Mandibular kinematics and masticatory muscles EMG in patients with short lasting TMD of mild-moderate severity

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Mandibular kinematic and standardized surface electromyography (sEMG) characteristics of masticatory muscles of subjects with short lasting TMD of mild-moderate severity were examined. Volunteers were submitted to clinical examination and questionnaire of severity. Ten subjects with TMD (age 27.3 years, SD 7.8) and 10 control subjects without TMD, matched by age, were selected.

Mandibular movements were recorded during free maximum mouth opening and closing (O–C) and unilateral, left and right, gum chewing. sEMG of the masseter and temporal muscles was performed during maximum teeth clenching either on cotton rolls or in intercuspal position, and during gum chewing. sEMG indices were obtained. Subjects with TMD, relative to control subjects, had lower relative mandibular rotation at the end of mouth opening, larger mean number of intersection between interincisal O–C paths during mastication and smaller asymmetry between working and balancing side, with participation beyond the expected of the contralateral muscles (P < 0.05, t-test). Overall, TMD subjects showed similarities with the control subjects in several kinematic parameters and the EMG indices of the static test, although some changes in the mastication were observed.

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1. Introduction

Mastication is performed by combining contractile activity of several orofacial muscles which results in structure movements and force. Among them, jaw muscles must be able to control the position and motion of the mandible and to adapt to varying functional demands (Grünheid et al., 2009). Muscle pain is known to influence muscle activity and function (Bakke and Hansdottir, 2008).

The main cause of pain of non-dental origin in the orofacial region is temporomandibular disorder (TMD), a collection of dysfunctions and pain in the masticatory muscles, temporomandibular joints (TMJs) and associated structures, that often coexist with headaches, neck and shoulder pain. TMD can occur in children and adolescents (Tecco et al., 2011), and in a normal adult population 5–9% of people have significant TMD symptoms (Al-Saleh et al., 2012; Monaco et al., 2012; Oono et al., 2012). This disorder was reported to remit over a 5-year observational period in 33–49% of diagnosed cases and to remain persistent or recurrent in the remainder (Maixner et al., 2011).

TMD has been associated to the recruitment strategy of motor units in order to prevent pain (Peck et al., 2008), changes in the jaw-closing muscles fiber-type composition (Grünheid et al., 2009; Nickel et al., 2012) and functional limitation, oftentimes related to pain persistence and severity (Plesh et al., 2011; Rollman et al., 2012). Long-lasting TMD can compromise the oral food processing, feeding and life quality, and an early diagnosis may offer a better prognosis.

Mandibular kinematic and surface electromyography (sEMG) analyses together can be useful to better understand TMD (Sforza et al., 2009; Monaco et al., 2012), although the reliability and validity of these diagnostic tools for TMD is still under debate (Al-Saleh et al., 2012).

Optoelectronic analyzers allow a detailed analysis of mandibular three-dimensional (3D) motion, with minimal obstruction, if compared to the standard kinesiographic analysis, permitting to study also the relative contribution of rotation and translation components of the TMJ condyle-disc assembly (Ferrario et al., 2005; Gallo et al., 2006; Mapelli et al., 2009; Naeije, 2002; Naeije and Hofman, 2003; Sforza et al., 2009). The amount of mandibular condylar motion has been suggested to be a good index to assess
TMJ conditions (Miyawaki et al., 2001). sEMG of masticatory muscles allows to analyze muscle activities and coordination (De Felício et al., 2012; Forrester et al., 2010; Tartaglia et al., 2011).

The current study aimed to assess the mandibular kinematics and the sEMG characteristics of masticatory muscles, during the performance of static and dynamic tasks, of subjects from community (no-patients) with short lasting and mild-moderate severity TMD.

2. Materials and methods

2.1. Subjects and clinical examination

This study included 20 subjects, 10 with TMD (TMD group: three men and seven women; mean age 27.3 years, SD 7.8) and 10 subjects, matched by age, without TMD (control group: five men and five women; mean age 31.9 years, SD 16.3). All participants, who were students and staff at Milan University, volunteered for the study after a detailed explanation of the experiment and possible risks involved. The study protocol was approved by the local ethic committee.

