# Effect of Excessive Chewing on Pain Thresholds

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**ABSTRACT**

Pain and dysfunction in the jaw region may be related to fatigue and delayed onset muscle soreness (DOMS) following overstrain. The aim was to investigate development and course of subjective muscle fatigue, pain intensity, together with pressure pain thresholds (PPT) over the masseter and temporalis muscles during a 24-hour period in healthy men and women after an intense chewing task. Twenty healthy subjects (ten males and ten females) chewed seven pieces of hard chewing gum (ELMA) for 10 minutes at the pace of 80 beats per minute on their preferred chewing side. PPT at the temporalis, masseter were measured with an algometer before chewing (baseline), directly after, one hour after and 24 hours after chewing. Subjective fatigue and pain intensity were rated on a numerical rating scale (NRS). All subjects managed to complete the chewing task. The results showed that for both men and women, self-rated fatigue and pain intensity levels peaked directly after chewing and returned close to baseline values after one hour. The masseter PPT levels were significantly reduced one hour after chewing. Directly after chewing, the temporal muscle PPT increased significantly in men but not in women. Compared to women, men had higher PPT directly after chewing in both the masseter and temporal muscle sites. The results indicate that that intense chewing induces transient subjective local fatigue and pain but not DOMS in healthy subjects. Pressure pain thresholds remained fairly stable among women whereas a tendency for increased thresholds directly after the exercise was observed in men.

## INTRODUCTION

Temporomandibular disorders (TMD), includes pain and dysfunction in the jaw-face region and is characterized by pain in front of the ear, the cheeks and/or temporal area, limitations in jaw movement and joint sounds (Dworkin, 2011). In relation to chronic pain conditions in the whole body, TMD is third in prevalence after headaches and back pain (Dworkin, 2011) and is the most common cause of chronic orofacial pain. TMD is more common in women, and the prevalence is around 10 % (Le Resche, 1997; Carlsson, 1999; Dao and LeResche, 2000) with the highest prevalence in the 20 to 40 age groups (LeResche, 1997; Perez et al., 2013).

Muscle pain in the jaw-face region affects jaw movements and muscle function and jaw opening, biting and chewing can increase jaw muscle fatigue and pain (Dworkin and LeResche, 1992; Okeson, 2008). The mechanisms behind the development of jaw muscle pain are not fully understood. Both peripheral and central mechanisms are involved, where the central mechanisms are likely to have a greater emphasis on chronic pain. Jaw muscle pain is considered to be multifactorial (Greene, 2001) driven by predisposing, initiating and perpetuating factors. Risk factors can be psychological distress, pain in other locations, trauma, gender (Fillingim et al., 2011) and bruxism which in turn also involve both peripheral and central mechanisms (Lobbezoo et al., 2006). It has also been suggested that overload of jaw muscles can be an initiating and perpetuating factor to musculoskeletal pain (Greene, 2001). The nociceptive activity from muscle tissue is sensitive to stimuli that can modulate the pain transmission, with both enhancing and inhibitory mechanisms (Mense, 2003).

Eating requires interaction between different muscle groups and nerves acting as a sensory-motor system. Morphologically, jaw closing muscles consist of a mixture of fatigue resistant type 1 and forceful and fatigable type 2 muscle fibers (Eriksson et al., 1982; Eriksson and Thornell, 1983), which allow us to both chew boluses for a long time and bite with a great force and precision. Masseter and anterior temporalis muscles are active during chewing with the highest activity level on the chewing side (Farella et al., 2008; Moller, 1966) but also activity on the contralateral side.

As for other skeletal muscles, excessive muscle activity can exhaust jaw muscles, and excessive gum chewing may cause overload with ensuing muscle fatigue or pain (Allen et al., 2008). These activities can lead to a reduction in blood flow with localized hypoxia and accumulation of metabolites, with fast transient if the muscles are allowed to recover (Yoshida et al., 2012).

