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Research Report

Repeated tongue lift movement induces neuroplasticity in corticomotor control of tongue and jaw muscles in humans

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ABSTRACT

This study investigated the effect of repeated tongue lift training (TLT) on the excitability of the corticomotor representation of the human tongue and jaw musculature. Sixteen participants performed three series of TLT for 41 min on each of 5 consecutive days. Each TLT series consisted of two pressure levels (5 kPa and 10 kPa). All participants underwent transcranial magnetic stimulation (TMS) and electromyographic (EMG) recordings of motor evoked potentials (MEPs) in four sessions: (1) before TLT on Day 1 (baseline), (2) after TLT on Day 1, (3) before TLT on Day 5, and (4) after TLT on Day 5. EMG recordings from the left and right tongue dorsum and masseter muscles were made at three pressure levels (5 kPa, 10 kPa, 100% tongue lift), and tongue, masseter, and first dorsal interosseous (FDI) MEPs were measured. There were no significant day-to-day differences in the tongue pressure during maximum voluntary contractions. The amplitudes and thresholds of tongue and masseter MEPs after TLT on Day 5 were respectively higher and lower than before TLT on Day 1 ($P<0.005$), and there was also a significant increase in tongue and masseter MEP areas; no significant changes occurred in MEP onset latencies. FDI MEP parameters (amplitude, threshold, area, latency) were not significantly different between the four sessions. Our findings suggest that repeated TLT can trigger neuroplasticity reflected in increased excitability of the corticomotor representation of not only the tongue muscles but also the masseter muscles.

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1. Introduction

Neuroplasticity is one of the most prominent features of the central nervous system and has a role in several functions including the ability to adapt to changes in the environment and to store information in memory associated with learning (Johnston, 2004). It is well known that cortical control of the tongue motor system allows for fine control and accurate coordination of tongue movements in both animals and humans (Murray et al., 1991; Lin et al., 1993; Yoshida et al., 2000; Shibukawa et al., 2004; Iida et al., 2007). Some animal studies have demonstrated a role of the primary face motor cortex (M1), including the tongue motor cortex, for fine control of tongue movements such as those associated with tongue protrusion and the semiautomatic movements associated with chewing and swallowing (Murray and Sessle, 1992; Martin et al., 1997, 1999; Yao et al., 2002; Arce et al., 2013; Arce-McShane et al., 2014). In addition, neuroplasticity in the motor cortex of monkeys can be evoked by training the monkeys in a novel tongue-protrusion task (Sessle et al., 2005, 2007; Arce et al., 2013; Arce-McShane et al., 2014). Our previous human studies have also shown that neuroplasticity of the corticomotor excitability specifically related to tongue motor control can be induced when human participants learn to perform tongue-protrusion tasks (Svensson et al., 2003, 2006; Boudreau et al., 2007, 2010, 2013; Arima et al., 2011). However, there is so far no information on the effect of repeated tongue lift movements (in contrast to tongue protrusion movements) on the central nervous system related to the tongue muscles.

In patients with oromotor dysfunction, Yoshida et al. (2006) have suggested that tongue pressure measurement during a tongue lift task could reveal clinical signs of dysphagic tongue movements. Utanohara et al. (2008) suggested that reduction in maximum tongue pressure during the tongue lift task is primarily correlated with aging. In addition, Tsuga et al. (2012) showed that the maximum tongue pressure in frail elderly persons was significantly lower than in healthy dentate persons. These studies have thus demonstrated that tongue pressure during a tongue lift plays a key role in oropharyngeal swallowing. In the oral rehabilitation of patients with dysphagia, it is therefore important to clarify the mechanisms controlling tongue pressure during tongue lifting and the possible interrelationship in corticomotor representations of the jaw and tongue musculature.

