Previous research has shown that mastication reduces shifts in the center of gravity of persons standing still. The present research was conducted to determine whether mastication improves reactive balance in the standing position in response to unanticipated external disturbances. The subjects were 32 healthy male adults (mean age 21.1 years, standard deviation (SD) 0.7 years). Latency data determined with the Motor Control Test of Computerized Dynamic Posturography (CDP) were compared for the three conditions of mastication status, the direction of translation, and the magnitude of translation, using three-way repeated measures ANOVA and lower-order ANOVA with the three conditions separated. Latency was significantly shorter with mastication than with the lower jaw relaxed ($P < 0.00001$). Mastication alone, however, cannot be considered significant because of the complex interactions involved among the three conditions. Mastication increases not only static balance but also reactive balance in response to unanticipated external disturbances. Gum chewing may therefore reduce falls among elderly persons with impaired balance.

Key words: Balance; Latency; Mastication; Posturography

Introduction

Mastication, apart from its obvious role in food consumption, is known to affect systemic motor function in a variety of ways. One function that mastication impacts is balance in the standing position. Research has shown that maintained mastication inhibits shifts in the center of gravity in persons who are standing still. Measurements of the H reflex of the ankle extensors and flexors, which contribute to balance in the standing position, have demonstrated that the H reflex remained heightened during mastication.

Similar research indicated that occlusion improved the reactive balance required to maintain a standing position in response to external disturbances. In this research, reactive balance was assessed according to latency in the Motor Control Test, a component of Computerized Dynamic Posturography (CDP).

Falls among the elderly are attributable to tripping, slipping, and other unanticipated events, which makes reactive balance in response to external disturbances more appropriate for evaluating how prone subjects are to falls than shifts in the center of gravity in a static standing position.

CDP is a verified technique capable of detecting differences according to age, sex, and history of falls.
Despite the benefits occlusion provides to balance, it is infeasible to maintain occlusion throughout daily activities to better prepare for unanticipated external disturbances. Mastication, in contrast, could potentially help people maintain balance in response to unanticipated disturbances, but no relevant research has been conducted.

Therefore, mastication, which is easier than occlusion to maintain persistently on a routine basis, was selected, and whether mastication improves reactive balance in persons standing upright was investigated.

**Materials and Methods**

Thirty-two healthy adult males with no history of stomatognathic function abnormalities or leg disorders and no prostheses were selected from among volunteers who consented to participate in this research. Their mean (standard deviation (SD)) age, height, weight, and body mass index were 21.1 (0.7) years, 173.3 (5.3) cm, 67.8 (10.3) kg, and 22.5 (2.5) kgm⁻². This research was approved by the ethics committee of Ryotokuji University, and all subjects provided their written informed consent.

Balance was measured with the EquiTest® system (MPS-3102, NeuroCom®, Clackamas, OR, USA), which, with two platforms, measures shifts in the center of gravity caused by sudden forward or backward shifts applied as external disturbances. Latency was measured with the Motor Control Test (MCT) of the EquiTest® system⁴. The subjects, after planting their feet, were asked to maintain a comfortable standing position with their arms hung at their sides and their eyes open, gazing at the view in front of them. A safety harness was attached to the subjects to prevent falls. The subjects were instructed to maintain their original position as best as possible after external disturbances (Figure 1)¹⁴⁻¹⁷.

The subjects were asked to stand at rest on the platforms over the 2-minute period preceding balance measurement. When they were to keep the lower jaw relaxed, the subjects were instructed to close their lips without occluding the teeth and to keep their mouths relaxed. For mastication, the subjects were asked to chew one piece of chewing gum (Green Gum® Lotte Co., Ltd., Tokyo, Japan). The side of mastication was unspecified, and the subjects were free to choose the rhythm and speed of chewing. The subjects were instructed to continue masticating throughout the measurement period and the 2-minute period preceding the start of measurement. Measurements were conducted on two days one week apart. On one day, the subjects relaxed the lower jaw (R for relaxed), and on the other, the subjects masticated (M for mastication). In order to prevent any bias in the results arising from the learning effects of the experience on the first day, the measurements were performed in a randomized order under the condition that the number of subjects who relaxed their lower jaw on the first day was kept the same as the number of subjects who masticated on the first day.

Five minutes were needed to measure balance, so 7 minutes were required to measure the balance of one subject with the lower jaw relaxed and masticating. On one measurement day, balance was measured with the total of six randomly ordered combinations of conditions: the direction of translations (DT: forward and backward) and
magnitude of translations (MT; small, medium, large).

