

N93-16807

**ANTARCTIC BIOMEDICAL SCIENCE WORKING GROUP: NASA - NSF****EXERCISE DURING LONG TERM EXPOSURE TO SPACE****Value of Exercise During Space Exploration****PHYSIOLOGICAL**

There appears to be two general physiological reasons why exercise will be beneficial to space travelers who will experience a weightless and isolated environment for many months or a few years; one, to alleviate or prevent tissue atrophy (principally bone and muscle), to maintain cardiovascular function, and to prevent deleterious changes in extracellular and cellular fluid volumes and plasma constituents, especially electrolytes; and two, to maintain whole organism functional physical and physiological status with special reference to neuromuscular coordination (physical skill) and physical fitness (muscle strength and power, flexibility, and aerobic endurance). The latter reason also relates well to the ability of the crew members to resist both general and local fatigue and thus ensure consistent physical performance.

**PSYCHOLOGICAL**

It seems important to utilize all available resources to provide distractions and diversions to isolated space crews who will not be continuously busy with pertinent tasks. Various forms of exercise, performed regularly, could help alleviate boredom and assist the travelers in coping

with stress, anxiety, and depression.

#### COMPLIANCE TO HABITUAL EXERCISE

There have been numerous exercise training studies conducted over several weeks or months and even under the most optimal conditions the subject attrition rate in these studies is very high. Even under conditions where the consequence of not exercising regularly is life-threatening it is difficult to maintain the interest and compliance of participants. However, the results are obvious if a highly motivated and highly specialized and homogeneous group (e.g., astronauts, elite athletes) engage in a regular program of physical exercise. The awareness of astronauts and athletes of the important intrinsic benefits and values of exercise provide them the necessary incentive to comply.

#### IMPORTANT EXERCISE TRAINING FACTORS

1. Type
2. Frequency
3. Duration
4. Intensity

1. **Type.** The type or types of exercise recommended for long-term space exposure should be both physically and psychologically appealing. That is, the exercises should meet the physical, physiological, and health goals of NASA and at the same time should be preferred by the participants. Exercise training should emphasize the development and maintenance of flexibility, muscular strength and power, and aerobic endurance. A training program with

this emphasis will help insure optimal and cardiovascular-respiratory function, muscle tone, and joint mobility. The type or types of exercise will, for the most part, be determined based on the limitations of the space habitat and 0g environment. If exercise has priority in long-term space exposure then the development of exercise equipment and apparatus especially designed to elicit specific training stimuli in a weightless environment must be carefully considered. The use of stationary exercise equipment designed to simulate walking-running (treadmills), stepping, cycling, rowing and cross country skiing should be carefully considered in order to elicit the optimal aerobic response whereas specially designed flexibility and strength training equipment should also be considered. Furthermore, opportunity for choices and diversity of exercises will help maintain interest and compliance among participants.

2. **Frequency.** The number of recommended exercise sessions per week will depend on individual fitness status and previous training habits although a minimum of three days/week is sufficient to cause a training effect while two days/week can maintain fitness gains. The usual recommendation for the recreational athlete is 3-5 days/week but if regular exercise participation is projected to also serve as a diversion to the boredom of isolation the frequency can be safely increased to 7-14 sessions per week (maximum of 2 exercise training sessions per day).

3. **Duration.** Similar to frequency, the duration of each exercise training session will depend on the fitness status of each crew member and will also be determined by the specific objectives of each exercise session. Participants

with low fitness status usually use a 10-20 min range; those with average fitness status, 15-45 min; while highly fit crew members can exercise for 30-60 min.

The length of the training session will therefore depend on the energy level of the participant and the intensity of exercise.

**4. Intensity.** The most critical of the four training factors is exercise intensity as only a small change in this stimulus can have dramatic effects on the training response. The intensity levels for flexibility, muscle development, and cardiovascular respiratory exercises can be determined in the following ways:

Flexibility -- easy to control as specific static stretching exercises are performed for only 10 sec followed by full recovery.

