SPACE MEDICINE BRANCH REPORT

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Exercise on Space Station—A Preventive Countermeasure?

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If present NASA plans are realized, exercise will be used as a countermeasure to prevent adverse physical effects from a tour of duty on Space Station. For a long time, researchers in NASA Life Sciences have believed that inflight exercise could be used as a substitute for pharmacological countermeasures. In a preliminary way, exercise was used by the crew of the 14-day Gemini 7 mission (one-half minute use of a bungee cord exerciser, 70 pound pull, twice a day) and during the Skylab missions (bicycle all three missions, Mini-Gym missions 3 & 4, and a treadmill, mission 4 only). Personal exercise, using the devices available to each Skylab crew, varied from 21–80 $W \cdot min^{-1} \cdot kg^{-1}$ body weight. Exercise is regularly used by the U.S.S.R. during long-duration missions. In the 237-day mission, 2 hours a day were spent doing exercise. This was a half hour less than that used in previous missions. In addition, the U.S.S.R. crews wear a "Flight Load Suit," called a Penguin Suit, which maintains tension on the legs throughout daily work activities. At a recent conference, in answer to the question, "Does exercise help?", the attending Cosmonaut physician, Oleg Atkov, stated that since the U.S.S.R. has always used inflight exercise, he could not be sure whether it has helped the Cosmonauts readapt on their return. Even with their regimented exercise program, U.S.S.R. researchers report significant decrements in the cardiovascular system and in muscle strength. The decrements are quite similar in extent to those reported from the U.S. program, where exercise is still a crew preference item. Due to the short duration of Space Shuttle missions, inflight exercise was neither planned nor considered necessary.

Exercise has the potential for reducing or eliminating some of the physiological effects which are part of the adaptation to microgravity but which could degrade inflight operational performance or be deleterious when the astronaut returns to gravity. It is surprising that nearly everyone espouses this theory but, to date, it has not been proven in either the U.S. or U.S.S.R. flight programs. Thornton and Rummel have stated in the *Biomedical Results of Skylab* that "muscle in space is no different from muscle on Earth; if it is properly nourished and exercised at reasonable load levels, it will maintain its function. I think that a properly designed treadmill used for considerably less than an hour a day will not only protect leg and trunk musculature, but will also provide aerobic exercise to cover the cardiorespiratory system." The development of operationally convenient physiologic countermeasures is necessary, not only to facilitate readaptation to 1-G but also to maintain conditioning for vigorous EVA activities and emergency egress.

Limited inflight experience suggests that degradations in aerobic capacity and muscular strength can be reduced if crewmembers perform appropriate and sufficient inflight exercise. Because of the small amount of inflight data available from Skylab and the longer U.S.S.R. missions, NASA scientists do not yet know the requirements for the workloads and the type of exercise equipment needed to inhibit or prevent performance degradation. The Space Station engineers require this information to incorporate it into the specifications for Space Station. There are many years between the identification of a requirement and its translation into a Space Station module. This process is forcing NASA flight physicians to take a stand about the need for exercise before they have the desired knowledge.

NASA management has recognized this deficiency and is designing a series of bedrest studies "to establish unequivocally" a rational exercise prescription for the crews of Space Station. This goal will not be an easy task since it is difficult to duplicate in a bedrest simulation the exact muscular activity of the microgravity environment. Some researchers believe this can only be done in microgravity. Present plans are to design a treadmill-like device for the bedrest studies, rather than use the more traditional bicycle ergometer.

Thus, even after the start of Space Station operations, NASA may still need to experiment with various exercise protocols. It could be necessary to instrument the equipment and the crewmember inflight for NASA to develop and optimize the exercise equipment and protocols. Historically, the inflight exercise data was obtained only during the Skylab missions. In those missions, a bicycle ergometer designed to maintain predetermined heart rates was used as part of the metabolic activity studies of E. L. Michel and co-workers. Only during exercise on the bicycle was metabolic rate measured.

