DF

MEMORANDUM

TO: DF/Joseph P. Kerwin

FROM: DF/William E. Thornton, M.D.

SUBJECT: Exercise Devices for Future Flights

There should be two distinct efforts here, research and operational. Both efforts should depend heavily on what was learned in Skylab, but this is especially true of the operational devices. The operational device is designed simply to be the best that the current state of knowledge allows. Of course research devices are just that, and are used for exploring better and more efficient ways. A number of fairly well accepted principles were demonstrated once again on the Skylab missions. Cardiovascular conditioning alone does not insure adequate performance by the entire body. For example, there was no question that the bicycle ergometer maintained my ocardiol function very well. Conversely, it did very little for the legs which require high, near maximal, forces to maintain both mass and performance. The constant relatively light loading of the ergometer, while producing a large energy cost very efficiently, does not meet these latter requirements Conversely, as shown by the relatively short periods of usage on the treadmill, relatively brief amounts of exercise at high levels are adequate to maintain muscle function.

What then is wanted is a device which will provide efficient loading of the body such that reasonably long period of high work output and high O_2 cost can be maintained that will allow exercise through realistic range of motions and actions that would be expected on return, especially as regards walking; a device that will provide high force levels for trunk and back muscles; a device that will exercise the muscle of the leg veins, e.g., lower body negative pressure (this afea is, of course, the least well known of the others)] and a device which will allow other selected exercises of as great a variety and load level as possible for arms, neck, etc. In addition, the device must be comfortable, easy to use, and as efficient, i.e., take as little of the crew time as possible. At the same time it should, it must, meet operational constraints such as minimal size, weight, compatibility with environmental specifications and should ideally use no power or external connections, and above all be capable of being stowed and used in the smallest possible space.

Looking first at the physiological requirements, a treadmill is the only currently available method to both load the limbs and at the same time provide high energy cost for a prolonged period of time. Let me emphasize that I am not talking about a substitute for a treadmill, such as the device flown on Skylab 4. Rather, I am talking about a true treadmill with a moving surface against which one can walk and run easily. This can be combined with a collapsible lower body negative pressure device (we tested extensively and successfully such a device for use on MOL, at the school of aerospace medicine, which had a bicycle ergometer mounted inside the lower body negative pressure apparatus).

The following scheme is proposed to meet these requirements, and remember that it is simply nothing more than a point of departure for what should be an investigation of the problem. It is not the sort of thing for which one can write specifications, etc., etc., and let a contract on. I am reasonably sure the final product would differ in many, many ways. Conversely, the underlying principles are felt to be sound. A very low friction treadmill using some form of coupled rollers of small diameter, or a very low resistance belt with all forms of mechanical friction reduced to a minimum, would form the heart of the device. Such a treadmill when placed on an angle can extract useful work from an animal, including man. The history books will attest to this device. If one now takes the output and through a suitable speed transformation derives some form of air pump, probably a centrifugal pump, this pump when controlled by a constant pressure regulator (I'm not going into details on the gas dynamics of the control and loading system here) would then provide the pressure source for the negative pressure which can also be used in a control fashion to provide a suitable load for the treadmill. A collapsible negative pressure "skirt" would then be placed around the subject and at the waist level a flat surface of suitable area would be attached to the waist seal and then this mechanically coupled through straps or belts to the subject's body. The negative pressure inside would then provide a loading on the subject.

It will not be hard to devise the necessary instrumentation, also passive, to allow recording of the work done such that the device can be quantitative. Further, if arm exercises are desired once a negative pressure source is available, pistons or other arrangements can be used to provide a good approximation of weight such that a series of synthetic weights could be generated for arm exercises during the same period.

This is a device that I would like to produce in prototype form, for I feel that it will meet most of the requirements for spaceflight for many years to come. If I have access to a decent shop, or even an individual with the shop, I feel that I could reach prototype stage in a matter of months with a cost of a relatively few thousand dollars.

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Since there will be requirements for other exercises from time to time, and the bicycle ergometer is bound to raise its head again and again, I would recommend strongly that an ergometer compatible with weightlessness and, at the same time, of resonable size and weight and requireing no power be developed, or rather packaged, for use in future flights. Numerous individuals have voiced similar hopes from time to time. When the current Skylab ergometer was developed I made a strong plea to incorporate some of the features, especially of the configuration, of the ergometer that is proposed here. Figure 3 is a sketch of such an apparatus. The force unit can be entirely passive and yet have the necessary inertia and be suitably instrumented to give quantitative results. Although a constant work device can be designed without overmuch complication, it is recommended that a simple variable load design be used (the work done would, of course, be proportional, in this case, to the pedal speed). There are many adequate load cell designs that are available, but I would favor either a permanent magnet eddy disc arrangement in which the magnetic coupling would be varied, or else a simple hydraulic unit. A hydraulic unit would undoubtedly be most flexible and constant work could be very easily accomplished with this. The coupling of man to machine should correspond to that required for zero g. Since the loads are low they could be taken very well by the arms and/or head.; however, I do not consider this an optimum arrangement. The only reason for a seat bicycle is to offset or support the gravity vector. When one is seated, of necessity the legs must be flexed at an angle; however, both anatomically and from experience on Skylab, there is a tendency to place the vector from the pedals in the long axis of the body, i.e., the body should be in a straight line with the force cell directly beneath. At the same time, the shoulders are the logical place to support the load. While there may be some question of this arising from the use of the Skylab restraint harness, this was an entirely different situation and case. Such a device can be very easily accomplished, probably $5000 would suffice to produce one or more demonstration units and exhaustively test them. For example, I have designed both hydraulic and magnetic units, some of which have found their way into the commercial market. One such unit, weighing as I recall some 12 pounds, was considered seriously for the Apollo flight, but as I recall, was turned down for lack of a requirement."

Again, because of my previous experience and desired work in the field, I would very much like to pursue this, but the work can only be pursued successfully with a responsive group and for both of these efforts I would recommend letting a time and material contract to the School of Aerospace Medicine Instrument Shop, and a great deal could be learned and produced in a very short time. There are other sources that I would recommend, or if I were given direct access to an engineer such as Bill Huber on the treadmill project and to the local shop wtth adequate priority to insure that work were in fact done on it, it could be done here. It cannot be done with the sort of controlling PE arrangement that was present on Skylab 4 MMD and digital temperature. There is no place for such an engineer at this stage of the game, for I shall be doing my own engineering, such as is required. Conversely, there is no objection to having a laision engineer so long as he cannot become involved in the development precesses.

William E. Thornton, M.D.

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Joe, I feel strongly that we should try to retain the prerogative of personal exercise in this office, except where research efforts are involved; and the best way that I can think of to do this is to make this aspect of crew training a part of this office and make the development of such devices a necessary part of the job.

The source of this problem with project engineers has just occurred to me. While they are essential to the average nontechnical researcher, there can be nothing but conflict with an investigator who does his own' project engineering and design which is the only way I can assure success. I have always been designer, project engineer, and manager of my projects and for years in industry, so conflict is inescapable, especially if grossly incompetent "engineers" who have either forgotten or never knew engineering are assigned, to say nothing of having no expereinces in the field of work.

William E. Thornton