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What is This?
Experimental Masticatory Muscle Pain

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Ten female subjects with no history of temporomandibular disorders performed five exercises designed to induce masticatory muscle pain. Three of the exercises were replications of Christensen’s tooth-clenching (1970) and tooth-grinding (1971) studies and Scott and Lundeen’s mandibular protrusion (1980) study. The other two exercises were designed to induce specific unilateral masticatory muscle pain. The amount of muscle pain as well as the time of onset and the duration were assessed by a clinical palpation exam and a pain questionnaire.

These five pain-inducing methods did not consistently produce masticatory muscle pain in non-pain subjects. However, certain individuals appeared to be very susceptible to developing pain during or after most of the exercises. These susceptible individuals demonstrated a bilateral muscle pain pattern after the unilaterally stressful exercises. None of the five exercises produced a statistically significant amount of site-specific masticatory muscle pain as determined by either the palpation examination or the pain questionnaire, even when the exercise was intended to produce such specificity. The fact that some subjects did develop masticatory muscle pain is indicative that muscle exercise and fatigue may lead to TMD-like symptoms.


Introduction.

Pain is a major disabling aspect of temporomandibular disorders (TMD). Bell (1982) states that masticatory muscle pain is predominant in the TMD patient. Many treatment modalities have been used to mitigate the masticatory muscle pain of TMD (Guttu and Spектор, 1981), most of which are based on the assumption that muscle hyperactivity is the cause of the muscle pain. Successful clinical treatment of the muscle pain component of TMD is often accomplished by a decrease in masticatory muscle hyperactivity (Rugh, 1982; Clark, 1982). Thus, a search for a muscle pain model has taken place to determine the cause(s) and its effect.

Two experimental model systems for inducing masticatory muscle pain have been used in a series of studies by Christensen in normal subjects. One system generated masticatory muscle pain following tooth grinding as an isometric exercise (Christensen, 1967, 1971). The other generated masticatory muscle pain following tooth clenching as an isometric exercise (Christensen, 1970, 1979, 1980a, 1980b, 1981). The basic difference in outcome between the two model systems was the time of onset of the pain: Pain latency was 2-3 hours for tooth grinding and 1-3 minutes for tooth clenching.

In a recent study, Villarosa and Moss (1985) combined Christensen’s tooth-clenching exercise and Scott and Lundeen’s (1980) mandibular protrusion exercise with two other exercises. These investigators found similar results in the time of onset, the intensity, and the location of the induced muscle pain. These exercises generated a generalized, non-specific type of masticatory muscle pain that involved muscle groups on both sides of the head and neck. Many patients with masticatory muscle pain, however, present with a unilateral, very specific muscle pain pattern.

Case studies by Malmo (1959) have been cited to explain clinically observed unilateral, specific masticatory muscle pain. These case studies demonstrated the hyperactivation of a single muscle or group of muscles producing pain on only one side. This unilateral, specific muscle pain was found in the neck, thigh, and forearm muscles.

The purpose of this study was to determine whether specific muscle exercises might produce a more specific masticatory muscle pain model in normal subjects than that demonstrated by previous studies. A lack of positive results in a previous pilot study necessitated a replication of the studies of Christensen (1970, 1971) and Scott and Lundeen (1980), on whose results the current study was based.

Materials and methods.

Subjects. — Ten normal, healthy female volunteers, ages from 18 to 26, from the general population participated in this study. All subjects were free of masticatory or other systemic pain. They were also free of any neuromuscular or metabolic diseases, internal derangement discrepancies, or degenerative processes within the temporomandibular joints. The subjects were asked not to take any palliative medications for 12 hours after the experimental session.

Equipment. — A Model M53 EMG instrument (J&J Enterprises, 22797 Holgar Ct., N.E., Poulsbo, WA 98370) was used to enable each subject to maintain a prescribed standard minimum masticatory muscle EMG level. A pair of surface electrodes and a ground electrode on the earlobe were used with this instrument. The instrument was calibrated so that a maximum clench effort registered at the 100% level on the instrument meter.

An acrylic splint was constructed to fit the mandibular teeth with a horizontal 77-mm rod attached at the midline. A 454-g weight was suspended from a cable which ran through a pulley and then horizontally to the end of the rod. This equipment was used only in Exercise #4. Two acrylic unilateral bite-opening splints were fabricated for use in Exercise #5. These splints covered the central incisor, lateral incisor, and cuspid teeth of the maxillary and mandibular arches on the same side to open the vertical dimension 5 mm.

Three methods of measurement of pain. — Three dependent variables were used in this study to assess the resultant masticatory muscle pain. First, calibrated pre- and post-exercise palpation examinations (Burch, 1982; Gross and Gale, 1983) were performed on each subject by a “blind” examiner. A four-point ordinal scale with a range of 0-3 was used in the examinations to assess the pain levels in each of 12 bilateral masticatory muscles. A pain-rating questionnaire with a six-
point ordinal scale, ranging from 0-5, was used as a second dependent variable. The questionnaire was completed by the subject at hourly increments up to 12 hours after the exercise. The questionnaire recorded two types of subjective pain: (1) unprovoked, spontaneous pain, and (2) evoked, functional pain. Evoked, functional pain was defined as the pain caused by the functional movement of the mandible, i.e., chewing, speaking, etc. Finally, the time of onset of any muscle pain that occurred within the exercise period was recorded as a third dependent variable.