For the MTs (small, medium, and large), the platform moved a relative distance of 1.0, 2.5, and 4.5, respectively. The disturbances were maintained for 250, 300, and 400 ms, respectively. The absolute distances of movement, automatically corrected for subject height, were 0.5, 1.25, and 2.25 \times \frac{\text{height}}{72} \text{(cm)}, respectively. For each condition, balance was measured consecutively three times separated by a random interval (1.5 to 2.5 s). The mean latency output by the left and right platforms was calculated. Then, the lower of the mean left and right latency values was used.

The data for the 12 combinations of mastication status (2 conditions), DT (2 conditions), and MT (3 conditions) obtained with the 32 subjects were analyzed using three-way repeated measures ANOVA. When an interaction was detected with three-way repeated measures ANOVA, two-way repeated measures ANOVA and one-way repeated measures ANOVA were conducted for multiple comparisons. The significance level was set at $P < 0.05$. Statistical analysis was conducted with SPSS version 19.0 (SPSS Inc., Chicago, IL, USA).

### Results

Three-way repeated measures ANOVA showed the main effect of mastication status (M) to be highly significant ($P < 0.00001$) and the main effect of direction of translation (DT) to be significant ($P < 0.05$) (Table 1). The interaction of the two parameters mastication status (M) and direction of translation (DT) (M × DT), however, was also significant ($P < 0.05$), as was the interaction of the three parameters mastication status, direction of translation, and magnitude of translation (M × DT × MT) ($P < 0.05$). An unequivocal conclusion about the main effect cannot be reached based on the ANOVA results alone.

A multiple comparison using two-way repeated measures ANOVA (M × DT) was therefore conducted with the three individual conditions of MT (Figure 2). The interaction between mastication and direction of translation was insignificant for the small and large magnitudes (small, $P = 0.662$; large, $P = 0.420$). At the small magnitude, latency was significantly shorter with mastication (119.22 ms) than with the lower jaw relaxed (123.75 ms; $P < 0.001$) (Figure 2).

### Table 1

Three-way repeated measures ANOVA table for the effect of mastication status (M), direction of translations (DT), and magnitude of translations (MT) on the latency of postural responses.

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects (S)</td>
<td>31</td>
<td>14516.667</td>
<td>468.280</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Mastication (M)</td>
<td>1</td>
<td>1426.042</td>
<td>1426.042</td>
<td>36.118</td>
<td>0.000001***</td>
</tr>
<tr>
<td>M × S</td>
<td>31</td>
<td>1223.958</td>
<td>39.483</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Direction of translations (DT)</td>
<td>1</td>
<td>1001.042</td>
<td>1001.042</td>
<td>6.923</td>
<td>0.013*</td>
</tr>
<tr>
<td>DT × S</td>
<td>31</td>
<td>4482.292</td>
<td>144.590</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Magnitude of translations (MT)</td>
<td>2</td>
<td>57.813</td>
<td>28.906</td>
<td>0.396</td>
<td>0.675</td>
</tr>
<tr>
<td>MT × S</td>
<td>62</td>
<td>4525.521</td>
<td>72.992</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>M × DT</td>
<td>1</td>
<td>150.000</td>
<td>150.000</td>
<td>4.982</td>
<td>0.033*</td>
</tr>
<tr>
<td>M × DT × S</td>
<td>31</td>
<td>933.333</td>
<td>30.108</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>M × MT</td>
<td>2</td>
<td>31.771</td>
<td>15.885</td>
<td>0.337</td>
<td>0.715</td>
</tr>
<tr>
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<td>62</td>
<td>2918.229</td>
<td>47.068</td>
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<td>NA</td>
</tr>
<tr>
<td>DT × MT</td>
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<td>222.396</td>
<td>111.198</td>
<td>2.228</td>
<td>0.116</td>
</tr>
<tr>
<td>DT × MT × S</td>
<td>62</td>
<td>3094.271</td>
<td>49.908</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>M × DT × MT</td>
<td>2</td>
<td>254.688</td>
<td>127.344</td>
<td>4.024</td>
<td>0.023*</td>
</tr>
<tr>
<td>M × DT × MT × S</td>
<td>62</td>
<td>1961.979</td>
<td>31.645</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

* $P < 0.05$,  
*** $P < 0.001$,  
NA : not applicable
2A). At the large magnitude, latency was significantly shorter with mastication (118.75 ms) than with the lower jaw relaxed (122.66 ms; P < 0.001) (Figure 2C). Latency was also shortened with mastication at the medium magnitude (P < 0.05), but there was an interaction between mastication status and direction of translation (P < 0.001), which prevents us from concluding unequivocally that mastication shortened latency.

The effects of mastication were therefore evaluated using one-way ANOVA for each directional condition at the medium magnitude. In the forward direction, latency was significantly shorter with mastication at 120.31 ms than with the lower jaw relaxed at 126.88 ms (P < 0.001) (Figure 2B). In the backward direction, latency was unaffected by mastication status (P = 0.831). This demonstrates that a shorter latency was seen with mastication at the medium magnitude because of the large latency present without mastication in the forward direction.

