Long-term Tongue Lift Training Effects on Tongue Function

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Abstract

The purpose of this study was to investigate the effect of 3 weeks of tongue lift training (TLT) for suprahyoid muscle activities and tongue pressure during tongue lift movement in healthy participants.

Eight healthy participants performed a standardized 41 min of TLT consisting of three series for 3 weeks (5 consecutive days/week). Tongue pressure and electromyogram activity (EMG) from suprahyoid muscles were recorded during TLT at Day-1 in Week-1, Day-1 in Week-2, Day-1 in Week-3, and Day-5 in Week-3. During TLT, in the first and third series, all participants performed tongue lift movement (at 10, 20, and 40% of maximum voluntary contraction (MVC)) without visual feedback. During second series, all participants performed tongue lift movement with visual feedback of the force level.

The tongue pressures during 100% MVC at Day-1 in Week-3, and Day-5 in Week-3 were significantly higher than the tongue pressure during 100% MVC at Day-1 in Week-1 as baseline ($P < 0.05$). Coefficients of determination (CDs) of the target force level–tongue pressure, which were used to evaluate the accuracy of performance, at Day-1 in Week-2, Day-1 in Week-3, and Day-5 in Week-3 were significantly higher than that at Day-1 in Week-1 ($P < 0.05$). However, there were no significant differences in relative ratios of root mean square of EMG amplitude on the first series among any of the measurement points in each force level.

Our findings suggest that long-term of TLT with day off (assuming of weekend) improved not only accuracy of the performance to reach target force level, but also the maximum tongue pressure without the alternation of suprahyoid muscles activities in healthy subjects. Our results could have the potential to implicate for the rehabilitation program for stroke patients with swallowing dysfunction.

Keywords :

tongue lift, tongue pressure, motor learning, suprahyoid muscles, electromyography

Introduction

Tongue pressure (TP) during tongue lift movements has an important role during swallowing. To polish up the diagnosis and therapy for patients with swallowing disorders, it is essential to clarify the mechanism of control about TP during tongue lift movements in human. Past studies investigate the role of tongue lift movement

during swallowing in humans. TP measurement during the tongue lift movement has an important role as clinical signs of dysphagic tongue movements (1). Utanohara et al. demonstrated the negative correlation between maximum tongue pressure (MTP) during the tongue lift movement and aging (2). Tsuga et al. showed that there was a significant difference in MTP between elderly participants with frail and healthy participants (3). MTP of amyotrophic lateral sclerosis patients during the tongue lift movement were significantly lower than that of

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healthy participants(4). Since these studies shows that MTP during the tongue lift movement is one of useful tools to evaluate the function of swallowing, tongue lift movement may have the potential to establish the rehabilitation program for patients with swallowing dysfunction. Final aim of our project is to establish the rehabilitation program using tongue lift movement for the stroke patients with swallowing dysfunction based on evidence from experimental data. To make the evidence about the rehabilitation program using tongue lift movement, we have previously demonstrated that repeated tongue lift training(TLT)for five continuous days or 41 min of TLT within one day can trigger neuroplastic changes in the motor cortex related to the tongue muscles in central nervous system in healthy participants(5). We also investigated the effect of TLT for 5 continuous days on suprahyoid muscle activities and TP in healthy participants, and suggested that accuracy of performance was improved without affecting MTP(6). However, orofacial motor task as rehabilitation for the stroke patients with swallowing dysfunction will be performed for long term. To apply our experimental data to the clinical situation, it is essential to investigate the effect of long-term tongue lift movements as rehabilitation for TP and muscle activities related to swallowing.

The hypothesis of the present study was that long term of repeated tongue lift movement would improve not only the accuracy of performance but also MTP in healthy participants. The purpose of this study is to investigate the effect of 3 weeks of tongue lift training on suprahyoid muscle activities and TP during tongue lift movement in healthy participants.

Materials and Methods

Participants

The study involved 8 healthy individuals(4 women, 4 men; mean ($\pm$ standard error of the mean) age, 28.2 ± 2.1 yr) with normal stomatognathic function. All participants reported no medical, physical or psychological problems. Informed consent was obtained from all participants before the start of the experiment. The Institutional Ethics Committee approved the study(EC14-019), and the guidelines set out by the Declaration of Helsinki were followed.

