Influence of repeated oral and maxillofacial region movement to stomatognathic and central nervous system

（口腔顎顔面領域における反復運動が顎口腔系および中枢神経系に及ぼす影響）

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Abstract: The aim of this study was to investigate the effect of repeated oral and maxillofacial region movement to stomatognathic and central nervous system. Study 1 investigated the analysis of neuroplasticity changes in corticomotor control of tongue and jaw-closing muscles by repeated tongue lift movement in humans. 16 participants performed tongue lift training (TLT) on each of 5 consecutive days, and underwent transcranial magnetic stimulation (TMS) and electromyographic (EMG) recordings of motor evoked potentials (MEPs). The motor thresholds (MTs) and amplitudes of tongue and masseter MEPs were significantly differences between before TLT on Day-1 and after TLT on Day-5. The MT and amplitude of first dorsal interosseous (FDI) MEP were not significantly differences between Day-1 and Day-5. This study suggests that repeated TLT can trigger neuroplasticity changes in the corticomotor control of not only the tongue but also the jaw-closing muscles. Study 2 investigated the effects of repeated tooth clenching task (TCT) on masseter muscle activities. 16 participants performed a TCT on each of 5 consecutive days. Each day, participants performed tooth clenching at maximum effort to determine the 100% maximum voluntary contraction (MVC) before the TCT. During measurements, EMG activities of both masseter muscles were recorded. To evaluate the accuracy of the performance, the coefficient of determination (CD) of the target force level-EMG curve from the EMG root-mean-square (RMS) values was calculated. No significant day-to-day differences in EMG amplitudes were observed during MVC. CDs on Day-4 and Day-5 were significantly higher than CDs on Day-1. The findings suggest that a rigorous

training paradigm may improve the performance of masseter muscles in terms of accuracy but not MVC. These results might have provided further evidence that repeated oral and maxillofacial region movement induces not only the improvement of the performance in the stomatognathic but also neuroplasticity change in corticomotor area.

キーワード：舌挙上，クレンチング，リハビリテーション，顎口腔系，神経可塑性変化

要旨：本研究は，口腔顎顔面領域における反復運動が顎口腔系および中枢神経系に及ぼす影響を検討した。実験 1 において，舌挙上運動の反復が，舌運動に関与する大脳皮質の運動野および解剖学的に近接した下顎運動に関与する大脳皮質の運動野に生じる神経可塑性変化について検討を行った。16 人の被験者は 5 日間連続で舌挙上トレーニング（TLT）を行い，経頭蓋磁気刺激法（TMS）および筋電計（EMG）を用いた運動誘発電位（MEP）の記録を行った。5 日目の TLT 後の舌および咬筋 MEP の運動閾値および MEP 振幅は 1 日目の TLT 前の運動閾値および MEP 振幅と比較して有意差を認めた。しかしながら，第一背側骨間筋（FDI）MEP の運動閾値と MEP 振幅はトレーニング 1 日目と 5 日目の間に有意差を認めなかった。以上の結果から， TLT の反復により，舌運動に関与する大脳皮質の運動野のみでなく解剖学的に近接した下顎運動に関与する大脳皮質の運動野においても神経可塑性変化を生じることが示唆された。実験 2 においては，噛みしめ運動（クレンチング）の反復が，咬筋筋活動へ及ぼす影響について検討した。16 人の被験者は, 5 日間連続でクレンチングを運動課題としたトレーニング（TCT）を行った。各日の TCT 前に最大噛みしめを行い，その値を 100% maximum voluntary contraction（MVC）と定義した。トレーニング中は両側咬筋から EMG 波形の計測を行い，計測した EMG 波形から実効値を算出した。指示した運動課題の 5 日間における運動学習を評価するため運動課題-EMG 曲線は，各日において 3 種類のフィードバック条

件の各運動課題における両側咬筋の実効値から算出し，算出した運動課題-EMG 曲線から決定係数（CD 値）を算出した。100% MVC 時の両側咬筋における実効値は，各日間において有意差を認めなかった。4 日目および 5 日目における CD 値は 1 日目の CD 値と比較して有意に高い値を認めた。以上の結果より，クレンチングの反復は，最大咀嚼筋筋活動量の向上を認めなかったが, 運動学習に関係する運動精度の向上の発現に寄与することが示唆された。以上の 2 つの実験結果から，口腔顎顔面領域における反復運動は大脳皮質の運動野において神経可塑性変化を生じると同時に顎口腔系の運動精度に影響を及ぼすことが示唆された。

Introduction

In patients with oromotor dysfunction, Yoshida et al. have suggested that tongue pressure measurement during a tongue lift task could reveal clinical signs of dysphagic tongue movements[1)]. Utanohara et al. suggested that reduction in maximum tongue pressure during the tongue lift task is primarily correlated with aging[2)]. In addition, Tsuga et al. showed that the maximum tongue pressure in frail elderly persons was significantly lower than in healthy dentate persons[3)]. These studies have thus demonstrated that tongue pressure during a tongue lift plays a key role in oropharyngeal swallowing.

In central nervous system, 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[4)]. 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[5-9)]. 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[10-15]. In addition, neuroplasticity in the motor cortex of monkeys can be evoked by training the monkeys in a novel tongue protrusion task[14-17]. 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[18-23]. 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 addition, since no studies have addressed the interrelationships in tongue and jaw closing muscles representations in the human motor cortex, it is therefore important to clarify the mechanisms controlling tongue pressure during tongue lifting and the possible interrelationship in corticomotor representations of the tongue and jaw musculature in the oral rehabilitation of patients with dysphagia.

On the other hand, sarcopenia is defined not only by a loss of muscle quantity, but also by a loss of muscle quality in old age[24]. In the stomatognathic system, Murakami et al. demonstrated that reduction in chewing ability is primarily correlated with sarcopenia[25]. Our previous study investigated the effects of repeated tooth clenching tasks (TCTs) over 5 consecutive days on corticomotor excitability of the masseter muscle as assessed by transcranial magnetic stimulation (TMS), and suggested that the performance of repeated TCTs can trigger neuroplasticity changes in corticomotor control of the jaw closing muscles[26]. However, detailed information about behavioral data related to masticatory muscle performance remains scant. To clarify the mechanism of performance improvement of masseter muscles, the development of

evidence-based rehabilitation program for patients with mastication disorder by sarcopenia will also be needed.

The aim of this study was to investigate the influence of repeated oral and maxillofacial region movement for the stomatognathic and central nervous system.

Materials and methods

Study 1: Analysis of neuroplasticity changes in corticomotor control of tongue and jaw closing muscles by repeated tongue lift movement in humans

The study was carried out in 16 healthy participants (8 women and 8 men with mean ± standard error of the mean (SEM) age of 23.4 ± 2.5 years). Informed consent was obtained from all participants before the experiment. Exclusion criteria were medical or psychological problems, epilepsy, metal implants in the head, a pacemaker, an implanted medicinal pump and pregnancy.

