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Heteronymous reflex responses in a hand muscle when maintaining constant finger force or position at different contraction intensities

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ABSTRACT

Objective: This study compared heteronymous reflex responses evoked in the first dorsal interosseous muscle by electrical and mechanical stimuli during force and position tasks performed at different target torques.

Methods: Twenty-two healthy human participants contracted the first dorsal interosseus muscle either to produce a constant force against a rigid restraint (force task) or to maintain a constant position of the index finger (position task) against a constant load of 20, 40, and 60% of maximum.

Results: The amplitude of the short-latency reflex evoked by electrical stimulation of the median nerve was significantly greater when maintaining finger position, whereas no difference was present for the long-latency responses. In contrast, the reflex responses (short- and long-latency) did not differ between tasks when elicited by tendon-taps.

Conclusions: Task difference in reflex responsiveness depended more on the type of stimulus applied than the reflex pathway and was consistent across three voluntary contraction forces.

Significance: The results suggest that afferent input from homonymous and heteronymous pathways is modulated similarly at the spinal level during such tasks, and implies the significance of presynaptic inhibition during motor performance.

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1. Introduction

When an individual performs a submaximal isometric contraction with the first dorsal interosseus (FDI) either to produce a constant force against a rigid restraint (force task) or to maintain the position of the index finger against a constant load (position task), the amplitude of the stretch reflex (Doemges and Rack, 1992a; Maluf et al., 2007) and the tendon-tap reflex (T-reflex) (Maluf et al., 2007; Jordan et al., 2007) are similar during both tasks. In contrast, when a reflex was elicited in the FDI by electrical stimulation of the median nerve (heteronymous H-reflex), the amplitude of the reflex response was larger during the position task than during the force task (Maluf et al., 2007; Jordan et al., 2007). Similar results have been observed with single motor units recorded in FDI in response to the T-reflex and median nerve H-reflex (Jordan et al., 2007).

These divergent results for electrically and mechanically induced reflexes might be attributable either to the reflex pathway involved (i.e., homonymous for the stretch and T-reflexes and heteronymous for the median nerve stimulation) or to the type of stimulus applied (mechanical and electrical stimulus). Previous work, however, suggests similar modulation of the afferent input onto the motor neuron pool from the homonymous and heteronymous pathways (Meunier and Pierrot-Deseilligny, 1989). Moreover, the electrically induced reflex response is more sensitive to presynaptic inhibition compared with stretch and tendon-tap reflexes (Morita et al., 1998). If the different adjustments in the T- and H-reflexes during the force and position tasks are attributable to presynaptic inhibition, the greater amplitude of the heteronymous H-reflex during the position task should be present during contractions performed at different contraction intensities as presynaptic inhibition does not change with contraction force (Meunier and Pierrot-Deseilligny, 1989). Similarly, the absence of a difference in the T-reflex across tasks should not change with contraction force. If confirmed, these results suggest that changes in the efficacy of presynaptic inhibition, as observed in elderly adults (Butchart et al., 1993; Earles et al., 2001; Tsuruike et al., 2003), stroke patients (Aymard et al., 2000), individuals with spasticity (Morita et al., 2001), and in healthy subjects after a few weeks of limb immobilization (Lundbye-Jensen and Nielsen, 2008) and the consumption of ethanol (von Dincklage et al., 2007), could compromise motor performance.

The aim of the study was to compare heteronymous reflex responses evoked in the FDI by electrical and mechanical stimuli when the force and position tasks were performed at three target forces. These results indicate a similar modulation of homonymous and heteronymous afferent input onto the motor neuron pool of

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the agonist muscle, but a different adjustment of presynaptic inhibition during the force and position tasks. In addition, our results underscore that the use of the H-reflex method appears as a better tool to investigate fine differences in the afferent synaptic input onto the motor neuron pool between tasks compared with the mechanically evoked reflex.

2. Materials and methods

After informed consent was obtained, experiments were conducted on 22 subjects (9 women) aged between 18 and 37 yr (25.0 ± 5.7 yr; mean ± SD). None of the participants reported any signs of neurological disorder or cardiovascular disease. Subjects were all right-handed and were asked to refrain from exercising the arm muscles for 24 h before testing. The Human Subjects Committee at the University of Colorado in Boulder approved the experimental procedures.

2.1. Experimental apparatus

The subject was seated in a modified dental chair with the left arm supported to minimize activity in shoulder and arm muscles. The upper arm was slightly abducted (~20°) and the elbow joint was flexed to ~95°. The left hand was placed in a vertical position midway between supination and pronation and supported by means of a custom-made apparatus. The index finger was splinted in full extension at the proximal and distal interphalangeal joints and attached to a torque transducer (TRT-25, Transducer Techniques, Temecula, CA). The transducer was mounted on the shaft of an electrical torque motor (PMA44Q, Pacific Scientific, Rockford, IL). The metacarpophalangeal joint of the index finger was aligned with the shaft of the torque motor, which enabled abduction–adduction movements about the joint. The thumb was abducted by 45° and fixed in the same plane as the palm of the hand (Fig. 1).

