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Influence of voluntary teeth clenching on the stabilization of postural stance disturbed by electrical stimulation of unilateral lower limb

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ABSTRACT

Studies on the relationship between dental occlusion and body balance have suggested that occlusion status contributes to the maintenance of postural balance. However, little has been reported about the effects of voluntary teeth clenching on the stabilization of postural stance in novel environments. In the present study we investigated whether teeth clenching influenced adaptation to the perturbation introduced by electrical stimulation of a unilateral lower limb. Subjects (12 adults) stood on a force plate, from which motion data were obtained in the horizontal plane with and without voluntary teeth clenching and were instructed to maintain the position throughout the experiment. We evoked a novel environment by supramaximal percutaneous electrical stimulation of the common peroneal nerve. Electromyograms (EMG) were recorded from the masseter and the peroneus longus (PL) muscles with bipolar surface cup electrodes. When the disturbed postural stance was generated by electrical stimulation, the maximum reaction force in the anterior–posterior (A/P) direction with teeth clenching (CL) was significantly smaller than that without voluntary teeth clenching (control; CO) ($p < 0.05$) and the peak time of the ground reaction force/body mass (GRF/BM) in the A/P direction occurred earlier in the CL condition than CO ($p < 0.05$). There were no significant differences in the peak-to-peak amplitude of GRF/BM and the peak time of GRF/BM, in the M/L direction under both CL and CO conditions.

Thus, the present study showed that voluntary teeth clenching contributed to stabilization of the postural stance perturbed transiently by electrical stimulation. We concluded that voluntary teeth clenching plays an important role in rapid postural adaptation to the anterior–posterior perturbation in the upright position.

1. Introduction

In recent years, an increasing number of analyses have been made of the possible correlation of teeth clenching with the efficiency of motor performance as well as muscle strength of the extremities [1–4]. Previous studies in our laboratory investigated the relationship between teeth clenching and isometric muscle strength of the upper and lower extremities in healthy volunteer subjects, and revealed a possible correlation between the magnitude of muscle strength required and the force of teeth clenching [1,3]. Moreover, Sumita et al. studied the relationship between voluntary teeth clenching and the isokinetic strength of lower extremities in healthy volunteer subjects, and demonstrated that teeth clenching had the effect of increasing isokinetic muscle strength at lower angular velocities [2].

On the other hand, studies on the relationship between dental occlusion and body balance have suggested that occlusion status contributes to the maintenance of postural balance. As an example, it has been reported that altering dental occlusion by wearing an occlusal splint could make certain subjects modify their postural attitude through the use of Fukuda-Unterberger experimental stepping test to check the postural attitude [5]. Additionally, Hosoda et al. demonstrated that occlusion could bring about the maintenance of postural balance when unexpected swaying occurred in the standing position by use of EquiTest (MPS-3100, NeroCom, OR, USA) dynamic posturographic model [6]. To date, however, little has been reported about the effects of voluntary teeth clenching on the stabilization of postural stance in perturbation, which was introduced by electrical stimulation of a unilateral lower limb. In the present study, we elucidated whether teeth clenching influenced adaptation to the novel environment.

2. Materials and methods

2.1. Subjects

Experiments were performed on 12 young adults (10 males and two females: aged 28.50 ± 4.64 years; height 170.88 ± 8.39 cm; body mass 64.16 ± 12.92 kg mean $\pm$ SD). All subjects had stable intercuspal position without malocclusion,

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toothache, pain of orofacial muscles, temporomandibular joint problems or a previous history of injury in the lower extremities. The study was approved by the Ethical Committee for Human Research, Faculty of Dentistry, Tokyo Medical and Dental University and the subjects gave informed consent according to the institutional guideline.