All participants performed three series of tongue lift training (TLT) for 41 min on each of 5 consecutive days, which was based on the experimental design in our previous studies[26, 27] (Fig. 1A). In this experiment, the tongue pressure measurement system (JMS Co., Hiroshima, Japan) was used to measure tongue pressure during the TLT task[28]. During TLT, participants sat upright and relaxed in a dental chair with the head supported by a headrest, and kept a tongue pressure probe on their lips and their left hand. Each day, participants performed a maximum tongue lift to determine the 100% maximum voluntary tongue pressure before the TLT. In the first and third series, each participant received no visual feedback (VF) but was simply instructed to target different tongue pressure levels. During the second series, VF of the tongue pressure level, via the tongue pressure measurement system data, was displayed to participants

on a monitor. One series consisted of two tongue pressure levels (5 kPa and 10 kPa) in randomized order (Fig. 1B). 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 (Fig. 1C). The variability at each force level was calculated as the coefficient of variations (CVs) of three series of actual tongue pressure values during TLT. All participants rated tongue muscle fatigue after each series by using a 0-100 visual analog scale (VAS), where ´0´ denoted 'no fatigue' and '100' denoted 'most fatigue imaginable'.

The electromyographic (EMG)（Disa Co.，15C01，Skovlunde，Denmark）activities from first dorsal interosseous (FDI), left side of the tongue dorsum (LT) and masseter muscle (LM), the right side of the tongue dorsum (RT) and masseter muscle (RM) were recorded. On the tongue, disposable self-adhesive silver chloride electrodes (Alpine Biomed, Type 9013S0225, Skovlunde, Denmark) were placed on the dorsal surface of the relaxed tongue (2-3 mm from the midline, 10 mm from the tongue tip) with an inter-electrode distance of 20 mm. On the hand, disposable surface electrodes (Neuroline 720; Ambu, Copenhagen, Denmark) were placed over the FDI. On the jaw, the disposable surface electrodes were placed 10 mm apart along the central part of the masseter muscles, midway between the anterior and posterior borders and the superior and inferior borders.

The measurements of TMS-evoked motor evoked potentials (MEPs) were carried out in four sessions: (1) before TLT Day 1, (2) after TLT Day 1, (3) before TLT Day 5, and (4) after TLT Day 5. In each session, participants performed 15 s of tongue lift at three tongue pressure levels (5 kPa, 10 kPa, 100% maximum voluntary tongue pressure). The EMG activity during epochs of 15 s was quantified by calculation of the

root mean square (RMS) amplitude of MEPs from the LM, LT, RM, and RT. During TMS measurements, participants were placed on a patient examination table in the supine position with the head tilted toward the right side and supported by a headrest. The TMS was performed using a Magstim 200 stimulator (Magstim Co., Whitland, Dyfed, UK) and a focal figure-of-eight stimulating coil. EMG activity was recorded from the RT, RM, and right FDI through the same EMG electrodes placed for the TLTs. During the recording of the tongue MEPs and FDI MEPs, all participants were instructed to keep the tongue and the hand in a natural and relaxed position. During the recording of the masseter muscle MEPs, participants held a special biting device[26, 27] between the anterior teeth to secure a constant pre-activation of the masseter muscles, which is required for TMS to elicit an MEP[29, 30]. The biting device was calibrated to 10 N when providing the participant with feedback on the targeted bite force level. A flexible cap was placed over the head in a standardized way that was based on anatomical markers and in accordance with the International 10-20 Electrode Placement System[31]. A coordinate system with a 1 cm solution was drawn on the cap. The coil of the stimulator was oriented 45 degrees obliquely to the sagittal midline, so that the induced current flowed in a plane perpendicular to the scalp sites [18, 19, 32, 33]. The scalp sites at which EMG responses were evoked in the tongue, masseter, or FDI muscles at the lowest stimulus strength were determined. The motor threshold (MT) of a muscle was measured and was defined as the minimum stimulus intensity that produced 5 of 10 discrete MEPs clearly discernible from the background EMG activity in the muscle[18, 19, 26]. The onset latency was measured on the non-rectified, averaged MEPs[18, 19].

The MEPs were assessed by two methods: stimulus-response (S-R) curves and motor cortex mapping. S-R curves were constructed by 90% MT, 100% MT, 120%

MT, and 160% MT. Eight stimuli were presented at each stimulus level with an interstimulus interval of 10-15 s. For motor cortex mapping, TMS stimuli were delivered at the sites over the scalp identified by the snugly fitting, flexible cap marked with the 1 × 1 cm grid in an anterior-posterior and lateral-medial coordinate system[34]. The stimulator output was set at 120% MT, and eight stimuli were delivered to each site. The grid was stimulated in a regular pattern, beginning at the center of the "hot spot" and then moving anteriorly then posteriorly at increasing and decreasing latitudes (the sites typically covered 5 cm from the vertex and 5 cm anterior and posterior to the interaural line, corresponding to 25 grids). The motor cortex map areas (cm^2) of the tongue, masseter, and FDI MEPs having amplitudes greater than 5 μV (tongue), 10 μV (masseter), and 50 μV (FDI) were determined on the 1 × 1 cm grid. The center of gravity (COG) was calculated in accordance with Ridding et al.[35].

The EMG-RMS values of three tongue pressure levels (5 kPa, 10 kPa, and 100% maximum voluntary tongue pressure) were compared between four sessions (before and after TLT, Day 1 and Day 5) by using one-way analysis of variance (ANOVA) at each measurement point. The CVs of three series of actual tongue pressure values during TLT were analyzed using two-way ANOVA with tongue pressure levels (5 kPa and 10 kPa) and training series (first, second, and third series) as factors. The tongue fatigue VAS score in each day were analyzed using one-way ANOVA. The MT and onset latencies at MT of the tongue, masseter, and FDI MEPs in each session were analyzed using one-way ANOVAs. The MEP amplitudes were analyzed using two-way ANOVA with stimulus intensity and sessions (before and after TLT, Day 1 and Day 5) as factors. The COG measures and MEP areas were analyzed using one-way ANOVA. When appropriate, the ANOVAs were followed by post-hoc Tukey tests to

compensate for multiple comparisons. P values less than 0.05 were considered statistically significant.

Study 2: Effect of a repeated TCT on masseter muscle activities

The study was carried out in 16 healthy participants (8 women and 8 men with mean ± SEM age of 25.5 ± 1.1 years) with no history of neurological disorders and without abnormalities of stomatognathic function or bruxism based on a dental history including standard questionnaires, self-report, an oral examination and examination of the temporomandibular joint and masticatory muscles using the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD)[36].

All participants performed a standardized to TCT repeated for 5 consecutive days[26]. Each day, participants performed tooth clenching at maximum effort to determine the 100% maximum voluntary contraction (MVC) before the TCT. In the first and third series, each participant received no VF but was simply instructed to target different force levels in percentage of their MVC. During the second series, VF of the muscle activity level, via EMG data, was displayed to participants on a monitor. One series consisted of three measurements (10%, 20% and 40% of MVC) in randomized order, and one measurement consisted of one force level (10%, 20% or 40% of MVC) (Fig. 7). 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.

