The maintenance of erect posture during external disturbance or displacement from the center of gravity depends on postural strategies of the hips and ankles as well as anticipatory postural adjustments resulting from preprogrammed, involuntary and centrally controlled actions aimed at predicting the intensity of the disturbance, especially under static conditions. The function of sensory afferents depends on both internal and external structures. Alterations or reprogramming of some of these structures can alter the information of the other structures, resulting in a rearrangement of postural control and consequently altering the balance of the body.

The function of sensory afferents depends on both internal and external structures. Alterations or reprogramming of some of these structures can alter the information of the other structures, resulting in a rearrangement of postural control and consequently altering the balance of the body. Based on these concepts, a growing number of studies have focused on the investigation of the potential influence of components of the stomatognathic system on postural control.

Proprioception of the stomatognathic system is associated with receptors in the muscles of mastication (neuromuscular spindle, tendon organ), receptors of the periodontal ligament and free nerve endings in the synovial space of the temporomandibular joint and is directly related to the trigeminal complex. Neuroanatomic evidence demonstrates an interaction between the projection of the trigeminal complex and the vestibular nucleus. Signals from the latter converge in the upper spinal cord with signals from the stomatognathic system through the trigeminal complex and alterations in the nucleus of the trigeminus may affect postural stability.

This suggests a potential functional connection from the trigeminal afferents to other systems related to balance control in humans. Thus, alterations in the muscles of mastication, ligaments and related structures may result in alterations in the positioning of the mandibular axis, resulting in changes in postural control.
in compromised postural control mechanisms\textsuperscript{8,9}.

Despite this morphofunctional evidence, the relationship between the stomatognathic system and postural control is not yet clarified\textsuperscript{10}. Stabilometry can contribute to a better understanding of the association between components of the stomatognathic system and body posture\textsuperscript{10}. However, the low quality of the studies found in the literature underscores the need to conduct further investigations\textsuperscript{8,9}.

The clinical importance of this evaluation is related to joint assessments and clinical treatment, such as in the case of occlusal therapy founded on the numerous anatomic connections between the trigeminal nerve and structures involved in the maintenance of posture\textsuperscript{7}. There is considerable interest in the confirmation of interconnections between the stomatognathic system and postural control. If this confirmation is achieved, there will be a need for the integration and establishment of novel clinical strategies involving both dentistry and physical therapy for a more complete evaluation of individuals with alterations in the stomatognathic system, especially those with TMD.

Thus, the aim of the present study was to determine whether non-habitual (isotonic) bilateral and unilateral mastication with eyes open and eyes closed influence static balance in individuals without temporomandibular disorder (TMD).

**Methods**

This study received approval from the Human Research Ethics Committee of the Universidade Nove de Julho (Brazil) under process n° 364287/2010. Written informed consent was obtained from all participants and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

An observational, cross-sectional study was carried out involving 20 individuals (3 men and 17 women) recruited from a total of 45 consecutive individuals who sought the Movement Biodynamics Laboratory of the Universidade Nove de Julho (Sao Paulo, Brazil), this laboratory conducts assessments and consultations related to TMD.

The calculation of the sample size was carried out with $\alpha = 0.05$ (5% chance of type I error) and $1-\beta = 0.90$ (power 90%) as well as the results of a pilot study performed at our laboratory involving 10 healthy adults (Mean age: 29.6 ± 2.10 years; Mean height: 1.69 ± 11.70 m; Mean weight: 70.48 ± 10.60 Kg).

The following were the inclusion criteria: age between 20 and 40 years; absence of TMD [as determined by the administration of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD)]; absence of pain and/or fatigue in the temporalis and/or masseter muscles; Angle class I occlusion; and body mass index not surpassing 25 Kg/m$^2$.

The following were the exclusion criteria: missing teeth (except third molars); open bite; overbite; crossbite; use of dentures (complete or partial); use of orthodontic or orthopedic appliance; history of trauma to the face or temporomandibular joint; history of fracture or injury in the lower limbs or back; use of arch supports; systemic conditions (arthritis, arthrosis and diabetes); alterations in the vestibular system; systemic neuromuscular disease; being currently in physical therapy, dental or medicinal (analgesics, anti-inflammatory agents or muscle relaxants) treatment; and the ingestion of alcoholic beverages in the 24 hours prior to the evaluation.