Pressure-pain threshold (PPT) is defined as the amount of pressure needed to perceive a stimulation as painful (Svensson et al., 1995), i.e. the change from pressure stimuli to painful stimuli. As this is an individual assessment, PPT values are subjective with large inter-individual variations. Some studies have proposed that women generally have around 30% lower PPT than men in all muscles (Chesterton et al., 2003). Others (Isselée et al., 1997; Isselée et al., 1998) have not confirmed these results, therefore there is currently a lack of consensus with regard to proposed gender differences.

Intense chewing has been used as an experimental method to induce jaw muscle fatigue, pain and lower PPT. In men, measurements before and after intense chewing have shown short-lasting fatigue and pain in the temporalis and masseter muscles (Koutris et al., 2009). In a study of healthy individuals, (Christensen et al., 1996), no-one experienced jaw muscle pain from gum chewing although 75% experienced tiredness. However, only one soft chewing gum was used to provoke fatigue in the jaw muscles. Karibe (Karibe et al., 2003), showed that women, compared to men, experienced higher levels of pain intensity in the jaw muscles after chewing. Other studies have shown that intense chewing exercises can both provoke fatigue and pain and decrease PPT in jaw muscles in healthy subjects (Farella et al., 2001; Koutris et al., 2009). In the study by Farella (Farella et al., 2001), only women participated and only one chewing gum were used which may not induce sufficient load on the jaw muscles. In the study by Koutris (Koutris et al., 2009), only men were examined, and therefore gender differences could not be analyzed.

Usually, muscle fatigue is defined as the inability to produce a pre-existing level of tension, or velocity of contraction, following static or dynamic activities. Muscle fatigue is also defined as a subjective sensation of localized slight discomfort and weakness (Christensen, 1986). Insufficient supply of oxygen and energy to the muscles can result in the use of an anaerobic metabolism to produce energy (Noakes, 2000), which can result in muscle fatigue with weakness and less ability to maintain force and velocity. This fatigue is reversible with rest (Allen et al., 2008). Muscle soreness can be divided into two different types, acute and delayed. Direct soreness, an acute temporary type of muscle soreness associated weakness caused by lactic acid, occurs during or directly after exercise. The second type, delayed onset muscle soreness (DOMS) is characterized by strength loss, restrained range of motion and increased creatine kinase levels in the blood in the affected muscles (Cheung et al., 2003). During anaerobic metabolism of glycogen, lactic acid is produced as a byproduct, which may lead to immediately muscle pain and tenderness. DOMS appear particular after eccentric (muscle lengthening) contractions with pain, fatigue, stiffness and/or tenderness in the muscle. The symptoms usually appear from a couple of hours to days after exercise, with a peak after 1-3 days, and disappear within a week after the exercise (Clarkson and Hubal, 2002). The specific cause for DOMS is still unknown but it is hypothesized to be the result of muscle structure re-modelling by addition of new interior structure of muscle cells, as well as to the surrounding connective tissue, with the purpose to adapt to increased load (Yu et al., 2002; Yu et al., 2003) that may cause an inflammatory response from the circulation (Jensen et al., 1994). However, these studies were performed on the soleus muscle, which may not resemble DOMS in the jaw muscles.

No previous studies have evaluated gender differences in PPT levels of jaw muscles after intense chewing at high pace with hard gum, and strict unilateral chewing during the whole chewing session. The hypothesizes of this study are that in jaw muscles i) intense excessive muscle activity lowers PPT and lasts over a 24 hour window, ii) women have a lower PPT s compared to men; iii) unilateral chewing will lower the PPT more on the chewing side. The aim of the present study was to investigate development and course of subjective muscle fatigue, pain intensity and PPT over the masseter and temporalis muscles in healthy men and women after an intense chewing task.

## MATERIALS AND METHODS

### Ethical reflection

All participants were healthy students at Umeå University. They were informed that participation could be abandoned at any time without giving any specific excuse. The participants were equipped with a stop-button which they were instructed to press when the pressure from the algometer reached their PPT. The method only cause minor transient pain and discomfort during the test. To fulfil the inclusion criteria, the participants received an examination of the jaw muscle system free of charge and if they had any TMD, they would be notified and informed. The Ethics Forum at the Department of Odontology in Umeå finds that appropriate ethics considerations have been integrated into this degree project.