EMG of the LM and RM muscles during all measurements was recorded using disposable bipolar surface electrodes (Neuroline 720; Ambu, Denmark) placed 10 mm apart along the central part of the masseter muscle, midway between the anterior and

posterior borders and the superior and inferior borders[26, 37]. In this data analysis, EMG activity during each task was initially quantified by calculating the RMS EMG amplitude in each 5 s epoch from each EMG channel in all participants. Second, the variability at each force level was determined as the CV of the EMG activity in each channel. The target force-EMG curve was also calculated from the RMS EMG amplitude at each force level in each task during the three series. Finally, since behavioral data on the accuracy of reaching a certain force level without visual feedback are lacking, the coefficient of determination (CD) for a linear fit from the target force-EMG curve in each series on each day was calculated for each EMG channel in all participants in order to evaluate the accuracy of the performance (e.g. motor learning of jaw movement system) in a regression analysis. In addition, to evaluate the test-retest reliability of the EMG measurements between each day, interclass correlation coefficients (ICC) from LM and RM were calculated during 100% MVC.

Differences in RMS EMG amplitude during 100% MVC in LM and RM were analyzed with one-way ANOVA between each day. RMS EMG amplitudes at LM and RM on each day were analyzed with two-way ANOVA with force level (10%, 20%, and 40% MVC) and series (first series, second series, and third series) as repeated measures. CVs of RMS EMG amplitudes at LM and RM on each day were analyzed with two-way ANOVA with force level (10%, 20%, and 40% MVC) and series (first series, second series, and third series) as repeated measures. CDs calculated from the target force-EMG curve in LM and RM was analyzed with one-way ANOVA between series in each day. When appropriate, the ANOVAs were followed by post-hoc Tukey tests to compensate for multiple comparisons. P values less than 0.05 were considered statistically significant.

Results

Study 1: Analysis of neuroplasticity changes in corticomotor control of tongue and jaw closing muscles by repeated tongue lift movement in humans

1. Performance of TLT

There were no significant differences in the EMG-RMS values during the TLT task in the LT, RT, LM, and RM between before TLT Day 1, after TLT Day 1, before TLT Day 5, and after TLT Day 5 at 5 kPa, 10 kPa, and 100% maximum voluntary tongue pressure ($P > 0.108$) (Fig. 2). CVs were significantly dependent on the three series (with or without visual feedback) of tongue pressure each day ($P < 0.001$). Post-hoc testing demonstrated that CVs of tongue pressure in the second series (with VF) were significantly smaller than CVs in the first and third series (without VF) on each day ($P < 0.001$) (Fig. 3). The tongue fatigue VAS score was significantly dependent on the training day ($P < 0.001$). Post-hoc tests demonstrated that VAS fatigue scores were significantly lower at Day 2 to Day 4 compared with Day 1 ($P < 0.001$) (Fig. 4).

2. MEP recordings

The MTs of the tongue and masseter MEPs were significantly different between the four sessions ($P < 0.05$), and post-hoc tests demonstrated that the MTs after TLT Day 5 were significantly lower than before TLT Day 1 ($P < 0.05$). The MTs of the right FDI MEPs were not significantly different between the four sessions ($P = 0.978$) (Table 1). The onset latencies of the tongue MEPs, the masseter MEPs, and the FDI MEPs were not significantly different between the four sessions ($P = 0.898$) (Table 2).

3. S-R curve

The tongue MEPs were significantly dependent on stimulus intensity ($P < 0.001$) and on task session ($P < 0.001$). Post-hoc tests demonstrated significantly higher tongue MEPs after TLT Day 5 (with 120% MT and 160% MT stimulus intensity) when compared with those before TLT Day 1 ($P < 0.001$) and after TLT Day 1 ($P < 0.001$) (Fig. 5A). The masseter MEPs were significantly dependent on stimulus intensity ($P < 0.001$) and on task session ($P < 0.005$). Post-hoc tests demonstrated significantly higher masseter MEPs after TLT Day 5 (with 160% MT stimulus intensity) when compared with those before TLT Day 1 ($P < 0.001$) (Fig. 5B). However, although the FDI MEPs were significantly dependent on stimulus intensity ($P < 0.001$), the FDI MEPs were not significantly dependent on task session ($P = 0.879$) (Fig. 5C).

4. Motor cortex maps

The tongue MEP motor cortex map areas were significantly different among the four sessions ($P < 0.001$). Post-hoc tests demonstrated significantly larger tongue MEP areas after TLT Day 1 (20.6 ± 4.1 mm^2), before TLT Day 5 (21.6 ± 3.9 mm^2), and after TLT Day 5 (23.9 ± 1.5 mm^2) when compared with those before TLT Day 1 (17.4 ± 3.0 mm^2) ($P < 0.05$, 0.005, and 0.001 respectively). Interestingly, the masseter MEP areas were also significantly different among the four sessions ($P < 0.05$). Post-hoc tests demonstrated significantly larger masseter MEP areas after TLT Day 5 (23.5 ± 2.1 mm^2) when compared with those before TLT Day 1 (15.9 ± 8.7 mm^2) ($P < 0.05$). On the other hand, the FDI MEP areas were not significantly different among the four sessions ($P = 0.575$) (Table 3, Fig. 6). There were no significant changes among the four sessions for any of the COG outcomes (Table 4).

Study 2: Effect of a repeated TCT on masseter muscle activities

No significant day-to-day differences in EMG-RMS values on LM and RM were seen during MVC ($P > 0.05$) (Fig. 8). Evaluations of ICCs according to Shrout's classification were "good" in LM and RM[38] (Table 5). Positive linear relationships were found between target force level and RMS EMG amplitude for all series in LM and RM. No significant effects on the series of RMS EMG amplitudes in each day were seen in LM ($P > 0.05$) or RM ($P > 0.05$) (Fig. 9). CVs were significantly dependent on the three series (with or without visual feedback) in RMS amplitude at LM and RM on each day ($P < 0.001$). Post-hoc testing demonstrated that CVs of RMS EMG amplitude in the second series (with visual feedback) were significantly smaller than CVs in the first and third series (without visual feedback) on each day on both sides ($P < 0.001$) (Fig. 10). CDs differed significantly between the five days in both LM and RM ($P < 0.001$). Post-hoc testing demonstrated that CDs in the second and third series on all days in LM and RM were significantly higher than the CDs in the first series on Day 1 ($P < 0.05$). In addition, CDs in the first series on Day 4 and Day 5 in LM and RM were significantly higher than CDs in the first series on Day 1 ($P < 0.05$) (Fig. 11).

Discussion

In study 1, this study used TMS in humans to investigate the analysis of neuroplasticity changes in corticomotor control of tongue and jaw closing muscles by repeated tongue lift movement, and demonstrated 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.

