Abstract

We tested the feasibility to load a facial muscle, the zygomaticus major (ZM), by applying resistance to the facial skin in five healthy and one unilateral facial palsy subjects. The force of maximal voluntary contraction (MVC) was reliably measured revealing 170.21±57.34 gf from the healthy ZM muscles and 55.90 gf from the weakened muscle. The subjects were able to tolerate the electrical stimulation up to the intensity to generate around 50% of MVC. The methods and preliminary results of this study would be useful for further studies of facial neuromuscular electrical stimulation.

1. INTRODUCTION

Among many treatment options for facial palsy, facial neuromuscular electrical stimulation (NMES) has been widely utilized to reduce the residual facial weakness and asymmetry. There have been several reports to show that NMES could reverse the deterioration of muscle contractile properties resulted from chronic peripheral denervation in human leg muscles.[1][2] In contrast to these positive effects of NMES on denervated and reinnervated limb muscles, the effect of facial NMES has produced conflicting results.[3][4] This discrepancy may originate from the fact that the stimulation intensity and duration for facial muscles were much lower and shorter than those for limb muscles because of lower tolerance of facial skin. Since it is well known that applying loads to paralyzed muscles during NMES is an important factor to increase the amount of muscle adaptation,[5] the anatomical difference between facial and limb muscles should be considered as another factor to explain the discrepancy. For facial muscles, it is hard to generate enough tensions by applying loads since they insert into skin while limb muscles insert to bones. It is hypothesized that facial NMES would be more effective if a certain amount of load or tension could be applied while the facial muscles are contracting voluntarily or by electrical stimulation.

The purpose of this study was to test whether a facial muscle, the zygomaticus major (ZM), can be loaded especially under an isometric condition and subsequently to quantify the isometric force generation capacity of the muscle in normal and paralyzed subjects.

2. METHODS

1.1. Subjects

Five healthy subjects (30.0 ± 6.5 years old, 2 females and 3 males) and a female patient (54 years old) with facial palsy participated in the study. The patient has been in the condition since 3 years ago when she got a left side Bell’s palsy. It was confirmed that none of the healthy subjects had any recent medical illness, neurologic problems or previous facial surgery history.

1.2. Kinematic Analysis

To quantify the function of the ZM, we measured the deviations of the bilateral mouth corners during a smile by tracking reflective markers (figure 1) placed on the face using a motion analysis system (APAS, ADI in LA). The subject was seated in a chair and asked to smile as big as one can. A facial coordination system was defined by taking the rhinion, the bony–cartilaginous junction along the nasal dorsum, as the origin, the vector from the rhinion to the nasion as the positive Y axis direction, and a vector from left to right being perpendicular to Y axis as positive X axis direction.[9] The deviations of the mouth angles were quantified by the excursions of the mouth corner markers in the directions of X, Y axes and also in the 2-dimensional plane (figure 2).

1.3. Electrophysiological Study

The electrophysiological measurement of the ZM was done by recording compound muscle action potentials (CMAPs) with supramaximal
facial nerve stimulation at the point just anterior to the mastoid process. A standard electrodagnostic machine (Medelec Synergy, Oxford Instruments in Oxon) was used. The active recording electrode was placed on the belly of the ZM at the half way from the mouth angle to the insertion area in the zygomatic bone, where the reference electrode was attached. The ground electrode was put on the forehead. The peak to peak amplitude of a CMAP was measured.

Figure 1. The marker placement and 2-dimensional coordinate system for the kinematic study are shown. RMCN and LMCN are mouth corner markers of right and left, respectively.

Figure 2. The displacement of right (A, C) and left (B, D) mouth corners of a healthy subject (A, B) and facial palsy patient (C, D) during a big smile. Although the values of the X and Y axes in each plot are different, the ranges are adjusted to have the same value (=1.5cm) for better visual comparison.

1.4. Force Generation Capacity Measurement

A custom made plastic bridge, having a load cell (CSBA-10L, CAS in Seoul) mounted in the middle, was attached on the lateral surface of the face while the subject was lying on one’s side. Two surface electrodes (2cm in diameter) were positioned under the plastic bridge to stimulate the ZM. The data acquisition system sent programmed digital output to an FES system (EMGFES 3000, Cybermedic in Seoul), which delivered 50 μsec pulse width, rectangular electrical stimulation in biphasic mode at 60 Hz of frequency (figure 3).

Figure 3. Equipment setting for the isometric force generation capacity measurement. The custom made bridge is attached on the skin of the face. The proximal limb, on the zygomatic bone area, of the bridge is angulated to accept the angle formed by the two skin surfaces.