2.2. Experimental procedures

The general experimental setup is illustrated in Fig. 1. The subjects were required to stand barefoot on a force plate (Type 4080S, Bertec Co., OH, USA) with their feet shoulder-width apart. They were instructed to maintain an erect posture and open their eyes throughout the experiments. The ground reaction force (GRF) was obtained in anterior/posterior (A/P) and medial/lateral (M/L) directions from the force plate. We evoked a novel environment by supramaximal percutaneous electrical stimulation, which was applied to the common peroneal nerve through a surface electrode (diameter 8.0 mm). The cathode was placed on the thigh at the external edge of the popliteal fossa, 2–4 cm above the caput fibulae. The anode (35 mm × 45 mm) was located on the thigh, proximal to the patella. Stimuli were rectangular electrical pulses, 1 ms in duration, delivered by a constant current stimulator (Electronic Stimulator, Nihon Kohden, Tokyo, Japan). Stimulus intensity was adjusted to evoke maximal motor responses in the peroneus longus (PL) muscle. They never reported discomfort associated with electrical stimulation. Electromyograms (EMG) of the PL and masseter muscle were recorded by bipolar surface electrodes (NE-121J, Nihon Kohden, Tokyo, Japan), 8 mm in diameter, placed 2 cm apart on the muscle bellies of the PL and masseter muscle.

A session consisted of 5–6 stimuli during 15–20 s (strength: 50–80 V, interval: 3 s). Sessions were alternatively performed with two dental occlusal conditions: (1) with clenching (CL) and (2) without voluntary teeth clenching (control; CO). A 5-min interval was assigned after the 6th session to avoid fatigue. A total of 12 sessions were successively performed in 1 day.

The strength of teeth clenching was monitored by the amplitude of the full-wave rectified, integrated masseter EMG. Two horizontal cursors were shown on an oscilloscope (CS-4025, Kenwood Co., Tokyo, Japan) placed 1.0 m in front of the subject. The cursor in the top half of the display (target cursor) indicated 80% of the maximum contraction. The level of maximum contraction was defined as the amplitude of the full-wave rectified, integrated masseter EMG during voluntary teeth clenching with a maximum effort of 3 s. The cursor at the bottom half of the display (force cursor) continuously indicated the instantaneous amplitude of the full-wave rectified, integrated masseter EMG during the instructed muscle contraction. It moved from the bottom to the top on the display with an increase in contraction of the right masseter muscle. The bottom and top ends of the display corresponded to the 0% and 100% levels of the voluntary muscle contraction, respectively. The subject under the CL conditions was instructed to match the position of the force cursor to the target cursor by adjusting the strength of contraction of the masseter muscle.

2.3. Data analysis

The GRF and the EMG were analyzed with data analysis software (Power Lab, AD Instruments, Castle Hill, Australia). Before stimulus, the ground reaction force, that developed when the subject was standing up on the force plate, was reset to zero for the purpose of measuring the deviation of ground reaction force caused by the perturbation. Ground reaction force/body mass (GRF/BM) in the A/P and M/L directions was averaged with about 36 traces, respectively, and we measured the peak-to-peak amplitude of GRF/BM in the A/P and M/L directions and the peak time of GRF/BM in the A/P and M/L directions (Fig. 2). The sum of the absolute values of the positive and negative integrals was calculated for GRF/BM components of the A/P and M/L directions, respectively. The onset time of GRF/BM was defined as the point where the root mean square of GRF/BM was two standard deviations higher than the mean of resting activity during standing. The time between the onset of stimulation and that of the root mean square of GRF/body mass (STGR) was measured. The statistical significance of the results was assessed using the Wilcoxon signed-rank test. The significance level was set at $p = 0.05$.