**Participants**

Twenty healthy (10 male and 10 female) subjects, aged 18–30 years (mean 25, SD 2.5 years), were recruited among the students at Umeå University. Before participating in the experiment a screening of the jaw function by a questionnaire and a clinical examination were performed applying the exclusion criteria.

The exclusion criteria were:

- Pain or dysfunction in the jaw-face-neck region
- Elite athletes.
- Using any medication alternating pain perception.
- Using chewing gum on a daily basis (>30 min/day).
- Neurological disorders, tumors, regular headaches, diabetes or joint- or muscle diseases.

The participants were asked to abstain from alcohol and pain killers 24 hours before the study.

**Experimental design**

The experiment was carried out in four registrations; i) baseline, ii) immediately after the chewing exercise (Post chew), iii) one hour after baseline (Post 1h), and iv) 24 hours after baseline (Post 24h). The participants were placed in a chair in an upright position and equipped with a stop-button, which they were instructed to press when the pressure from the algometer reached their PPT. When the button was pressed the measuring stopped and a measure value were acquired (kPa). Investigator 1 was responsible for the computer and randomized measuring order and investigator 2 performed the measurements.

Measurements were carried out on five sites on the facial skin; bilaterally on the masseter and temporalis anterior muscles, and the thumb muscle (first dorsal interosseus muscle) of the dominant hand. The measuring sites were marked with a felt pen to ensure that all measurements were performed at the same site (Fig. 1). The order of measurement where randomized with the help of a SPSS program and blinded to investigator 2.

PPT were measured with a handheld electronic algometer (Somedic) with a probe area of $1cm^2$, which was pressed against the measurement sites with the increasing speed of 20 kPa per second. Before baseline measurement a trial measurement was performed at the thumb muscle on the non-dominant hand to familiarize the participant with the procedure. Each muscle site was measured three times to obtain a site-specific mean value. Before each set of measurements the participants rated their jaw muscle pain and fatigue on a numeric rating scale (NRS-11).

After the baseline measurements, the participants chewed 7 chewing gums (ELMA Chios mastiha) into a bolus. Thereafter, they chose a preferred chewing side and performed unilateral chewing for 10 minutes at a pre-set rate. To ensure that all participants were chewing with the same pace, a metronome (Seiko) set to 80 bpm was used. Directly after chewing, the second set of measurements was performed. The participants were instructed not to eat or chew during the one-hour break before the third set of measurements. The final set of measurements was performed 24 hours after chewing.

**Literature search**

For the background research, articles were found on PubMed by using the MeSH terms; Chewing Gum, Pain Threshold, Adult, Mastication, Muscle Fatigue/physiology, Humans, DOMS, Algometer. To select relevant articles, the same exclusion criteria as for the participation were used. To complement our search with the MeSH terms, some studies were found on google scholar.

**Statistical methods**

All measurement data was stored in Somedic software and transferred to SPSS v.21 for statistical calculations, analysis and figures. The data from each muscle was presented as mean-values of the three measurements for each participant at the four registrations together with standard deviation (SD). Statistical analyses were done with a paired sampled t-test to compare the PPT- values at the jaw muscles and Wilcoxon signed rank test were used to analyze the differences in NRS values. A p-value $<0.05$ was considered statistically significant.

## RESULTS

All subjects completed the chewing task.

### Self-rated fatigue and pain

For both men and women, fatigue and pain peaked directly after chewing and returned close to baseline values after one hour.

Only two of the participants reported fatigue before chewing, but immediately post chewing all subjects reported increased fatigue from the jaw muscles (median 5, p=0.000). One hour after the chewing, the fatigue decreased almost back to the baseline level (median 1, p=0.002) and 24h after chewing the reported fatigue level was back to the baseline (median 0, p=0.061) (Fig. 2).

Men and women showed similar patterns with no fatigue at baseline, followed by fatigue directly after chewing (median 5, p=0.005 both men and women), which reduced after 1h close to the baseline values (median 1, p=0.027 women and p=0.024 men) and reduced further after 24 h (median 0.5, p=0.038 women; median 0, p=0.461 men). There were no significant differences between men and women at any of the measurements

None of the participants reported pain before chewing, but 11 of the 20 participants experienced some muscle pain (median 1, p=0.003) immediately after chewing, but one hour later, the majority of the participants experienced no pain at all. (Fig. 2).

