Masticatory muscle pain: Causes, consequences, and diagnosis

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Chapter 2

Effects of intense chewing exercises on the masticatory sensory-motor system

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ABSTRACT
Nociceptive substances, injected into the masseter muscle, induce pain and facilitate the jaw-stretch reflex. It is hypothesized that intense chewing would provoke similar effects. Fourteen men performed 20 bouts of 5-minutes chewing. After each bout, 20 minutes and 24 hrs after the exercise, muscle fatigue and pain scores and the normalized reflex amplitude from the left masseter muscle were recorded. Before, 20 min, and 24 hrs after the exercise, signs of temporomandibular disorders and pressure pain thresholds of the masticatory muscles were also recorded. Fatigue and pain scores had increased during the exercise ($P<0.001$), but the reflex amplitude did not ($P=0.123$). Twenty minutes after the exercises, 12 participants showed signs of myofascial pain or arthralgia. Pressure-pain thresholds were decreased after 20 min ($P=0.009$) and 24 hrs ($P=0.049$). Intense chewing can induce fatigue, pain, and decreased pressure-pain thresholds in the masticatory muscles, without concomitant changes in the jaw-stretch reflex.

Key words: jaw-stretch reflex, chewing exercises, fatigue, pain

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INTRODUCTION

Chewing is an oral function that is of vital importance for the biological and social life of human beings. As a prerequisite for this function, a healthy masticatory system, characterized by the absence of pain at rest and during functional movements of the mandible, is required. Pain, in contrast, may influence the characteristics of the masticatory sensory-motor system (Svensson and Graven-Nielsen, 2001, Lobbezoo *et al.*, 2006).

Study to the jaw-stretch reflex can provide insight into the characteristics of the masticatory motor system (i.e., sensitivity of the motor neurons and muscle spindles). Studies have demonstrated that nociceptive substances such as hypertonic saline, glutamate, and capsaicin, injected into the masticatory muscles, can modulate the amplitude of this reflex (Wang *et al.*, 2000, 2002, 2004; Svensson *et al.*, 2001a, 2003; Cairns *et al.*, 2003; van Selms *et al.*, 2005). However, the characteristics of muscle pain, reported by persons with myofascial temporomandibular disorders (TMD), are probably more similar to those of exercise-induced muscle pain than to those of acute, short lasting pain evoked by exogenous pain provocation techniques (Stohler, 1999; Svensson and Graven-Nielsen, 2001). Therefore, the aim of this study was to investigate the effects of exercise-induced muscle fatigue and pain upon sensory-motor aspects of the masticatory system. Sensory aspects were assessed by analysis of the visual analog scale (VAS) scores for muscle pain and fatigue, by determination of the muscles' pressure-pain threshold, and by assessment of the muscle pain according to the research diagnostic criteria for TMD (RDC/TMD). Motor aspects were assessed by analysis of the amplitude of the jaw-stretch reflex.

MATERIALS & METHODS

Participants

Fourteen men (age, mean ± SD = 24.4 ± 2.8 years), free of dental pathologies, or TMDs (Dworkin and LeResche, 1992), participated in the study. Individuals, who chewed gum regularly (i.e., more than 30 min a day), or who reported sleep or wake bruxism were excluded. Before the start of the experiment, participants signed a written informed consent. The study was conducted in accordance with the Helsinki Declaration and was approved by the local Ethics Committee (20040074).

Study design

Participants underwent 20 consecutive bouts of 5-minute chewing exercise. During each chewing bout, subjects chewed on 7 pieces (7 x 1.4 gr = 9.8 gr) of hard chewing gum (ELMA®, Mastiha, Chios, Greece), at a speed of 1.5 times their individual chewing pace (van Selms *et al.*, 2005). After each chewing bout, the VAS scores of fatigue and pain intensity, and the normalized peak-to-peak amplitude of the jaw-stretch reflex were recorded. The same data were also collected 20 min and 24 hrs after the end of the last chewing bout. Before the start of the experiment, and 20 min and 24 hrs afterwards, participants also underwent a clinical examination according to the RDC/TMD, and pressure pain thresholds of the left (LM) and right (RM) masseters and the left (LAT) and right (RAT) anterior temporalis muscles were determined.

Fatigue and pain intensity

Fatigue and pain intensity in the jaw muscles were recorded on two, 100-mm VASs, with left anchor words “No fatigue at all” and “No pain at all”, and right anchor words “Fatigue as worse as it could be” and “Pain as worse as it could be”, respectively.

