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Trajectory control in targeted force impulses

I. Role of opposing muscles

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Summary. The functional role of opposing muscles in the production of isometric force trajectories was studied in six adult subjects producing impulses and steps of elbow flexor force, with different rise times and amplitudes. Rapidly rising forces were invariably associated with an alternating pattern of EMG activity in agonist and antagonist muscles: an agonist burst (AG1) initiated the development of force in the desired direction while a reciprocal burst in the antagonist (ANT-R) led to the deceleration of the force trajectory prior to the peak force. The temporal pattern of agonist and antagonist activation was dependent on force rise time. Force trajectories with long rise times (> 200 ms) were entirely controlled by the agonist, and EMG activity closely followed the contours of the rising force trajectory. For rise times of about 120 to 200 ms, agonist activation formed a discrete EMG burst, and force continued to rise during the subsequent silent period. For brief force rise times (< 120 ms), reciprocal activation of the antagonist muscle occurred at about the time of the peak dF/dt. The integrated magnitude of AG1 was dependent on peak force but was independent of force rise time. AG1 duration varied directly with both peak force and force rise time. The integrated value of ANT-R varied as an inverse function of force rise time and was minimally influenced by peak force. ANT-R was present with the same magnitude and timing in both force impulses and steps when rise times were equal; therefore it did not serve to return force to baseline. Rather it served to truncate the rising force when very brief rise times were required, thus compensating for the low-pass filter properties of the agonist muscle. Subjects were able to voluntarily suppress ANT-R in rapidly accelerated force trajectories, indicating that the linkage between the commands controlling agonist and antagonist is not obligatory; however AG1 was then prolonged. Our findings emphasize that neuronal commands to opposing muscles acting at a joint must be adapted to constraints imposed by the properties of the neuromuscular plant.

Key words: Human subjects – Isometric – Trajectory control – Agonist-antagonist EMG pattern – Muscle properties

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Introduction

The purpose of the series of studies introduced by this paper was to characterize the processes used by normal human subjects to control the amplitude and direction of limb trajectories aimed to a target. We have approached this problem by examining trajectory control in a simple motor response, the aimed isometric force impulse. The first group of papers of this series (Gordon and Ghez 1987a; Gordon and Ghez 1987b) defines a general control strategy used by subjects to accurately vary the size of targeted responses and assesses the influence of mechanisms acting concurrently to correct initial trajectory errors. The second group of papers (in preparation) examines how antecedent stimulus information from a target triggers the occurrence of a response and determines its trajectory (Hening et al. 1983; Hening and Ghez 1984; Favilla et al. 1985, 1986).

We have studied the control of motor responses under isometric conditions in order to minimize several problems which complicate the experimental analysis of position control mechanisms. First, as the limb changes position during movement, there are complex shifts in internal and external forces acting on the joints. Second, stretch reflexes, evoked by changes in muscle length during movement, interact