**Experimental design.**—Each subject was randomly assigned to a pre-arranged, counterbalanced exercise order. The variation in the order of the exercises attempted to minimize the influence of the muscle pain experienced in previous exercises. Five experimental sessions were spaced one week apart to allow for full recuperation between exercises. There were two groups of five subjects each: One group performed the unilateral exercises on the right side, while the other performed these exercises on the left side.

**Procedure.**—After the volunteers qualified for the experiment, an acrylic mandibular splint with an extension rod and two small acrylic bite-opening splints were constructed. Each subject was then randomly assigned to a regular day and time for the experimental session. The five exercises are summarized in Table 1.

Prior to Exercises #1 and #2, a pair of bipolar surface electrodes was placed over the non-working-side masseter, with a ground electrode on the earlobe. Then, the EMG instrument was calibrated to a 100% meter reading during a maximum clench (MC). The subject was then taught the specific exercise procedure.

In Exercise #1, the subject moved the mandible from the centric occlusion position to the lateral cuspid-to-cuspid position and returned. This cycle was repeated continuously for five minutes while an EMG level of greater than 50% MC was maintained, followed by a three-minute rest period. The sequence of exercise and rest was repeated six times and replicated Christensen’s 1971 study. This exercise was expected to generate muscle pain within 2-3 hours, but no pain was expected during the exercise. It was expected to produce a greater amount of muscle pain in the non-working-side lateral pterygoid, compared with the same muscle prior to the exercise. This exercise was also expected to produce a greater amount of muscle pain in the non-working-side lateral pterygoid muscle compared with its control muscle, the non-working-side medial pterygoid muscle.

In Exercise #2, the subject was instructed to maintain a tooth clench in centric occlusion for five minutes while maintaining the EMG activity level above 70% MC in order to replicate Christensen’s 1970 study. This exercise, after examination, was expected to produce a greater amount of pain in both masseters and both anterior temporalsis muscles, compared with the same muscles before the exercise as well as their respective control muscles, the medial pterygoids. Finally, this exercise was expected to produce masticatory muscle pain during the exercise period after approximately one minute.

Exercise #3, a replication of the study of Scott and Lundeen (1980), asked the subjects to protrude the mandible forcefully for five minutes. No EMG control was used in this exercise. After the examination, this exercise was expected to produce a greater amount of pain in both lateral pterygoid muscles after the exercise, compared with the same muscles before the exercise as well as their respective control muscles, the medial pterygoids. Finally, this exercise was expected to produce masticatory muscle pain during the exercise period after approximately one minute.

Exercise #4 was designed to stress selectively and induce pain in one lateral pterygoid only. The acrylic splint was inserted over the mandibular teeth, and a cable with a 454-g horizontal-lateral pull was attached to the end of the rod. During a 45-second exercise period, each subject was asked to protrude the mandible maximally and hold the position for 30 seconds, then alternately retract and protrude the mandible for 15 seconds. The subject was then asked to rest for 15 seconds without touching the mandibular splint to the maxillary teeth. This cycle was repeated continuously for 30 minutes. No EMG control was used in this exercise. This exercise was expected to generate muscle pain within 2-3 hours after the exercise, but no pain was expected during the exercise. Exercise #4 was expected to produce a greater amount of pain after the exercise in the lateral pterygoid on the same side as the 454-g force, compared with the same muscle prior to the exercise as well as its medial pterygoid control muscle.

Exercise #5 was designed to stress specifically the working-side anterior temporalsis. After placement of the electrodes over the appropriate anterior temporalsis, the unilateral acrylic bite-opening splints were inserted in order to calibrate the EMG instrument for 100% MC. Then, the subject was asked to maintain a clench of 70% MC for 45 seconds and rest for 15 seconds. This sequence was repeated continuously for 30 minutes. Like Exercises #1 and #4, this exercise was expected to generate muscle pain within 2-3 hours after the exercise, but no pain was expected during the exercise. This exercise was predicted to produce a greater amount of pain afterward in the working-side anterior temporalsis, compared with the same muscle prior to the exercise as well as its control, the non-working-side anterior temporalsis.

The expected results of these five exercises were based on two sources: the original studies being replicated and a series of biomechanical analyses of the masticatory system and the temporomandibular joint (Barbenel, 1972, 1974; Smith, 1984; Smith et al., 1986). These biomechanical model analyses were used to design the method used in exercises #4 and 5 to stress the hypothesized muscle selectively. Physiological evidence in humans (Gibbs et al., 1984; Wood et al., 1986; Wood, 1986) has demonstrated that many other masticatory muscles besides the hypothesized muscle would also be active during these exercises. These studies have shown extensive “co-activation” through synergistic activity. Therefore, all the exercises were expected to generate activity in both the hypothesized and control muscles. The hypothesized muscle was statistically compared with the same muscle before and after the exercise as well as with an active control muscle.