They had permanent dentition, no loss of posterior support or crossbite, no dental pain or periodontal problems, neurological or cognitive deficit, previous or current tumors or traumas in the head and neck region, current or prior orthodontic, orofacial myofunctional or TMD treatment, current use of analgesic, anti-inflammatory and psychiatric drugs. Also, women declared to be not pregnant.

The inclusion criteria for TMD group were:

- to have a short lasting TMD (duration shorter than 6 months) with mild-moderate signs and symptoms severity;
- to have not sought care to TMD.

The inclusion criterion for control group was to have no TMD. All subjects were evaluated by the same experienced examiner, according to the Research Diagnostic Criteria for TMD (RDC/TMD), Axis I (Dworkin and LeResche, 1992). Table 1 shows TMD group distribution.

TMD signs and symptoms severity was determined by self-judgment, according to the validated ProTMDmulti-part II questionnaire; the total severity score varies between zero (absence) and 360 (the highest possible severity) (De Felício et al., 2012).

For TMD group the total severity score was 33.30 ± 20.75, range 9–77. The control group showed no features for the classification of TMD; their main symptom was cervical pain and the total severity score was 3.0 ± 3.89, range 0–12.

2.2. Data collection

All procedures were non-invasive and did not provoke pain or discomfort to the subjects, who were free to stop their examination in any moment.

2.2.1. Mandibular kinematics

Free maximum mouth opening (MMO) and closing were performed three times, while the subject sat on a chair without headrest, with the head in natural position, and were recorded by an anthropometric and Extraskeletal 3D video system (ARTec 3D GmbH, Germany). The measurement was standardized with the subject in a natural head position, by a self-developed system. The anthropometric and Extraskeletal system provided the 3D coordinates of the markers by means of a 3×3 camera array. The current study aimed to assess the mandibular kinematics and the sEMG characteristics of masticatory muscles, during the performance of static and dynamic tasks, of subjects from community (no-patients) with short lasting and mild-moderate severity TMD.

2.2.2. Surface EMG

sEMG recordings and analyses were performed according to Sforza et al. (2010) and Tartaglia et al. (2011). Briefly, the masseter and anterior temporal muscles of both sides (left and right) were examined. Disposable silver/silver chloride bipolar surface electrodes (diameter 10 mm, interelectrode distance 21 ± 1 mm; Duo-Trode; Myo-Tronics Inc., Seattle, WA, USA) were positioned on the muscular bellies parallel to muscular fibers (Hermens et al., 2000). A disposable reference electrode was applied to the forehead.

EMG activity was recorded using a computerized instrument (Freely, De Götzsen srl; Legnano, Milano, Italy). The analog EMG signal was amplified and digitized (gain 150, peak-to-peak input range 28 mV, 12 b resolution, 2230 Hz A/D sampling frequency, theoretical resolution 16 μV) using a differential amplifier with a high common mode rejection ratio (CMRR = 105 dB in the range 0–60 Hz, input impedance 10 GΩ), and filtered (analog filtering: low-pass filter with a bandwidth in the frequency range 0–580 Hz; digital filtering: range 30–400 Hz; band-stop for common 50 Hz interference with a notch filter, approximate range 47–53 Hz).

To standardize the EMG potentials, two 10 mm-thick cotton rolls were positioned on the mandibular second premolar/first molars of each subject, and a 5 s-maximum voluntary contraction (MVC) was recorded (COT). Then, the subject was invited to clench as hard as possible with the maxillary and mandibular teeth in maximum contact (ICP), and to maintain the same level of contraction for 5 s (CLENCH). Then, EMG activity was recorded during

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<td>Ia</td>
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<td>x 1</td>
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</tbody>
</table>

Ia: myofascial pain, fb: myofascial pain with limited opening.
Ila: displacement with reduction, IIa: arthralgia, N: number of subjects.
The tests were explained and shown to the subjects, who practiced before actual data acquisition. For all tests, the subjects sat with their head unsupported and were asked to maintain a natural erect position. To avoid any fatigue's effect, a rest period of at least 3 min was allowed between each test.

