Electromyographic responses from the stimulation of the temporalis muscle through facial acupuncture points

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Abstract

Objective: This study measured the electromyographic (EMG) responses of the temporalis muscle to electrical stimulation at 10 acupuncture points (acupoints) of the face and assessed whether electrical stimulation of these acupoints may improve the rhythmic activity of the muscles that open and close the jaw.

Methods: Fifty healthy adults clenched 2 thin pieces of wood between their teeth and kept a constant bite force for 30 seconds. The left anterior temporalis muscle was chosen for spontaneous EMG stimulation and recording.

Results: The mean EMG responses were positive at 10 points in early reflexes but negative at points Jiache, Chengjiang, and Dicang for late reflexes. No statistically significant difference was observed in the responses between age and stimulation intensity for both areas, but a significant inverse correlation existed between the distance from the acupoint to the recording electrode and the response.

Conclusion: This study showed that the surface electrical current applied to facial skin acupoints may excite or inhibit the anterior temporalis muscle via reflex pathways. The result from this stimulation may be applied to treat temporomandibular joint disorder occlusion of muscular origin.

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Introduction

Electromyography (EMG) is the recording and study of spontaneous and voluntary electrical activity of

Fig 1. Front view of acupoints.

muscles.¹ It had little direct relevance to clinical neurology until the introduction of the concentric needle electrode.² Surface EMG is a nonlinear summation of the electrical activity of the motor units in a muscle.³ Each action potential from each active unit contributes a small and constant increment to the total electrical signal recorded at the skin. The amplitude and duration of this increment can be determined by spike-triggered averaging from unit potentials in the muscle to the surface EMG signal.⁴ Over the last half century, many clinicians have turned to EMG to provide objective evidence of craniomandibular disorders.⁵

This study measures the EMG responses on acupuncture points (acupoints) of the masticator muscles. There are 4 pairs of these muscles in humans. The masseter and the medial pterygoid are both powerful elevators of the mandible. The lateral pterygoid muscles run in a different direction from the other muscles of mastication, their fibers lying horizontally instead of vertically. The temporalis muscle is a large fan-shaped muscle that arises from the temporal fossa and also from the overlying temporal fascia. The temporalis muscle is our main focus in this study.

Acupuncture can be traced back at least 3000 years. The manipulation of acupoints could be an efficient method of diagnosis and therapy.⁶ A principle in electroacupuncture therapy is that positive pulse stimulation of a point sedates its corresponding function, whereas negative pulse stimulation tonifies the function.⁷ In the past years, increasing interest has been shown in the diagnosis and management of

neurostomatological diseases by applying a pulsed electrical current to acupoints of the face.⁸⁻¹⁴

Methods

Subjects

Fifty healthy adult volunteers (30 men, 20 women) 20 to 50 years old were chosen, with consent obtained before the study in accordance with the guidelines of the University of Hong Kong Ethical Committee. The experimental protocol was approved by this Ethical Committee.

Selection of stimulated points and recording muscle

The stimulated acupoints, numbered 1 to 10 (Fig 1, Table 1), were selected following the acupuncture map and the International Standard Nomenclature of Acupuncture and Moxibustion Points.^{15,16} The left anterior temporalis muscle was chosen because, as a spindle-rich jaw closer, the isolated EMG recordings of its action could be made from the skin surface and the stimulation points were all located away from the muscle.

Experimental protocol

The trials were carried out in an air-conditioned room maintained at around 20°C. The subjects sat in a comfortable dental chair with the head upright. They were invited to bite on 2 thin pieces of wood clamped to a force transducer (MIE Medical Research, Leeds, United Kingdom). The distance between the pieces was about 2 cm, and participants were required to maintain a constant bite force of 80 N. The EMG was recorded

Table 1 Distance from various acupoints to active (recording) electrode

Points	Acupoints	Distance to the Active Electrode (mm)
1	Shangguan	73
2	Xiaguan	93
3	Jiache	125
4	Daying	132
5	Chengjiang	157
6	Dicang	118
7	Shuigou	130
8	Yingxiang	110
9	Quanliao	82
10	Taiyang	52

on a digital storage oscilloscope (CS-8010; Kenwood Test and Measuring Instruments, Yokohama City, Japan). All volunteers were tested for the thresholds of points 1 to 10 (Evomatic 4000 DT 2821; Dantec Electronics [Far East], Hong Kong) by varying the voltage (in millivolts) delivered at 1 Hz. Cutaneous electrical stimulation was made with a handheld bipolar stimulator with the cathode and anode separated by 2 cm. The EMG was recorded as twice of the threshold values were applied to each point for 30 seconds. Between each stimulus, the subjects rested for at least 5 minutes to avoid muscle fatigue or possible habituation of the stimulus-induced effects.

