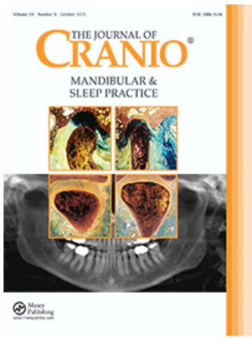

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Jaw muscle activity patterns in women with chronic TMD myalgia during standardized clenching and chewing tasks

Roberta Valentino, DDS[a], Iacopo Cioffi, DDS, PhD[b], Stefano Vollaro, MD, PhD[a], Roberta Cimino, DDS[a], Roberta Baiano, DDS[a] and Ambrosina Michelotti, DDS[a]

[a]Department of Neuroscience, Reproductive Sciences and Oral Sciences, University of Naples "Federico II", Naples, Italy; [b]Faculty of Dentistry, University of Toronto Centre for the study of Pain, Toronto, ON, Canada

ABSTRACT

Objective: To examine jaw muscle activity of women with chronic temporomandibular myalgia (mTMD). It was hypothesized that mTMD patients had a different masticatory muscle activity, increased work during isometric clenching, and a reduced chewing frequency as compared to TMD-free subjects.

Methods: The electromyographic (EMG) activity of temporalis anterior (TA) and masseter (MM) of 27 women with mTMD and 18 TMD-free women was recorded during clenching tasks and while chewing. EMG indices comparing the activity of paired jaw muscles were computed.

Results: Women with TMD myalgia had greater muscular work than controls ($p = 0.025$). The activity of TA and MM were similar between right and left sides in both groups. mTMD patients had a greater activity of MM than TA ($p = 0.028$). No between-groups differences were found in chewing rate.

Conclusion: Women with mTMD showed an abnormal recruitment of the jaw-closing muscles during functional tasks, which may predispose to further tissue injury.

KEYWORDS
Temporomandibular joint disorders; masticatory muscles; surface electromyography; chewing; bruxism

Introduction

Temporomandibular disorders (TMD) include a set of different pathological conditions affecting the masticatory muscles and/or the temporomandibular joint with a multifactorial etiology [1]. Previous studies have reported that jaw muscle activity during rest and functional tasks is different between patients with TMD and healthy subjects [2–5]. A recent study has revealed that patients affected by TMD myalgia have an average greater electromyographic (EMG) activity of the masseter muscle compared to individuals without pain because of the high frequency of oral parafunctions [6]. On the other hand, other studies have shown that jaw muscle activity is decreased in TMD patients [3,5,7], in agreement with the pain adaptation model, which suggests that muscular activity decreases to limit movements and protect the sensory-motor system from further muscle tissue injury [8–10].

Surface electromyography (sEMG) has been largely used to investigate the activity of masticatory muscles and to identify possible muscular impairments. However, the assessment of jaw muscles activity by means of sEMG has been questioned for its low reliability [11]. Indeed, biological variations, low repeatability in electrode placement, and artifacts can account for possible discrepancies between studies and conflicting results [12,13]. To overcome this limit, EMG protocols using standardized EMG signals and indices were introduced [14].

The EMG protocol [14] proposed by Ferrario et al. has been largely used [2–5,15,16]. This protocol allows computing indices of jaw muscle activity by using standardized EMG signals recorded during maximum voluntary contraction (MVC) in maximal intercuspation and on cotton rolls. This method reduces biological and technical noise and allows comparison of the activity of paired jaw muscles by providing indices of asymmetric muscle activation during function.

The extent of jaw muscle asymmetry during maximum contraction of elevator muscles has been measured in normo-occlusion subjects suffering from TMD [2–4]. Some studies found a larger asymmetric activation of the temporalis and the masseter muscles in TMD subjects as compared to TMD-free controls as a result from an increased activity of the temporalis or a relatively reduced activity of the masseter [5,15]. On

CONTACT Roberta Valentino valentino.roberta88@gmail.com Department of Neuroscience, Reproductive Sciences and Oral Sciences, University of Naples "Federico II", Via Pansini 5, Naples, Italy

the other hand, a recent study by Da Silva et al. [17] has shown that TMD patients do not present a greater asymmetric activation of the masticatory muscles than healthy controls during standardized tasks.

This study aimed at examining jaw muscle activity patterns of women with chronic TMD myalgia using standardized EMG indices, which evaluate jaw muscle asymmetric activation during function, muscular work, and chewing rate to determine whether asymmetric or abnormal activation of paired muscles is associated with chronic TMD pain. It was hypothesized that patients with chronic TMD myalgia have more asymmetric muscular activity and increased muscular work during experimental isometric clenching, as well as abnormal chewing frequency.