The volunteers were assessed on a single day. Stabilometry and electromyography were administered simultaneously during static posture, with the evaluation of signals in three moments (pre-mastication, during mastication and post-mastication). Each volunteer was instructed to perform different types of mastication under four conditions, obeying the following sequence: (1) non-habitual (isotonic) bilateral chewing with eyes open (EO); (2) non-habitual (isotonic) bilateral chewing with eyes closed (EC); (3) non-habitual (isotonic) unilateral (right side) chewing with EO; (4) non-habitual (isotonic) unilateral (right side) chewing with EC.

The evaluations were performed using both bilateral and unilateral (right) chewing conditions to determine possible connections between chewing side and body sway. Parafilm “M”\textsuperscript{\textregistered} was used for the different chewing conditions (bilateral and unilateral [right side]). This material was folded to obtain an approximate size of 35 mm in length by 15 mm in width and 3 mm in thickness and positioned either bilaterally or unilaterally between the upper and lower premolars, first molars and second molars. This procedure led to the lowest variability in the electromyographic records of chewing activity\textsuperscript{11}.

Verbal commands were given to initiate the action (chewing or clenching). These commands (“chew, chew” or “clench, clench”) were continued throughout the duration of the activity for 30 seconds, coordinated with the aid of a metronome calibrated to 60 beats per minute. The volunteer stood barefoot with bipedal support in a comfortable stance on the force plate with unrestricted width of the foot base, heels in alignment, arms alongside the body and gaze fixed on a circular target (5 cm in diameter) at the height of the glabellum attached to a pedestal at a distance of 1.5 meters. Each reading lasted 120 seconds, with a 60-second interval between readings. The volunteers were instructed to sit in a comfortable chair for 60 seconds between each evaluation.

The force plate was used to determine the displacement from the center of pressure (COP) in the antero-posterior ($\text{COP}_{ap}$) and mediolateral directions ($\text{COP}_{ml}$) as well as the COP area. For such, a force plate system was used (BIOMEC 400 v1.1\textsuperscript{a}, EMG System do Brasil Ltda\textsuperscript{a}), which consisted of four load cells with an internal circuit
that changes in electrical resistance upon the application of force. The data were recorded with 100 Hz for a 60-second sampling frequency.

Electromyographic activity of the masseter muscles (synchronized with the force plate readings) was evaluated to determine the beginning and end of the chewing cycle. The electromyographic signals were captured by an eight-channel signal conditioning module (EMG System®, EMG System do Brasil Ltda), using a band pass filter with a frequency of 20-500 Hz, amplifier with a 1000 x gain and common rejection ratio > 120 db. All data were captured and processed using a 16-bit analog-to-digital converter with a 1 kHz sampling frequency. The system was composed of bipolar active electrodes with a 20 x pre-amplification gain.

For the synchronization of electromyographic and stabilometric activity, one channel of the electromyographic signal conditioning module was enabled to receive input from an optical mouse, which, upon being clicked, initiated the synchronized readings, generating a mark on the electromyographic signal of the muscles of mastication and determining the exact instant for the onset of the signal capturing (Fig. 1).

The electromyographic and stabilometric data were normalized in time using the onset of electromyographic activity as the reference for the different variables: COP$_{ml}$ and COP$_{ap}$ displacement and oscillation area. The synchronized readings were divided into three 30-second evaluations: T1 – pre-mastication (reading terminated 2 seconds prior to chewing phase); T2 – mastication (reading initiated 2 seconds after onset of chewing and terminated 2 seconds prior to termination of chewing phase); and T3 – post-mastication (reading initiated 2 seconds after termination of chewing phase) (Fig. 1).

Data analysis was processed and calculated using the Matlab 7.1 program (The Math Works, Inc. Natick, MA, USA) performed by a blinded researcher. A low-pass Butterworth filter was used to filter the COP data at 10 Hz. For the 30-second period were computed the area of the COP sway and COP$_{ap}$ and COP$_{ml}$ displacement. COP area was calculated using principal component analysis, with 95% of the data points (see [Eq. 3])$^{12)}$. Mean COP displacement in each direction (COP$_{ap}$ and COP$_{ml}$) was calculated from the sum of the distances between all consecutive points defined by the COP trajectory divided by the number of points$^{31)}$.