As was stated, mastication cannot be unequivocally claimed to be the main effect because of the complex interactions among the three factors, but, overall, reaction latency did decrease with mastication at the small and large magnitudes, and the main effect of mastication was found to be highly significant on three-way ANOVA.

**Discussion**

Overall, response latency following an unanticipated external disturbance was shorter with mastication than with the lower jaw relaxed (P < 0.00001). This finding, when considered with the data of previous research, indicates that the use of the jaw muscles in mastication and occlusion improves static and reactive balance.

However, one cannot claim that mastication alone is the main effect in latency shortening because of the complex interactions encountered among mastication status, the direction of translation, and the magnitude of translation. Lower-order ANOVA of these interactions attributed these interactions to the lack of a difference according to mastication status.
Effect of mastication on reaction latency

status following backward disturbance of a medium magnitude.

Although the cause is unclear, Figure 1 shows little difference in the forward and backward directions for a small-magnitude disturbance ($P = 0.467$), but a significant difference according to mastication status ($P < 0.001$). At a large magnitude, the same difference was seen according to mastication status ($P < 0.001$) and also according to the direction of translation ($P < 0.01$). Measurements were taken following three disturbances for each condition, which allowed the subjects to foresee the direction and magnitude of translation on the second and third runs. Latency was likely shorter for the large magnitude because the subjects were able to brace themselves, but there was no difference according to the direction of translation at the small magnitude because the subjects were able to maintain balance without bracing themselves. At the medium magnitude, the differences for the direction of translation were identical to those for the large magnitude when the subjects were not masticating, but with mastication, there was no difference according to the direction of translation, as was the case at the small magnitude. The lack of a difference according to mastication status in response to the medium-magnitude backward disturbance is likely due to the coexistence of the typical patterns seen at the small and large magnitudes.

Previous research has shown occlusion to shorten latency and improve reactive balance in the standing position\(^4\). Hosoda et al. found that maintaining occlusion with 50% maximum voluntary contractions (MVC) shortened latency by an average of 1.59 ms at a small magnitude, 9.42 ms at a medium magnitude, and 13.92 ms at a large magnitude. In the present research, mastication shortened latency by an average of 4.53 ms at a small magnitude, 3.13 ms at a medium magnitude, and 3.91 ms at a large magnitude. Occlusion shortened latency more at medium and large magnitudes, but mastication shortened latency more at the small magnitude. Moreover, occlusion provided greater latency-shortening effects as the magnitude increased, but no magnitude-related differences were seen for mastication. The reason for this difference is unclear. Research must be conducted with a single set of subjects subjected to external disturbances while occluding and masticating.

Occlusion shortened latency more than mastication at the medium and large magnitudes. The difference between occlusion and mastication may be that the force of occlusion during mastication is less than 50% MVC. This hypothesis could be validated by controlling occlusion force during mastication to measure the effects on latency. However, as stated in the introduction, constantly maintaining occlusion to reduce the risk of falls is an impractical way to reduce falls among the elderly. Mastication is reported to reduce shifts in the center of gravity and improve balance in a static standing posture\(^1\). The present research shows that mastication not only improves balance in the static standing posture, but it also improves reactive balance.

Although mastication did not reduce reaction latency as much as occlusion, continued mastication may be an effective physical activity for reducing falls. The degree to which shortened latency translates into actual fall reduction requires examination.

Mastication is thought to reduce latency by improving spinal reflexes. Studies measuring the H reflex of ankle extensors and flexors found that mastication continually improved the H reflex\(^2,3\). This improvement occurred not only during occlusion over the course of mastication, but it was also observed irrespective of mastication period when the mouth was open. In greater detail, mastication increases spinal reflex excitability by increasing brain activity, which continually increases the excitability of the extension reflex of the legs necessary to maintain a standing position and allows one to quickly react to unanticipated external disturbances. Latency in our research was likely shortened because of this.

Although mastication may improve balance in response to external disturbances and reduce the risk of falls, similar research would need to be conducted with elderly subjects, who are more prone to falls, to substantiate this speculation. Since the present research involved young, healthy subjects, it is unknown if the results are directly applicable to elderly persons. We will therefore have to conduct measurements in subjects of moderate age in addition to elderly subjects to determine the impact of age. Only male subjects were included to reduce data variability, but it is important to also check for sex-based differences.

Conclusions

Mastication shortened the Motor Control Test
latency in comparison to when the lower jaw was relaxed. This indicates that mastication may allow people to react quickly to external disturbances and improve reactive balance when standing.

Conflict of Interest Statement

None of the authors have any financial or personal relationships with other people or organizations that could have inappropriately influenced their work.

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