Materials and methods

Study sample

Adults seeking a TMD consultation at the Department of Neuroscience, Section of Orthodontics and Temporomandibular Disorders at the University of Naples Federico II, Italy, were examined using the Diagnostic Criteria for TMD (DC/TMD) clinical examination protocol [18]. Women with a diagnosis of TMD myalgia with self-reports of pain from at least 6 months were recruited.

One hundred subjects contacted at the Hospital, including employees and students, were invited to fill in the TMD pain screener [19]. Individuals reporting pain in the jaws and/or temples in the last 30 days were excluded. For both groups, exclusion criteria were neurological disorders, craniofacial syndromes, and current orthodontic or dental treatment.

The total sample included 45 women: 27 patients with chronic TMD myalgia (mTMD, mean age ± standard deviation: 38.3 ± 12.8 years) and 18 TMD-free subjects (CTR, mean age ± standard deviation: 36.2 ± 12.9 years).

The Research Ethics Board at University of Naples "Federico II" approved the research protocol (protocol 22616). The research was conducted in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. All subjects gave written informed consent to participate before entering the study.

Questionnaires

Patients with mTMD filled out the Graded Chronic Pain Scale included in the DC/TMD instrument [18]. All subjects filled out the following checklists, scales, and questionnaires:

- *The Oral Behavior Checklist (OBC)* [20] was used to identify and quantify the frequency of self-reported oral behaviors [20]. The OBC investigates nocturnal bruxism (2 items) and different wake-time oral behaviors (19 items). Each participant chose among five response options: *"none of the time," "a little of the time," "some of the time," "most of the time,"* and *"all of the time,"* which were scored from 0 to 4. In this study, the authors analyzed a reduced 6-items version (OBC-6), which includes items #3 ("*grind teeth together during waking hours*"), #4 ("*clench teeth together during waking hours*"), #5 *("press, touch or hold teeth together other than while eating – that is, contact between upper and lower teeth*"), #10 ("*bite, chew, or play with your tongue, cheeks, or lips*"), #12 ("*hold between the teeth or bite objects such as hair, pipe, pencils, pens, fingers*), and #13 *("use chewing gum*") [6,21,22].
- *The State Trait Anxiety Inventory* (*State Anxiety*: STAI Y1, 20 items – *Trait Anxiety*: STAI Y2, 20 items) was used to assess the state and trait anxiety of participants. Trait anxiety includes constructs such as *"I feel inadequate," "I lack self-confidence,"* and *"I have disturbing thoughts."* Participants had to select one of the following options: *"almost never," "sometimes," "often,"* or *"almost always."* Each answer was graded from 1 to 4 [23].
- *The Somatosensory Amplification Scale (SSAS)* was used to assess the degree of somatic awareness. It includes 10 statements to analyze an individual's sensitivity to bodily sensations, such as, *"I hate to be too hot or too cold," "I have a low tolerance for pain,"* and *"I am often aware of various things happening within my body."* Each participant chose among the following options: *"not at all," "a little," moderately," "quite a bit,"* or *"extremely."* Each answer was graded from 0 to 4 [24].

EMG assessment

The activity of the superficial masseter (MM) and temporalis anterior (TA) muscles of both sides (left and right) was recorded during standardized tasks by means of sEMG, as previously described [16]. Silver-silver chloride bipolar surface pre-gelled electrodes (ECG electrodes, Kendall, Mansfield, MA, USA) with a diameter of 24 mm were placed on the skin along the main direction of the muscle fibers detected by palpation while the participant clenched in maximum intercuspation. For the TA, electrodes were placed over the anterior border of the muscle on the area corresponding to the fronto-parietal suture; for the MM, the electrodes were placed at the intersection between the tragus-labial commissure and the exocanthion-gonion (mandibular angle) lines. Before placing the electrodes, the skin was cleaned with abrasive paste (Everi – Spes Medica, Genova, Italy) to minimize impedance. The recordings were performed 5–6 m later to allow the conductive paste to adequately moisten the skin surface. The electrodes were positioned at the beginning of the experimental session, and all tasks were performed without any modification of the electrodes or of their position. During the recording, each participant sat on a chair with the head in a natural erect position. An EMG system (TMJOINT, BTS SpA, Garbagnate Milanese, Italy), with wi-fi probes (weight, 10 g) clipped to the electrodes was used.