Electromyographic recordings

All recordings from the anterior left temporalis muscle were made using disposable monopolar surface EMG electrodes, with the most commonly used electrodes having round and flat plates 1.0 cm in diameter.¹ The skin over the stimulating and recording positions was scrubbed with 70% alcohol to reduce impedance, and the electrodes were filled with conductive paste (KY Jelly; Johnson & Johnson, London, United Kingdom). The electrodes had an active (recording) area of $4 \times 5 \text{ mm}^2$; and they were attached to the skin over the anterior temporalis muscle, defined by palpation during clenching using adhesive tape. The reference electrode was placed 2 cm underneath the active electrode, with a filter placed 2 cm below the reference to reduce noise. Ground for safety purposes was located 2 cm below the left mandibular angle and ear (Fig 1). The output was fed to P55 AC preamplifier (Astro-Med, West Warwick, RI) with a gain of 1000 bandpass filtered from 30 Hz to 1 kHz. The recordings were transferred to the computer for analysis.

Data collection and analysis

The duration of each trial was 200 milliseconds with a frequency of 2000 Hz for each 30-second stimulus. Sampling was triggered 50 milliseconds before each stimulus and delayed for 50 milliseconds for collection at one channel. The triggering data were collected from the stimulator. The digitized data (DT98SF, model card: ADDA DT21EZ; Data Translation, DK 3540, Lynge, Denmark) were rectified and averaged to produce an average response for a 30-second trial period.

Measurement of reflex response

The reflex responses were measured in the computer. Reflexes were observed at 2 latencies after the stimulus. The area of an early reflex (T1) was measured in 54.5 to 64 milliseconds, and a late reflex (T2) was measured in 64 to 77.5 milliseconds.

Calculation of reflex area

To remove any effects of changes in background EMG levels, the area values for equivalent periods before the stimulus (T3 and T4) were subtracted to give area A ($T1 - T3$) and area B ($T2 - T4$) (Fig 2). The reflex responses for each point were measured as the mean values of 2 areas (Vms): A and B (Table 2).

Statistical analyses

The mean areas of A or B between any 2 points were analyzed by 1-way analysis of variance using SPSS 11.0 (SPSS, Chicago, IL). Student *t* test was used to test whether there was a statistical difference in the mean of area A or B between male and female subjects.

Fig 2. Averaged full-wave rectified EMG.

Table 2 Reflex responses for each acupoint in 2 areas

Point	No. of Cases Tested	Area A (Vms)		Area B (Vms)	
		Mean	SD	Mean	SD
1 (Shangguan)	50	0.641	0.540	0.198	0.210
2 (Xiaguan)	50	0.364	0.589	0.017	0.134
3 (Jiache)	50	0.030	0.142	-0.079	0.288
4 (Daying)	50	0.151	0.308	0.109	0.139
5 (Chengjiang)	50	0.029	0.124	-0.192	0.333
6 (Dicang)	50	0.206	0.295	-0.049	0.282
7 (Shuigou)	50	0.212	0.240	0.134	0.318
8 (Yingxiang)	50	0.251	0.489	0.120	0.409
9 (Quanliao)	50	0.109	0.227	0.041	0.184
10 (Taiyang)	50	0.794	0.693	0.440	0.593

Linear regression models were applied to analyze the response effects from other factors, such as age, stimulation intensity, and distance from acupoint to electrode.

Results

Figs 3 and 4 show the mean size of the 2 areas with standard error bars for each point of all cases. In area A, responses from all points were positive. The highest response was measured from point 10 (Taiyang, 0.794 Vms), followed by point 1 (Shangguan and Ermen, 0.641 Vms) and point 2 (Xiaguan,

0.589 Vms); and the lowest responses were from points 3 (Jiache, 0.030 Vms) and 5 (Chengjiang, 0.029 Vms). In the B area, negative responses were tested from points 3 (Jiache, -0.079 Vms), 5 (Chengjiang, -0.192 Vms), and 6 (Dicang, -0.049 Vms). Point 10 had the highest positive response in both areas, but the value was higher in area A (0.794 Vms) than in area B (0.593 Vms).

In area A, the 9 points were compared with point 1; the mean response area from points 3 to 9 was significantly lower. Similarly, for point 10, the mean response area from points 2 to 9 was also significantly lower. There was no statistical significance between any 2 points of 1 to 10. All points showed the highest responses to early reflex. In area B, the mean response area from points 2 to 9 was significantly lower than that of point 10. The mean response of point 5 was significantly lower than that of points 1, 2, 4, 7, 8, and 10. There was no statistically significant difference in the mean responses between any 2 of the following points: 1, 3, 4, 6, 8, and 9. Point 10 showed the highest responses of late reflex.

The relationship between EMG responses and some relevant factors is shown in Table 3. As the data were pooled for analysis, there was no significant difference between men and women for both A ($P = .114$) and B areas ($P = .144$). The reflex responses were not significantly correlated to age for both A and B areas, but significantly correlated to the distance of the acupoint to recording electrode ($P < .001$) (Table 1),

Fig 3. Electromyographic responses from 10 points for area A (N = 10).