### Masseter (PPT)

Compared to baseline, there was no significant difference in PPT directly after chewing (p=0.231) but a significant reduction one hour after chewing (p=0.045). After 24h the PPT were back to baseline levels (p=0.795) (Table 1) (Fig. 3A).

When men and women were analyzed separately, men had significantly higher thresholds immediately after chewing compared to women (p=0.028), whereas there were no significant differences at baseline (p=0.122), after 1h (p=0.323) or after 24h (p=0.138) (Table 2).

**Temporalis (PPT)**

Compared to the PPT values at baseline, there was no significant difference in thresholds at any of the measurements (Table 1) (Fig. 3B).

When men and women were analyzed separately, the PPT for men increased directly after chewing (p=0.026), whereas 1h after (p=0.929) and 24h after chewing (p=0.811) there were no significant differences. For women however, there were no significant differences post chewing (p=0.488), 1h after (p=0.421) or 24h after chewing (p=0.508). Men had significantly higher thresholds immediately post chewing compared to women (p=0.040), whereas there were no significant differences at baseline (p=0.590), after 1h (p=0.292) or 24h (p=0.808) after chewing (Table 2).

**Comparison chewing and non-chewing side**

When analyzing the chewing and the non-chewing sides separately, for masseter and temporalis muscles, there were no significant differences in PPT for the chewing side directly after chewing compared to baseline. However, for the masseter, but not for temporalis, 1h after chewing, there was significantly lower PPT (p=0.045) at the chewing side.

The non-chewing side of the masseter showed no significant differences in PPT at any of the measurements compared to the baseline, whereas the PPT of the non-chewing side of the temporalis were significantly higher directly after chewing (p=0.039) and after 24 h (p=0.045) compared to baseline. For both muscles, there were no significant difference 1h after chewing (p=0.522). There were no significant differences between the chewing and the non-chewing sides (Table 1)

## DISCUSSION

The main findings in this study were generally small variations in PPT in the jaw muscles after intense chewing but lower PPT in the masseter muscle one hour after chewing. However, men showed higher PPT values in the jaw muscles directly after chewing compared to women.

All participants experienced jaw muscle fatigue with a peak directly after chewing. After one hour the experienced muscle fatigue had dropped almost back to baseline levels and after 24h, almost none of the participants experienced any fatigue at all. This result is consistent with previous studies (Farella et al., 2001; Koutris et al., 2009), where the participants experienced fatigue and pain with a peak directly after chewing, which decreased almost back to baseline values 20 min after chewing.

The self-reported pain, albeit only minor and temporary, was higher directly after chewing but already an hour after, the majority of the participants experienced no pain at all. One explanation to why there was no fatigue or pain one hour and 24 hours after excessive chewing, could be due to quick recovery of blood flow in the jaw muscles which meant that the ischemia in the jaw muscles was quickly rescinded (Inoue-Minakuchi et al., 2001).

When analyzing differences in fatigue and pain before and after chewing, participants were used as their own controls, which reduces the risk of error even if each individual refer to fatigue and pain subjectively.

A previous study (Farella et al., 2001) showed an increase in PPT among women directly after chewing which then dropped back to baseline values after 24 hours. The study did not investigate PPT values one hour after chewing, and can therefore not provide information on how quickly the jaw muscles recovered. In contrast to this, we found an increase in PPT directly after chewing for men, but not for women.

Our finding of decreased PPT in the masseter muscle after one hour indicates that the load effect on the muscle tissues are present for more than one hour, even if the perceived fatigue and pain has reduced. This also indicates that muscles can withstand the load for one hour, to be able carry out the work, and then fatigue after the excercise.

One hypothesis was that intense excessive jaw muscle activity could lower PPT over a 24-hour window. Instead, our results showed increased PPT values directly after chewing. One hour after chewing, however, signs of hyperalgesia were present with decreased PPT. At the 24 hour registration, the PPT had returned to the baseline levels and did not indicate DOMS. Thus, the results showed that the jaw muscles are hypoalgesic directly after chewing and hyperalgesic 1h after chewing, but recovered after 24 hours.

