

## Effects of Postural Set on Anticipatory Muscle Activation Prior to Rapid Arm Flexion

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*Key words:* posture, microgravity, postural set, voluntary movement

It is well documented that electromyographic activity (EMG) in the trunk and leg muscles precedes the initiation of rapid shoulder flexions from a standing position (Belen'kii, Gurfinkel, & Pal'stev, 1967; Bouisset & Zattara, 1981, 1988; Lee, Buchanan, & Rogers, 1987). This anticipatory postural activity ensures that the body's center of mass remains within the base of support during the forthcoming arm movement. It has been proposed that anticipatory postural activity is a component of the central motor program used to control arm movement (Bouisset & Zattara, 1981, 1988). Other authors have suggested that postural and agonist musculature is controlled by parallel processes that allow subjects to "independently vary the weighting of postural and focal commands, or 'sets', to meet cognitive and mechanical demands of specific voluntary tasks" (Lee et al., 1987, p. 257). It has recently been demonstrated that automatic postural responses to external perturbations are influenced by a subject's central set (Horak, Diener, & Nashner, 1989).

If the anticipatory postural activity is a component of the motor program controlling the forthcoming arm movement, an invariant order of muscle recruitment should be evident across a series of arm raises. Schmidt (1985) suggested that one criterion to indicate that the same motor program is controlling a series of similar movements is a fixed relationship between muscle activity onsets. This requirement necessitates an invariant order of muscle onsets. Conversely, if the agonist and postural muscle activity are controlled by independent

but parallel processes, then recruitment order would be free to vary depending on the subject's postural set.

Postural sets are based on the perceived postural requirements for the movement as signaled from sensory input and cognitive information about the task (Brooks, 1986; Cordo & Nashner, 1982; Lee et al., 1987). Cordo and Nashner's (1982) subjects suppressed anticipatory postural activity during standing handle pulls following the placing of a finger on a rail next to the posture platform. The authors believed this suppression was the result of changes in postural set due to cognitive factors, not changes in somesthetic input. Manipulation of the sensory conditions under which a movement is performed may also lead to variations in the subject's postural set, with concomitant changes in agonist and postural activity patterns. For example, it has recently been reported that anticipatory biceps femoris activity is absent prior to arm movements in free-floating subjects during the microgravity phase of parabolic flight (Layne & Spooner, 1990).

The present study provides insight into the central programming versus parallel processing question by characterizing the relationships between anticipatory paraspinal and anterior deltoid (agonist) musculature activity during a unilateral shoulder flexion task following manipulation of sensory input. In particular, a weightless environment during KC-135 parabolic flight was used to alter normal otolith and proprioceptive input associated with gravity. Such insight is important for understanding the processes controlling the postural and voluntary components of movement.

### Method

#### Subjects

Three males, ages 22, 33, and 51, volunteered and provided informed consent. All subjects were members of Kansas State University's BioServe Space

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Technologies program and had passed the Air Force Flight Class III Physical Examination. The subjects had also completed the Advanced Physiological Training Program of the United States Air Force Space Command.

### Tasks

To manipulate the postural set associated with arm movements, the subjects were exposed to three unique environmental conditions. Subjects performed rapid, self-initiated unilateral shoulder flexions in each of the three conditions. In Condition A, the subjects initiated 20 arm movements from a comfortable upright standing position. Condition B involved performing the arm movements during the microgravity phase of parabolic flight aboard NASA's KC-135 aircraft. The flight profile of the aircraft results in approximately 25 s of microgravity during each parabola. During periods of microgravity the subjects were able to complete between 2 and 6 arm movements, depending on their ability to regain a stable body configuration. Between 10 and 15 parabolas were dedicated to the experiment, resulting in approximately 20 to 35 arm movements performed in microgravity. During movements in microgravity, subjects were free floating about the cabin; subjects were instructed to maintain an erect posture for at least 2 s prior to movement initiation. This requirement ensured that anticipatory muscle activity related to arm movement could be identified above a quiet EMG baseline level. In Condition C, 20 arm movements were initiated from a supine position supported by a standard gymnastic mat placed on the laboratory floor.