The Shapiro-Wilk test was used to test the data with regard to Gaussian distribution and CoP data were not normally distributed. The results were expressed as mean and standard deviation values. Data on COP$_{ml}$ and COP$_{ap}$ displacement and COP area at the three evaluation times (T1, T2 and T3) under right side unilateral and bilateral mastication conditions demonstrated asymmetric distribution. A repeated-measure generalized linear model was adjusted to determine differences between evaluation times considering the gamma distribution with a reciprocal link function. Analysis was performed using the GENMOD procedure of the SAS program for Windows, v.9.2. Multiple comparisons between evaluation times were performed using the DIFF option of the same procedure. The level of significance was set to 5% (p < .05).

**Results**

Table 1 displays the anthropometric data on the 20 volunteers of the present study. Table 2 displays the mean COP$_{ap}$ and COP$_{ml}$ displacement and oscillation area values in the different evaluation times (pre-mastication, during mastication and post-mastication). During bilateral mastication, a statistically significant difference between evaluation times was found only regarding oscillation area with eyes open (p < .05).
Regarding right unilateral mastication, significant differences were only found for oscillation area with eyes open and COP<sub>ml</sub> with eyes closed (p < .05).

**Table 1.** Anthropometric data of participants (expressed as mean and standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>Height (m)</th>
<th>Body mass (kg)</th>
<th>BMI (Kg/m&lt;sup&gt;2&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>24.10</td>
<td>1.76</td>
<td>73.04</td>
<td>23.37</td>
</tr>
<tr>
<td>SD</td>
<td>4.60</td>
<td>0.04</td>
<td>5.54</td>
<td>1.08</td>
</tr>
</tbody>
</table>

BMI: body mass index; SD: Standard deviation.

**Table 2.** Mean and standard deviation values of oscillation area and anteroposterior (COP<sub>ap</sub>) and mediolateral (COP<sub>ml</sub>) displacement from the center of pressure during pre-mastication, mastication and post-mastication phases [bilateral and unilateral (right side)] under visual conditions of eyes open and eyes closed

<table>
<thead>
<tr>
<th>Type of mastication</th>
<th>Mastication period</th>
<th>Pre Mean ± SD</th>
<th>During Mean ± SD</th>
<th>Post Mean ± SD</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area (cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilateral EO</td>
<td>1.12 ± 1.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.78 ± 0.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.18 ± 0.98&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt; 0.05</td>
<td></td>
</tr>
<tr>
<td>Bilateral EC</td>
<td>1.21 ± 0.76</td>
<td>1.10 ± 0.50</td>
<td>1.39 ± 1.40</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Right EO</td>
<td>1.38 ± 1.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.02 ± 0.83&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.43 ± 1.41&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt; 0.05</td>
<td></td>
</tr>
<tr>
<td>Right EC</td>
<td>2.05 ± 1.65</td>
<td>1.50 ± 1.24</td>
<td>1.89 ± 1.65</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

Displacement (cm)

|                     |                  |               |                 |                |         |
| Bilateral COP<sub>ap</sub> EO | 0.24 ± 0.14 | 0.22 ± 0.09 | 0.25 ± 0.11 | ns             |
| Bilateral COP<sub>ap</sub> EC | 0.25 ± 0.07 | 0.26 ± 0.07 | 0.26 ± 0.11 | ns             |
| Bilateral COP<sub>ml</sub> EO | 0.15 ± 0.07 | 0.13 ± 0.06 | 0.16 ± 0.07 | ns             |
| Bilateral COP<sub>ml</sub> EC | 0.15 ± 0.06 | 0.14 ± 0.04 | 0.16 ± 0.10 | ns             |
| Right COP<sub>ap</sub> EO   | 0.25 ± 0.10 | 0.24 ± 0.10 | 0.29 ± 0.18 | ns             |
| Right COP<sub>ap</sub> EC   | 0.30 ± 0.10 | 0.28 ± 0.11 | 0.31 ± 0.14 | ns             |
| Right COP<sub>ml</sub> EO   | 0.18 ± 0.08 | 0.15 ± 0.08 | 0.16 ± 0.08 | ns             |
| Right COP<sub>ml</sub> EC   | 0.22 ± 0.13<sup>a</sup> | 0.17 ± 0.08<sup>b</sup> | 0.18 ± 0.10<sup>b</sup> | < 0.05 |

Different superscript letters denote significant differences between mean values. SD: standard deviation; EO: eyes open; EC: eyes closed; ns: non-significant

Discussion

The aim of the present study was to determine whether non-habitual (isotonic) bilateral and unilateral mastication with eyes open and eyes closed influence static balance in individuals without temporomandibular disorder (TMD).

