Exp Brain Res (1982) 45: 115–125

Experimental Brain Research

The Control of Rapid Limb Movement in the Cat*

III. Agonist – Antagonist Coupling

C. Ghez and J.H. Martin

Center for Neurobiology and Behavior, Departments of Physiology and Neurology, Columbia University, College of Physicians and Surgeons, New York, NY 10032, USA

Summary. Electromyographic (EMG) activity associated with rapid voluntary limb movements exhibits a characteristic "three burst pattern". The first burst is in the agonist muscle (AG1), the second is in the antagonist (ANT) and the third is again in the agonist (AG2). The present study was undertaken to determine whether ANT and AG2 reflect preprogrammed commands or responses to stretch consequent upon limb displacement. To answer this question EMG activity of agonist and antagonist muscles was examined in cats performing a tracking task. To dissociate centrally programmed muscular events from their intended mechanical consequences, isometric and anisometric conditions were presented in either a predictable or unpredictable sequence. A torque motor was used to control limb trajectory and to impose passive angular displacements.

Whereas AG1 was present under both isometric and anisometric conditions, ANT and AG2 required limb displacement and were time locked to movement parameters. ANT occurred within 15 ms following the onset of acceleration. Its magnitude varied linearly with this parameter and inversely with AG1. Passive displacements stretching the antagonist elicited responses with similar latencies and greatest magnitude for a given acceleration. AG2 was only present in underdamped movements with terminal oscillations and typically occurred when the position reached its peak and the velocity recrossed zero. Its magnitude was a function of both limb deceleration and of intended force.

The data indicate that both ANT and AG2 represent responses to muscles stretch whose amplitudes are modulated by descending commands. Reciprocal mechanisms operating at a spinal level could account for the reduction of the antagonist response as a function of intended force. The increased sensitivity of late stretch responses in the agonist with higher intended forces is compatible with motoneuron facilitation by tonic descending commands. It is proposed that the stretch evoked responses function to dampen terminal oscillations which ensue from rapid displacement of the mass of the limb against elastic forces of muscle and soft tissue.

Key words: Voluntary movement – Cat – Triphasic – EMG – Antagonist

* Supported by NIH Grant NS 15750

Introduction

In previous communications we argued that the central commands responsible for rapid isometric force adjustments (Ghez and Vicario 1978b) and rapid limb displacements (Ghez 1979) include two primary components. An initial phasic command, modulated in amplitude, determines the rate of force change or the limb trajectory in the case of displacement. A later tonic command is responsible for maintaining the final steady state force or the final limb position. The time course and configuration of electromyographic (EMG) activity of agonist and antagonist muscles during rapid force adjustments are compatible with this view. A rapid change in the level of force exerted is accompanied by an initial burst of EMG activity followed by tonic activity in the agonist muscles when the resting force requires tonic contraction of neither agonist nor antagonist muscles. Whereas the magnitude of the integrated EMG activity during the initial burst varies with the rate of force change, the duration of the burst is independent of both final force achieved and rate of force change in both the cat and man (Ghez and Vicario 1978b; Freund and Büdingen 1978). Tonic EMG activity varies with the level of steady force maintained.

0014–4819/82/0045/0115/$ 2.20