Tongue lift training

During the TLT, a TP measurement system(JMS Co., Hiroshima, Japan) (7) was used to measure TP according to our previous study(6). Participants sat upright and relaxed in a dental chair with the head supported by a headrest, and they kept a TP probe on their tongue and their right hand during TLT. All participants performed a standardized 41 min of TLT consisting of three series for 3 weeks(5 consecutive days/week). In each day, participants performed a maximum tongue lift movement to determine the 100% maximum voluntary contraction (MVC) before the TLT(defined as MTP during tongue lift movement). In the first and third series, participants received no visual feedback but were simply instructed to target different force levels. During the second series, muscle activity level via the TP measurement system data was displayed on a monitor for visual feedback to participants. One series consisted of three measurements (10, 20, and 40% MVC), and one measurement consisted of one force level(10, 20, or 40% MVC). During all measurements, participants alternated between a 30-s rest-block and a 30-s task-block for 360 s. In the task-block, participants alternated between a 5-s rest-block and a 5-s task-block, at a given auditory signal. To avoid tongue muscle fatigue, a 30-s rest period was allowed between each series.

The TP from the TP measurement system, were recorded during all tasks at Day-1 in Week-1, Day-1 in Week-2, Day-1 in Week-3, and Day-5 in Week-3(Fig. 1). TP during each task was also calculated for each 5 s period for all participants. To evaluate the accuracy of the performance on each day, the coefficient of determination (CDs) of the target force level-TP curve were calculated from the first and third series on the measurement points.

Electromyogram(EMG) of the left suprahyoid(LS) and right suprahyoid(RS) muscles was recorded using disposable bipolar surface electrodes(NM319Y; Nihon Kohden, Tokyo, Japan) at Day-1 in Week-1, Day-1 in Week-2, Day-1 in Week-3, and Day-5 in Week-3. EMG activity during each task was initially quantified by calculating the root mean square(RMS) of EMG amplitude in each 5-s period from LS and RS. Relative ratios of RMS of EMG amplitude in each force level on each first series were calculated.

Fig. 1. Over view of experimental protocol(A)and Overview of tongue lift training(B)
Abbreviations: EMG, electromyogram; TLT, tongue lift training; VF, visual feedback.

Fig. 2. Comparison of the maximum tongue pressure during tongue lift movement among Day-1 in Week-1, Day-1 in Week-2, Day-1 in Week-3, and Day-5 in Week-3.

* indicates significantly higher than at Day 1 in week 1 ($P < 0.05$).

Fig. 3. Comparison of the first and third series on coefficients of determinations(CDs)of the target force level-tongue pressure among Day-1 in Week-1, Day-1 in Week-2, Day-1 in Week-3, and Day-5 in Week-3.

* indicates significantly higher than at Day-1 in Week-1 ($P < 0.05$).

Abbreviations: S1, first series; S2, second series; S3, third series.

Statistical analysis

All data was presented as mean values and standard errors of the means. MTP during tongue lift movement was analyzed with one-way analysis of variance(ANOVA)among the measurement point. CDs of the target force level-TP curve was analyzed with two-way ANOVA with series(the first and third series)and measurement points(Day-1 in Week 1, Day-1 in Week-2, Day-1 in Week-3, and Day-5 in Week-3)as repeated measures. As suprahyoid muscles activities, relative ratios of RMS of EMG amplitude in each force level on the first series were analyzed with one-way ANOVA among the measurement point. Values of $P < 0.05$ were considered sig-

nificant.

Results

Figure 2 shows the comparison of MTP during tongue lift movement among the measurement point. MTP during tongue lift movement at Day-1 in Week-3, and Day-5 in Week-3 were significantly higher than that at Day-1 in Week 1($P < 0.05$). Figure 3 shows the comparisons of first and third series on CD of the target force level-TP at among the measurement point. CDs of the target force level-TP curve were significantly dependent on the series(the first and third series)and measurement points(Day-1 in Week-1, Day-1 in Week-2, Day-1 in

Fig. 4. Comparison of relative ratios of root-mean-square of electromyogram(RMS EMG)amplitude among Day-1 in Week-1, Day-1 in Week-2, Day-1 in Week-3, and Day-5 in Week-3 on 10 % maximum voluntary contraction(MVC)in LS(A), 10 % MVC in RS(B), 20 % MVC in LS(C), 20 % MVC in RS(D), 40 % MVC in LS(E), and 40 % MVC in RS(F).