Both the masseter and temporalis muscles followed the same pattern for PPT, with increased values directly after chewing followed by reduced levels after one hour and normalized levels after 24 hours. The explanation for the increased PPT directly after chewing, may be due to lack of recovery and insufficient supply of oxygen but the ischemia and lack of oxygen alone, may not be enough to cause the hyperalgesia (Jensen et al., 1994). One hour later a post-exercise edema may have arisen because of reactive hyperemia, transcapillary filtration of intravascular fluid and fluid retention and this may have caused hyperalgesia (Jensen et al., 1994). The ischemia may also cause a serotonin release increasing the sensitivity of pain receptors in the muscles. Since we only examined healthy individuals, the load from the chewing did not exceed the capacity of the jaw muscles and the participants did therefore not experience any DOMS.

When comparing the PPT and self-rated fatigue and pain,, there was an increase in fatigue and pain immediately after chewing but without a concomitant reduction in PPT. On the contrary, one hour after chewing, the masseter muscle seemed to be hyperalgesic with lower PPT values whereas the pain and fatigue values were almost back at baseline levels. This indicates a delay between the subjective feeling of fatigue and pain and the physiological changes within the muscles. One hour after chewing the sensory effect on the nerves in the jaw-muscles are reversed which resulted in no experienced pain. On the other hand, the arisen edema makes the muscles physiologicly more sensitive to pressure from the algometer (Jensen et al., 1994). These processes seemed to be reversible with rest, with virtually normalized values for both fatigue, pain and PPT 24 hours after the chewing exercise.

Another hypothesis was that unilateral chewing would lower the PPT more on the chewing side. We found lower PPT on the chewing side of the masseter muscle one hour after chewing and for the temporalis muscle, an increase in PPT at the non-chewing side. It could be argued that the masseter muscle is the main muscle involved in chewing, which would provide some support for our hypothesis. In a previous study using EMG (Moller, 1966), the masseter and temporalis muscle activity was fairly balanced on the contralateral side during chewing. This could explain our finding of no differences in PPT between the chewing and non-chewing sides.

Our final hypothesis was that women generally have lower PPT in jaw muscles. Previous studies have shown gender differences with lower PPT for women (Chesterton et al., 2003). In our study there was a tendency, albeit non-significant, for lower PPT among women at the baseline recording, especially for the masseter muscle. It is possible, that the fact that we only had 10 women and 10 men made this analysis underpowered, due to the large inter-individual variability in PPT. There were however, significant gender differences for the masseter muscle one hour after chewing as well as for temporalis directly after chewing, which indicates that women, have lower PPT in the jaw muscles in response to a chewing load.

Abnormal use of chewing gum can increase the risk for pain and fatigue in the jaw muscles as indicated by decreased PPT among healthy individuals. In the present study, we used a hard chewing gum which has been used in similar studies and is known for being able to provoke fatigue and pain in jaw muscles (Koutris et al., 2009).

Our results showed a tendency for jaw-muscles to become hypoalgesic among men directly after chewing and then hyperalgesic an hour after chewing. This finding suggests that in healthy individuals, excessive gum chewing may cause overload on jaw muscles with directly ensuing transient muscle fatigue and hypoalgesia. This process seemed to be reversible with rest, with recovery within an hour and with virtually normalized values 24 hours after chewing. It would be interesting to find out exactly how quickly this recovery takes place and therefore, further studies should therefore investigate this by performing measurements with shorter time intervals after chewing.

Another factor is whether the experienced pressure pain is elicited from the muscle or from other tissues, such as the underlying periosteum or the skin. It is difficult to determine if this is the case, but we assume that the pain mainly comes from the myofascial tissue. To make sure only the jaw-muscles were affected by the excessive chewing and exclude that CNS and therefore other muscles were affected, the thumb-muscle was used as a control site. Since the PPT mean values for this muscle remained almost the same during the whole test it is suggested that only the jaw-muscles were affected and that there is sufficient reliability in the repeated measurements. .