In the present study, statistically significant differences between evaluation times were found in oscillation area during with eyes open. These findings contrast those reported another study<sup>14</sup>, who evaluated male and female individuals with regard to postural control and occlusion and found no statistically significant differences in oscillation area under different occlusal conditions. While the study cited used a more sensitive analysis involving a dynamic stabilometric platform and employed inclusion criteria similar to those of the present study, no diagnostic method was used for the determination of TMD. This lack of diagnosis may have compromised the results, as individuals with TMD exhibit multi-factor alterations<sup>15</sup> that alter chewing activity and may cause an imbalance in postural control<sup>9</sup>.

Regarding unilateral mastigation, the individuals evaluated in its entirety, the left side of masticatory predominance, contrary to reports of other authors<sup>16</sup>, that most individuals are right-handed and therefore exhibit greater activity in the musculature on the right side than the left side, directly compromising the pterygoid muscle, for which unilateral contraction results in the movement of the mandible to the opposite side.

Alterations on the sagittal plane (COP<sub>ap</sub>) are generally more characteristic than those on the frontal plane (COP<sub>ml</sub>)<sup>17</sup>, which may be directly related to the recurrent use of ankle strategies for the maintenance of static balance<sup>1</sup> and not mastication, as found in the present study during left-side chewing. Likewise, other authors<sup>4,5</sup> con-
ducted an experiment soliciting unilateral mastication and found no alterations in postural control, stating that changes in postural control would only occur under extreme conditions. Exemplifying this, another study in anesthesia of the trigeminal nerve, provoking bodily imbalance on the side contralateral to the procedure; however, significant results were only found under the eyes closed condition, as in the present study.

Vision is one of the major systems involved in postural control and alterations in visual acuity can compromise this control. Compensatory and anticipatory postural adjustments are hindered under conditions without vision. This makes it difficult to confirm the influence of mastication over postural control in some of the variables used in the present study that exhibited statistically significant differences, such as the difference in COP displacement between the pre-mastication and mastication periods. However, even with the changes recorded, there was a tendency toward a reduction in the stabilometric data for a large part of the variables analyzed, demonstrating greater stability during mastication. This stability was either maintained or there was an increase in the values in the post-mastication period, which is in agreement with findings described by Hosoda, who report that the onset of recovery in individuals submitted to external perturbation was diminished when occlusion was performed.

The increase in stabilization may be related to the H reflex of the soleus and tibialis muscles. As afferent impulses and periodontal mechanoreceptors may be related, occlusion may trigger this reflex in these muscles, providing greater postural control and leading to a reduction in stabilometric data. When the stimulus is removed, postural control requires different strategies for the new postural condition, which may explain the increase in some variables after the termination of the chewing activity.

The present study has characteristics similar to those found in the study by Fujino, as some of the variables exhibited a tendency toward greater postural stabilization during mastication. However, the results of the perturbation employed in the present study (mastication activity) regarding the majority of stabilometric variables are in agreement with those reported by Bracco and Perinetti, as this form of perturbation was insufficient to demonstrate a relationship between components of the stomatognathic system and postural control. Significant differences between evaluation periods were found with eyes open for some variables and with eyes closed for other variables, but never under both visual conditions, which hinders the demonstration of this relationship.

The findings displayed in Table 2 demonstrate a tendency with regard to stability, which appears to become more compromised in the comparison between the first and final evaluation. It is therefore possible that the data acquisition sequence may have exerted an influence on the variables studied, especially oscillation area. Thus, future studies should be carried out with a different data acquisition protocol to minimize this possible influence.

Despite the statistically significant results obtained for some of the variables analyzed, the findings are insufficient to declare that chewing pattern causes changes in the stomatognathic system in individuals without TMD, as no significant results occurred under the two visual conditions (eyes open and eyes closed).

The main limitation of the present study was the non-use of a scale or assessment tool capable of determining the pressure pain threshold, which could demonstrate the degree of pain in each individual, as different intensity of pain may come influence the achievement of masticatory activity.

Conclusion

In summary, the different types of chewing promoted changes in the different variables of static balance, however, are necessary to carry out further studies to analyze and understand, especially, the variables that showed no changes in either masticatory types and none of the studied visual conditions.

References

10) Perinetti G, Contardo L: Posturography as a diagnostic aid in...