The EMG signals were amplified (gain 150) and digitally filtered (low-pass filter set at 500 Hz; high-pass filter set at 10 Hz) with muscle activity assessed as the root mean square (RMS) of the EMG amplitude. The device was directly interfaced with a computer software (Dental Contact Analyzer, BTS SpA, Garbagnate Milanese, Italy) that presented the data graphically and stored data for further quantitative and qualitative analyses. An algorithm processed the RMS values to generate indices of muscle activity and asymmetry.

The EMG protocol used in this study included two static and two dynamic tests [14–16] separated by a 3-m interval. The static tests included:

(1) *Maximum voluntary contraction (MVC) in intercuspal position (CLENCH)*: each participant was asked to clench as strong as possible for 5 s;
(2) *MVC in intercuspal position on cotton rolls (COT)*: each participant was asked to clench on 10 mm thick cotton rolls (Intermedical, Terlano, Bolzano, Italy) as hard as possible for 5 s; the cotton rolls were positioned from the mandibular first molar to the canine in each side.

The dynamic test included:

(1) chewing gum (Air Action Vigorsol, Lainate, Italy) on the right side (15 s);
(2) chewing gum on the left side (15 s).

For the 5-s static tests, 200 25 ms RMS samples were collected, and the 3-s period with the highest RMS values (rolling average) was used to calculate the indices. The differences of the left and right TA and MM EMG waves of each subject (120 samples) with and without cotton rolls were superimposed sample by sample, and the ratio between the superimposed areas and the total areas was computed. For each subject, the software expressed the EMG potentials recorded during the MVC as the percentage of the mean RMS potential recorded during MVC with cotton rolls (EMG standardized potentials). As reported in previous studies, a set of EMG indices was computed [16].

The following indices were obtained during the static tests:

(1) *POC (percentage of overlapping coefficient)*. This index compares the standardized EMG waves of the left and right TA and MM by computing a percentage overlapping coefficient (POC, unit: %, range: 0–100, norm values 85% ≤ POC ≤ 100%). A perfect symmetric activation of the left and right muscles corresponds to a POC value of 100%. Conversely, a POC value of 0% is expected if there is no overlapping activation of paired muscles (no symmetry). The POC indices were computed for TA and for MM (POC MM). A POC medium was also calculated [14,16].
(2) *Tc (torque coefficient)*. This index was calculated by measuring the overlapping activity (standardized EMG waves) between the left MM and right TA and the right MM and left TA. The greater muscle activity of one couple (i.e. left MM and right TA) over the other (i.e. right MM and left TA) results in a torqueing effect on the lower jaw. Tc varies between 0% (asymmetric activation, greatest torqueing effect) and 100% (symmetric activation, no torqueing effect). Normal values are 90% ≤ Tc ≤ 100% [14,16].
(3) *IMPACT (total standardized muscle activity)*. This index was computed as the integrated area of the EMG standardized potentials of both MM and TA over time (5 s MVC). Norm values are 85% ≤IMPACT ≤ 115%. Lower values indicate that the EMG standardized potentials were reduced during the clenching tasks, which suggest a lower muscular work [14,16].
(4) *ATTIV (Activity Index)* compares the muscle activity of TA to MM. It is positive (up to 100%) when the MM standardized potentials are greater than the TA ones, negative (up to −100%) when the TA muscle potentials are larger, and null when they are equal [14,16].

The following indices were obtained during the dynamic tests:

(1) *FREQ (Frequency index*), which measures the number of masticatory cycles in 1 s for both sides (Hz) during the chewing tasks.

Statistical analysis

The sample size calculation indicated that a sample of 21 subjects per group was sufficient to detect a 5% (SD = 4.55%) [14] difference between-groups in the POC medium index (α = 0.05 and 1-β = 0.9). The distribution of the data was tested using the Kolgomorov-Smirnov test. Means and Standard Deviations (SD) were computed for all the outcome measures. Total scores of STAI Y1, STAI Y2, SSAS, OBC, and OBC6 were computed. Independent samples *t*-tests were used to assess difference between groups for all the computed EMG indices and for STAI Y1, STAI Y2, SSAS, and OBC6. The statistical significance was set at $p < 0.05$. All data were analyzed by using IBM SPSS Statistics for Windows (IBM Corp. Released 2012, Version 21.0. Armonk, NY: IBM Corp).