## Conclusions

This study shows that intense chewing induces transient subjective local fatigue and pain but not DOMS in healthy subjects. The results show a gender difference in in healthy individuals immediately after an intense chewing exercise, with fairly stable pressure-pain thresholds among women whereas a tendency for increased thresholds directly after the exercise was observed in men.

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Table 1. Mean and standard deviation (SD) for pain pressure thresholds (PPT) (kPa) for the group (n=20) for both sides pooled, and for the ipsilateral chewing side (Chew) and the contra-lateral non-chewing side (Non-chew). For masseter (both sides pooled and the chewing side) the PPT levels 1hour after chewing was significantly reduced. For temporalis there were significant higher levels on the non-chewing side directly after and 24 hours after chewing.

| | Masseter<br><br>Mean (SD) | Temporalis<br><br>Mean (SD) | Masseter Chew<br>Mean (SD) | Temporalis Chew<br>Mean (SD) | Masseter Non-chew<br>Mean (SD) | Temporalis Non-chew<br>Mean (SD) |
|---|---|---|---|---|---|---|
| Baseline | 146 (±42) | 173 (±50) | 150(±38) | 177(±53) | 143(±47) | 169(±47) |
| Post chew | 152 (±53) | 182(±59) | 158(±51) | 178(±58) | 145(±55) | 185*(±62) |
| Post 1h | 136* (±48) | 170(±48) | 132*(±43) | 175(±49) | 140(±53) | 165(±49) |
| Post 24h | 145 (±49) | 177(±46) | 145(±41) | 170(±46) | 145(±57) | 184*(±46) |

* indicate significant difference compared with baseline.

Table 2. Mean and standard deviation (SD) for pain pressure thresholds (PPT) (kPa) for men (n=10) and women (n=10) for masseter and temporalis. Note, for men, there was significantly reduced PPT level for masseter 1 hour after chewing and significantly higher PPT level for temporalis directly after chewing. Men showed significantly higher PPT level for both masseter and temporalis immediately after chewing compared with women.

| | Masseter Men Mean (SD) | Masseter Women Mean (SD) | Temporalis Men Mean (SD) | Temporalis Women Mean (SD) |
|---|---|---|---|---|
| Baseline | 157(±45) | 136(±38) | 177(±45) | 168(±55) |
| Post chew | 170(±99) | 134**(±41) | 201*(±65) | 163**(±46) |
| Post 1h | 143*(±54) | 128(±41) | 178(±50) | 161(±46) |
| Post 24h | 157(±56) | 133(±39) | 179(±46) | 175(±47) |