In the motor cortex, Penfield and Boldrey (1937) were the first to demonstrate closely approximating areas in the cerebral sensorimotor cortex that represented jaw and tongue movements. However, although some animal studies have demonstrated closely approximating and often overlapping motor cortical sites representing both tongue and jaw muscles (Huang et al., 1988, 1989; Murray and Sessle, 1992; Martin et al., 1997; Avivi-Arber et al., 2010, 2011, 2015), no

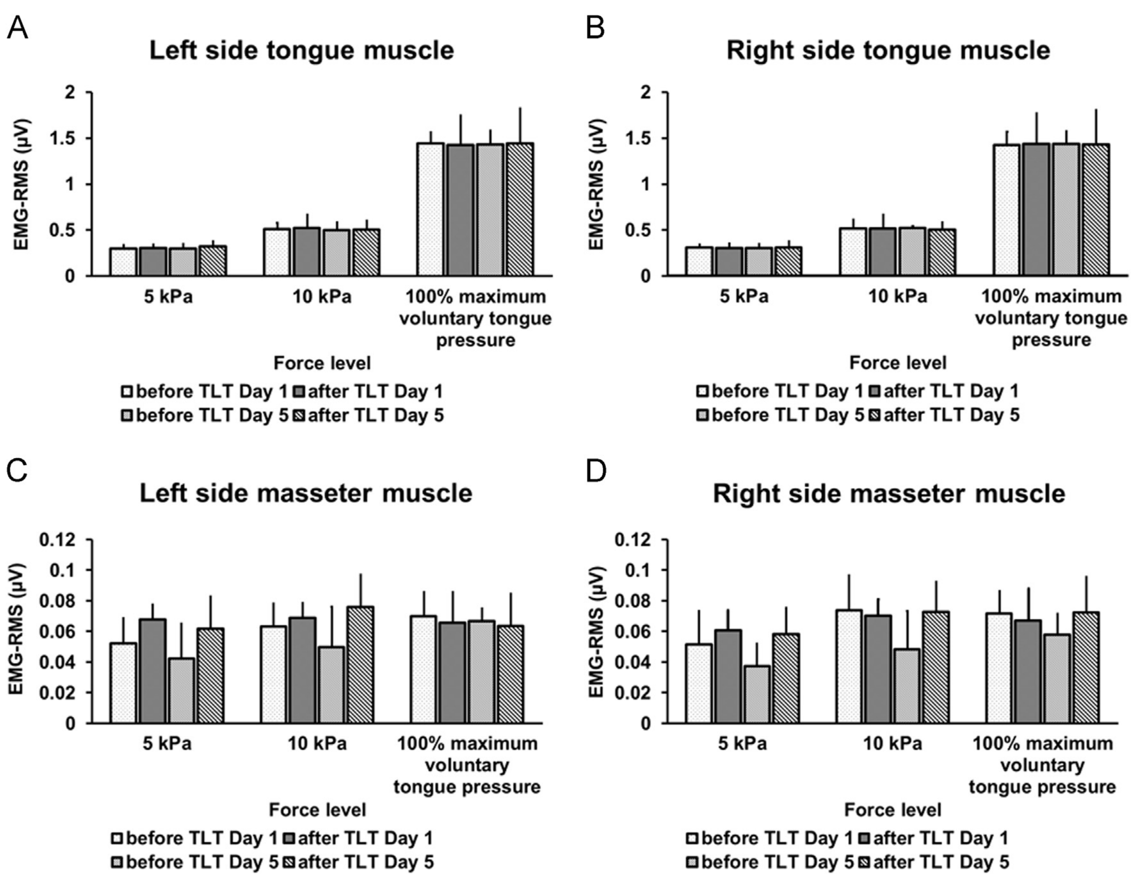

Fig. 1 – Electromyographic root-mean-square (EMG-RMS) values of each measurement point during four sessions and three tongue pressure levels. Left side tongue muscle (A), right side tongue muscle (B), left side masseter muscle (C), right side masseter muscle (D). TLT, tongue lift training.