### Instrumentation and Data Analysis

Surface EMG was recorded from the left paraspinals (PA) and right anterior deltoid (AD), using Ag/AgCl electrodes with 8 mm diameters, separated by 2 cm. The ground electrode was placed over the right mastoid process. Measuring from clearly identifiable anatomical landmarks to the site of electrode placement assured identical electrode placement across experimental conditions. Prior to arm movement the subjects used the medial boarder of their hand to depress a microswitch attached to a velcro strap around the thigh. The initiation of movement was demarcated by voltage shifts resulting from release of the microswitch. The signals were converted from analogue to digital at a sample rate of 1 kHz. The EMG signals were full wave rectified and low pass filtered (10 ms time constant) before individual trials were analyzed by determining each muscle's activity onset latency relative to arm movement initiation (i.e., microswitch signal). This allowed quantification of the duration of the muscle activity prior to arm movement initiation. This measure was defined as muscle duration. Muscle onset was defined as activity exceeding mean

amplitude baseline activity by two standard deviations, with the activity remaining at least one standard deviation above the mean baseline for a minimum of 30 ms. Ratios between anterior deltoid and paraspinal durations for each subject, for each condition, were calculated to assess the relationship between the two muscle durations. This procedure resulted in standardizing the data across the three conditions. Mean ratios and standard deviations for each subject, in each of the three conditions, were determined. The data were analyzed as three separate single-subject experiments (Higgins, 1978). The data were first tested for serial correlations and none were found. Satterthwaite's (or unequal variance) modification of Student's *t*-test was used to test for differences between conditions (Satterthwaite, 1946).

### Results and Discussion

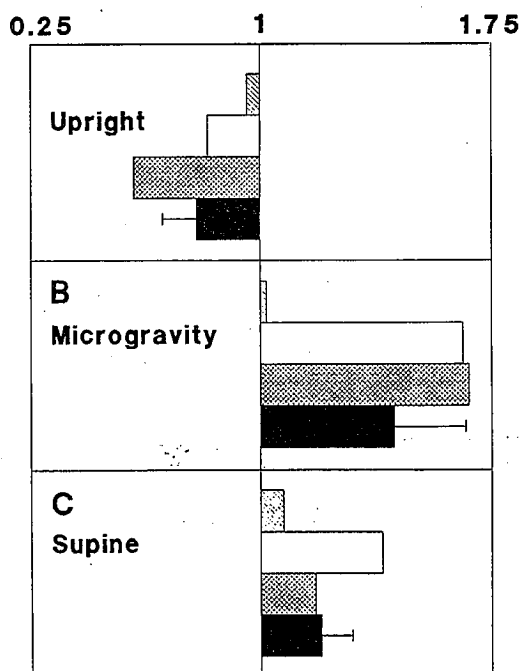
Although other investigators have demonstrated a suppression of anticipatory postural activity when postural requirements associated with arm movement are reduced (Clément, Gurfinkel, Lestienne, Lipshits, & Popov, 1985; Cordo & Nashner, 1982; Layne & Spooner, 1990), the present results indicate a reversal of recruitment order between the agonist and a postural muscle. Figure 1 displays the mean anterior deltoid/paraspinal duration ratio pattern found in each condition, for each subject (see Figure 1). The group mean ratio (with standard deviation) is also shown. Ratio values less than 1 indicate that the paraspinals were recruited prior to the anterior deltoid. Values greater than 1 indicated that anterior deltoid recruitment preceded that of the paraspinals. In each of the subjects, a significant shift in the recruitment order occurs in the supine condition compared to the upright standing condition, (Subject 1,  $t [19] = 5.23$ ; Subject 2,  $t [19] = 2.32$ ; Subject 3,  $t [24] = 9.18$ ;  $p < .05$ ). Two of the subjects also display a significant shift between the upright standing and microgravity condition (Subject 2,  $t [21] = 7.36$ ; Subject 3,  $t [19] = 4.27$ ;  $p < .05$ ), while the remaining subject displays a similar trend. It should be noted that the reversal in recruitment order appeared during the first trial in both microgravity and in the supine condition, indicating that the shift in onset order was not a learned response (i.e., the subjects had no opportunity to practice the movement in the microgravity and supine conditions). Figure 2 shows representative EMG records from the three conditions, illustrating the shift in muscle recruitment order (see Figure 2).

