Pergamon

Adv. Space Res. Vol. 14, No. 8, pp. (8)381–(8)384, 1994

0273–1177/94 $6.00 + 0.00

MICROGRAVITY EFFECTS ON "POSTURAL" MUSCLE ACTIVITY PATTERNS

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ABSTRACT

Changes in neuromuscular activation patterns associated with movements made in microgravity can contribute to muscular atrophy. Using EMG to monitor "postural" muscles, it was found that free floating arm flexions made in microgravity were not always preceded by neuromuscular activation patterns normally observed during movements made in unit gravity. Additionally, manipulation of foot sensory input during microgravity arm flexion impacted upon anticipatory postural muscle activation.

INTRODUCTION

Numerous authors have reported that neuromuscular activation of the lower limbs precedes rapid arm movement. This anticipatory postural activity (APA) is specific to the forthcoming movement and generally serves to insure the body's center of gravity (COG) remains within the base of support during the arm movement. Several investigators /1,2,3/ have demonstrated that the APA can be adapted rapidly when the postural support requirements are altered. For example, the latency and/or amplitude of the neuromuscular activity of the postural muscles may be modified and, in certain instances, even eliminated, in response to changes in the initial support conditions. Microgravity offers a unique environment to investigate the impact of an extreme change in the postural support conditions on the APA associated with rapid arm movement. If the APA functions exclusively to regulate the COG and there is no COG, modifications in the APA would be expected. Such changes may include an absence of activation of certain lower limb muscles prior to arm movement. Most lower limb muscle atrophy in microgravity results from the loss of tonic activation in the antigravity extensors muscles. The absence of normal anticipatory postural muscle activity may further enhance the degree of muscle atrophy experienced by the antigravity muscles and contribute to postflight postural instabilities. During arm movements made in unit gravity, sensory input from the soles of the feet is always available to the perceptual-motor system. Foot sensory input ordinarily signals that ground reaction forces, which contribute to the regulation of the COG, will be generated in response to postural muscular forces. The perception that useful ground reaction forces are available to assist in postural control may be critical for the expression of the APA prior to arm movement. For instance, Clement *et al.* /1/ reported that when cosmonauts aboard the Mir space station were strapped at their feet to the support surface, the APA was observed prior to arm movement. Conversely, the APA is absent when the functional utility of the reaction forces are minimized by strapping a subject to a wall, thereby eliminating anterior-posterior sway. Such evidence points to the fact that the motor

*+This work has been supported by NASA grants NAGW 2328 and NAGW 1197.

control system can utilize available sensory information to formulate an effective response to a specific situation. However, it has been demonstrated that certain patterns of sensory input can result in perceptual assessments which persist despite the subject's cognitive awareness that the perception is incorrect /4/. These findings suggest that in the absence of other sensory inputs, foot input alone could trigger the expression of the APA prior to arm movement. The purpose of this investigation was to determine if the APA was present prior to arm movements made by freefloating subjects in microgravity and to assess the effect of foot sensory input during such movements. The investigation was divided into two series of parabolic flights aboard NASA's KC-135 aircraft.

METHODOLOGY AND RESULTS

Experiment One. In the first series of experiments, three volunteers, informed of their rights as subjects, performed rapid, self-initiated right arm shoulder flexions. The neuromuscular activity of the right anterior deltoid, left biceps femoris, and left paraspinals was monitored with the use of surface electrodes. The time of movement initiation was monitored by using a microswitch attached to the subject's hip. Prior to arm movement the medial boarder of the hand was used to depress the switch and a change in the circuit voltage signaled that the hand had left the switch. The EMG signals were bandpassed (20-250 Hz), digitized at 1 KHz, and stored for off-line analysis along with the hand switch circuit signals. Twenty baseline trials of arm raises were performed prior to data collection aboard the KC-135. During the microgravity phase of parabolic flight, the subjects were freefloating with the signals being transmitted to a pulse code modulated VCR recording device through a 15' flexible cable. The subjects assumed a stable body configuration for approximately two seconds prior to each movement in order to insure stable baseline EMG measures. Depending upon the quality of the parabola, subjects were able to complete between three and eight arm movements per parabola. Twenty parabolas were devoted to the experiment and 134 arm raises were performed. Baseline recordings of raw EMG confirmed previous reports /5/ of paraspinal and biceps femoris neuromuscular activity preceding arm movement. During movements made in microgravity, anticipatory paraspinal activity was present in 98% of the trails while anticipatory biceps femoris activity was absent in 75% of the trials (Figure 1).