Abbreviations: MVC, maximum voluntary contraction; S1, first series; S2, second series; S3, third series; LS, left suprahypoid muscle; RS, right suprahypoid muscle.

Week-3, and Day-5 in Week-3) ($P < 0.01$). Post-hoc testing demonstrated that CDs of the target force level-TP at Day-1 in Week-2, Day-1 in Week-3, and Day-5 in Week-3 were significantly higher than that at Day-1 in

Week-1 ($P < 0.05$).

In suprahypoid muscles activities, Figure 4 shows the comparisons of relative ratios of RMS of EMG amplitude calculated recorded from LS and RS in each force level

on the first series. There were no significant differences in relative ratios of RMS EMG amplitude on first series among any of the measurement points in each force level.

Discussion

In the present study, our results demonstrated that when human continuously perform 41 min of TLT for 5 continuous days/week, the accuracy of performance about TLT was significantly improved after 1 week, and TP during 100% MVC was significantly increased after 2 weeks. On the other hands, there were no significant differences in suprahyoid muscles activities during TLT within 3 weeks.

Our previous study showed that a 5 consecutive days of TLT improved not MTP but the accuracy of performance about tongue lift in healthy participants(6). In addition, 5 consecutive days of TLT can trigger neuroplastic changes in motor cortex related to tongue muscles(5). These findings just suggested neuroplasticity in the motor cortex related to tongue movements in central nervous system occurred faster than improvement of MTP in peripheral system(5, 6). On the other hands, our present results demonstrate that TP during 100% MVC at Day-1 in Week-3, and Day-5 in Week-3 were significantly higher than that at Day-1 in Week-1. Our present results suggest that repeated TLT has some potential to improve not only neuroplastic change in central nervous system but also MTP in peripheral system in healthy participants. Further studies applying the patients with dysphasia will be needed to clarify the control mechanism of tongue lift to establish the rehabilitation program for swallowing.

To evaluate the accuracy of the target force level about TLT, we analyzed CDs calculated from TP. Our previous study investigated the effect of 5 continuous days of TLT as same as the present study paradigm and showed that the CDs of TP in the fifth day become significantly lower than in the baseline in the first day(6). Since experimental design in the present study set 5 consecutive days/week for TLT, 2 days/week set as day off (assuming of weekend). Our present results also demonstrated that CDs of the target force level-TP in the first series on Day-1 in Week-2 were significantly higher than that at Day-1 in Week-1. In addition, Kim et al. also investigated the effect of tongue-to-palate resistance training for 4 weeks(5 days/week) on tongue muscle activity

and oropharyngeal swallowing function and demonstrated that the effectiveness of the training in increasing tongue muscle activity and improving the function of swallowing in dysphagia patients(8). Our results suggest that an adequate rest does not affect improvement of the performance of TLT.

In jaw movements as orofacial motor task, a past study investigated the effect of jaw movement task for 10 weeks on masticatory muscle activities recorded by EMG, and showed that masticatory muscle activities were significantly lower after 10 weeks than before training when the participants perform the same bite force, which may be due to motor adaptations(9). Our previous results also demonstrated that effect of tooth clenching training for masticatory muscle activities and demonstrated that tooth clenching training significantly improve the accuracy of the performance within 5 days(10, 11). These findings suggests that training paradigm of jaw movements may improve accuracy of performance to reach target force level. On the other hands, our previous study showed although accuracy of the performance of TP was improved by TLT, suprahyoid muscle activities were not significantly changed within 5 days. Although our present study applied long-term TLT for 3 weeks, there were no significant differences in suprahyoid muscles activities within 3 weeks. Our present results suggest that although repeated orofacial motor task can improve the performance due to motor learning, mechanism of motor adaptation related muscle activities during orofacial motor task may be difference between jaw and tongue movements. However, since suprahyoid muscles activities measuring by surface EMG did not evaluate the pure muscle activities during tongue motor task as a technological limitation, this limitation may influence the no significant differences in suprahyoid muscles activities on each measurement point. Further studies are needed to investigate the motor learning of muscle activity related to swallowing.

In conclusion, our present findings suggest that long-term of TLT improve not only the accuracy of performance to reach target force level, but also MTP without the alteration of suprahyoid muscles activities in healthy participants. Our results could have the potential to implicate for the rehabilitation program for stroke patients with swallowing dysfunction.

Conflict of interest

The authors declare that they have no competing financial interests.

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