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Lateral dominance and motor unit firing behavior

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Twelve subjects were classified as left-handed (LH) or right-handed (RH) using Annett's hand dominance classification. Motor unit recordings were obtained from the first dorsal interosseous (FDI) muscle of each hand using a quadrifilar needle electrode. Firing occurrences of individual motor units were then identified and the firing rates of all motor units recorded during the contraction were cross-correlated. The results demonstrated significantly greater firing rate cross-correlation scores in the dominant hand than in the non-dominant hand for both LH and RH subjects. This association between hand dominance and the *common drive* of motor unit firing rates lends credence to the idea that one or more CNS sites may influence conjoint motor unit firing behavior.

Observations of firing behavior in human motor units have revealed that the firing rates of individual motor units within a muscle are not independent. Rather, the firing rates of groups of motor units within a single muscle tend to fluctuate in-phase; small increases in the firing rate of one motor unit occur concurrently with increases in firing rates of other units within the same muscle. This *common drive* phenomenon has been observed in several limb muscles[7,8], and in a muscle lacking muscle spindle receptors, the *orbicularis oris*[14]

The mechanism underlying *common drive* has yet to be clearly elucidated. There is evidence that sensory receptors influence a local pool of motor units[22], which lends credence to the idea that the joint fluctuation in motor unit firing rates may have peripheral origin. However, other data from human studies suggest that Ia input is distributed across a broad representation of the motoneuron pool without regard to muscle topography[18]. Thus, other spinal or supraspinal systems may play a role in *common drive*. The present experiment was designed to explore the role of central influences on motor unit firing behavior, by determining the relationship between handedness or lateral dominance and the degree of in-phase fluctuation of motor unit firing rates.

Motor unit activity was recorded using procedures outlined in earlier papers[16,17]. Briefly, an indwelling needle electrode was used to detect the activity of individual motor units. The electrode consisted of a 25-gauge cannula containing four wires emerging from a side port. Three channels of myoelectric (ME) activity were obtained from pairs of the four leads, amplified, bandpass-filtered (1 kHz–10 kHz) and recorded on FM tape. The firing occurrences of individual motor unit action potentials (MUAPS) were then identified from the recorded signals using a computer algorithm.

Recordings were made from left and right first dorsal interosseous (FDI) muscles in 12 subjects with no known neurological or neuromuscular disorders. Informed consent was obtained from all individuals. The subject was seated at a table with the hand placed in a specialized apparatus designed to measure isometric force during index finger abduction. Maximal voluntary isometric contraction (MVC) was determined while the subject attempted to abduct the index finger. A visual trajectory was then displayed on a computer display. The task required the subject to slowly increase force to 30% MVC over 3 s, maintain a 30% MVC effort for 12 s, and then slowly decrease force output to zero during the final 3 s. The subject was asked to track the trajectory with a smooth isometric contraction of the FDI.

The quadrifilar needle electrode was then inserted into the belly of the FDI. Using visual and auditory feedback from an oscilloscope and a speaker, the needle was positioned to obtain suitable recordings from several motor units. Trials during which stable recordings were obtained were later identified, digitized with a minicomputer, and the signals were decomposed to obtain individual motor unit action potential trains (MUAPTs). Annett's test of hand dominance[1] was used to determine the direction and magnitude of hand dominance for each subject.

The motor unit firing times were used to obtain a

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continuous firing rate signal by convolving the motor unit impulse train with a 400-ms width Hanning window filter and inverting the result. Firing rate cross-correlation functions were then computed for each pair of motor units whose firing rates were stable for at least 5 s. Almost all of the highest cross-correlation scores were obtained in an interval 50 ms to either side of the zero lag point in the cross-correlation function. Therefore, the highest cross-correlation score during this ±50 ms interval was used for further comparisons. For each muscle the mean cross-correlation score was the average score of all motor unit pairs recorded from that muscle.

Four of the twelve subjects were left-side dominant, with a mean dominance score of −0.82, compared with 0.86 for the eight right-handed subjects. A negative score indicates that subjects preferred to use their left hand for most of the items in Annett's classification of lateral dominance.

Data were analyzed from 122 different motor units recorded from the twelve subjects. The mean firing rate cross-correlation was greater among pairs of motor units in the dominant hand than in the non-dominant hand ($P < 0.05$; Fig. 1). This lateral dominance effect was quite consistent, producing greater cross-correlation scores among motor units in the dominant FDI in 11/12 subjects. There was no significant difference in firing rate cross-correlation scores between LH and RH subjects ($P < 0.05$).