The electrical torque motor was used to simulate an inertial load in a gravitational field for the position task by using a Labview Real Time system (2PCs using a PCI-6029 and a PCI-6021, National Instruments, Austin, TX). The torque transducer signal, analog signals of the simulated mass, and motor shaft position and angular velocity were A/D sampled at 200 samples/s (Power 1401, 16-bit resolution, Cambridge Electronic Design, Cambridge, UK) and stored on computer for subsequent analysis.

2.2. EMG recordings

The surface EMG from the FDI and abductor pollicis brevis (APB) muscles were recorded using bipolar surface electrodes (silver–silver chloride; 4-mm electrode diameter; 12-mm interelectrode distance; In Vivo Metric, Healsburg, CA). The electrodes were placed parallel to the radial border of the second metacarpal over FDI, just proximal to the junction with the distal tendon (Maluf et al., 2007), and over the muscle belly of the APB, close to the proximal insertion. The EMG activity from the antagonist muscle for FDI, second palmar interosseous (SPI), was recorded with a bipolar intramuscular electrode that comprised two Formvar-insulated stainless steel wires (50 μm diameter), with 1 mm of insulation removed from the distal tip of the two wires to increase the recording volume of the electrode. Reference electrodes were placed over bony prominences on the left elbow. The EMG signals were amplified (500–5000) and filtered (13–1000 Hz) prior to sampling at 2000 samples/s (Coulbourn Instruments, Allentown, PA) and storage on a computer.

2.3. Reflex responses

Heteronymous reflexes were evoked in FDI by electrical stimulation of the median nerve (H-reflex) and with tendon-taps applied to the distal tendon of the APB (T-reflex). Electrical stimulation (0.5-ms pulse; Grass S88K, Astra-Med, West Warwick, RI) of the

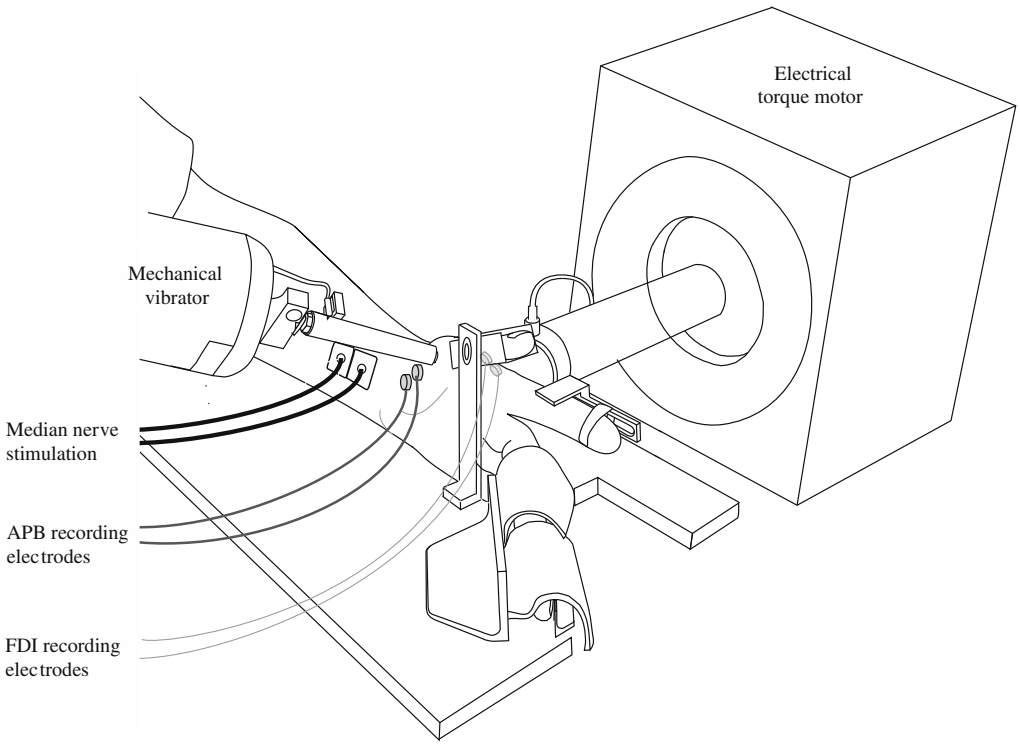

Fig. 1. Illustration of the experimental set-up. The index finger of the left hand is extended and contacts the lever attached to the shaft of the torque motor. The recording electrodes for the FDI are indicated in grey because they cannot be seen directly in this image.