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Full Length Article

# Effect of short-term training on fine motor control in trigeminally innervated versus spinally innervated muscles

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ABSTRACT

We hypothesized that the trigeminally innervated jaw muscles and spinally innervated hand muscles would differ in the force control and muscle activity when similar fine motor training tasks are performed. Sixteen healthy volunteers performed six series (with ten trials each) of an oral fine motor task (OFMT) and a hand fine motor task (HFMT), in random order. The task was to hold-and-break a test material (5 cm spaghetti pasta) placed on the force transducer between either their anterior teeth (OFMT) or the thumb and the index finger (HFMT). The hold and the break forces along with the electromyographic (EMG) activity of the left and right masseter (MAL and MAR), left anterior temporalis (TAL) and digastric (DIG) muscles during OFMT, and first dorsal interosseous (FDI) and abductor pollicis brevis (APB) during HFMT, were recorded. There was no significant difference in the relative change of holding force during the six subsequent series, neither for the OFMT ($P = 0.39$) nor for the HFMT ($P = 0.10$). The relative change of EMG activity of MAL ($P = 0.01$) and MAR ($P = 0.02$) during the hold phase decreased significantly during the six series of OFMT. Also the relative change of break force ($P = 0.001$) and the relative change of EMG activity of APB during the hold ($P = 0.003$) and break phases ($P = 0.002$) decreased significantly during the six series of HFMT. The results indicate functional differences between the jaw and hand muscles during a similar hold-and-break task, with the most pronounced changes for the spinally innervated hand muscles. Overall, these findings indicate that training-related neuroplasticity cannot be extrapolated directly from the spinal to the trigeminal system and vice versa.

## 1. Introduction

Over the past few decades, there has been considerable research in understanding the peripheral and central neural mechanisms underlying the initiation and regulation of jaw motor functions (Avivi-Arber, Martin, Lee, & Sessle, 2011). The fine coordination of the muscles during semiautomatic, repetitive movements like mastication and locomotion are mainly due to central pattern generators (CPGs) and the feedback system (Lund, 1991; Lund & Kolta, 2006; Sessle, 2011). The CPGs which are a pool of neurons in the brainstem, are responsible for the generation of movement patterns like jaw opening, jaw closing and the coordination of movements of the tongue, facial and jaw muscles (Lund, 1991, 2011; Lund & Kolta, 2006). The feedback system adapts these rhythmic patterns of

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the movement to the state of the internal and external environment (Dellow & Lund, 1971; Lund, 2011; Sessle, 2011). Thus, the interdependence of CPGs and the feedback system are responsible for the fine coordination of the movements which may be necessary to secure optimal responses and prevent potential tissue damage, during the act of mastication; for reviews, see (Lund, 1991, 2011; Lund & Kolta, 2006).

Trigeminal and spinal nerves innervate human jaw and hand muscles, respectively. These muscles are different in terms of mechanoreceptors, nerve tracts, mechanism of force execution etc., (Iida et al., 2013; Kumar, Tanaka et al., 2017). Indeed, a number of studies have indicated a difference in the mechanism of force execution and muscle activity in spinally innervated and trigeminally innervated muscles (Iida et al., 2013; Jacobs & van Steenberghe, 1993; Jacobs, van Steenberghe, & Schotte, 1992; Kumar, Tanaka et al., 2017; van Steenberghe, Bonte, Schols, Jacobs, & Schotte, 1991). It was suggested that the projection on the trigeminal motoneurone pool from visual inputs is poor in the trigeminal system compared to the spinal system (van Steenberghe et al., 1991). A functional magnetic resonance imaging (fMRI) study also showed that tooth clenching induced a more complex cerebral activity compared to the performance of a hand motor task during bilateral light fists clenching and light tooth-clenching exercises (Iida et al., 2010). Plasticity can be defined as the capacity or ability of a system to undergo structural and/or functional modifications under new constraints imposed by the environment (Tyc & Boyadjian, 2006). The plasticity of corticomotor pathways has been confirmed after a series of repetitive jaw movements (Berger et al., 2016; Hellmann et al., 2011), tongue movements (Baad-Hansen, Blicher, Lapitskaya, Nielsen, & Svensson, 2009; Boudreau, Hennings, Svensson, Sessle, & Arendt-Nielsen, 2010; Kothari et al., 2013; Svensson, Romaniello, Arendt-Nielsen, & Sessle, 2003; Svensson, Romaniello, Wang, Arendt-Nielsen, & Sessle, 2006), hand movements (Garry, Kamen, & Nordstrom, 2004; Muellbacher, Ziemann, Boroojerdi, Cohen, & Hallett, 2001) and leg movements (Perez, Lungholt, Nyborg, & Nielsen, 2004). These studies have suggested that training of motor tasks, trigger neuroplastic changes in corticomotor control and optimization of the muscle function (Hellmann et al., 2011; Kumar, Kothari, Grigoriadis, Trulsson, & Svensson, 2018; Svensson et al., 2003; Watson, Walshaw, & McMillan, 2000).