Muscle Strength-Endurance -- exercise intensity can be based on a variety of evaluations including isometric, isotonic, and isokinetic. For strength, a high resistance-low repetition evaluation regimen is recommended while muscle endurance is best evaluated by a low resistance-high repetition protocol.

Cardiovascular-Respiratory -- the determination of target heart rate seems to be the key to controlling intensity for cardiovascular-respiratory exercise training. Target heart rate is simply defined as the proportion (%) of maximal heart rate one intends to exercise. Maximal heart rate can be determined most accurately by exercise testing in the laboratory but can also be estimated by taking 220 and subtracting the age of the participant (low estimate) or taking 210 and subtracting age X 0.5 (high estimate). To determine the crew member's target heart rate simply multiply maximal heart rate by the desired exercise intensity. Based on individual fitness status

the usual recommendations are as follows:

fitness status	recommended % of maximal heart rate
low	60
fair	65
average	70
good	75
excellent	80-90

For example, if a participant's maximum heart rate is 180 beats per minute and if the desired exercise intensity is 70% the target heart rate would be  $180 \times 0.70$  or 126 beats/min. It is important to remember that target heart rate is not the rate to be achieved by the end of exercise but instead should be maintained for as near the whole duration of exercise as possible. Increasing exercise intensity to extremes can have deleterious physical and physiological effects culminating in general discomfort, muscle and joint pain, and possible injury.

There is no need to exercise at high intensities to realize gains in cardiovascular-respiratory fitness. Someone performing continuous exercise for as little as 10 min 3 days per week at "conversational pace" can see increases in fitness. "Conversational pace" means exercising at a pace or rate that would permit the participant to converse with someone.

#### PHYSICAL FITNESS EVALUATION

Before the exercise training factors can be used as a successful recipe for fitness, each participant must be evaluated. Fitness levels of crew members may differ significantly and thus it is important to individually

prescribe fitness programs based on the crew members' responses to tests of flexibility, muscle strength, power and endurance, and cardiovascular-respiratory function. Although periodic pre- and post-flight testing can be conducted in the laboratory, emphasis should be on simple, but effective, self-testing procedures designed to complement the laboratory tests. In this way both the immediate and long-term effects of exercise training can be measured.

#### EXERCISE AND ISOLATION

I am not aware of any studies that have reported data concerning the specific effects of isolation on physiological responses of exercise or vice-versa. In almost all cases where isolation was a factor the principal aspects of investigation were environmental, not isolation. In such cases, most data regarding the effects of isolation have been anecdotal. It is well known that training programs designed to improve and maintain physical fitness are, for the most part, very boring. This problem in concert with isolation could seriously jeopardize compliance.

Our earlier studies, which were designed to determine the effects of both acute and chronic altitude exposure on exercise, although involving isolation, did not specifically consider this factor. Over the last several years our laboratory has studied the effects of high intensity exercise training on the performances of elite athletes much of which was done in quite isolated conditions. The preparation for competition of these athletes has many similarities to potential problems to be encountered by crews on long space flights or isolated for long periods on station. Groups of 20 or more rowing athletes have consistently been cloistered and isolated for as long as 12

weeks for the purpose of team selection and training for international competitions including Olympic Games. These selection and training camps (as they are called) are characterized by a highly competitive atmosphere where athletes are competing for team positions, high intensity exercise training sessions, an extremely scheduled life style, and the monotony and boredom of twice-a-day training. In addition to the isolation, the athletes must often cope with environmental extremes, dehydration, hypoglycemia, negative nitrogen balance, decreased glycogen stores, rhabdomyolysis, and hematuria. Incidents of fatigue and overtraining are common. In addition, the athletes seem vulnerable to such communicable diseases as hepatitis, mononucleosis, upper respiratory infections, and viruses. Besides being chronically tired, the isolation of rowers during preparation for international regattas contributes to the rapid transmission of communicable diseases; the participants live close together and share sleeping, lounging, eating, and toilet facilities. Although the sport of rowing makes excessive physiological demands on the competitor where exaggerated stress is placed on muscles and joints, the most common medical problems relate to communicable diseases.