2.3. Data analysis

2.3.1. Kinematic analysis

The extraoral mandibular markers individuated the plane of mandibular motion (Ferrario et al., 2005). The relative motion between the head reference system and the mandibular one was computed by means of mapping operators, which allow analyzing mandibular pathway relative to the head. Subsequently, the displacements of the dental and condylar points were reported in the global reference system (head system), with their paths being evaluated in the horizontal, frontal, and sagittal planes. The data were mathematically smoothed using a second-order Butterworth’s low-pass filter (cut-off frequency of 8 Hz).

In each motion frame, the rotational angles made by the extraoral device (i.e. the mandible) around the three global axes were calculated using Cardan angles. The sagittal mandibular movement during mouth opening and closing was further divided into its rotation and translation components; in each frame of motion, the relative percentage contribution of the two components to the total movement was calculated. In order to compare different patients, the mandibular movement was normalized on MMO distance (sagittal projection): mouth opening and closing were sampled in 10% steps, and in each step the rotation and translation components were further considered (Mapelli et al., 2009).

To assess mastication kinematics, each chewing cycle was detected by an algorithm code written in Matlab. To be included as a valid cycle, each cycle had to last more than 250 ms and to be more than 3 mm long vertically. Then, each chewing cycle was broken down into two phases (open–close), and each path length, time duration and velocity were extracted. The total area delimited by the IP path in the frontal plane was evaluated, together with its percentage subdivision in the working and balancing sides.

The number of intersection between IP opening and closing paths was also computed.

2.3.2. EMG analysis

For each of the four analyzed muscles, the mean EMG potential evaluated on the most constant 3 s-interval of COT trial (mean of the root mean squared, RMS, calculated in 25 ms-temporal windows) was set at 100%, and all EMG potentials obtained during both CLENCH and gum chewing were expressed as a percentage of this value.

The EMG normalized signals of paired muscles were compared by computing a percentage overlapping coefficient (POC). POC is an index of the symmetric distribution of the muscular activity during the 3 s of CLENCH. The index, which ranges between 0% (no symmetry) and 100% (perfect symmetry), was obtained for each subject’s masseter and temporalis muscles.

Because an unbalanced contractile activity of contralateral masseter and temporalis muscles might prompt a potential lateral displacing component, the torsion coefficient (TC) was calculated by superimposing the right temporalis plus left masseter normalized EMG amplitudes over the left temporalis plus right masseter normalized EMG amplitudes: the area of the superimposition was assessed as a percentage of the total EMG amplitudes. TC ranges between 0% (complete absence of lateral displacing force) and 100% (no lateral displacing force). To individuate the most prevalent pair of masticatory muscles, an activity index (Ac) was computed as the percentage ratio of the difference between the mean masseter and temporalis standardized potentials, and the sum of the same standardized potentials. This index is positive (up to +100%) when the masseter muscles standardized potentials are larger than the temporalis muscles ones, negative (down to −100%) when the temporalis muscles potentials are larger. Finally, the mean (masseter and temporalis) total standardized muscle activity was calculated as the integrated area of the EMG potential over time (Sforza et al., 2010, Tartaglia et al., 2011).

EMG signals of gum chewing were normalized on COT. Two main parameters were computed: the masticatory frequency and the confidence ellipse (Hotelling’s 95%) of the simultaneous maximum differential right–left masseter and temporalis standardized activity extracted from each cycle (Lissajous’s plot) (Sforza et al., 2010, Tartaglia et al., 2008).

From the pairs of coordinates, the position of the unknown population centre is estimated by the sample centre. The phase angle gives the inclination of the ellipse relative to the coordinate axes, whereas the amplitude gives the distance of the centre of the ellipse from the centre of the coordinate axes. To assess if the unilateral chewing tests were performed with symmetrical muscular patterns, the symmetric mastication index (SMI) was computed using the centres of the two confidence ellipses (left and right-side chewing). In subjects with a normal neuromuscular coordination, the centres of the ellipses describing unilateral chewing plotted as a Lissajous’s figure should be located in the first (right side) and third (left side) quadrants (Kumai, 1993). A symmetrical muscular pattern would then produce a SMI close to 100%. To directly compare right- and left-side chewing, this latter’s phase was mirrored, subtracting 180° to its value.

Furthermore, the mean (masseter and temporalis) total muscle activities during chewing were assessed as the integrated areas of the standardized EMG potentials over time. Both the activity normalized on the number of performed cycles, and its percentage referred to the working side, were also computed (Sforza et al., 2010).