Jaw-stretch reflex recordings

Jaw-stretch reflexes were evoked by jaw displacements of 1 mm with a ramp time of 10 ms, using a muscle stretcher as described previously (Miles *et al.*, 1993). The initial jaw gape, determined by the distance between the upper and lower jaw bars, was 4 mm.

Electromyographic activity of the left masseter muscle was recorded with bipolar surface electrodes (4 x 7 mm recording area, 720-01-k, Neuroline, Medicotest, Ølstykke, Denmark). Electrodes were placed 10 mm apart, parallel to the main direction of the muscles fibres over the palpated belly of the muscle, after skin preparation with alcohol. A ground electrode, soaked with saline, was attached to the right wrist. To ensure that the electrodes were placed accurately at the same sites at the 24-hour-recovery appointment, we made a lateral drawing of the head on transparent plastic foil. The electromyographic signal was amplified (200 to 5000 times), filtered (bandwidth 20 Hz to 1 kHz), sampled (4 kHz), and stored for offline analysis.

During the recordings of the reflexes, the subjects were seated upright in front of the muscle stretcher, while biting with their incisors on 2 jaw bars. They contracted their muscles at a clenching level of about 15% of the pre-fatigued maximum electromyographic activity of the left masseter muscle. The pre-fatigued maximum activity was determined before the start of the exercises, by three, 5-second maximal clenches performed with the central incisors on the bars of the jaw-stretcher. The mean electromyographic value of the three clenches was taken as the pre-fatigued maximum electromyographic activity (van Selms *et al.*, 2005).

After each chewing bout, 20 jaw-stretch reflexes were evoked. For each stimulus, 300 ms of peri-stimulus electromyographic activity was recorded, with 100 ms pre-stimulus and 200 ms post-stimulus. The 100 ms electromyographic signal preceding each stimulus was full-wave rectified, and its averaged value was calculated. The mean of these 20 average electromyographic values was considered the mean pre-stimulus electromyographic activity. The electromyographic signals following each stimulus were averaged over the 20 sweeps and the jaw-stretch reflex appeared as a biphasic potential in this average sweep. The amplitude of the reflex was the peak-to-peak value of this biphasic potential. Subsequently, the reflex amplitude was normalized with respect to the mean pre-stimulus electromyographic activity.

Pressure-Pain Threshold values

Pressure-pain threshold is defined as the amount of pressure (kPa) which the participants first perceived as painful (Svensson *et al.*, 1995). We used an electronic pressure algometer with an algometer probe diameter of 1 cm (Somedic AB, Farsta, Sweden) to assess the muscle's pressure-pain threshold. At each occasion, four pressure pain threshold recordings *per* muscle were made at a constant application rate of 30 kPa/s. The mean values of the last 3 recordings were used in the subsequent analysis (Isselee *et al.*, 1998). For determination of the site for the pressure application, participants were asked to clench and relax several times, and the area of greatest bulge of the muscle was marked on the same plastic transparent foil used for the electrodes.

Statistical analysis

During the chewing exercise, changes in the VAS scores of muscle fatigue and pain, and in the normalized jaw-stretch reflex amplitude, were analyzed by the cumulative sum (CUSUM) technique (Ellaway, 1978). CUSUM is calculated according to the equation:

$$CUSUM_i = \sum_{j=1}^{j=20} (VAR_{i,j} - k_i)$$

where the subscript 'i' denotes subject 'i', k_i indicates the pre-exercise value of the variable 'VAR', and '$VAR_{i,j}$' corresponds to the variable value of subject 'i' at time 'j'. One-sample t-tests assessed whether the CUSUM values immediately after the chewing exercise differed from zero.

The VAS scores and reflex data collected before, and 20 min and 24 hrs after the exercise were analyzed with ANOVA for repeated measures, with time as a within-subjects factor with 3 levels (Before, After 20 min, After 24 hrs). Pressure-pain threshold values were also analyzed by ANOVA for repeated measures, with as additional within-participant factor "muscle", consisting of 4 levels (LM, RM, LAT, and RAT). When sphericity was violated, conservative Greenhouse-Geisser corrected values of the degree of freedom were used (Mauchly, 1940; Greenhouse and Geisser, 1959). Pairwise comparisons were performed using Dunn-Sidak *post hoc* correction for multiple comparisons.

The level of statistically significant difference was set at $\alpha = 0.05$. All analyses were performed with SPSS software, version 12.0.1.