The physical and physiological problems related to extreme isolation may seem pale compared to the potential psychological stress imposed on the space travelers. Although our information is strictly anecdotal the following responses have been observed consistently over several years of my association with National and Olympic rowing camps; participants tire of: spartan living conditions, close living, each other, lack of privacy, and competitive tension (often a prolonged selection process where team candidates are constantly pitted against one another in order to earn a position on the team).

Our elite athlete model also represents many personality characteristics

that are comparable with those of astronauts. Successful elite rowers are:

1. A part of a highly selected homogeneous group possessing very high egos
2. Bright, intelligent, and usually well educated
3. Aggressive and highly competitive
4. Dedicated, highly motivated and have excellent work habits
5. Tenacious, push themselves to exhaustion and have increased pain tolerance
6. Quick learners, highly skilled, and have high energy levels
7. Narrowly and highly focused and cool under pressure
8. Constantly seeking evaluation
9. Loyal and take pride in their training and competitive efforts
10. Excellent leaders but can function equally well as cooperative team players

#### HELPING COMPLIANCE IN EXERCISE

There have been considerable data reported describing successful efforts to encourage people to maintain an exercise training program (see references) however most compliance studies have dealt with physical fitness exercise training for the recreational athlete and exercise rehabilitation following coronary infarction or bypass surgery; little or no data are available for special asymptomatic groups.

A variety of methodologies have been used to help compliance most of which were very straight forward and simply involve common sense. The trick is to keep people exercising. The development and nurturing of a positive attitude toward exercise is very important. This will probably not be a



difficult obstacle in the case of prospective space dwellers as they will most likely have a similar attitude toward exercise as our elite athlete model. Exercise must be a priority with emphasis on inherent physiological and psychological benefits. Exercise must be as normal and as regular as eating and sleeping. Successful exercise training programs, even for highly motivated groups, must be realistic, attractive, varied, and individually designed. It has been our experience that highly motivated groups such as astronauts and elite athletes seem to enjoy challenges thus exercise training should have an element of competition, e.g. racing against a computer competitor or time on a bicycle ergometer. However, at the same time keep training fun and include as many game situations as possible. Although there is controversy concerning whether a participant should associate or dissociate themselves during exercise training, it appears that dissociation or distraction from the boredom of exercise is a common ploy for the recreational athlete; witness the widespread use of television and audio tapes to keep the exerciser compliant. On the other hand I would strongly recommend that a highly motivated group such as the astronauts and elite athletes emphasize association so that they may keep "in tune" with their bodies. Association before, during, and following exercise training can be an important source of information for evaluation of the effects of training. This more subjective self-evaluation should be complemented periodically with more objective evaluation procedures that can measure specific effects of exercise training. Whether these objective tests are self-administered or conducted by an onboard specialist, portable and accurate technology is currently available to easily assess a host of physiological functions. These evaluations will probably prove valuable in maintaining compliance. An introduction of a simple awards

system often insures compliance as well as the use of partnership or group participation; mutual or reciprocating motivation is often an excellent compliance stratagem. I have found through my research with the isolated and highly trained elite athlete that the keys to maintaining compliance are leadership, communication, and education. Whether this leadership comes from an exercise specialist or a designated crew member, it must be a part of any successful exercise training program. Constant accurate and reliable information concerning the effects of exercise must be communicated to the crew at a level and language they understand and in this way education becomes a bonus of the program.