2.4. Statistical analysis

Descriptive statistics were computed for all variables that were normally distributed. Mean values were compared by Student’s t tests for independent samples (open/close and mastication kinematics; EMG in MVC and mastication). For group comparisons, right and left side chewing data were pooled.

Three-way analysis of variance (ANOVA) was employed for the relative contribution of rotation in both opening and closing (two groups × two condyles × 10 frames each), followed by post hoc Student’s t-tests.

The percentage of subjects having a non-correct location of the centres of Hotelling’s ellipses was also computed separately for each group.

The level of significance was set at $P<0.05$ for all statistical analyses. All calculations were made using the Statistica software (StatSoft Inc., Tulsa, Oklahoma, USA).

The repeatability of mandibular movements and EMG variables had already been investigated, and found to be good (De Felício et al., 2012; Ferrario et al., 2005; Sforza et al., 2009).

3. Results

3.2. Kinematic analysis

At maximum mouth opening (MMO) there were no differences between groups either in the displacement of the IP and CRPs or in
of closing as a percentage of MMO; Fig. 1. Rotation component of the condylar movement in opening and closing as a percentage of the total mandibular movement in C and TMD group.

Table 2
Absolute values of IP and condylar cartesian projections and mandibular angles at MMO.

<table>
<thead>
<tr>
<th>Unit</th>
<th>C (n = 10)</th>
<th>Mean</th>
<th>SD</th>
<th>TMD (n = 10)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP MMO</td>
<td>mm</td>
<td>45.1</td>
<td>7.5</td>
<td>43.7</td>
<td>8.4</td>
<td></td>
</tr>
<tr>
<td>IP caudal component</td>
<td>mm</td>
<td>37.1</td>
<td>6.1</td>
<td>36.1</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>IP dorsal component</td>
<td>mm</td>
<td>25.0</td>
<td>7.7</td>
<td>23.4</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>IP lateral deviation</td>
<td>mm</td>
<td>2.0</td>
<td>1.3</td>
<td>1.9</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Sagittal angle</td>
<td>deg</td>
<td>32.5</td>
<td>5.7</td>
<td>31.8</td>
<td>6.1</td>
<td></td>
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<tr>
<td>Frontal angle</td>
<td>deg</td>
<td>0.6</td>
<td>3.5</td>
<td>0.0</td>
<td>2.7</td>
<td></td>
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<tr>
<td>Horizontal angle</td>
<td>deg</td>
<td>0.9</td>
<td>2.6</td>
<td>0.5</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>rCRP caudal component</td>
<td>mm</td>
<td>8.3</td>
<td>3.3</td>
<td>7.0</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>rCRP ventral component</td>
<td>mm</td>
<td>12.3</td>
<td>7.3</td>
<td>10.0</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>rCRP lateral component</td>
<td>mm</td>
<td>1.3</td>
<td>0.9</td>
<td>1.5</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>ICRP caudal component</td>
<td>mm</td>
<td>8.3</td>
<td>2.5</td>
<td>6.5</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>ICRP ventral component</td>
<td>mm</td>
<td>11.5</td>
<td>7.4</td>
<td>11.5</td>
<td>5.9</td>
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<tr>
<td>ICRP lateral component</td>
<td>mm</td>
<td>1.3</td>
<td>1.0</td>
<td>1.5</td>
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MMO, maximum mouth opening; IP, mandibular interincisor point; rCRP/lCRP, right/left condylar reference point.

Table 3
Mandibular rototranslation during mouth opening and closing.

<table>
<thead>
<tr>
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<th>C</th>
<th>TMD</th>
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<tbody>
<tr>
<td>Opening condylar translation (mm)</td>
<td>Mean 21.0</td>
<td>20.9 18.5 20.6</td>
</tr>
<tr>
<td>SD 6.2</td>
<td>5.0 3.9 4.6</td>
<td></td>
</tr>
<tr>
<td>Closing condylar translation (mm)</td>
<td>Mean 22.3</td>
<td>22.6 18.8 21.4</td>
</tr>
<tr>
<td>SD 8.6</td>
<td>6.9 4.7 6.3</td>
<td></td>
</tr>
<tr>
<td>Opening rotation component (%)</td>
<td>Mean 69.7</td>
<td>69.5 70.7 68.8</td>
</tr>
<tr>
<td>SD 5.9</td>
<td>4.9 7.2 8.7</td>
<td></td>
</tr>
<tr>
<td>Closing rotation component (%)</td>
<td>Mean 68.8</td>
<td>68.2 70.3 68.3</td>
</tr>
<tr>
<td>SD 8.3</td>
<td>7.2 7.4 8.8</td>
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R, right side; L, left side.
Student’s t-tests: P > 0.05.

