammenfassung

Kurzzeitige Reproduzierbarkeit der Druckschmerzschwellen in den Kamuskeln, Gemessen mit Einem Neuen Algometer

Das Ziel dieses Projektes war es, die Reproduzierbarkeit eines neuen und preiswerten Algometers innerhalb eines Tages und zwischen mehreren Tagen zu testen. Zwölf symptomfreie Männer und neun Frauen nahmen teil. Die Druckschrnerzschwellen (PPTs) der Mm masseteri und temporales auf beiden Seiten wurden während vier Sitzungen (morgens und nachmittags an den Tagen 1 und 3) beurteilt. Während jeder Sitzung wurde jeder Palpationspunkt der Kaumuskeln viermal gemessen. Zwischen den Messungen 1 und 2 war ein Intervall von nur wenigen Sekunden, ebenso zwischen den Messungen 3 und 4, während zwischen den Messungen 2 und 3 eine Pause von wenigstens 5 Minuten erlaubt war. Die PPT-Werte zwischen den morgentlichen und nachmittäglichen Sitzungen sowie zwischen den Tagen 1 und 3 waren nicht signifikant verschieden. Wenn die Reproduzierbarkeit innerhalb einer Sitzung für alle Muskeln betrachtet wurde, waren nur die PPT-Werte zwischen den Messungen 2 und 4 nicht signifikant verschieden. Die Varianzanalyse zeigte, dass die interindividuelle Variabilität der PPTs 1.4 bis 6.8 mal höher war als die Variabilität, welche innerhalb oder zwischen den Sitzungen und Tagen beobachtet wurde. Es wurden keine Unterschiede im Bezug auf das Geschlecht gefunden.