In tongue movement, previous TMS studies have demonstrated that a neuroplasticity of the corticomotor excitability specifically related to tongue motor control can be induced when human participants learn to perform tongue protrusion tasks[18-22] and more complex tongue tasks[39]. Our TMS study used a novel TLT, and our results are consistent with these previous studies on the S-R functions, latency, and motor cortex maps of the MEPs elicited by TMS in the human tongue musculature[18-22, 39]. They are also consistent with several studies in monkeys that have shown neuroplasticity of the motor maps and activity of neurons in the orofacial sensorimotor cortex as a result of training the monkeys in a tongue-protrusion task[14-17]. Changes in the TMS/MEP curve over a period of time may be caused either by changes in the distribution of excitability in the corticospinal or corticobulbar system or by changes in the spatial distribution of excitable elements in the cortex[40, 41]. Some TMS studies have demonstrated that TMS-related maps of the motor cortex change following experimental interventions, and are often reflected in an increase in the size of the map, which may indicate that there has been an increase in excitability of the corticofugal projection rather than a true reorganization[42-44]. Since our present TMS study also documented increases in the tongue and masseter MEP motor map area as a result of TLT, our present findings suggest that the performance of a repeated and standardized TLT also can trigger neuroplasticity changes in the motor cortex. Although the present study has demonstrated that there were no significant differences in EMG-RMS values during 100% maximum voluntary tongue pressure in each muscle between Day 1 and the Day 5, the findings do suggest that the performance of a repeated and standardized TLT can trigger neuroplasticity changes in the central nervous system. Our present findings indicate that changes in the motor cortex related to tongue movements may occur faster

than improvement of the tongue performance.

Recently, Arakawa et al. investigated a tongue rotation exercise for 2 months and showed maximum tongue pressure increased with the progress of continuous tongue training[45]. Kothari et al. suggested that force level, complexity, and introduction of motivational conditions of tongue training influenced behavioral aspects of tongue motor learning and motor performance[39, 46]. Thus, these studies suggest that repeated TLT may also improve the performance of tongue pressure to recover the function of swallowing. Some studies have demonstrated that the tongue pressure during a TLT plays a key role in oropharyngeal swallowing[1-3]. Our results may therefore suggest that the motor cortex involved in tongue motor control can be influenced by rehabilitation of the swallowing function for patients with dysphagia. Further studies are needed to determine the clinical utility of specific TLT tasks for oral rehabilitation purposes.

In study 2, this study in humans investigate the effects of repeated TCT on masseter muscle activities, and demonstrated that a rigorous training paradigm may improve the performance of masseter muscles in terms of accuracy but not MVC. In jaw movements, Hellmann et al. compared masticatory muscle activity during long-term jaw movement training for 10 weeks using EMG and found that EMG activities of masticatory muscles after 10 weeks of training were significantly lower than those before training[47]. The present results demonstrated that CDs in the first series on Day 4 and Day 5 in LM and RM were significantly higher than CDs in the first series on Day 1. Our findings suggest that the masticatory muscles are prone to show improvements in the accuracy of performance caused by motor learning within five days. In addition, since the present study also demonstrated that CDs in the second and third series on all days in LM and RM were significantly higher than CDs in the first series on Day 1, our

results may suggest that repeated TCTs are, indeed, prone to undergo changes in the quality of performance caused by repetitive motor learning and neuroplasticity in the corticomotor pathways. Our previous study also demonstrated that the performance of repeated TCTs can trigger neuroplastic changes in the corticomotor control of the jaw closing muscles[26]. These findings demonstrate that repeated orofacial movements lead to neuroplasticity in the central nervous system. In addition, some TMS studies have suggested that bruxism may be mainly influenced by brainstem networks[48, 49]. To evaluate motor learning in the jaw system, the learning effect in masseter muscle activities using visual feedback was compared over five days in this study. Our findings may lead to the speculation that repeated jaw closing muscle behaviors in patients with sarcopenia using oral rehabilitation program would be associated with specific alterations in the control of the jaw muscles.

Conclusion

These results might have provided further evidence that repeated oral and maxillofacial region movement induces not only the improvement of the performance in the stomatognathic system but also neuroplasticity in corticomotor area.

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Tables and Figures

Table 1: MTs for the tongue, masseter, and FDI MEPs

	MT (%)			
Measurement point	**before TLT Day 1**	**after TLT Day 1**	**before TLT Day 5**	**after TLT Day 5**
Tongue	**48.1±6.0**	**45.3±6.7**	**43.4±6.0**	**41.6±6.0 ***
Masseter	**44.7±6.2**	**41.9±8.1**	**39.4±8.3**	**37.2±7.1 ***
FDI	**44.1±5.5**	**44.1±6.4**	**44.7±5.6**	**44.7±5.0**

The MT of a muscle was measured and was defined as the minimum stimulus intensity that produced 5 of 10 discrete MEPs clearly discernible from the background EMG activity in the muscle.

*Significantly lower at after TLT Day 5 compared with before TLT Day 1 ($P < 0.05$).

Table 2: Onset latencies of the tongue, masseter, and FDI MEPs

	Latency (ms)			
Measurement point	**before TLT Day 1**	**after TLT Day 1**	**before TLT Day 5**	**after TLT Day 5**
Tongue	**8.2±0.3**	**8.2±0.4**	**8.3±0.4**	**8.2±0.4**
Masseter	**7.5±0.5**	**7.4±0.5**	**7.6±0.4**	**7.5±0.4**
FDI	**28.3±2.9**	**29.6±2.6**	**27.3±3.0**	**28.4±2.4**

Table 3: Motor cortex map areas for the tongue, masseter, and FDI MEPs

	Motor cortex map area (cm^2)			
Measurement point	**before TLT Day 1**	**after TLT Day 1**	**before TLT Day 5**	**after TLT Day 5**
Tongue	**17.4±3.0**	**20.6±4.1** †	**21.6±3.9** #	**23.9±1.5** *
Masseter	**15.9±8.7**	**18.9±8.5**	**19.0±6.4**	**23.5±2.1** ‡
FDI	**17.0±3.9**	**18.3±3.9**	**17.4±3.7**	**18.7±3.9**

*Significantly higher than before TLT Day 1 ($P < 0.001$)

#Significantly higher than before TLT Day 1 ($P < 0.005$)

†Significantly higher than before TLT Day 1 ($P < 0.05$)

‡Significantly higher than before TLT Day 1 ($P < 0.05$)

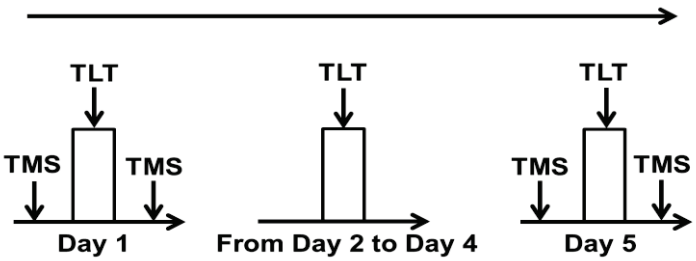
Table 4: COG measures from the tongue, masseter, and FDI cortical motor

Measurement point		COG measure (cm)	
		Ant-Post	Lat-Med
Tongue	before TLT Day 1	3.3±0.3	7.2±0.3
	after TLT Day 1	3.3±0.2	7.1±0.3
	before TLT Day 5	3.2±0.4	7.3±0.3
	after TLT Day 5	3.1±0.2	7.1±0.2
Masseter	before TLT Day 1	4.1±0.2	9.0±0.3
	after TLT Day 1	4.1±0.2	9.1±0.3
	before TLT Day 5	4.1±0.3	9.1±0.3
	after TLT Day 5	4.1±0.2	9.1±0.2
FDI	before TLT Day 1	1.7±0.4	6.1±0.4
	after TLT Day 1	1.6±0.2	6.0±0.4
	before TLT Day 5	1.6±0.3	6.1±0.5
	after TLT Day 5	1.6±0.4	6.0±0.3