the mandibular rotational angle (Table 2). Cumulative values of rotation and translation components during mouth opening and closing were not significantly different between groups (Table 3).

Regarding the relative contribution of rotation for each of the 10% steps in opening, the 3-way ANOVA showed a significant effect of frame of motion ($F_{9,324} = 5.29; P < 0.001$), and a group $\times$ frame of motion interaction ($F_{9,324} = 2.69; P < 0.005$). In closing, there was only a significant effect of frame of motion ($F_{9,324} = 9.75; P < 0.001$). A significant between groups difference was found in the last 10% of opening (90–100% frame, Fig. 1). The relative rotation was larger in the C group (84.12 ± 9.92%) than in the TMD group (67.78 ± 25.11%) (t-test, $P = 0.01$).

No significant differences were found between the right and left sides of the frontal plane projection of IP pathway during chewing movements in both groups. The frontal plane chewing characteristics were similar in the two groups (Table 4, t-test, $P > 0.05$); the only significant difference was found in the mean number of intersection within each cycle between IP opening and closing paths ($P = 0.025$). The TMD group had a larger mean number of intersections per cycle than the C group. No significant differences were found between groups in the sagittal plane analysis (data not shown).

3.3. EMG analysis

During MVC test, no significant differences were found between groups for EMG symmetry (masseter and temporal POCs), TC, activity index and total muscular standardized activity. During chewing, only the mean amplitude significantly differed between groups; it was higher in the C group than in the TMD group ($P = 0.04$). Overall, in the TMD group there was smaller asymmetry between working and balancing side, with participation beyond the expected of the contralateral muscles (Table 5, t-test, $P > 0.05$).

In the C group the centres of the ellipses describing the unilateral chewing were located in the correct quadrants of the Lissajous's plot (first quadrant for right-side chewing, third quadrant for left-side chewing), except for one subject. In the TMD group, 50% of the subjects had the centre not located in the correct quadrants: 30% during right chewing, 10% during left chewing, and 10% on both sides.

4. Discussion

In the current study, we examined whether subjects with TMD of mild-moderate degree and of short duration, who had not
sought treatment, presented any changes in their mandibular kinematics and/or in the EMG characteristics of their masticatory muscles, with respect to a control group. Both 3D analysis (Gallo et al., 2006; Naeije, 2002) and EMG (Forrester et al., 2010; Sforza et al., 2008) have been applied in research laboratories for stomatognathic functional analysis.

Most of kinematic parameters of mouth opening/closing were not significantly different between groups, and were comparable to those of previous control groups (Ferrario et al., 2005; Mapelli et al., 2009); although, some exceptions were observed.

The pattern of mouth opening and closing determined more by condylar rotation than translation, which is characteristic of subjects with a healthy stomatognathic system (Mapelli et al., 2009), was observed in both the C and TMD groups. However, in the C group, the contribution of rotation was stable in the first 80% of mouth opening and increased in the remaining 20%, in accord with previous findings (Ferrario et al., 2005), while in the TMD group no increment was observed, and a significant difference was found between groups in the last 10% of opening.

Since the global (opening/closing) relative contribution of condylar rotation and translation did not show differences between groups, it seems that in the current TMD group a delayed condylar translation during mouth opening has been compensated at the end of the movement. Gallo et al. (2006) found a sudden change in the rototranslation ratio accompanying the clicking sound in patients with TMD-DDR, i.e. when the condyle overcomes the disc obstacle during opening and when it slides behind the disc during closing. The reduction of the disc at the end of mouth opening in some of our eight TMD-DDR subjects may have significantly contributed to the larger condylar translation of the TMD group during the last step.