Table 1. Individual Cumulative Sum (CUSUM) values at the end of the chewing exercise for the VAS scores of fatigue and pain, and for the normalized reflex amplitude. (the p-values indicate whether the CUSUM values were significantly different from zero) (N=14)

	Cumulative Sum (CUSUM) values		
Participant No	VAS Scores of Fatigue	VAS Scores of Pain	Normalized reflex amplitude
1	804	466	-5.6
2	1342	240	-10.1
3	553	420	135.3
4	334	0	-126.8
5	1188	189	76.2
6	60	5	195.6
7	596	4	101.6
8	1234	772	-17.2
9	1088	0	-79.2
10	674	573	-6.9
11	245	36	153.9
12	658	375	30
13	1029	392	26.4
14	1382	588	47.9
Mean value ± SD	799 ± 422.3 (P < 0.001)	290 ± 259.5 (P < 0.001)	39.3 ± 89.4 (P = 0.123)

Table 2. Mean value and standard deviation of the visual analogue scales (VAS) scores of fatigue and pain, and of the normalized reflex amplitude, recorded before the start of the chewing exercises (Before), 20 min after the end of chewing (After 20 min) and 24 hrs after the end of chewing (After 24 hrs). (N=13)

	Before	After 20 Min	After 24 Hrs	ANOVA
VAS scores of fatigue	1.4 ± 2.3	26.8 ± 22.5	4.8 ± 9.5	F = 11.0; P = 0.004
VAS scores of pain	1 ± 2.3	4.9 ± 8.9	0.3 ± 1.1	F = 3.2; P = 0.1
Normalized reflex amplitude	19.9 ± 11.3	21.8 ± 13	19.3 ± 10	F = 0.6; P = 0.5

RESULTS

Twelve participants completed the entire exercise of 20 chewing bouts. One participant was already exhausted after the 16th chewing bout, and one participant after the 18th chewing bout. One person did not participate in the 24-hours-recovery measurements, and his data were excluded from the analysis of the recovery data.

Provocation

The mean chewing pace for the participants was 106 cycles/min. During the chewing exercise, the mean VAS scores for fatigue and pain gradually increased. Their CUSUM values at the end of the exercise were significantly different from zero (P<0.001) (Fig. 1, Table 1). The normalized reflex amplitudes showed no tendency to change during the chewing exercise (Table 1, P=0.123).

Recovery

ANOVA for repeated measures showed a significant effect of the factor time on the VAS scores of fatigue, but not on the VAS scores of pain or on the normalized reflex amplitude (Table 2). *Post hoc* analysis showed that 20 min after the last chewing bout, the VAS scores of fatigue were significantly different from those before the start of the experiment (P = 0.004), while after 24 hrs, no difference was found (P = 0.5).

The pressure-pain threshold values showed no difference between the muscles studied (F = 1.077, P = 0.354), but there was a significant influence of the factor time (F = 7.934, P = 0.002). *Post hoc* analysis showed significant differences between the baseline pressure pain threshold values and the values 20 min (P = 0.009) and 24 hrs (P = 0.049) after the exercise (Fig. 2).

The RDC/TMD examination, performed after the chewing exercise, revealed the clinical characteristics of a myofascial pain without limited mouth opening in 11 participants; one of them still had these characteristics 24 hrs later. The characteristics of myofascial pain with limited mouth-opening and of arthralgia in both the temporomandibular joints were observed in another participant, also 24 hrs after the exercise. The two participants who reported pain after 24 hrs were also contacted one day later, and reported no longer experiencing pain or fatigue.

a.

b.

c.