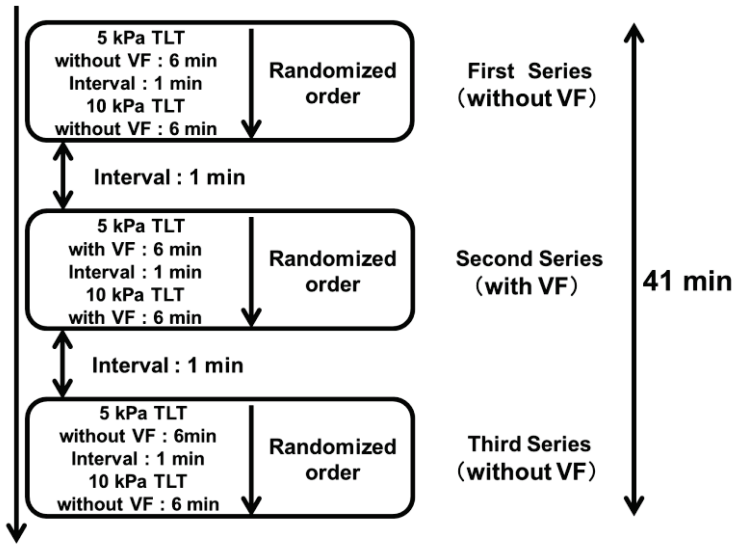
Table 5: Comparison of ICC during 10%, 20%, and 40% MVC with visual feedback and 100% MVC at LM and RM

	10% MVC	20% MVC	40% MVC	100% MVC
LM	0.709	0.749	0.791	0.771
RM	0.701	0.746	0.772	0.764

(A)



(B)



(C)

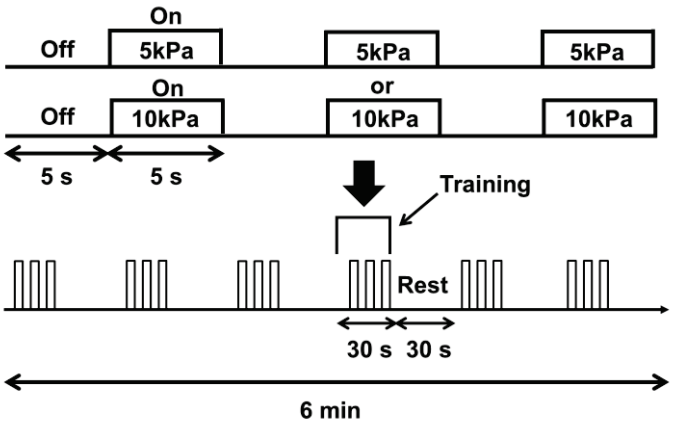


Fig. 1: Overview of the study 1 designs (A), overview of the TLT (B) and details of the TLT task (C)

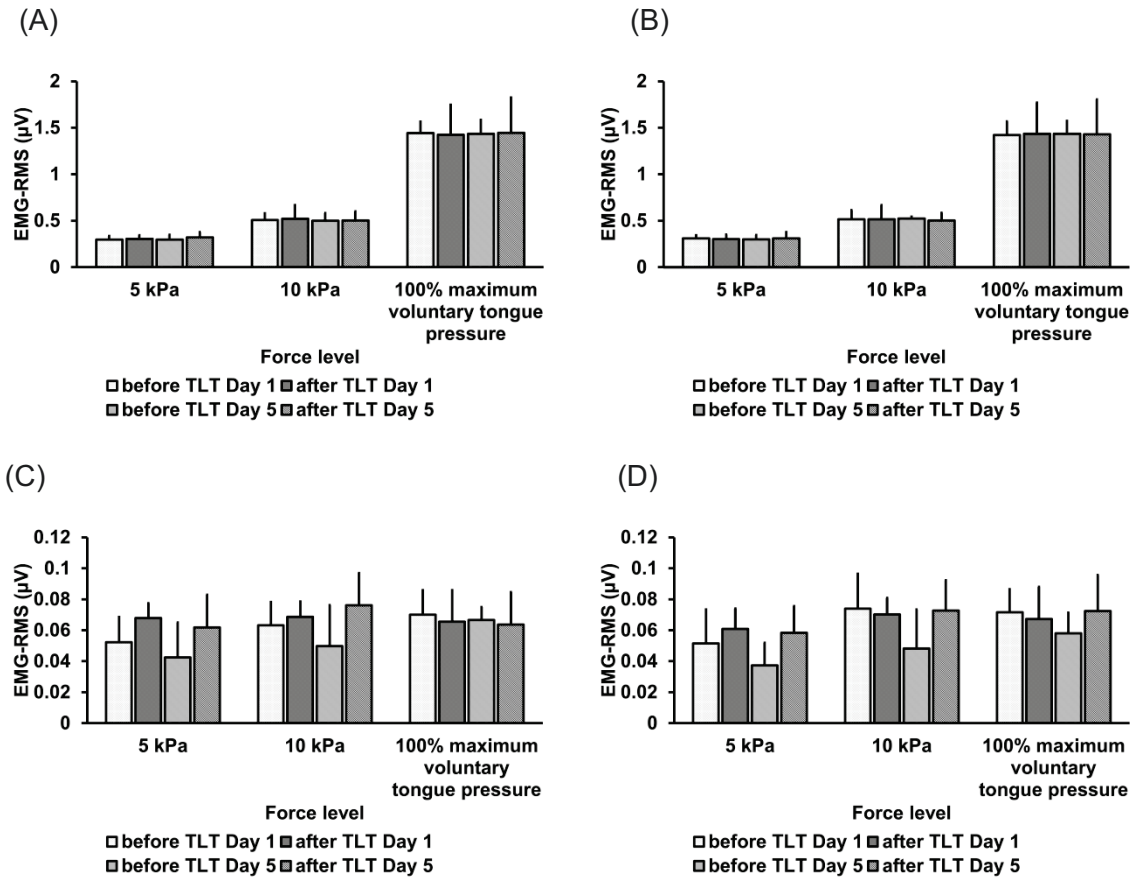


Fig. 2: EMG-RMS values of each measurement point during four sessions and three tongue pressure levels

LT (A), RT (B), LM (C), RM (D)