Results

Questionnaires

The mTMD participants reported a mean pain intensity (± SD) in the last 30 days of 49.3 ± 27.1 mm on a 100 mm Visual Analog Scale (left endpoint: "*no pain*"; right endpoint: "*the worst pain I can imagine*"). Ten patients had GCPS grade II, and 17 had GCPS grade III. A significant difference for self-reported oral behaviors was found between groups: the mTMD group reported greater OBC-6 scores than the CTR group ($p = 0.002$). No differences were found for either SSAS, STAI Y1 or STAI Y2 between the study groups (all $p > 0.05$) (Table 1).

EMG indices

Descriptive statistics and between-group comparisons for the EMG indices are reported in Table 2. Both groups had a similar asymmetric contraction pattern of the TA and MM muscles during clenching (POC TA, $p = 0.187$; POC MM, $p = 0.161$). No significant between-group differences were found for the POC medium index ($p = 0.184$). The Tc index did not differ between mTMD patients and CTR subjects ($p = 0.238$). When comparing TA and MM muscles activities, a significantly greater activity of the MM muscles in mTMD patients compared to CTR was found (ATTIV, $p = 0.028$). Muscular work (mV/sec) was significantly different between groups (IMPACT, $p = 0.025$) and greater in the mTMD group than CTR subjects. The frequency of chewing did not differ between groups for either the right or left side (FREQ right side, $p = 0.302$; FREQ left side, $p = 0.513$).

Table 1. Descriptive statistics and between-groups comparisons for OBC-6, SSAS, STAI-Y1, STAI-Y2 scores.

	mTMD	CTR	*p*-value
OBC-6	9.42 ± 5.95	3.77 ± 2.89	**p = 0.002**
SSAS	12.56 ± 4.64	11.38 ± 5.36	p = 0.487
STAI-Y1	24.27 ± 6.24	21.69 ± 3.45	p = 0.176
STAI-Y2	21.92 ± 7.04	20.00 ± 4.71	p = 0.380

Bold type: statistically significant; mTMD: group with TMD myalgia; CTR: control TMD-free group; OBC-6: Oral Behavior Checklist, 6 items; SSAS: Somatosensory Amplification Scale; STAI-Y1: State Anxiety; STAI-Y2: Trait Anxiety.

Table 2. Descriptive statistics and between-group comparisons for the EMG indices.

	mTMD	CTR	*p*-value
POC TA	73.63 ± 21.11	81.04 ± 12.42	p = 0.187
POC MM	75.98 ± 20.66	83.08 ± 4.86	p = 0.161
POC medium	77.79 ± 11.97	82.06 ± 7.35	p = 0.184
Tc	84.08 ± 9.74	86.64 ± 8.72	p = 0.374
ATTIV	−3.54 ± 21.88	−17.88 ± 18.81	**p = 0.028**
IMPACT	139.81 ± 84.59	89.33 ± 44.83	**p = 0.025**
FREQ right side	1.30 ± 0.27	1.38 ± 0.192	p = 0.302
FREQ left side	1.37 ± 0.28	1.43 ± 0.28	p = 0.512

Bold type: statistically significant. mTMD: group with TMD myalgia; CTR: control TMD-free group; POC TA: percentage overlapping coefficient temporalis anterior; POC MM: percentage overlapping coefficient masseter; POC medium: percentage overlapping coefficient medium; Tc: torque coefficient; ATTIV: activity index; IMPACT: total standardized muscle activity; FREQ: frequency index. For details about the EMG indices, refer to the materials and methods section.

Discussion

The present study demonstrated that both women with chronic TMD myalgia and healthy controls present a slight asymmetric activation of the jaw-closing muscles during clenching [14]. However, there were no significant differences between the study groups. In both groups, the ATTIV index demonstrated that the activity of temporalis muscles is increased compared to that of masseter muscles. However, the activity of masseter muscles was relatively higher in the mTMD group compared to the control group, as shown by the higher value of the ATTIV index.

Furthermore, patients with TMD myalgia had greater muscular work and self-reported frequency of oral parafunctions (OBC-6 scores) than controls.