The elimination of the biceps femoris activity occurred on the first trials performed in weightless, indicating the change in neuromuscular activation was not the result of a learning process. The consistent elimination of anticipatory biceps femoris activity during freefloating arm movements contrasted with Clement and his colleague's /1/ findings of a persistence of anticipatory activity when subjects where strapped to the support surface in microgravity. Therefore, a second series of flight experiments were conducted aboard the KC-135 in order to determine what effect sensory input from the soles of feet would have on the APA during freefloating movements.

Experiment Two. The data collection procedures used during the second series of parabolic flight were identical to the first series with two exceptions. During the second series the ipsilateral biceps femoris was also monitored and during some parabolas foot sensory input was provided by the use of a harness of bungy cords and slippers attached around the subject's waist. During movements made with the addition of foot input, vision was eliminated with darkened goggles. In order to assess the effect of vision on the APA, a number of freefloating movements were made with only the goggles applied. Twenty trials in unit gravity were performed while approximately 20 trials were performed in each of the microgravity conditions.

In comparison to the first experimental subjects, the subjects in the second series of flights were less successful in producing quiet EMG baselines, particularly during the movements made in the absence of sole sensory input. Therefore, instead of analyzing single trials, the EMG data from the second series of flights was averaged (relative to movement onset) in order to discern the

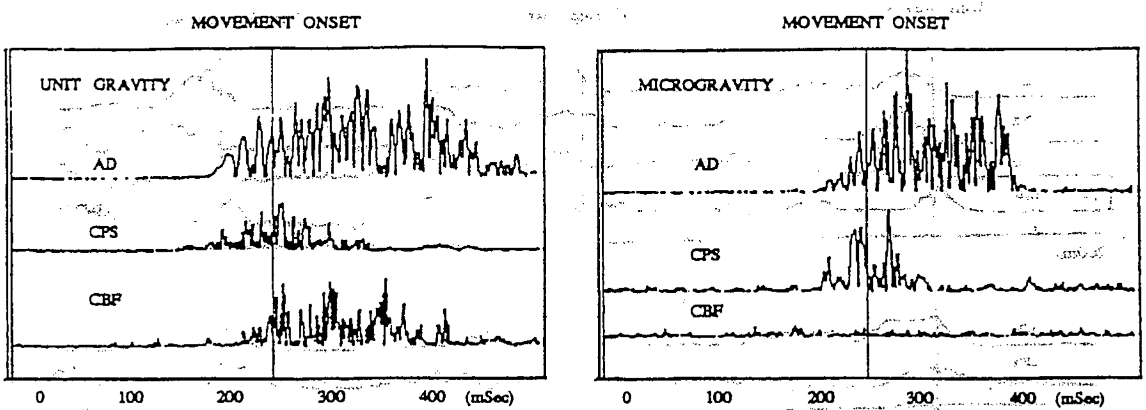

Fig. 1. Single trial EMG record of neuromuscular activation pattern of the anterior deltoid (AD), contralateral paraspinals (CPS) and contralateral biceps femoris (CBF) associated with arm flexion during movements made in unit gravity and in microgravity. Vertical line indicates arm movement initiation. Note the absence of the anticipatory CBF activity during movements made in microgravity.

neuromuscular activation patterns. The EMG data from one of the three subjects in the second series of flights was unavailable due to the loss of the reference electrode. Consistent with the results of the first experiment, the APA in unit gravity consisted of paraspinal and contralateral biceps femoris prior to arm movement. Anticipatory ipsilateral biceps femoris activity was also present. During movements made in microgravity, the contralateral biceps femoris activity was absent with the paraspinal activity remaining intact. However, during freefloating movements without foot sensory inputs, regardless of visual condition, one subject (RG) displayed no consistent anticipatory ipsilateral biceps femoris activity associated with the arm movement while the other subject's (BK) APA included prepatory ipsilateral biceps femoris activity (Figure 2). During freefloating movements which included foot sensory input, both subjects displayed anticipatory ipsilateral biceps femoris activity.

DISCUSSION

The finding that the contralateral biceps femoris "drops out" of the APA during arm movements made under any conditions in microgravity is consistent with earlier findings that the APA can be rapidly adapted when postural support requirements are modified. This finding emphasizes the need for space neurophysiological researchers to focus, not only on the agonist and antagonist muscles involved in a task, but on the more peripheral neuromuscular components of movement. Complete absence of postural neuromuscular activity normally associated with arm movements will contribute to the muscle atrophy experienced by space travelers.

