



Muscle Changes in Weightlessness

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What Happens to Coordination in Space ?

Control strategies used by the Central Nervous System must by necessity undergo change when weight is no longer a consideration. Consider what would happen in 0G if an astronaut exerted the normal (1G) force in moving her fork from her food to her mouth or in putting in contact lenses. Life in space could be very dangerous! Such adjustments are learned rapidly, however, as the brain finds just the right force to use to push off and move from one side of the Spacelab to the other, for instance, or realizes the need to anchor one's feet before trying any torquing activities with the upper body (otherwise the screw would turn the astronaut). In all instances the anti gravity (usually extensor) muscle activity is most affected. The clearest outward manifestations of such changes include the neutral buoyancy posture observed in all space travelers in which the neck, trunk and hips are flexed relative to the 1G stance and the almost total reliance of the upper body for locomotion.

Electrical recordings from flexor and extensor muscles in flight indicate that a flexor bias definitely exists in space. Although the precise mechanisms is not understood, it is likely that this bias results from a greater (vs 1G) facilitation of the flexor contractions and less inhibition of the extensors. Reduced sensory (proprioceptive) input from the joints and muscles might contribute to this phenomenon, which is especially apparent when astronauts are asked to stand erect and lean "slightly forward". The observed tilt is typically four times greater than that seen on earth. In addition certain spinal reflexes, such as the knee jerk and foot sensitivity, are also reduced in 0G, suggesting that the

neurovestibular system is not the only system affecting movement control to change during spaceflight.

It should be obvious to you what problems may occur on reexposure to a gravitational environment and why this is a concern for piloted spacecraft upon reentry, in emergency egress situations or in situations (Moon or Mars expeditions) where ability to perform work and tasks requiring coordination could be a problem. Such coordination problems and a general sense of "heaviness" may persist for several days or even weeks after return to Earth.

What Are the Best Countermeasures?

(abstracted verbatim from R. Edgerton and R. Roy, Adaptations of Skeletal Muscle to Spaceflight. In: Fundamentals of Space Life Sciences. S. Churchill, ed. Krieger Press, 1994.)

To maintain muscle mass, only a relatively small amount or duration of activity per day may be needed. In humans, exercises for 30, 60 or 180 minutes per day have similar effects on muscle mass. However, some minimum amount of muscle activation and force may be required to maintain muscle mass. The evidence to date suggests that the extensor muscles of the legs, hip, trunk (postural) and neck will require the most effort to maintain mass. It also appears that these muscles will be most affected by spaceflight. In contrast, the functional requirement of the flexors of each joint will not be as affected as are the extensors in a 0G environment.

A key question is how much and what pattern of activation and resulting force per day is essential to maintain muscle mass. The same questions must be asked for each muscle property. For example, how much and what kind of activity and force patterns are needed to maintain normal speed or endurance properties? On the other hand, it remains to be determined with certainty that the activity and force patterns as they are altered in spaceflight cause the changes that occur in muscle.

In defining exercise protocols and devices as countermeasures. for the effects of spaceflight, there is one principle that should be followed. The most efficacious exercise countermeasure may be unique for each tissue, organ, or physiological system. In the case of muscle tissue, the most efficacious exercise countermeasure may be unique for a muscle

group (i.e., extensors vs. flexors) and muscle type (i.e., muscles that are comprised predominantly of slow vs. fast fibers). Further, the exercise that best prevents muscle atrophy may not be the same as the one which is the most efficacious in preventing demineralization of bone. However, cross-over effects of these countermeasures can be expected. It seems likely that compromises in exercise prescription can be made so that a cosmonaut or astronaut does not have to exercise several hours each day in order to maintain a reasonable functional capacity.