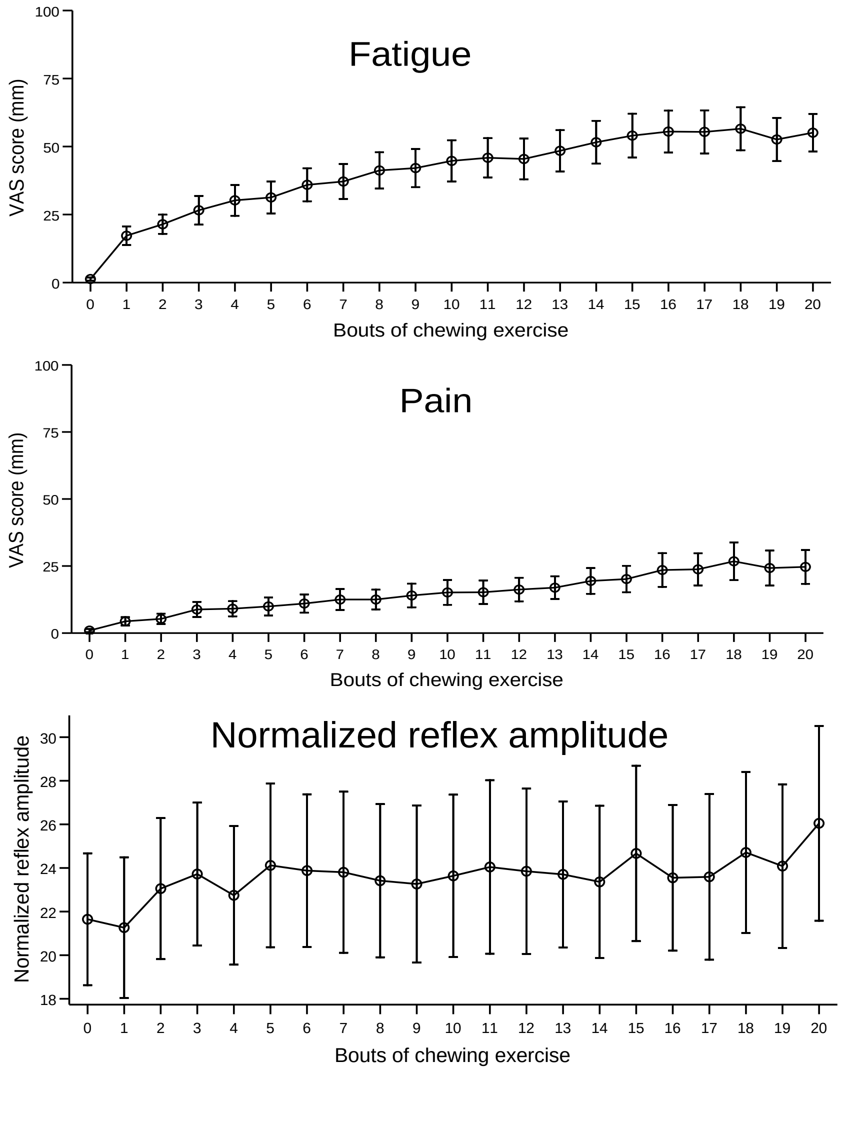

Figure 1. Mean value and standard deviation of the fatigue visual analogue scales (VAS) scores (**a**), the pain VAS scores (**b**) and the normalized jaw-stretch reflex amplitude (**c**), recorded before and during the protocol of 20 bouts of chewing (n=14).

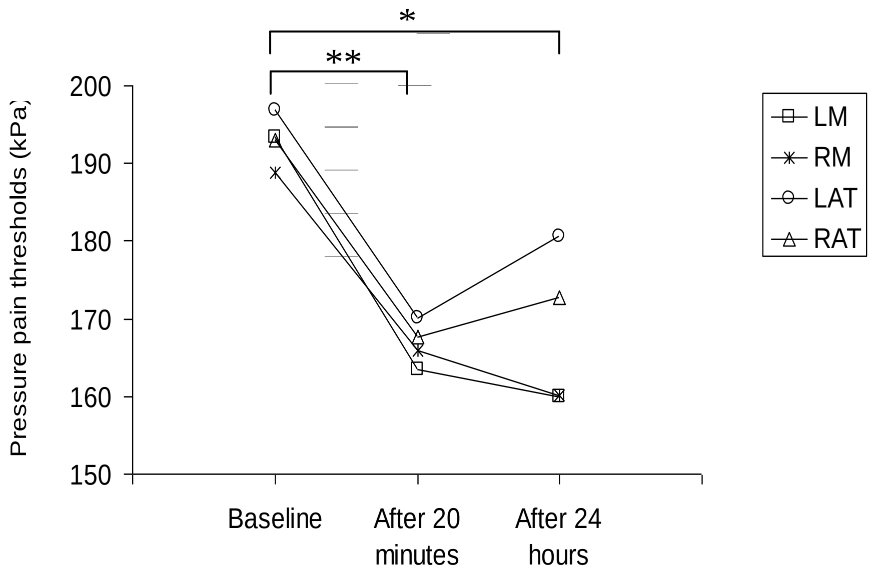

Figure 2. Pressure pain threshold values of the left masseter (LM), right masseter (RM), left anterior temporalis (LAT) and right anterior temporalis (RAT), recorded before, 20 min after, and 24 hrs after the chewing experiment (*: P < 0.05, **: P < 0.01) (N=13).