The mixed findings from the second experiment serve as a reminder that individuals are uniquely impacted by microgravity. The fact that one subject displayed anticipatory ipsilateral biceps femoris activity during freefloating conditions without additional sensory input modifications makes it difficult to interpret the finding that both subjects displayed this anticipatory activity during movements made with additional foot sensory input. Although BK was our lone female subject, there is no hypothesis, a priori, which would predict females to display anticipatory postural neuromuscular activation patterns different from males. Both our subjects were reasonably proficient athletes, possessed healthy cardiovascular fitness levels, and were first time flyers, leading us to believe that the differences could not be attributed to either experience or fitness level. It may be that the neuromuscular components of the postural synergy responsible for the APA were more tightly linked in BK and therefore less adaptable during the short periods of weightlessness.

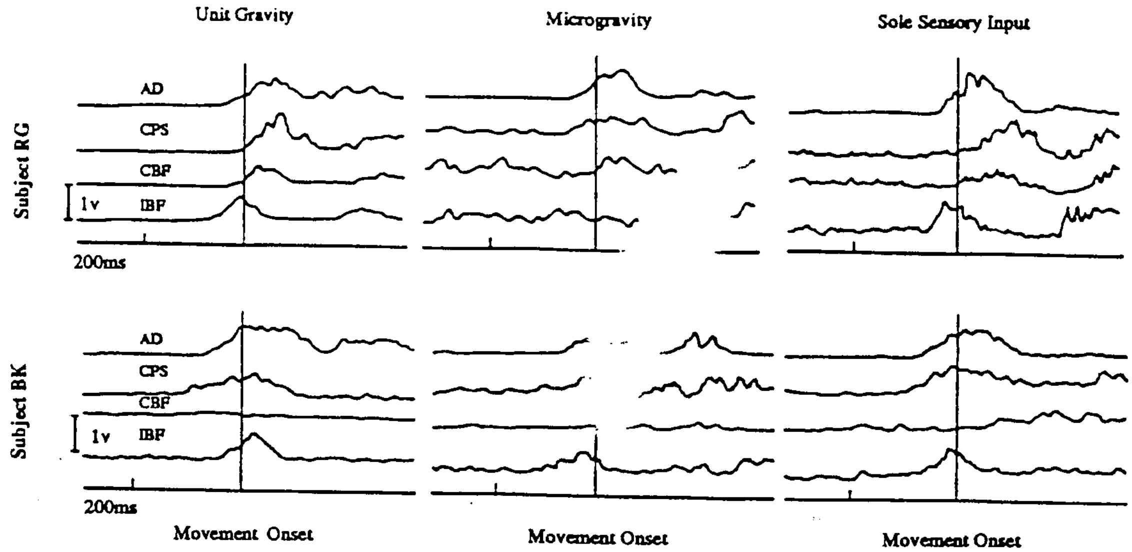

Fig. 2. Averaged EMG records of anterior deltoid (AD), contralateral paraspinals (CPS) and contralateral biceps femoris (CBF) and ipsilateral (IBF) associated with arm flexion during freefloating arm movements and freefloating arm movements with sensory input to the soles of the feet. In contrast to subject RG, subject BK displays anticipatory IBF activity during freefloating movements while both subjects display this activity during movements made with additional foot sensory input.

The presence of anticipatory ipsilateral biceps femoris activity during arm movements made with additional foot sensory input indicates that this input may be heavily weighted by the perceptual-motor system in the absence of other reliable sensory inputs. Since foot sensory input is normally interpreted as meaning that the feet are in contact with a support surface capable of providing ground reaction forces, our subjects may have produced APAs consistent with such an interpretation. The idea that our subjects relied on sole sensory input to obtain information about their environment, despite their cognitive awareness of the unreliability of the information, is consistent with the findings of Lackner and Graybiel /4/. These authors reported that when otolith input is minimized, pressure and touch receptors determine orientation and that the pressure cues can not be disregarded despite the cognitive awareness of the cue's inappropriateness. The present findings, although preliminary, suggest that the perceptual motor system's properties of adaptability can be taken advantage of by careful manipulation of sensory inputs to produce a full range of neuromuscular responses in weightlessness.

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