* indicate significant difference compared with baseline,

** indicate significant difference between men and women.

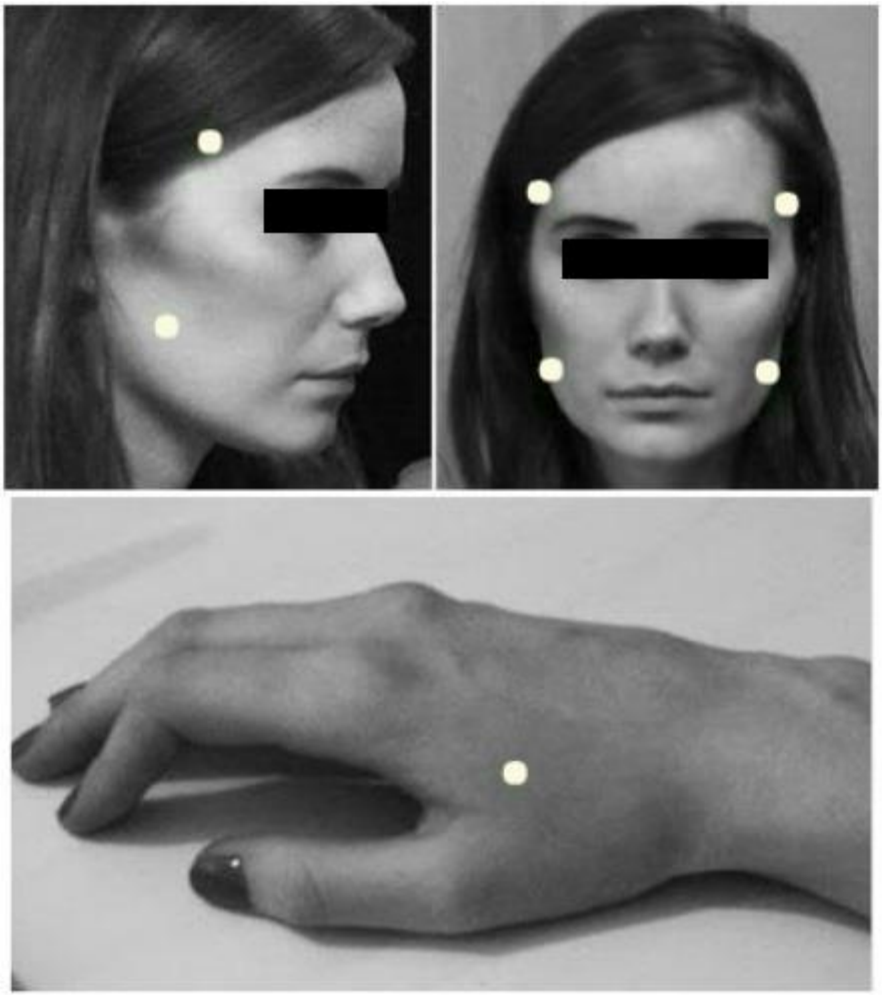

Figure 1. The 5 measurement points, (left and right belly of the masseter muscle, the left and right temporalis anterior muscle and the first dorsal interosseus muscle) where pain pressure threshold (PPT) were registrated with an algometer.