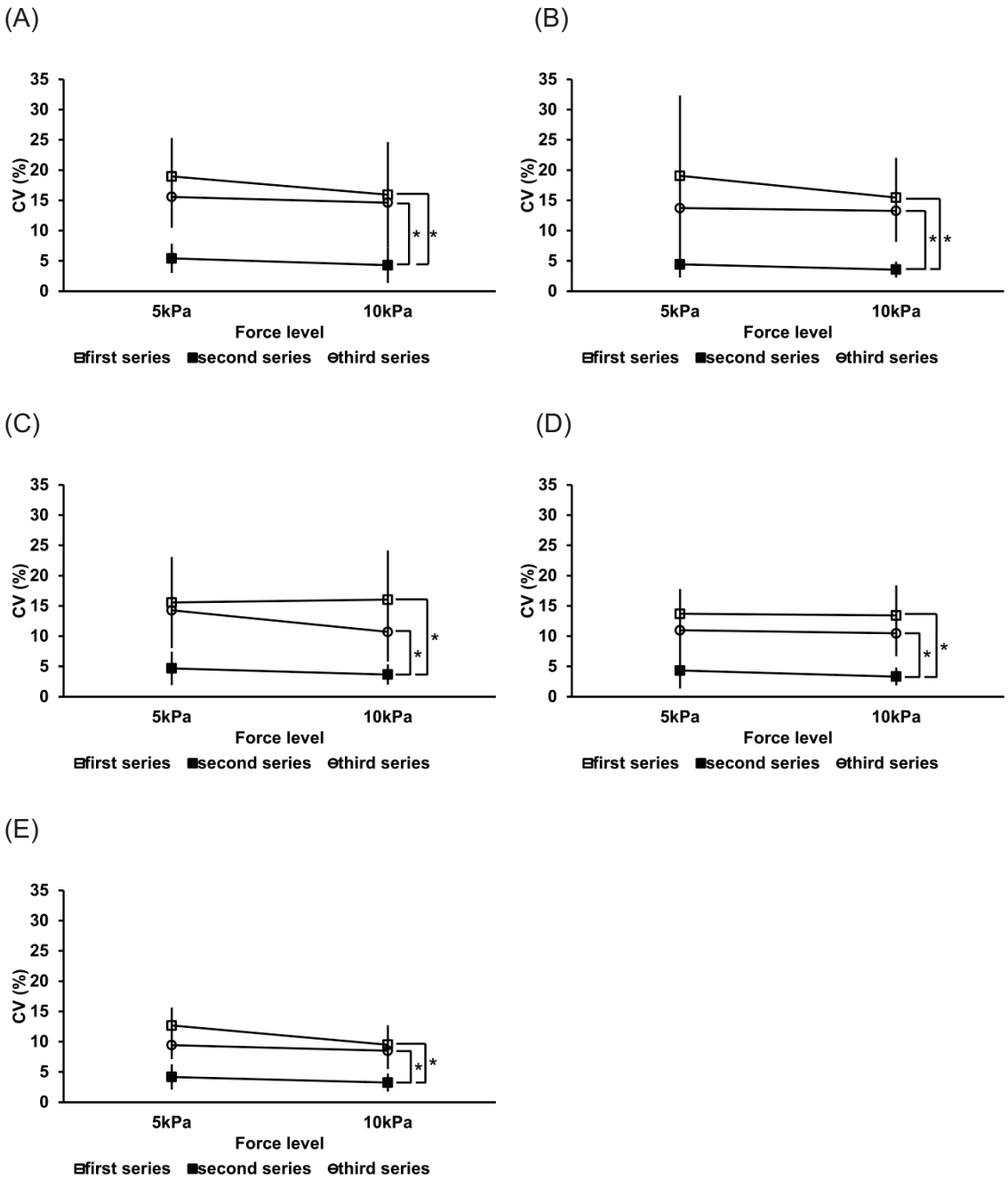


Fig. 3: Comparison of CVs of three series actual tongue pressure value during TLT. Training Day 1 (A), Training Day 2 (B), Training Day 3 (C), Training Day 4 (D), Training Day 5 (E)

*CVs during the second series were significantly lower than during the first and third series ($P < 0.001$).

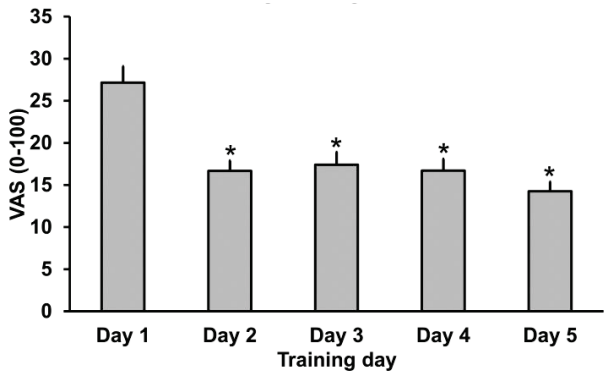


Fig. 4: Assessment of subjective sensations of fatigue in the tongue during 5 days of TLT

*Significantly decrease at from Day 2 to Day 4 compared with Day 1 ($P < 0.001$)

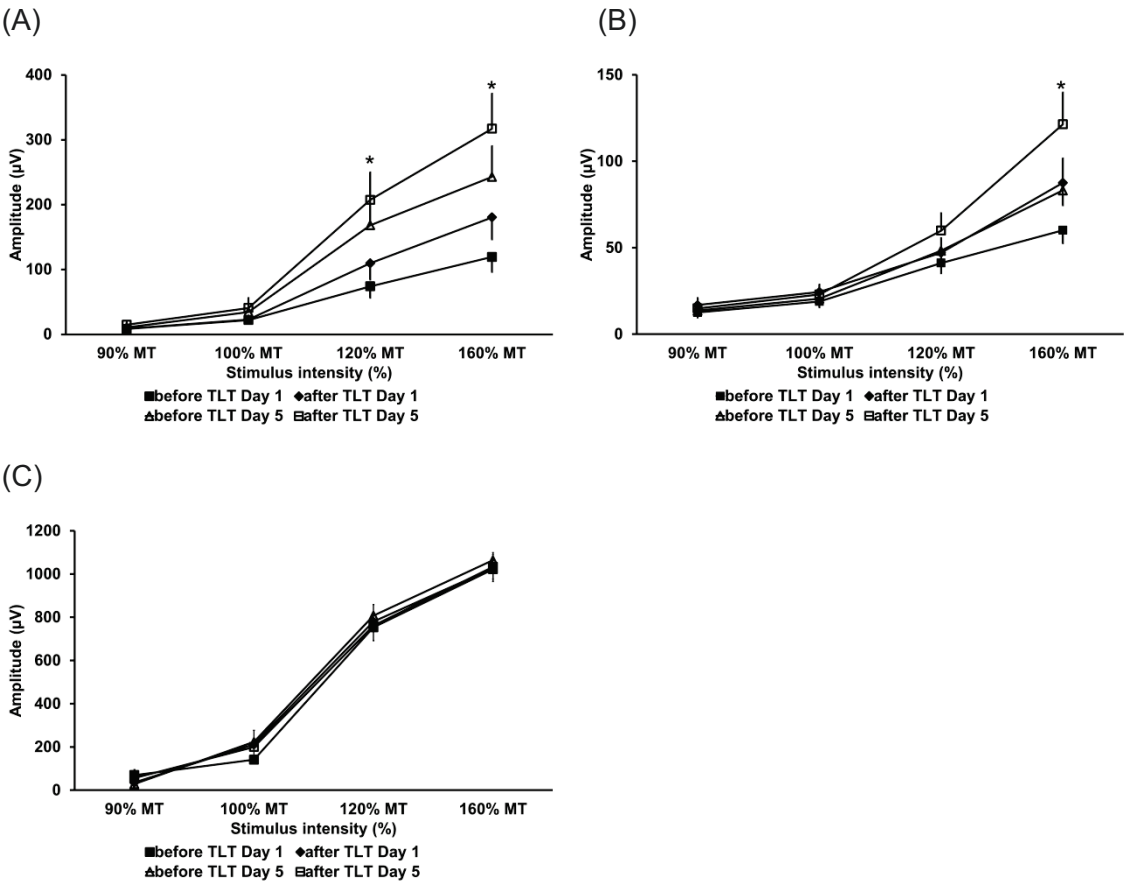
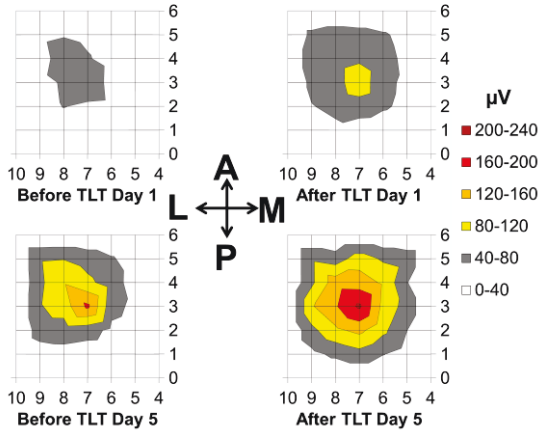


