COMMENTS ON WEIGHTLESS DECONDITIONING AND PREVENTION

(p 54-1)

Some manifestations of deconditioning are weight loss, orthostatic intolerance, instability in walking, sensation of heaviness to extent of postural changes, and coriolis effects.

The following is my theory of some of the changes. Three major systems are involved: neurological including the vestibular, cardiovascular and musculo-skeletal. This last system affects the first two. All of these are affected by nutrition. Taking these in order:

The vestibular organs are only one source of inputs used in balancing the body against one-g. One can walk and stand perfectly well without them. In walking down a street carrying a case of beer in one hand there is optical data from eyes, balance data from force transducers in tendons, and muscles and position data from joint transducers plus others, in addition to vestibular data. As in any closed loop servo system these inputs are processed and emerge as error signals to the servo motors, the muscles. Coriolis effects[1] were noted after return since these occur whenever the gravity field is changed, but there are many other nervous transducers that require adaptation. Everyone staggers a step or two after taking up a heavy load for example. No force servo loop is better than its generators, and the primary force generators for standing and walking are leg and lower back muscles. These muscles are relatively unused in flight, and degeneration not only occurred but should have been expected. In view of this unsteadiness is not surprising.

The second troublesome system is the cardiovascular. Cardiac output, i.e. the amount of blood pumped by the heart, is determined primarily by 1) the amount of blood available to fill the heart, 2) heart rate, and 3)

[1]Other effects of spatial disorientation were denied.

heart muscle condition. Normally, adequate blood for filling is present and cardiac output is a function of rate. Most of the body's blood reservoir is in the veins which can hold many times the entire blood volume. These veins using reflexes, aided by muscle pressure, normally operate at a size that ensures that adequate blood is returned to the heart. When one stands up, for example, a host of reflexes are sent to the veins to avoid pooling, i.e. distension caused by hydrostatic pressure. Under weightlessness reflexes to overcome hydrostatic pressures are not required. Any unused reflex tends to disappear. Further there may be some reduction in blood volume[2]. Blood which is normally in the legs moves into the chest and is "dumped" via urine as excessive. Reduced muscle tone[3] probably occurs in weightlessness with increased vein volume. The most important long term (months to years) consideration is heart condition. The heart is simply a specialized muscle, and just as other muscle improves with usage so does the heart. A given individual can reduce or increase his heart size by continued exercise or lack of it by 50% or more. This size, i.e. strength determines cardiac output at a given heart rate and venous return; Body muscles under exercise require the greatest blood supply, hence indirectly provide the heart's exercise. This last aspect remains an open question in S/L effects.

Any muscle which is unused, weakens and loses function. In space, in the absence of grasping feet, the arms are primarily used; and in a schedule as busy as Skylab may be expected to retain their function. Conversely the legs and low back have little usage. Under gravity the center of gravity is forward of the spinal column and opposed by back musculature. Under

[2]This was once considered the primary mechanism of weightlessness deconditioning including the weight loss.

[3]Tone is the normal small tension retained by a resting muscle.

weightlessness these muscles are unopposed[4] and tend to bend the body backward until adaptation occurs. Conversely opposing abdominal muscles are well used in this opposition and in bending. After return to one-g back muscles are weak and unused to supporting the forward body loads, hence the tendency to stoop. Although a bicycle ergometer is aboard, the forces (max force at 200 watts and 70 RPM is 37 pounds) compared to walking and standing are trivial. This was confirmed in SL-2 by reduced leg size, post-flight pain in lower legs, and measured weakness in the extensor, i.e. gravity opposing, muscles.

Any active system consumes energy, and biological systems require complex food compounds to live.

The diet on Skylab was designed to support a calcium balance experiment, and its nutritional adequacy is based on hospital population and similar studies. No athelete would consider such an excess of starches and sugars. Weight losses in Conrad and Weitz show virtually a straight line which begins from the day the diet was started. This in spite of the fact that Pete increased his calorie level to baseline, i.e. he did not make the 300 calorie reduction in flight. Kerwin's loss pattern was more complex but also compatible with inadequate food. Paul's loss pattern was like Pete's,

Prevention of deconditioning - With the equipment at hand it will not be possible to completely avoid deconditioning, but its effects can be offset by two means--exercise and as a corollary adequate food.

The exercise time has been doubled and should be adequate if properly used. In my opinion proper usage will be the maximum number of watt minutes that can be expended on the ergometer in the time allowed. This is solely

This amount should be on the order of 7,500 to 12,000 watt/mins for SL-3 crew.

[4] This might account for some low back pain in earlier flights.

cardiovascular conditioning for the maximum forces that can be obtained on the ergometer will not maintain leg extensors. A number of light reps. will not maintain the maximum force of a large muscle. An example of this would be a weight lifter who was lifting say 300 pounds. If now he did hundreds of reps at 50 lbs his muscle size and strength would rapidly dwindle. This is what happened in SL-2 with leg extensors, which in running may produce over 200 lbs per leg in a 160 lb man, and are capable of 250 - 350 lb peaks. On a bicycle with peaks of 35 - 50 pounds they must atrophy. The <u>average</u> muscle loss primarily legs on SL-2 was 6 pounds/crewman, and almost a week after return peak forces were only 75% of preflight.

The problem here is to impose large forces on the legs. Fortunately, relatively few repetitions are required to maintain maximum force. There are two devices on SL-2 which will aid in maintenance of legs--the MK-I exercises and the Exergym. Both of these allow development of high forces. Unfortunately neither is calibrated. The MK-I is easier to use but may not survive slow, maximal forces. Either device should be used for leg extension by starting from a squat with straight back and arms and simply rising to a standing position. Forces must be maximum that an individual can tolerate after a warmup. The low back muscles also participate in this and should be protected by it. A series of repetitions will be required and should consist of 5 sets of 10 - 15 reps with recovery periods between each set for marked fatigue will occur if these are done properly.

Under Skylab conditions it will be crucial not to get behind in weight or conditioning for unlike earth it will be impossible to catch up. The work loads in M171 are so low that by the time a decrement appears the individual will be well behind the power curve. There is no really good

indicator, but the two best are heart rate in the LBNP and body mass. A vigorous program should be started and maintained irrespective of other constraints. Whatever food is required to maintain body weight should be consumed. If this flight follows the pattern of SL-2 considerably more food than baseline will be required. As can be seen from the attached weight charts weight loss increased during flight which indicates an increasing energy requirement in flight. Note, however, that the loss began with the diet and continued. It has been agreed that whatever food is required if it is on board it can be used after ground consultation. If SL-3 crew comes back in poor condition SL-4 may be in serious trouble. Further it has been agreed that SL-4 will be resupplied if necessary.

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