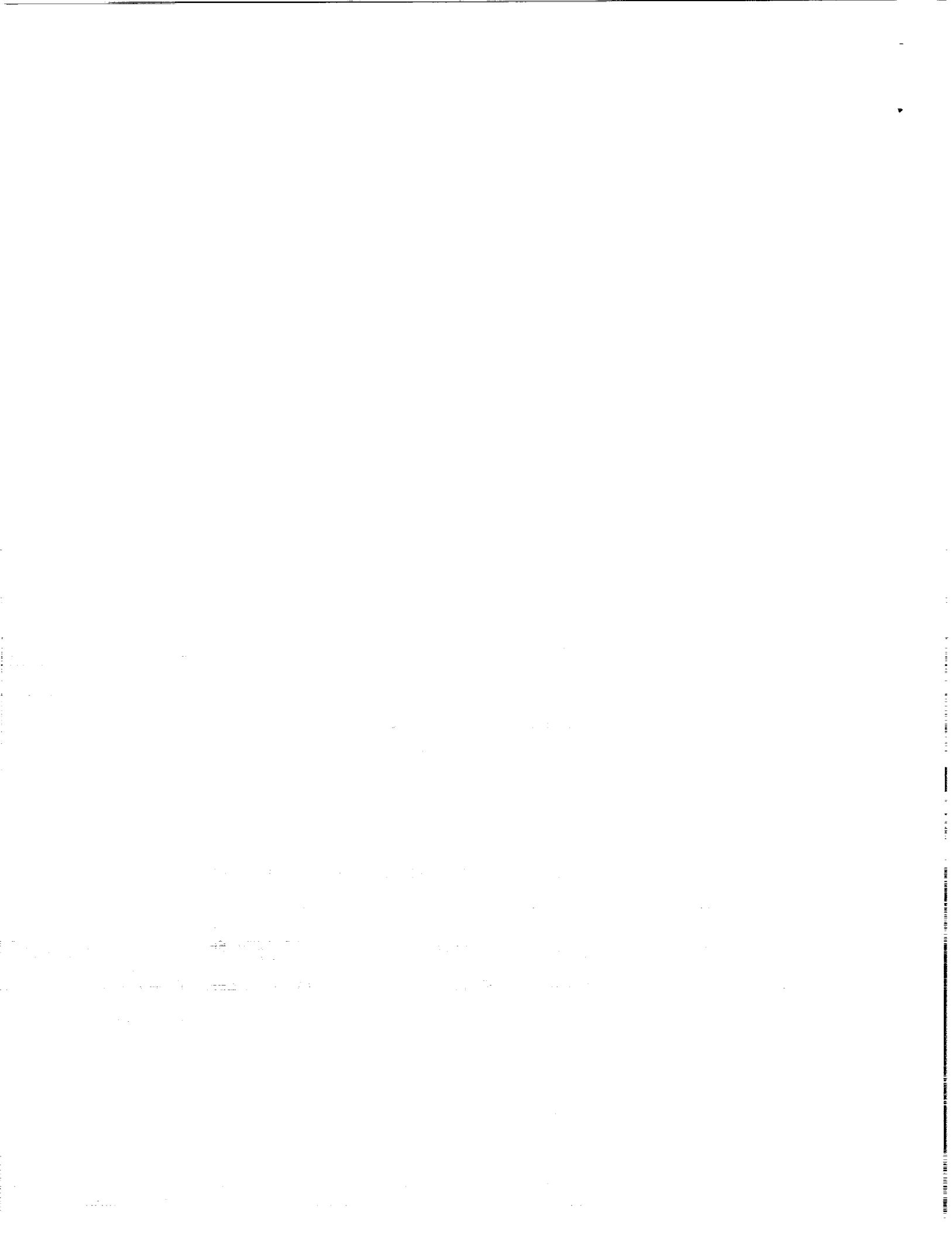
In summary, it seems that a regular and well-planned exercise training program in an isolated environment should be designed to blunt the boredom of isolation, prevent the expected anatomical and physiological deterioration of tissues associated with prolonged exposure to weightlessness, lessen the prospects of joint and muscle pain and injury, and alleviate fatigue. If exercise is a high priority for NASA in prolonged space exposure for the future, then it may be important to include a master motivator, communicator, and educator as an exercise training specialist as part of the crew. I also see exercise as being an integral part of possible interdisciplinary research with other pertinent NASA life science areas such as nutrition, immunology, biochemistry, circadian rhythms and sleep, endocrinology, and psychosocial sciences.

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# Attachment 13