In preparation, NASA personnel currently plan to obtain work rate, total work, heart rate, and oxygen consumption during exercise in Space Station. Inflight protocols will be iteratively improved and personalized to the particular crewmember and mission requirements. A treadmill, a bicycle ergometer, and an anaerobic upper body strength device are currently being considered as the major exercise modalities. For planning purposes, it is assumed that crewmembers will exercise 1–2 hours per day. The exercise equipment will automatically provide corrections for the particular crewmember's conditioning goals, past performance, and current state of physical conditioning. Real-time graphics and animated displays will provide performance feedback for motivation and comparisons. There could be three or more different exercise devices to help reduce the tedium of daily exercise. Boredom is a major factor in noncompliance to exercise routines on Earth and is expected to be a concern in space. It is reported that, in at least one U.S.S.R. flight, a crewmember refused to perform the entire daily exercise protocol.

If present plans are realized, the exercise equipment, displays, data acquisition, and the crewmember will be treated as an adaptive feedback control system. For the aerobic equipment (bicycle and treadmill), an exercise routine will be based on target heart rate profiles over time. The effectors, workload, and motivational display will automatically adjust to obtain the planned profiles. They will serve to drive the controlled system (the crewmember) to the desired state. This is somewhat similar to the Skylab ergometer. The exercise session workload will be defined as a sequence of heart rate set-points over time. The error signal will be the difference between the set-point and the actual heart rate at any time. A computer-based system will operate on this error signal as in any standard control system. Planned control actions include proportional, integral, and derivative terms. NASA now has software under development to allow the relative weighting or "gain" of these terms to be changed easily. In this way, system behavior can be "adapted" to the particular individual and his/her state of conditioning. Two other possibilities for reducing the deconditioning associated with space flight are lower body negative pressure and electrical muscle stimulation. Both of these techniques are being considered.

Although NASA has suffered a setback due to the Challenger tragedy, one can predict that, once the responsible cause is ascertained and corrected, NASA, like the phoenix, will be ready to soar to newer and greater heights. The delay will give NASA scientists time to ponder and experiment with the question of exercise efficacy. Unfortunately, because there are only a few years until fabrication of Space Station, any ideas developed in bedrest studies may not have the benefit of inflight testing; however, these issues certainly will be resolved in time for the Space Station launch.

Notice to all Associate Fellows

Scores for all Associate Fellows nominated for Fellow are shown on the biographical sketches circulated prior to the mail ballot. Since points are being used, it is important that they be accurately assigned and that all activities leading to point credit be fully reported. In the past, reports from many Associates have been incomplete or entirely missing.

In the past, forms have been sent to all Associate Fellows to be used in reporting points and the return of these forms has been excellent. However, it is now necessary to update them. Associate Fellows who have previously reported are requested to report all additional earned point credits as well as any additional points not reported at that time. Those who have not previously reported any points are requested to forward a complete report (reporting form on adjacent page) based on the following criteria:

1. **TIME IN AEROSPACE MEDICINE: Full time, 2 points per year; part-time, 1 point per year (Maximum 30 points).**
2. **EDUCATION AND TRAINING: Points for highest earned degree—Bachelor's, 2; Master's, 3; Doctor's or equivalent, 5. Postgraduate training—in aerospace medicine, 4 points per year; in other related fields, 3 points per year. Board certification in aerospace medicine, 5, or in another related field, 3. FAA seminars attended, 1 point each.**
3. **PRODUCTIVITY: Each publication or presentation (no duplication) in the field of aerospace medicine earns from 1 to 5 points, as assigned by a committee. Add 2 points for each FAA seminar taught, not just attended. (Maximum 30 points).**
4. **AEROSPACE MEDICAL ASSOCIATION ACTIVITIES: Membership, 1 point per year; annual meetings attended, 1 per year (2 per year if overseas); committees—1 point per year for committee members, 2 per year for chairman; AsMA officers or council member, 5 points per year; constituent organizations, ½ point per year for members, 2 points per year for presidents, 1 point per year for other offices; AsMA award winners, 10 points; constituent organization award winners, 5 points.**
5. **OTHER: (These are one-time scores, not per year). International Academy of Aviation and Space Medicine, 5 points; member/consultant to national aerospace medicine body, 3, or officer, 5; member/consultant to international aerospace medicine body, 4, or officer, 6; active pilot, 5 points.**
6. **All point score material must reach the home office by Oct. 1 to be considered for the next meeting.**