The lack of a significant difference in masticatory muscle asymmetry between mTMD patients and CTR reported in the current study is consistent with Tartaglia et al. [3]. In their report, the authors showed that only arthrogenous patients (Group II and III, according to the RDC/TMD) had a significantly greater asymmetric activation of the jaw-closing muscles than controls [3], whereas the degree of asymmetry during activation was similar between myogenous patients (Group I, according to the RDC/TMD) and controls [3]. In contrast, other studies found a greater asymmetric activity both for temporalis and masseter muscles in both patients and healthy subjects [2,4]. In the current experiment, the activation of the couples right temporal-left masseter and left temporal-right masseter was not different between groups (Tc index). An altered Tc index value may suggest the presence of a fulcrum that is the expression of unbalanced masticatory muscle activity in search of occlusal stability [3]. Hence, it is possible to hypothesize that both patients and controls had good occlusal stability, i.e., a proper intercuspation between the upper and lower dental arches. This result is in agreement with other studies, which showed that the Tc coefficient did not differ between subjects with TMD and healthy controls [3,4,15]. However, De Felício et al. found a significantly larger unbalanced activity in TMD individuals compared to healthy subjects [2]. These inconsistent findings could be explained by the different criteria adopted for the selection of samples [2].

In the current study, authors found a significant difference between the two groups for the ATTIV index, which compares the recruitment of temporalis and masseter muscles. A relatively greater activation of masseter muscles than temporalis muscles was found comparing mTMD and CTR groups. These results were not in agreement with other studies reporting an increased activity of the temporalis muscles. However, also in this case, discrepancies in diagnostic criteria may explain the differences between the studies [15,25]. In order to assess the relative activation of MM and AT muscles as a function of different oral behaviors, Farella et al. evaluated the effects of induced non-functional oral tasks on the pattern of activity of the masticatory muscles of healthy subjects [26]. They reported that the change of the relative activity of each couple of muscles was dependent on the type of task performed. A rather symmetric activation was reported in most oral tasks. However, masseter muscles showed a higher activation during tasks involving incisal biting; conversely, the activity of anterior temporalis predominated when tasks in intercuspal position were performed [26]. It could be supposed, that in the current study, mTMD patients showed a higher masseter activity and a relative anterior temporalis reduced one because of the muscle fatigue of AT related to a higher frequency of oral parafunctions performed in intercuspal position. Indeed, in the current study, oral behaviors were analyzed by calculating the OBC-6 score, which includes 6 items concerning intercuspal position tasks.

A significant difference between groups was found for the IMPACT, which was greater in mTMD patients compared to healthy subjects. IMPACT depicts the amount of muscular work produced by a muscle over time. It is represented geometrically by the area under the curve of electrical activity of the muscles during the 5-s clenching task. The greater IMPACT suggests that mTMD patients recruited more muscle fibers and produced more work than healthy controls to perform the same clenching task. However, it could also indicate that the muscle tone of mTMD patients was greater than controls. An increased muscle tone in painful muscles may contribute to an increased muscle hardness [27,28]. In a recent review analyzing the possible correlation between the hardness of masticatory muscles and myofascial TMD, it was reported that TMD patients have harder jaw-closing muscles than healthy subjects [29,30]. The association between jaw muscle pain and hardness could be related to a combination of sustained tonic contractions, tissue edema, and metabolic alterations [31,32]. With respect to the frequency of chewing, the present study did not find any difference between groups. This finding suggests that mTMD did not have a significant impact on chewing function in the current sample.

For this study, STAI and SSAS scores were collected to account for the possible effect of psychological factors on the outcome measured. Indeed, psychological factors may play a role in influencing the association between pain and motor activity [33]. However, neither parameters were different between mTMD and CTR groups; therefore, it was decided not to adjust the comparisons using these values.

Some studies reported that the EMG assessment of the jaw-closing muscles adds value to the clinical examination [3,34]. It may be questioned whether the assessment of the asymmetry of masticatory muscle via EMG could represent a good diagnostic tool for the identification of mTMD. Manfredini et al. reported a limited diagnostic accuracy of sEMG for myofascial pain [35]. However, it seems that the evaluation of muscular force during clenching could be helpful in identifying patients with TMD myalgia [3,35]. The current study demonstrated that the amount of muscle work produced during a clenching task (i.e. IMPACT index) is largely different between mTMD and healthy controls. Therefore, it may be helpful in identifying patients with chronic mTMD.

Conclusion

This study has demonstrated that the jaw-closing muscles of women with chronic TMD myalgia produce a greater muscular work than healthy individuals during a standardized clenching task, and that there is no association between asymmetric activity of the jaw-closing muscles and mTMD. Therefore, it may be concluded that an asymmetric pattern of contraction of the jaw-closing muscles during static and dynamic tasks is a normal physiological condition. However, the observational nature of this study does not allow for drawing definitive conclusions. Further longitudinal studies are needed to understand better the role of jaw muscle asymmetry on craniofacial development and signs and symptoms of TMDs.

Disclosure statement

The authors report no conflicts of interest.

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