Fig. 5: S-R curves obtained by TMS of the tongue motor cortex (A), masseter motor cortex (B), and FDI motor cortex (C) in 16 participants

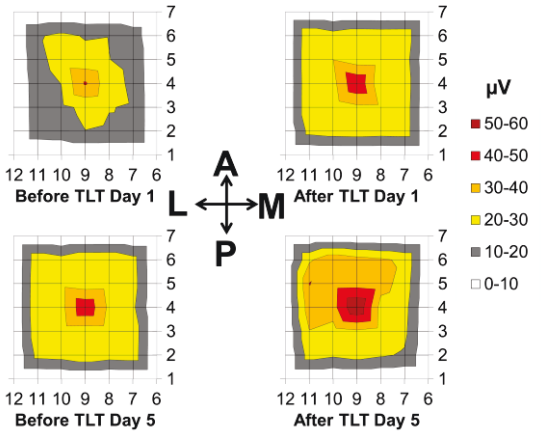
*Significantly higher at after TLT Day 5 compared with before TLT Day 1 and after TLT Day 1 ($P < 0.001$) (A)

*Significantly higher at after TLT Day 5 compared with before TLT Day 1 ($P < 0.001$) (B)

(A)



(B)



(C)

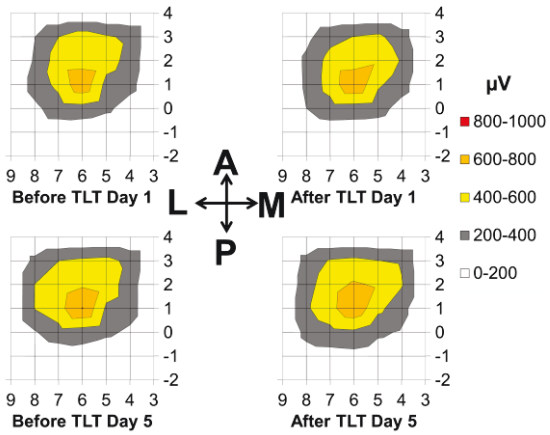


Fig. 6: Tongue (A), masseter (B), and FDI (C) motor cortex maps generated in 16 participants

Arrows indicate directions (A, anterior; L, lateral; M, medial; P, posterior)

