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Research Note

EMG Patterns in Antagonist Muscles During Isometric Contraction in Man: Relations to Response Dynamics*

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Summary. We studied the EMG activity of biceps and triceps in human subjects during isometric force adjustments at the elbow. Rapid targeted force pulses exhibited stereotyped trajectories in which peak force was a linear function of the derivatives of force and the time to peak force was largely independent of its amplitude. These responses were associated with an alternating triphasic pattern of EMG bursts in agonist and antagonist muscles similar to that previously described for rapid limb movements. When the instructions demanded rapid force pulses, initial agonist bursts were of constant duration, and their magnitude was strongly related to peak force achieved. The timing of EMG bursts in antagonist pairs was closely coupled to the dynamics of the force trajectory, and the rising phase of the force was determined by both agonist and antagonist bursts. When peak force was kept constant and rise time systematically varied, the presence and magnitude of antagonist and late agonist bursts were dependent on the rate of rise of force, appearing at a threshold value and then increasing in proportion to this parameter. It is proposed that antagonist activity compensates for nonlinearity in muscle properties to enable the linear scaling of targeted forces which characterizes performance in this task.

Key words: Triphasic EMG patterns – Isometric contraction – Muscle mechanics

Introduction

An alternating triphasic pattern of EMG bursts in agonist and antagonist muscles is known to characterize rapid limb movements (Wacholder and Altenburger 1926). An initial burst in the agonist (AG1) is followed by a silent period coinciding with a burst in the antagonist (ANT) and then by a second burst in the agonist (AG2). AG1 initially accelerates the limb, while ANT has generally been held to be specifically responsible for terminal deceleration (Hallett et al. 1975; Lestienne 1979; Marsden et al. 1983). Although the magnitude of ANT varies proportionally with limb velocity (Bouisset and Lestienne 1974) this relationship is subject to other complex dependencies (Marsden et al. 1983), particularly ones related to loads opposing movement (Lestienne 1979), intended torque (Ghez and Martin 1982), and instruction set (Waters and Strick 1981). The significance and mechanisms of these interactions are poorly understood, largely because the direct output of muscles is force, and the relationship between an intended position change and the associated muscle forces is not a unique one. To isolate the effect of intended torque from intended change in position, we have examined the relations between response dynamics and EMG activity in an antagonist pair over a wide range of forces and rise times under isometric conditions. The present results suggest that specific patterns of activation of opposing muscles at a joint are constrained by, and compensate for, frequency-dependent mechanical properties of muscles as well as the stereotyped features of motoneuron recruitment.

Methods

Experiments were conducted on three neurologically normal adult subjects, seated with right shoulder abducted to 90° and elbow flexed to 90°. The right forearm was fixed in a rigid cuff coupled to a strain gauge sensitive to flexion and extension torques generated at the elbow. The upper arm and shoulder were restrained to prevent movement of the elbow joint. The subject's force output

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