Figure 4. Typical raw data of the isometric force measurement of zygomaticus maior muscles. Data from a healthy (A - C) subject and facial palsy patient (D – I) are shown. MVC: maximal voluntary contraction. MSI: maximal stimulation intensity. SSI: submaximal stimulation intensity.
The isometric force generation capacity of the ZM was measured in two different modes of contraction: maximal voluntary contraction (MVC) and electrical stimulation. MVC of the ZM was achieved by asking the subject to contract the ZM as strong as possible. Constant current electrical stimulation was given through the surface electrodes attached on the ZM area. Two tetanic contractions were induced in each trial. The intensity of the electrical stimulation to activate the ZM was set at 6 mA at the beginning of the electrical stimulation trials. The electrical stimulation trials went on with 2 mA increment for each additional trial until the subject did not want to proceed further. The highest stimulation intensity that was tolerated by the subject was considered as the maximal stimulation intensity (MSI) and the intensity one step (2 mA) lower than MSI was defined as the submaximal stimulation intensity (SSI). The isometric forces of the ZM at both MSI and SSI were recorded (figure 4).

3. RESULTS

As summarized in Table 1, the mouth corner traveled 1.08±0.19 cm in 2-dimensional plane, 0.56 cm in X axis component and 0.92 cm in Y axis. The paralyzed side of the facial palsy patient showed far smaller motion of the mouth corner. It is noticed that the movement amount was also decreased in the contralateral side of the facial palsy.

Table 1. The summary of the kinematic analysis, electrophysiologic study and isometric force measurement

<table>
<thead>
<tr>
<th></th>
<th>Healthy</th>
<th>Facial Palsy Ipsilat. side</th>
<th>Facial Palsy Contralat. side</th>
</tr>
</thead>
<tbody>
<tr>
<td>X disp (cm)</td>
<td>0.56±0.12</td>
<td>0.52</td>
<td>0.07</td>
</tr>
<tr>
<td>Y disp (cm)</td>
<td>0.92±0.18</td>
<td>0.61</td>
<td>0.17</td>
</tr>
<tr>
<td>2D disp (cm)</td>
<td>1.08±0.19</td>
<td>0.80</td>
<td>0.19</td>
</tr>
<tr>
<td>CMAP (mV)</td>
<td>2.40±0.56</td>
<td>0.80</td>
<td>0.60</td>
</tr>
<tr>
<td>MVC (gf)</td>
<td>170.21±57.34</td>
<td>130.33</td>
<td>55.90</td>
</tr>
<tr>
<td>MSI (gf)</td>
<td>90.32±49.04</td>
<td>83.08</td>
<td>18.39</td>
</tr>
<tr>
<td>MSI (%)</td>
<td>55.44±21.31</td>
<td>63.74</td>
<td>32.90</td>
</tr>
<tr>
<td>SSI (gf)</td>
<td>80.84±50.96</td>
<td>55.27</td>
<td>14.44</td>
</tr>
<tr>
<td>SSI (%)</td>
<td>48.12±22.91</td>
<td>42.41</td>
<td>25.84</td>
</tr>
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</table>

The CMAP of the ZM was obtained very reliably (2.40±0.56 mV) in healthy people by the belly-tendon method. Lower amplitude of CMAPs was observed in both sides of the patient. However, the side to side difference of CMAPs was not as large as that of the MVC or mouth corner deviation (Table 1). In healthy subjects, the ZM could generate 170.21 gf at average. The individual variations were quite large (SD=57.34 gf). At the maximal intensity (MSI) of electrical stimulation that people could tolerate, 55.44±21.31% of MVC was generated. At the SSI, the force was slightly lower (48.12±22.91%) than that at the MSI. The MVCs of both sides of the patient were lower than those of normal but the paralyzed side revealed far less amount of force generation.

4. DISCUSSION AND CONCLUSIONS

There was a recent report[6] to measure the force generation capacity of healthy facial muscles. They utilized two methods: adhesive and probe. The force (MVC) of smile was reported to be 331.49gf by the probe method and 139.34gf by the adhesive method. The latter is comparable to the result of this study.

The force of maximal voluntary contraction (MVC) was reliably measured revealing 170.21±57.34 gf from the healthy ZM muscles and 55.90 gf from the weakened muscle. The subjects were able to tolerate the electrical stimulation up to the intensity to generate around 50% of MVC. The methods and preliminary results of this study would be useful for further studies of facial neuromuscular electrical stimulation.

References