Fig 4. Electromyographic responses from 10 points for area B (N = 10).

which ranged from 5.2 to 15.7 cm with a mean of 10.8 cm. The mean stimulation intensity was 1.75 mV with a range of 0.8 to 3.0 mV. The reflex responses constantly decreased 0.065 Vms in area A and 0.041 Vms in area B by increasing the distance from the acupoint to the recording electrode by 1 mm.

Discussion

In the present study, we found that an electrical stimulus to each of the 10 acupoints elicited responses to the anterior temporalis muscle. The responses

comprised early and late reflexes. The acupoints 1, 2, 4, 5, 6, and 10 were in the distribution of trigeminal nerve branch III; acupoints 7, 8, and 9 were located in trigeminal nerve branch II; and acupoint 3 lay in the distribution of the great auricular nerve (C_2 and C_3) (Fig 1). Our results showed that the acupoints in the trigeminal nerve pool in the oral-facial region had positive (excitatory) responses in A area and B area. This was because all the stimuli were in the same trigeminal nerve pool, so the reflexes followed relatively direct pathways to the anterior temporalis muscle.¹⁷ Acupoint 3, in the territory of the great auricular nerve (C_2 and C_3) region, showed negative (inhibitory) responses in early and late reflexes. Thus, stimulation in the cervical nerve region evoked reflexes through a different inhibitory pathway.¹⁷

Many experiments have been carried out on reflex responses in masticatory muscles. The stimulation of an upper tooth elicited an inhibitory reflex response followed by excitation in masseter and temporalis.¹⁸ Another report demonstrated that there were 2 distinct periods of suppression in EMG responses of the masseter and temporalis muscles after light tactile stimulation of the perioral zone.¹⁹ A single period of suppression was evoked by tactile stimulation of the mucosa of the hard palate or of the tongue, and threshold for suppression was lower in mucosa than skin.¹⁹ Two successive exteroceptive suppressions in the EMG of the masseter and temporalis muscles in a healthy man were elicited by delivering a single electrical stimulus to

Table 3 Correlation between reflex responses and relevant parameters using linear regression models

Parameters	Area	Correlation Coefficient	Coefficient	P
Age	A	0.09	-0.005	NS
	B	0.12	-0.005	NS
Stimulated Intensity	A	0.14	-0.132	NS
	B	0.17	-0.123	*
Distance ^a	A	0.43	-0.065	**
	B	0.36	-0.041	**

NS, Not significant.

^a Distance from acupoint to recording electrode.

* $P < .05$.

** $P < .001$.

the gums and mucosa inside the mouth.²⁰ All points, except points 3 and 5, were excitatory in early and late reflexes. It seems that stimulation of acupoints passes signals through the meridian system to obtain responses in the anterior temporalis muscle instead of the nerve. It has been proven that the conductance of acupoints was relatively uniform and asymmetry of conductivity did not exceed 3 μ A.²¹

Distance is one of the most important factors affecting the responses. The distance from acupoints to recording electrode (Table 1) ranged from 5.2 to 15.7 cm with a mean of 10.8 cm. The present study showed that the longer the distance, the lower the response (Table 3). Comparing acupoint 10 with others, both areas A and B responded the greatest because the evoked potential obtained from the stimulation point was of greater amplitude and shorter duration than those further from the recording electrode.²² Point 5 showed negative responses in both areas because the stimulation impulse had the longest distance to travel to the recording site.²³

Electromyographic responses measured at the anterior temporalis muscle after facial acupoint stimulation have previously been reported in a case study on the treatment of temporomandibular joint disorders (TMDs). Temporomandibular joint disorder has been related to early-stage disorders of the temporalis, masseter, and pterygoid muscles. In the early stage of TMD, this group of muscles is hyperactive, whereas at the latter stages, some of them became weaker.²⁴ Treatment of TMD by acupuncture is reported by stimulation of acupoints 2, 3, and 10 to excite or inhibit the activity of the masticatory muscles in early or late stages of the disorder.²⁵⁻²⁷ According to our results, points 2 and 3 were inhibitory, whereas point 10 showed the greatest excitation. These acupoints may be selected to treat early and late stages of TMD, respectively. It is also considered that points 5, 6, and 9 showed little inhibition by stimulation. They may be useful in treating early TMD hyperactivity. Furthermore, the acupoints evoking inhibitions could be used to block sensory neuron transmission in trigeminal neuralgia.

Conclusion

If the temporalis muscle can be excited or inhibited consistently by electrically stimulating certain facial cutaneous acupoints, they can be selected to aid in treating some common musculoskeletal dysfunctions in the oral-facial system, such as TMD. The present study,

for the first time, measured EMG responses of the temporalis muscle to electrical stimulation of 10 selected acupoints of the face. We showed that the temporalis muscle can be effectively excited or inhibited by electrical current stimulation of facial cutaneous acupoints.

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