**Results.**

The results are summarized in Table 2.

**Intra-muscle results and analysis.**—A one-tailed Sign Test (Daniel, 1978) for non-parametric ordinal data was used to compare the pre- and post-exercise palpation examination scores within the same muscle. All intra-muscle comparisons were tested for significance at the 0.05 level. In Exercise #4, six out of ten subjects experienced a change in palpation tenderness in the lateral pterygoid muscle, but this was not statistically significant (p = 0.38). All the other muscles demonstrated positive changes in a lesser proportion of the sample for this exercise. Exercises #1, 2, 3, and 5 demonstrated a positive change within the muscles examined in lower proportions of the sample, but no exercise resulted in a statistically significant increase in pain.

**Inter-muscle results and analysis.**—A one-tailed Fisher’s Exact Probability Test (Siegel, 1956) at the 0.05 level was
used to compare pain in the hypothesized target muscle with its control muscle.

Exercise #1 indicated a statistically significant change in the hypothesized lateral pterygoid muscle, compared with its medial pterygoid control muscle (5 out of 10 vs. 0 out of 10, p = 0.05). Exercise #4 demonstrated a statistically significant change in the hypothesized lateral pterygoid muscle, compared with its medial pterygoid control (6 out of 10 vs. 0 out of 10, p = 0.05). There were no statistically significant changes in the remaining exercises.

**Time of onset of reported pain during the exercise.** — Exercise #1 produced pain in only one subject within the exercise period, although six out of ten subjects reported some discomfort or tightness as a result of the exercise. Exercise #2 produced pain in nine out of ten subjects in a mean time of 74 ± 38 seconds. Exercise #3 produced pain in seven out of ten subjects in a mean time of 141 ± 95 seconds. Exercise #4 produced some pain or discomfort in five out of ten subjects at some point during the exercise, although the exact time of onset was not recorded. In Exercise #5, only one out of ten subjects reported pain or discomfort during the exercise.

**Time of onset of pain after the exercise.** — The pain questionnaire results indicated which facial areas experienced pain after each of the five exercises. The proportion of the sample that experienced any amount of pain in each facial area was determined from the summary of these questionnaires. Exercise #1 produced pain in nine out of ten subjects without regard to specific anatomical sites. Exercise #4 produced the highest proportion, six out of ten, of specific pain in a single area, i.e., the right cheek area, as compared with any of the exercises in this study.

**Discussion.**

Christensen (1970, 1971), Scott and Lundeen (1980), and Villarosa and Moss (1985), as well as the current investigators, have attempted to generate a masticatory muscle pain model system in normal subjects. This study confirmed that tooth-clenching (Exercise #2) and mandibular protrusion (Exercise #3) produced masticatory muscle pain within 1-3 minutes during the muscle contraction, as was found by previous investigators. While these two activities produced a similar rapid onset of masticatory muscle pain, a lesser proportion of the sample had latent pain. These investigations point to an apparent difference between the pain induced during the contraction and the latent pain in the post-exercise period. The
potential existence of two types of pain generated by the contraction may be important to the etiology and treatment of clinical pain.

The tooth-grinding method was employed both in the present investigation and by Christensen (1971) to produce a TMD-like masticatory muscle pain. Although specific muscles were not consistently involved, the proportion of non-specific muscle pain was significant in both studies. Christensen found that pain developed in eight out of nine subjects (p = 0.02), and the present study reported pain in nine out of ten subjects (p = 0.01). This method did not generate an immediate contraction pain—as did the tooth clenching and mandibular protrusion methods—only a latent pain. Therefore, tooth clenching, mandibular protrusion, and tooth grinding demonstrated two distinct differences between isometric and isotonic masticatory muscle activities. The different effects from these different types of muscle contractions may have implications for the etiology and treatment of masticatory muscle pain in TMD patients.

The unilateral exercises in this study attempted to stress a group of muscles differentially on one side of the masticatory muscle complex to evoke a response similar to that seen in the clinical unilateral TMD pain patient. No previous studies have demonstrated this specific pain pattern within the masticatory system in normal subjects. A unilateral muscle pain pattern was not generated, but an unexpected bilateral muscle pain pattern developed in susceptible individuals. This result may be due to the extensive synergistic “co-activation” of many muscles, as demonstrated by Gibbs et al. (1984), Wood et al. (1986), and Wood (1986). Exercises #1 and 4 have demonstrated a predilection for a pain response after exercise in the lateral pterygoid muscles, compared with the medial pterygoid muscles.

The exercises used in the present and previous studies produced a TMD-like muscle pain similar to that experienced by clinical patients. However, such exercises were not necessarily identical with the actual parafunctional activities of the pain patient. The fact that experimentally produced pains do not exactly mimic the clinical symptoms of TMD muscle pain does not diminish the value of showing that various forms of hyperactivity can produce some muscular fatigue and pain in some subjects. Furthermore, the fact that certain predicted muscles did not develop pain in the ways anticipated indicates that these experimental exercises elicited complex stomatognathic system responses instead of simple ones.

REFERENCES