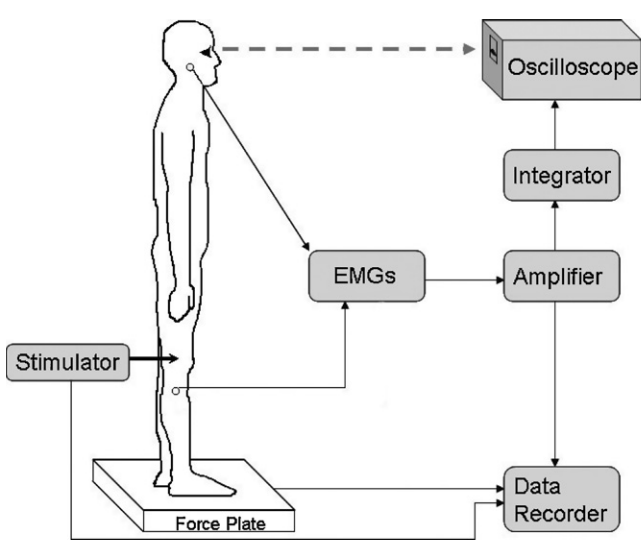

Fig. 1. Experimental setup.

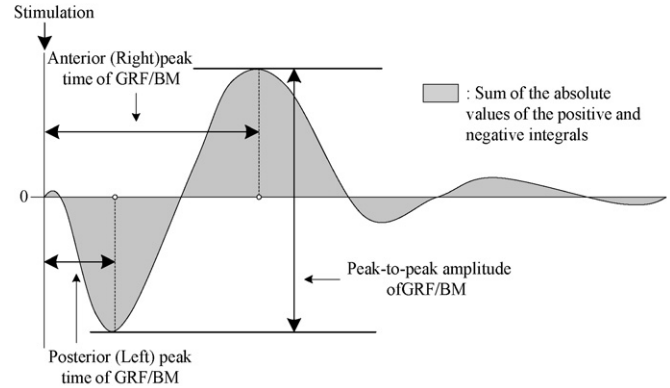

Fig. 2. Measurement of the peak-to-peak amplitude and peak time of GRF/BM. Shaded area in inset: integrals of the GRF/BM.

3. Results

Fig. 3 illustrates an example of the time course of GRF/BM after electrical stimulation of the right lower limb obtained from a subject. Every component wave comprising the GRF/BM in the A/P direction decreased in amplitude during CL compared to CO.

Table 1 shows the values of the peak-to-peak amplitude and the peak time of GRF/BM, in the A/P and M/L directions, respectively.

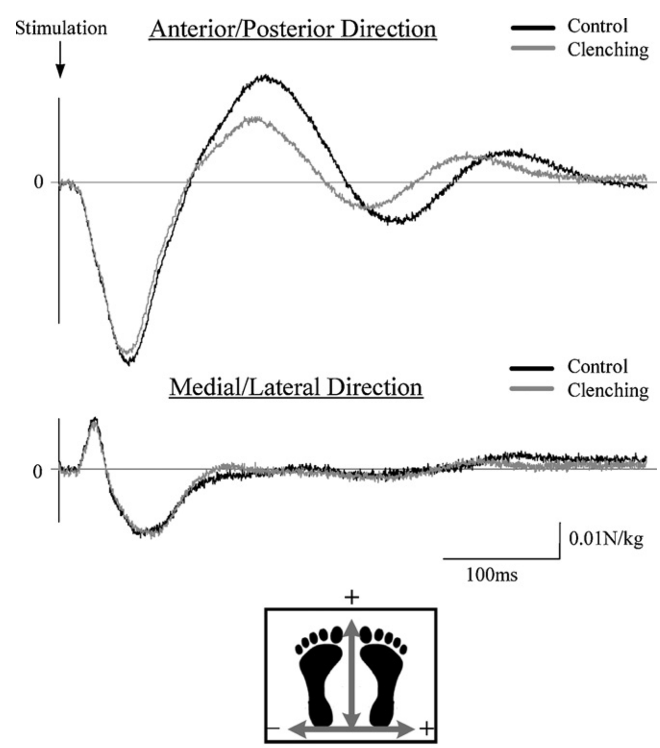

Fig. 3. Modulation of GRF/BM after electrical stimulation of right limb obtained from a subject. In A/P control, M/L control, A/P clenching, M/L clenching, the recordings were obtained by averaging 36 traces each.