The requirement for trunk stabilizing muscle activity to counteract gravity is eliminated in the microgravity environment and when the trunk is supported by the mat in the supine condition. Thus, these two conditions had fewer biomechanical postural requirements than move-

ments made from a standing position. The reduction in the postural requirements in these conditions would be perceived by the system as a result of a combination of altered sensory inputs relative to the upright condition. Presumably these sensory inputs would result in neuronal threshold or activation pattern changes in the somatosensory and motor cortex and/or dentate cerebellar neurons (Brooks, 1986). It is possible that motor neuron thresholds are also affected by changing sensory input. While the number of subjects limits the generality of the data, the observations suggest that our subjects perceived supine and microgravity conditions as having fewer postural requirements, and they adjusted their postural set accordingly. The change in the postural set resulted in a decrease in PA activation duration relative to AD duration prior to movement initiation. That is, agonist activation occurs in advance of the "anticipatory" postural activation. Analysis of the mean amplitude of the initial 100 ms of EMG following PA activation indicated no change across the conditions. Thus, the decrease in PA activity duration relative to AD duration was not compensated for by an increase in PA activation level.

**Figure 1.** Ratio of anterior deltoid/paraspinal activity onset, prior to movement initiation.

### Anterior Deltoid/Paraspinal Activity



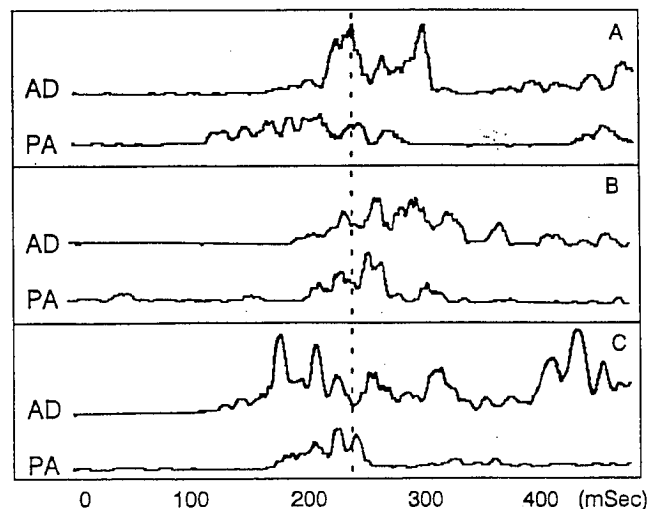
*Note.* The set of four bars in each panel is the ratio for three individual subjects plus the mean ratio for all subjects (solid bar). The ratios show that paraspinal activity precedes deltoid activation (ratios less than 1.0) in standing subjects (a), but that the relationship reverses (ratios greater than 1.0) in microgravity (b) and supine (c) environments. Standard deviations are also shown for the mean values.

The current findings support the theory that postural and agonist muscles are controlled by parallel processes. Lee et al. (1987) have argued that parallel control implies that muscles with unique biomechanical functions within the context of the movement are independently influenced by various factors. By independently weighting postural and agonist requirements, unique muscle activation patterns can be produced that are appropriate to achieve the specific demands of the movement. The shift in AD and PA recruitment order in the less demanding postural conditions, relative to upright stance, supports this concept. In contrast, control theories, suggesting that the postural and agonist muscle activity is part of the same central program, necessarily imply limits on the flexibility of muscle activation patterns associated with specific movements. The current observations do not support this viewpoint, as the shift in muscle recruitment order would not be predicted if postural and agonist activity were the result of the same movement program. However, if motor neuron thresholds are altered by varying sensory input, it is conceivable that a variety of muscle activation patterns would result from the same motor program.

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**Figure 2.** Representative traces of anterior deltoid (AD) and paraspinal (PA) EMG activity from one subject in each of the three conditions.



*Note.* (A) is upright standing, (B) is microgravity, and (C) is supine. The vertical dashed line represents movement initiation.

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### Authors' Notes

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