DISCUSSION

In this study, the effects of exercise-induced muscle fatigue and pain upon sensory-motor aspects of the masticatory system were analyzed. A heavy chewing protocol resulted in short-lasting muscle fatigue and pain and in a lower muscle pressure pain threshold, but not in a change in the amplitude of the jaw-stretch reflex.

Women show a tendency to report significantly elevated levels of muscle pain after a 6-minute chewing exercise, while men do not (Karibe *et al.*, 2003). Therefore, to exclude possible gender differences in the reports of muscle pain and fatigue, we selected participants of only one gender (males) in this study. Participants with self-reports of bruxism and with reports of gum chewing for more than 30 min on a daily basis, were also excluded, since these activities may influence the resistance to fatigability of the chewing muscles (Cheung *et al.*, 2003).

That a heavy chewing exercise can provoke fatigue and pain in the masticatory muscles has been reported before (Bakke *et al.*, 1996; Farella *et al.*, 1999, 2001). However, this study has shown that such a chewing exercise can also lead to signs and symptoms which are characteristic of myofascial pain and of arthralgia, as defined by the RDC/TMD. In two participants, these signs and symptoms were still present 24 hrs after the exercise.

This may underline the suggestion that signs and symptoms of TMD, as recognized by the RDC/TMD, may be associated with masticatory muscle hyperactivity (Okeson, 1996; Svensson and Graven-Nielsen, 2001).

It is likely that the pain experienced during and immediately after the exercise was caused by ischemia of the masticatory muscles and the subsequent accumulation of metabolic products in these muscles (Stohler, 1999; Svensson *et al.*, 2001b, Nicol et al., 2003). This would also explain why the feelings of fatigue and pain had disappeared so soon after the exercise; blood flow through the masticatory muscles is restored quickly after the cessation of exercise (Inoue-Minakuchi *et al.*, 2001). Despite the fact, that the pain and fatigue VAS scores after 24 hrs were not statistically different from their baseline values, the muscles' pressure-pain threshold values were still lower at that time. This indicates that participants whose muscles were pain-free after the exercise, may nevertheless show an increased sensitivity to palpation of these muscles. This stresses the need for further research into the role of palpation tests in the recognition of musculoskeletal disorders such as TMD (Dworkin and LeResche, 1992).

In this study, large differences in the response of the jaw-stretch reflex amplitude to the chewing exercise were found between participants, despite serious efforts to standardize the study protocol and despite the normalization of the reflex amplitude. Under the present experimental conditions and at a group level, the normalized reflex amplitude remained unchanged during the chewing exercise. These findings corroborate the results of a previous study in which fatigue induced by 6 min of chewing did not modulate the normalized reflex amplitude (van Selms *et al.*, 2005), but are in contrast to studies where pain, induced by injection of various substances into the masseter muscle, facilitated the jaw-stretch reflex. However, the injection of hypertonic saline induces pain of around 50 mm on a 100 mm VAS (Svensson *et al.*, 1995, van Selms *et al.*, 2005), while our chewing exercise resulted in lower VAS levels of around 25 mm. Even though there is discussion in the literature regarding the linear (Hofmans and Theuns, 2008) or non-linear (Pesudovs *et al.*, 2005) behaviour of the VAS, these results do indicate that the injection of hypertonic saline induces more pain in the muscles than does chewing exercise. These differences in the intensity of pain provoked by the two methods may account for the differences in the modulation of the jaw-stretch reflex. It also raises the question whether the jaw-stretch reflex changes, provoked by substance-induced muscle pain, will ever occur during 'everyday life' exercise-induced muscle pain.

Differences in the way exercise-induced muscle fatigue and/or pain influence the stretch reflex have also been observed in other muscles of the human body. Some studies showed an inhibition of the stretch reflex following exhaustive exercise (Nicol *et al.*, 1996, 2003, Regueme *et al.*, 2005), others showed no influence (Hjortskov *et al.*, 2005), while moderate muscle fatigue has been reported to cause a slight facilitation of the stretch reflex (Komi, 2000). Unfortunately, differences in the muscle pain and fatigue inducing protocols and in the skeletal muscles under study make it impossible to draw definite conclusions at this stage.

Within the limitations of this study, it can be concluded that intense and prolonged chewing exercise can induce fatigue, pain, and a decreased pressure pain threshold in the human masticatory muscles, without concomitant changes in the jaw-stretch reflex amplitude.

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