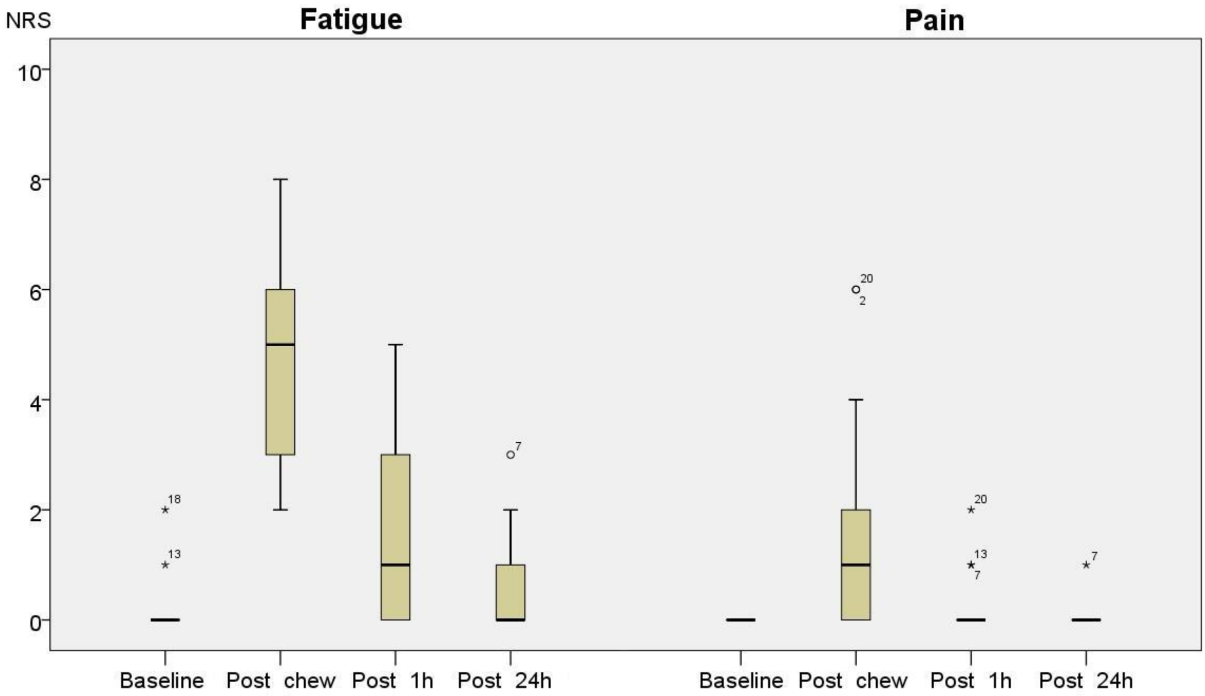


Figure 2. Box plots for self-rated fatigue and pain rated on a numerical rating scale (NRS) before (Baseline), immediately after (Post chew), 1 hour after (Post 1h) and 24 hours after (Post 24h) chewing. The values are group values for both men and women (n=20). Note, significant increased levels for fatigue immediately after and 1hour after chewing, compared with baseline. For pain, the level immediately after chewing was significantly increased compared with baseline. Only a few reported any pain 1 hour- and 24 hours after chewing.

A B

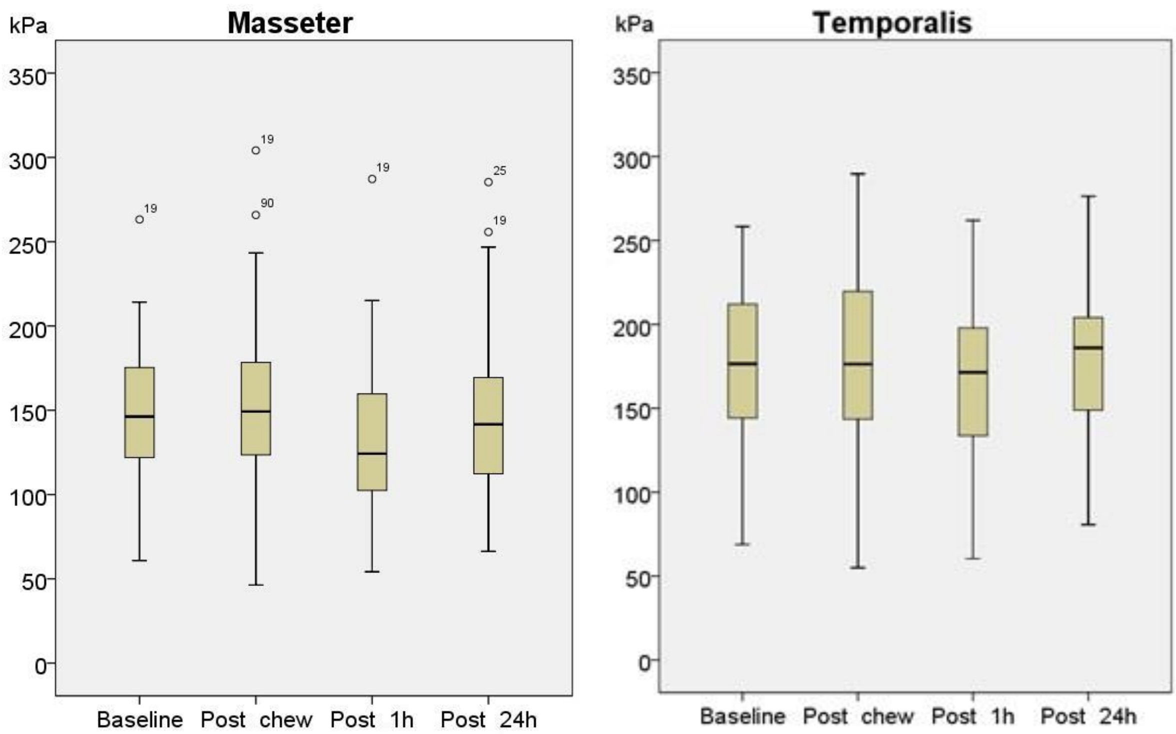


Figure 3. Mean PPT values (kPa) for masseter (A) and temporalis (B) before (Baseline), immediately after (Post chew), 1 hour after (Post 1h) and 24 hours after (Post 24h) chewing (n=20). Note, for the masseter there were significantly lower values 1 h after chewing compared with baseline. For the temporalis there was no significant difference in thresholds.