EFFECTS OF THE SPACE ENVIRONMENT ON THE HEALTH AND SAFETY OF SPACE WORKERS

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Large numbers of individuals are required to work in space to assemble and operate a Solar Power Satellite. Little is known about the physiological and behavioral consequences when large groups of men and women perform complex tasks in the vehicular or extravehicular environments over long periods of orbital stay time. The current data base is limited to United States and Soviet experiences involving only 2-3 persons at a time and for a maximum of 6 months. There are no specifically applicable data relating to inspace behavioral or social performance in populations of mixed gender.

Data relating to physiological performance are generally encouraging. The most disturbing consequences of exposure to the null-gravity environment relate to (1) a generalized cardiovascular deconditioning along with loss of a significant amount of body fluid volume, (2) loss of bone minerals and muscle mass, and (3) degraded performance of neural mechanisms which govern equilibrium and spatial orientation.

CARDIOVASCULAR DECONDITIONING:

The null-gravity environment contributes to redistribution of the labile body fluids. Such fluid shifts trigger reflex responses which serve to adjust total fluid volume. The influx of blood to regions of high compliance triggers a response in volume-sensing regions in the heart and central vessels, with the result that neurohormonal influences on the kidney mediate a loss of water and salt and reduce the total circulating blood volume. Such reflex accommodations were developed to maintain equilibrium in the face of naturally occurring temporal changes in body water, position, and activity. The physiological consequences of having triggered the blood volume control reflexes in null-gravity result in an inappropriate response because the evolutionary development of the system cannot account for lack of gravity. So long as the individual remains in the gravity-free state, the accommodative processes appear to interfere minimally with survival or performance. The inappropriateness of the accommodations to zero-gravity become evident when the individual returns to Earth where the force of gravity reestablishes hydrostatic columns at a time when total circulating blood volume is depleted. Refilling the dependent regions of the lower limbs and abdomen from a diminished total fluid supply results in the presentation of an inadequate volume to the heart for the perfusion of vital organs. The processes leading to such orthostatic hypotension, or the deficiency of volume for tissue perfusion, lend themselves to certain counteractive measures. Countermeasures include (1) application of pressure on the lower limbs and abdomen to reduce the volume available into which blood can pool, thus conserving the reduced blood volume, or (2) drinking excess water and salt while pharmacologically or otherwise inhibiting water and salt loss by way of the kidneys.

DEPLETION OF BONE MINERALS AND MUSCLE MASS:

The release from gravity reverses the physiological mechanisms that serve to build bones and strong muscles. Bone calcium is lost from the skeleton to the plasma and thence from the body via wastes. Muscles lose some strength as structural materials in muscle cells are lost from the muscle mass of the body. The anti-gravity or postural muscles are especially affected. There is no evidence that the rate of bone calcium loss diminishes or terminates during weightless exposure lasting as long as 3 months. Much research on the problem of space flight osteoporosis remains to be done. At present the countermeasures used include the provision of adequate bone replacement salts in the diet along with muscular exercise in an attempt to simulate the forces on bones and muscles normally provided by gravity. Exercise appears to be beneficial in moderating the loss of muscle strength and mass.

NEUROSENSORY DISTURBANCE:

For reasons as yet unexplained, the sensory systems affected by pressure, acceleration, position, and visual patterning appear to lose the fine tuning of their normal integrated interplay. Sensory confusion occurs below the level of consciousness and the conflict of incoming information may give way to dysfunction with resulting space motion sickness. The disturbance appears early in the exposure to null-gravity. Stomach awareness, malaise, and vomiting can occur. The symptoms appear to wane as exposure continues, and in the Skylab experience, the problems of orientation and "space motion sickness" disappeared after a few days. The most effective countermeasures presently available are drugs which dull the acuteness of the symptoms without impairing performance. Much more research must be done to understand the processes involved in this malady and to develop more effective countermeasures.

OTHER EFFECTS:

There have been measurable changes in the total mass of circulating blood cells, in several parameters of body fluid composition and regulation, and in the endocrine and immune systems. These latter changes are presently considered to be adaptive and not likely to interfere with the individual's ability to live and work productively in space.

An interesting relation can be drawn between the rate of onset of effects during exposure to weightlessness and the rate of recovery upon return to Earth. The rapid onset of cardiovascular and neurological disturbances is mirrored in rapid recovery. Disturbances in bone and muscle appear less rapidly, reflecting the relative sluggishness of these biochemical changes at the cellular level. However, the observed changes all appear to operate within the predictable range of physiological performance. All changes observed have been shown to be reversible. Although much more research has yet to be done on the long-term effects of space flight on man, there is no compelling evidence to discourage continued lengthening of the null-gravity exposures or increasing the complexity of tasks to be accomplished in space.