Thus, during a voluntary contraction the amount of joint fluctuation in motor unit firing rates is greater in the dominant hand than in the non-dominant hand. These observations might be attributable to differences in the organization of peripheral receptors or muscle topography between the dominant and the non-dominant limb. Some recent studies of muscle partitioning suggest that motor unit behavior may be influenced by subtle changes in activity from Ia afferents[15,22]. However, activation of a single human spindle afferent from a localized muscle area produces little change in motor unit activity[10].

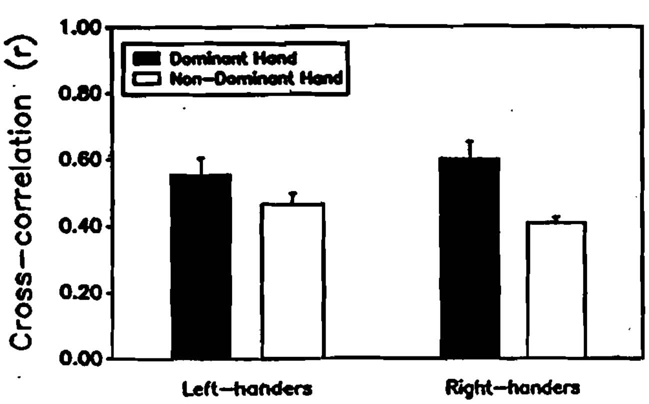

Fig 1. Average values for firing rate cross-correlations among pairs of motor units. For both left-handers and right-handers, the cross-correlation scores were greater ($P < 0.05$) in the dominant hand than in the non-dominant hand.

Quadrupeds manifest an asymmetry in H-reflexes that is related to the preferred limb[4], however, there is no evidence that receptor-motor unit influences are stronger on the dominant side. Although earlier studies suggested that right-side muscles contained a greater number of muscle spindles, post-hoc statistical analysis of the published data revealed no left–right differences[2,5]. A more recent examination of canine intrinsic forelimb muscles also found no left–right differences in muscle spindle density[3]. DeCorte et al.[6] concluded that the numbers of multiple-bag spindles were greater on the right side, but the data indicated that this was true for female cats only. Moreover, post-hoc statistical analysis of their data revealed a marginally greater right-side dynamic spindle component density ($t = 2.25$; 31 df; $P < 0.05$; from their Fig. 4). The static spindle component density was similar on both sides ($t = 0.94$; $P > 0.05$).

Friedli et al.[9] observed that the threshold for detecting the presence of percutaneously applied electrical stimuli was greater in the dominant arm, an effect that they attributed to an asymmetry in the peripheral nerves rather than cerebral lateralization. However, efforts to demonstrate asymmetry in sensory and motor nerve conduction velocities have produced equivocal results[20,23,26].

That some central site may be an important source of *common drive* is suggested by other electrophysiological observations. H-reflex studies typically demonstrate greater motoneuron excitability in the dominant upper limb[24,25]. It seems likely that tonic supraspinal influence is greater on the dominant side as well, since light contraction also produces a facilitation of the H-reflex that is greater on the dominant side[24].

A paradigm which has provided additional information regarding cognitive and motor central nervous pathways is the H-reflex recovery curve. The amplitude of the H-reflex recovery curve is greater in the dominant arm than in the non-dominant arm[24]. Goode et al.[11,13] noted that the asymmetry in the H-reflex recovery curve was related to cortical laterality scores in psychiatric patients. They later indicated that the level of asymmetry in H-reflex recovery curves may provide some measure of central dopaminergic activity in schizophrenic patients[12]. Observations of H-reflex recovery curves led Nativ et al.[19] to conclude that transcortical reflex pathways might be involved in lateral asymmetry.

Other observations point to a role for the supraspinal centers in the origin of *common drive* of motor unit firing rates. For example, there are more pyramidal fibres to the right hand than to the left hand in about 80% of adult human brains[27], and even rhythmic locomotor activity is marked by asymmetry in cerebral centers that may be related to lateral dominance[21]. However, we cannot rule out the possibility that there may be some asymmetry in the organization of spinal interneurons or influences from other central sources which impact on the control of motor unit firing rates.

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