Trulsson and Johansson (1996) introduced a “hold-and-split” task, in which the volunteers were instructed to hold and then to split a morsel of food on a force transducer positioned between a pair of opposing teeth. This task was used to analyze the bite forces exerted on different food morsels (Svensson & Trulsson, 2009), the role of periodontal mechanoreceptors in the motor control (Johnsen, Svensson, & Trulsson, 2007; Svensson & Trulsson, 2011; Trulsson & Gunne, 1998) and to measure the bite forces applied by different types of teeth (Johnsen et al., 2007). It was shown that repeated splitting of food morsels (in hold and split tasks) did not lead to optimization of jaw muscle activity when the task was repeated sixty times (Kumar et al., 2014). Therefore, the objective of the study was to investigate the similarities and differences in force control and muscle activation between the jaw and hand muscles during a series of repeated “hold-and-break” fine motor tasks. We hypothesized that the trigeminally innervated jaw muscles and spinally innervated hand muscles would differ in the force control and muscle activity when similar fine motor training tasks are performed repeatedly.

## 2. Materials and methods

### 2.1. Study participants

Sixteen healthy volunteers (nine men and seven women, mean age 29.4 ± 3.6 years) from the young staff and students of Aarhus University, Denmark participated in the study. The volunteers were invited to participate in the study through advertising the experiment by posting flyers in and around the university premises and webpage www.forsoegsperson.dk. The volunteers participating in the study neither reported any chronic disease, neurological disorder, abnormalities in stomatognathic function; nor were on any kind of medications. The participants were tested for right-hand dominancy and assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). The participants did not report any history of neurological, pathological or traumatic injury to the hand. The Ethics Committee Region, Midtjylland, Denmark approved this study, based on the guidelines set forth in the Declaration of Helsinki. The participants gave written informed consent prior to the start of the experiment.

### 2.2. Experimental protocol

The volunteers recruited in the experiment participated in a single experimental session of approximately one and a half hours. During each experimental session, the participants were asked to perform an oral fine motor task (OFMT) and a hand fine motor task (HFMT). The participants performed six series (with 10 trials each) of both the OFMT and HFMT behavioral tasks. Thus, in total the participants performed sixty repetitions (short-term training) each of both the OFMT and the HFMT during a single experimental session. The order of OFMT and HFMT were randomized. Two consecutive series were separated by a break of 3–5 min to ensure that the participants performed the training comfortably without any muscle fatigue. Further, the participants were also asked to clench with maximum voluntary bite force (MVBF) and subsequently pinch with maximum voluntary pinch force (MVPF) using a custommade force transducer before the start of the fine motor tasks. The force transducer has been described in more detail by Svensson and Arendt-Nielsen (1996).

### 2.3. Behavioral tasks

Based on a series of trials, it was observed that it took approximately 10–15% of the MVBF to break 50 mm (length) × 1.7 mm (diameter) of the test material (Spaghetti pasta, Budget, ZARA S.p.A., Italy) placed horizontally on a force transducer, with the