Our results of short lasting TMD with mild-moderate severity suggest changes in the step-related combination of these movement components, rather than the global translation reduction reported in patients with serious TMJ injuries (Sforza et al., 2009; Türp et al., 1996).

Also, during mastication, no changes were observed in the displacement, velocity and duration of the IP movement analyzed on the frontal plane. Similar results were previously described in human experimental pain (Lobbezoo et al., 2006). The only difference between our groups was a greater number of intersections between interincisal opening and closing paths during mastication in the TMD group. In contrast, patients with long-lasting TMD presented changes in masticatory movements, longer duration of the masticatory cycles and lower velocity compared to healthy subjects. These impairments have been attributed to current pain, but also to a mechanism of sensitization, pain adaptation and prolonged hypoactivity of mandibular elevator muscles (Bakke and Hansdottir, 2008; Peck et al., 2008).

The sEMG potentials recorded during both static (MVC-CLENCH) and dynamic (mastication) tests were standardized on the maximum clenching with cotton rolls (MVC-COT), an effective process for the investigation of differences in muscle function between different populations (Forrester et al., 2010; Tartaglia et al., 2011). Moreover, we calculated sEMG indices that describe the coordination of muscle activity (Forrester et al., 2010), and not simply the activity of each individual muscle.

In the current study, MVC parameters were similar between TMD and C groups, whereas long-lasting TMD patients were reported to differ from healthy subjects, showing a significant muscle asymmetry (Tartaglia et al., 2008). Previously, it was observed that the larger the sEMG standardized symmetry (POC), the smaller the score of the ProTMADmulti self assessment (De Felício et al., 2012). Since current TMD subjects had mild-moderate severity scores, the present results are not surprising. However, more investigations are needed.

During chewing task, sEMG results suggested less accurate recruitment of the jaw elevator muscles in TMD group than C group. The significant lower amplitude index found in the TMD group means increased relative activity of the muscles on the balancing side, while C group showed a more evident prevalent activity in both masseter and temporal muscles of the working side, as expected under normal conditions (Christensen and Mohamed, 1996). Also, in TMD subjects, the centre of the ellipse describing their unilateral chewing was located out of the expected quadrant of the Lissajous’s plot more frequently than in control group (50% vs 10%). Moreover, they showed larger variability (even not significant) of the differential muscular activation (wider confidence ellipses) than C, i.e. less repeatable alternate patterns of contraction of the muscles on the working and balancing sides (Tartaglia et al., 2008).

Overall, these findings may be interpreted as muscular incoordination; however, it is not possible to say whether this precedes or succeeds the TMD onset.

The literature explains muscular activity changes in terms of compensatory/adaptive behavior, as already mentioned, which may lead to future pain, injury and disabilities, (Peck et al., 2008), in some cases irreversible. Jaw-closing muscles disuse atrophy, increase in the percentage of fibers expressing fast MyHC types and a decrease in the cross-sectional area of slow-type fibers are often long term consequences (Grünewald et al., 2009; Nickel et al., 2012). Pain persistence is of great clinical significance (Plesh et al., 2011), it seems related to dysfunction of endogenous pain-modulatory systems (Ono et al., 2012), and it is a predictor of high pain-related disability, along with severity/pain intensity (Rollman et al., 2012).

So, an early identification of TMD would be worthwhile. However, this is not an easy task, because pain intensity and fear of jaw movements play an important role in the decision to seek care for orofacial pain complaints (Rollman et al., 2012). It would be important, therefore, that health professionals were able to recognize the commonest signs and symptoms of TMD to counsel their patients to seek a specialist.

This study highlights that severity, together with duration, should be considered for the composition of experimental TMD groups. The small number of subjects analyzed, a limitation of this study, was due to the fact that they were all non-patients and to the rigorous inclusion criteria for both TMD and healthy subjects.
5. Conclusion

Subjects with short lasting and mild-moderate severity TMD, relative to Control subjects, had lower relative rotation of the TMJ at the end of mouth opening, and larger number of intersections between interincisal opening and closing paths during mastication.

Increased temporal and masseter muscles EMG activity on the balancing side was also observed during chewing.

Our results support the importance of performing the examination of the stomatognathic system also in the dynamic condition.

Conflict of interest

The authors declare that they have no conflict of interest.

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