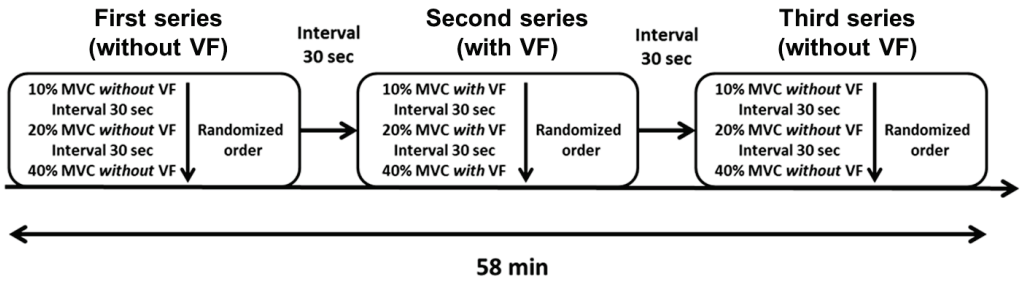


Fig. 7: Overview of study 2 design

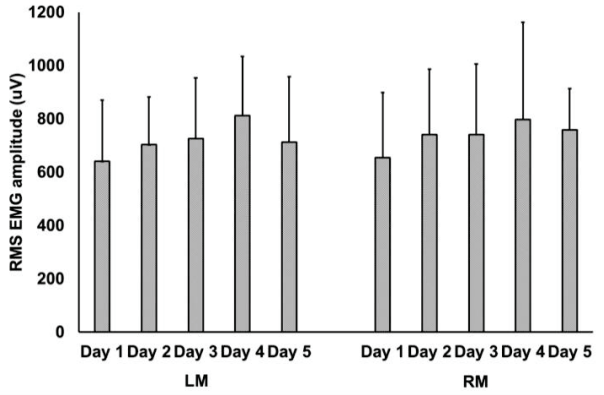


Fig. 8: Comparison of RMS EMG amplitude during 100% MVC in LM and RM at each day

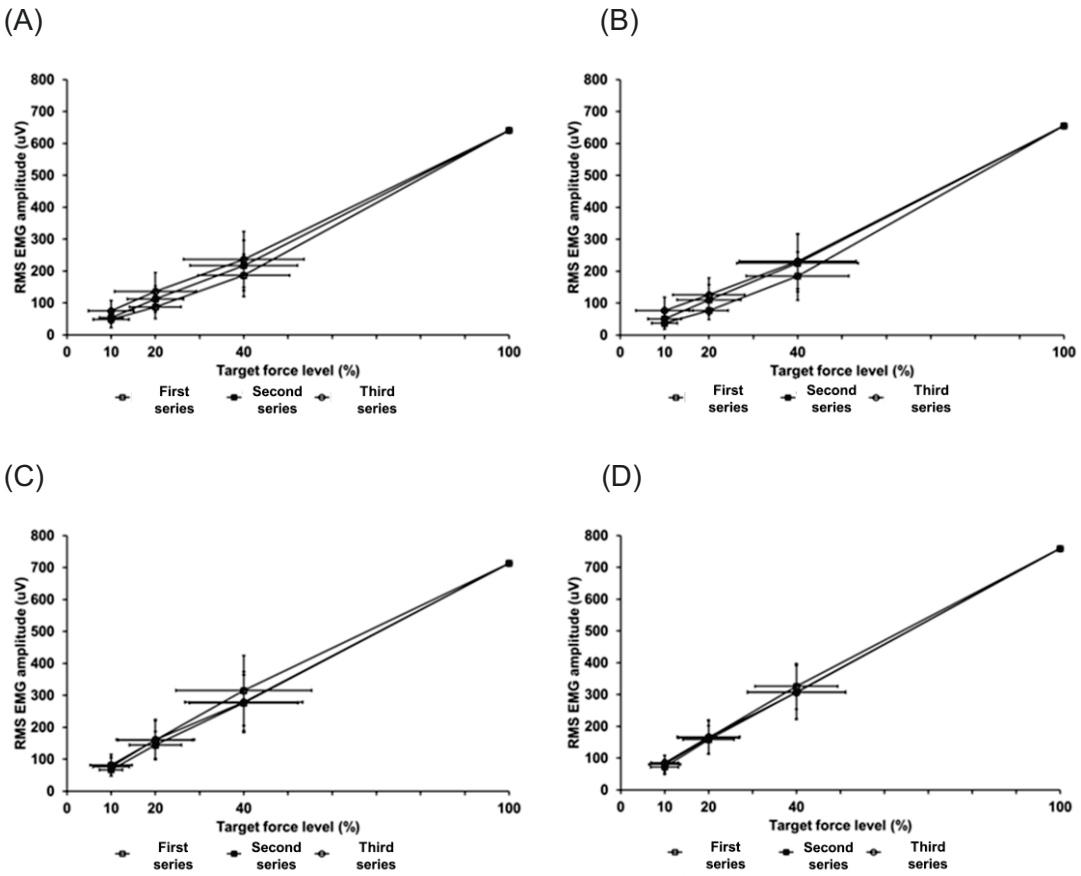


Fig. 9: Target force-EMG curves of TCT

LM in Day 1 (A), RM in Day 1 (B), LM in Day 5 (C), RM in Day 5 (D)

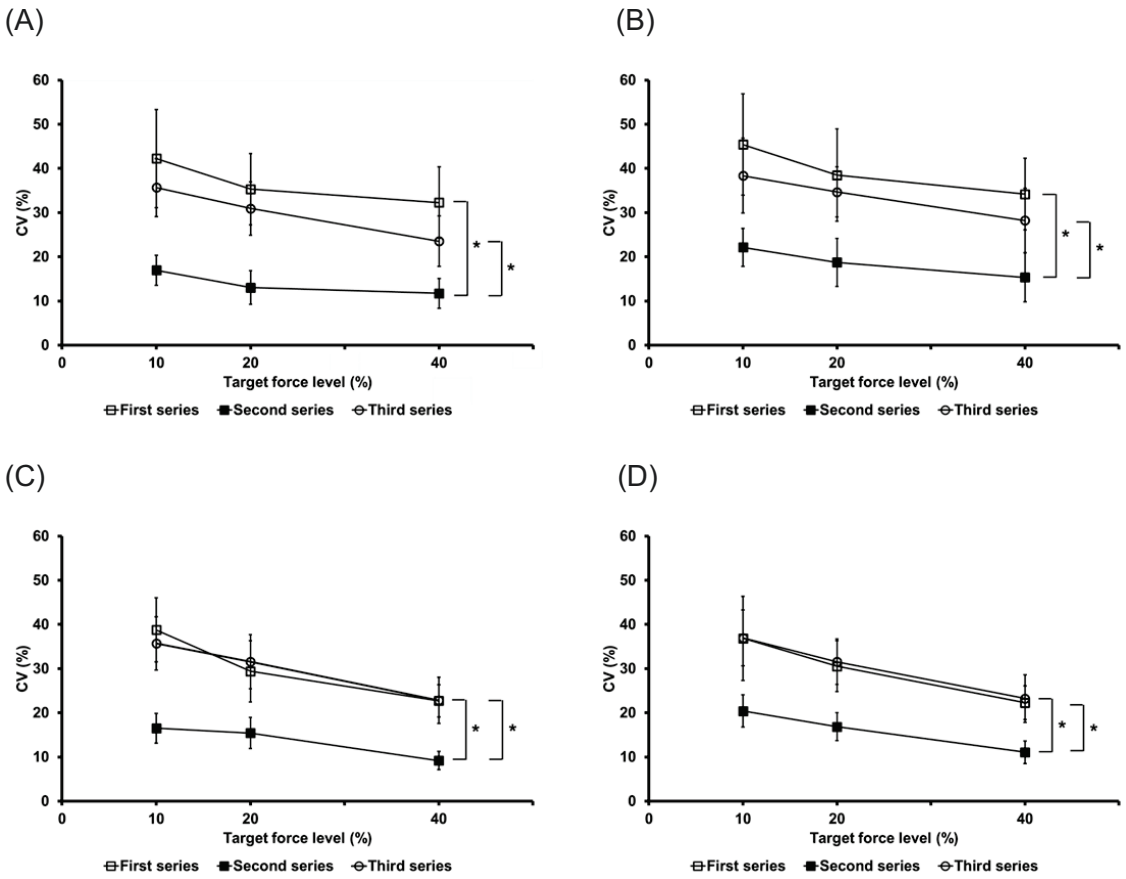
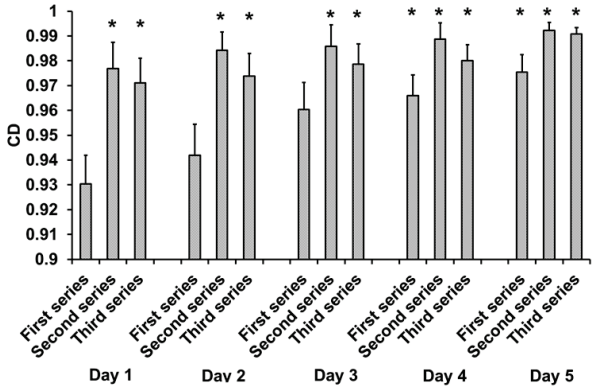


Fig. 10: Comparison of CVs of the RMS EMG amplitude in three series on LM and RM at Day 1 and Day 5

LM in Day 1 (A), RM in Day 1 (B), LM in Day 5 (C), RM in Day 5 (D)

* Indicates significantly lower CVs during the second series compared with first and third series ($P < 0.001$)

(A)



(B)

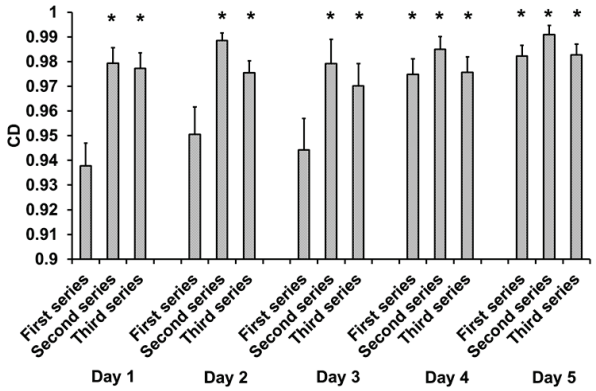


Fig. 11: Comparison of CDs in target force-EMG curves of TCT in LM (A) and RM (B) at each day

* Indicates significantly higher CDs compared with the first series at Day 1 ($P < 0.05$)